Working Paper: Consultation Draft

Energy Efficiency and Climate Change Considerations for On-road Transport in Asia

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This working paper was prepared under TA - 6261 (REG) : Energy Efficiency Initiative Consultation Workshop - Transport, Energy Efficiency and Climate Change by John Rogers (jarogers@adb.org) with contributions from Jerome Weingart, Charles Melhuish and Cornie Huizenga and may not reflect the views of ADB's Board of Directors. Comments may be submitted to Cornie Huizenga (chuizenga@adb.org) by 8 June, 2006

Asian Development Bank

ABBREVIATIONS

A/C	–	Air Conditioning
BRT	–	Bus Rapid Transit
CAI-Asia	–	Clean Air Initiative for Asian Cities
CDIAC	–	Carbon Dioxide Information Analysis Center, US DOE
CDM	–	Clean Development Mechanism
CI	–	Level of statistical certainty
CNG	–	Compressed Natural Gas
CO	–	Carbon Monoxide
CO_2	–	Carbon Dioxide
DFID	–	United Kingdom's Department for International Development
DMC	–	Developing Member Country
DPF	–	Diesel particle filter
EEI	–	Energy Efficiency Initiative
EPA	–	United States Environmental Protection Agency
EU	–	European Union
EURO	–	European emissions standards
G8	–	Group of Eight
GDP	–	Gross Domestic Product
GEF	–	The World Bank's Global Environment Fund
GNI	–	Gross National Income
GHG	–	Greenhouse Gas
HC	–	Hydrocarbons
HD	–	Heavy Duty
LD	–	Light duty
I&C	–	Inspection and certification
LPG	–	Liquefied Petroleum Gas
NGO	–	Non-governmental organization
NMT	–	Non-motorized transport
NOx	–	Nitrogen oxides
OECD	–	Organization for Economic Co-operation and Development
OEM	–	Original Equipment Manufacturers
PM	–	Particulate Matter
ppm	–	Part per million
PPP	–	Purchasing power parity
PRC	–	People's Republic of China
SCR	–	Selective catalytic reduction
SUV	–	Sport utility vehicle
UN	–	United Nations
UNFCCC	–	United Nations Framework Convention on Climate Change
USA	–	United States of America
WRI	–	World Resources Institute
WTW	–	Well to wheel

CONTENTS

I. RATIONALE

1. Stabilizing and reducing atmospheric greenhouse gas concentrations is essential to global sustainability and this will require intensified and ongoing efforts to increase overall global energy efficiency and a shift from fossil fuels to non-carbon energy sources.. The improvements in global energy efficiency need to be achieved in a context of a growing population and economy. In July 2005, the Group of Eight (G8) adopted the Gleneagles' Action Plan on Climate Change, Clean Energy and Sustainable Development. This Action Plan called for substantial improvements in Energy Efficiency and aims to shift a growing share of investment towards cleaner or more efficient energy technologies. Within this framework, the Asian Development Bank (ADB) has undertaken analytical work that will eventually lead to the formulation of a policy framework to guide investments and address energy efficiency and climate change in the transport sector in Asia. This paper is the first step in the formulation of such a policy framework[1].

A. Relevance of energy efficiency and climate change for on-road transportation in Asia

2. There is now extensive evidence, accepted by the international scientific community that the world is getting warmer with an increase in global average surface temperature of about 0.6℃ over the 20th century (Pachauri, 2006) (see Figure 1). The atmospheric concentration of carbon dioxide (CO_2) has increased by 31% since 1750 to levels that have not been exceeded during at least the past 420,000 years.

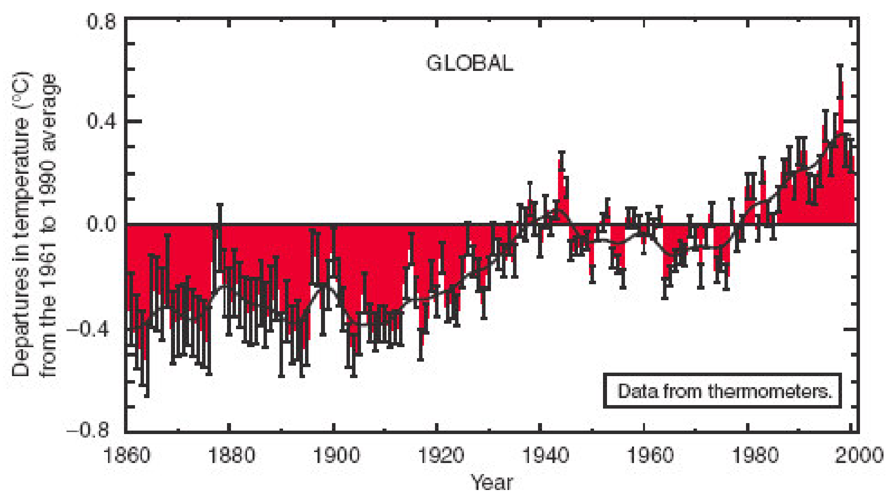

Figure 1 –Variations in the surface temperature of the planet over the last 140 years

Source: IPCC, 2001

3. While such a temperature change may seem modest it is now accepted that this is producing changes in our climate system that include an increase in precipitation in the Northern Hemisphere over most mid- and high latitudes accompanied by a decrease in rainfall

[1] ADB acknowledges the support provided by DFID for the formulation of this paper

over much of the sub-tropical land areas[2]. Warm episodes of the El Niño-Southern Oscillation phenomenon have been more frequent, persistent and intense since the mid-1970s, compared with the previous 100 years. These changes, which affect sustainable development and have severe equity implications, have been demonstrably and strongly linked to increasing anthropogenic activity and greenhouse gas (GHG) emissions[3] that principally derive from an unprecedented increase in carbon-based-energy consumption. In Asia these impacts on rainfall and agriculture are believed to be significant in addition to the overall threats for low –lying islands and coastal areas, some of which are densely populated.

4. The transport sector in 2002 used 21% of the worldwide all-sector total energy consumption and is projected to generate over 60% of the increase in total energy use through to 2025. The emerging Asian nations[4] are projected to provide much of that future growth in oil consumption – and Greenhouse Gas (GHG) emissions -- due to their strong economic and population growth. Emerging Asia (including China and India) is expected to account for 45 percent of the total world increase in oil use through to 2025 as the gap between their economies and the mature market economies substantially narrows. China's energy use for transportation is projected to grow by 6 - 9 percent per year and in India, energy demand in the transportation sector has been projected to grow at 5 - 8 percent a year over this period[5].

5. The emerging Asian economies are a net oil importer – in 2004 over half of their consumption was imported[6] -- and until recently, several governments in the region have not reflected the true increase in fuel prices to protect consumers from the impact of soaring oil costs but this has placed increasing pressure on their national budgets and balance of payments. The continued use of fuel subsidies, in Asian countries, apart from their direct costs[7], has the side-effect of retarding the development and diffusion of more fuel-efficient and cleaner technologies and policies, which hurts both global and local environmental sustainability.

6. Increasing energy efficiency in the road-transportation sector -- and the GHG emissions that it produces -- is crucial to resolving these issues. This document discusses four complementary approaches to achieve this in Asia. These approaches for the short -, medium – and long term are situated against a backdrop of rapidly increasing population and wealth and accompanied by the pressure of increasing personal mobility and the urgent need to eradicate poverty:

i. Improving the energy efficiency of individual vehicles, to increase the distance traveled per unit of fuel,
ii. Modal shift that promotes lower fuel consumption per passenger- or freight-kilometer traveled,

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[2] Snow cover and ice extent have decreased, global average sea level has risen and ocean heat content has increased leading to increasing precipitation in the Northern Hemisphere over most mid- and high latitudes by a statistically significant 0.5 to1% per decade accompanied by a decrease in rainfall over much of the sub-tropical land areas by about 0.3% per decade during the 20th century

[3] particularly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), halocarbon gases (e.g., $CFCl_3$ and CF_2Cl_2), and some other synthetic compounds (e.g., perfluorocarbons)

[4] Emerging Asia is used in this review to include China, India Bangladesh, Bhutan, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, Thailand and Viet Nam.

[5] lower growth forecasts by the US Energy Information Administration International Energy Outlook 2005; Higher growth forecasts are shown in appendices 2 & 3.

[6] 2004 production of oil 7176 thousand barrels daily (8.9% world total) and consumption of oil 14,870 thousand barrels daily (18.4% world total) (British Petroleum Statistical Review of World Energy June 2005)

[7] In Malaysia despite increasing retail prices, and a reduction in subsidy levels the government expects fuel subsidies to have cost almost $ 2.2 billion in 2005, compared to $ 4.8 in 2004

iii. Urban design that reduces the need to travel, requiring fewer passenger- or freight-kilometers; and by
iv. Changing to fuels with lower GHG emissions.

B. Rationale for the development community

7. The overarching agenda of the international development community [8] is poverty alleviation. Economic growth is essential to overcome poverty. This should, however, not be at the expense of the environment and the chances of future generations to utilize Asia's natural resources. Emerging Asian economies are trying to cope with high energy demands and oil prices, which threaten to slow down economic growth. At the same time, as outlined above, the growing energy use by the transport sector is increasingly contributing to climate change. A major effort is needed in Asia, from all stakeholders, including the international development community to promote on-road transport energy efficiency and fuel diversity. Such an effort must include the goal of reducing the Asian growth-induced pressure on climate change.

8. Promoting energy efficiency, fuel diversity and climate change friendly actions transcends the boundaries of energy policy. Policies on transportation, technology, environment, finance competition and investment all have an important role to play. Whilst funding for economic development is dominated by private investment, the international development community is an important source of policy and technical advice to developing countries on these issues and functions as a catalyst for improving the use of resources in responding to the energy development challenge and dealing with climate change and adaptation. It has a particularly important role to play in enabling private participation by assisting client country governments establish and maintain clear and comprehensive legislative and regulatory systems that bring financial and technical rigor to these projects and reduce the risk to potential lenders and investors. To support efforts by countries in the Asian region the international development community must focusing more systematically on energy efficiency and climate change and step up its initiatives to strengthen its technical capacity and better align its lending framework.

9. In recognition of this situation, ADB has already initiated substantive initiatives in the areas of energy efficiency and clean air (i.e., Energy Efficiency Initiative [EEI] and Clean Air Initiative for Asian Cities (CAI-Asia) and has made good progress in starting to address energy efficiency in the industrial and power sector[9]. However, based on an analysis of ADB lending of 11.228 billion dollars to the transport sector over the last 5 years[10] limited specific attention has been given to the climate impacts of transport.

C. Rationale for the developing countries in Asia

10. Countries in emerging Asia are all pursuing policies to achieve economic growth -- which is essential to overcome poverty – led by China and India, which if they are able to fulfill their potential, are likely to become a dominant force in generating spending growth over the next few decades possibly even exceeding the gross national product of the US and Japan (for China and India respectively) in less than a generation. This, however, should not be at the expense of

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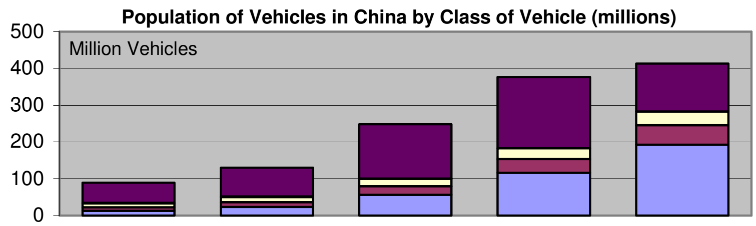
[8] The development community includes multilateral and bilateral development organizations as well as international foundations and NGOs with a mandate to assist developing countries in their economic and social development.
[9] See http://www.adb.org/Documents/PIDs/39578022.ASP and http://www.cleanairnet.org/caiasia/1412/channel.html
[10] 2000 to 2005

the environment and the chances of future generations to utilize each country's natural resources.

11. All countries in emerging Asia currently have low levels of personal motorization (which in many cases is based on 2-wheelers) that is likely to increase drastically as they achieve this economic growth due to a marked increase in urban population and an increasing ability to buy 4 wheelers (cars and SUVs). The increase in demand for 4 wheelers in Asian cities is expected to grow faster than GDP.

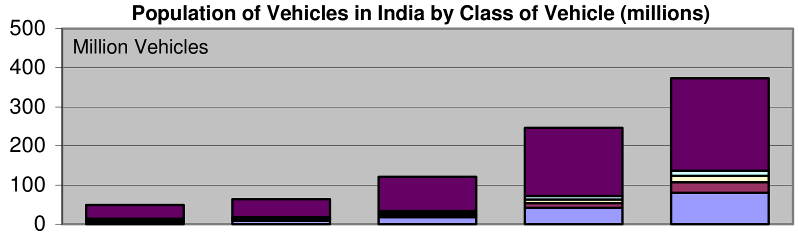


Population	2005	2008	2015	2025	2035
2-W	55.3	78.1	146.7	193.2	130.4
3-W	2.0	1.5	1.7	0.3	0.0
HCV	10.4	13.9	19.9	29.3	37.5
LCV	9.4	13.1	22.8	37.7	52.9
Car, SUV	12.9	23.4	56.8	115.8	192.7
Grand Total	90.0	130.0	248.0	376.4	413.6

Figure 2 – Forecast of vehicle populations in China[11]

12. Under a business-as-usual (BAU) scenario, the active population of cars and SUVs in China is forecast to grow to 15 times its present size in 30 years (from 12.9 million in 2005 to around 193 million in 2035; see Figure 2) whilst in India the expected increase is a mere 13 times (from 6.2 million in 2005 to around 80 million in 2035; see Figure 3). However India is expected to have a population of 236 million motorcycles (2-W) in 2035, up from 35.8 million in 2005 which reflects a larger increase than China (6.6 times for India vs. 2.4 times for China) which grows from 55.3 to 130 million in the same period. This difference reflects both the cultural and purchasing power differences between the two economies.

[11] The forecasts used in Figures 2 and 3 were developed by Segment Y plc (www.segmenty.com) based on the Goldman Sachs economic forecast in their "Dreaming with BRICs" report. In the graphs, motorcycles are shown as 2-W; 3-W are three wheelers, HCV are Heavy Duty Commercial Vehicles, LCV are Light Duty Commercial Vehicles and cars and SUVs are self explanatory.



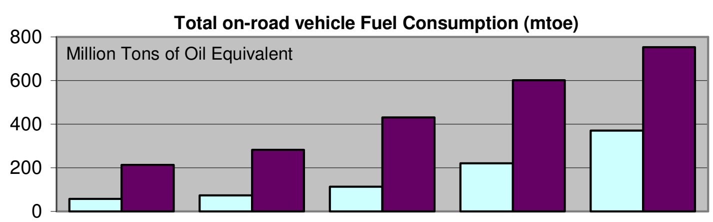
Population		2005	2008	2015	2025	2035
2-W		35.8	46.1	87.7	174.1	236.4
3-W		2.3	3.0	5.3	8.8	13.1
HCV		2.4	2.9	4.6	9.1	16.2
LCV		2.4	3.2	5.7	12.5	26.9
Car, SUV		6.2	8.8	18.0	41.6	80.1
Grand Total		49.1	63.9	121.3	246.1	372.7

Figure 3 - Forecast of vehicle populations in India

13. Such a projected increase in number of vehicles of a greater than order-of-magnitude increase in car population, will add significantly to the current congestion in the major metropolitan areas and will add to urban air pollution and a lack of road safety. Even if investment and land[12] were available, it is infeasible to consider building road infrastructure at a rate that matches the forecast growth of urban vehicle populations.

14. Economic growth which includes stimulated internal demand requires lengthening supplier and distribution chains and most of this increased required capacity in passenger and freight inter-city movement will be delivered by road transport. Thus emerging Asian economies will be faced with increasing energy demands from on-road transport that is based almost exclusively on petroleum fuels whose high prices place an increasingly heavy burden on growth and concerns for energy security.

15. Under this business-as-usual (BAU) scenario, the total fuel consumption of on road vehicles in China can be expected to grow three and a half times over the next 30 years whilst for India the fuel consumption in 2035 will be over six times that in 2005 as shown in Figure 4. These growth rates are less than those of the in-use population itself due to the anticipated improvement in vehicle fuel efficiency[13].



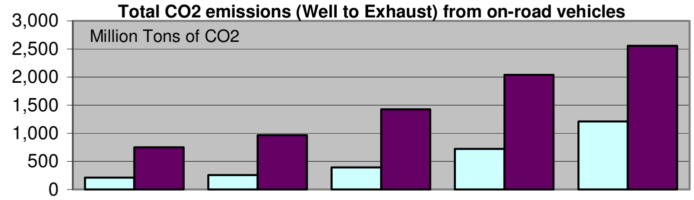
Economy		2005	2008	2015	2025	2035
China		215	284	431	602	753
India		58	73	115	221	371

Figure 4 - Total on-road vehicle Fuel Consumption (mtoe)

[12] Land availability is particularly seen as a constraint to road construction. The practice of constructing multi-layered express ways is increasingly seen as negatively affecting the quality of life and thereby also the economic attractiveness of such cities.

[13] The BAU calculations were performed using the IEA/SMP Reference Case Projection Model , L. Fulton, IEA / G. Eads, CRA; July 2004 together with the Segment Y population projections

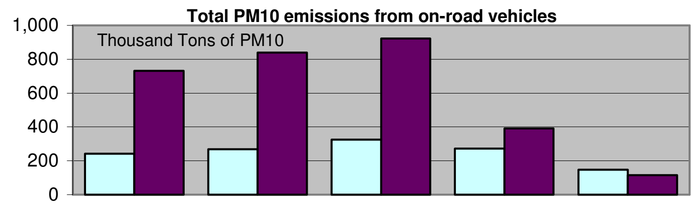
16. Correspondingly, the CO2 emissions from on-road transport can be expected to increase by 3.4 times for China and 5.8 times for India over the 30-year period to 2035 (see Figure 5).



Economy		2005	2008	2015	2025	2035
China		752	967	1,429	2,039	2,557
India		208	256	391	721	1,212

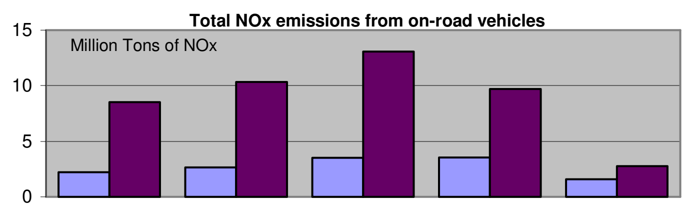
Figure 5 - Total CO_2 emissions (Well to Exhaust) from on-road vehicles

17. Expected changes in vehicle technology, however are manifested in the reduction of PM10 and NOx emissions over this period as evident in figures 6 and 7.



Economy		2005	2008	2015	2025	2035
China		732	839	922	392	115
India		241	268	326	271	147

Figure 6 - Total PM_{10} emissions from on-road vehicles



Economy		2005	2008	2015	2025	2035
China		8.5	10.3	13.1	9.7	2.8
India		2.2	2.6	3.5	3.6	1.6

Figure 7 - Total NOx emissions from on-road vehicles

18. Such considerable increases in the number of vehicles, congestion and consumed fuel threaten to severely limit the quality of life and economic growth of emerging Asia unless a different development scenario is applied in terms of on-road transport. A major effort will be required in emerging Asia, to promote the use of more efficient transport systems and fuel diversity to reduce this growth-induced pressure on both their national and metropolitan levels.

19. At the same time, as outlined above, the growing energy use by the transport sector is increasingly contributing to climate change which will have severe implications for low-lying areas in the region and will require substantial adaptation in many other areas.

20. None of these issues can be solved by one measure alone. A broad range of policies and actions with complementary co-benefits will be required to systematically address these energy efficiency and climate change concerns. The overriding rationale for most Asian countries at their national level will be energy security although the larger countries in emerging Asia are duly concerned about climate change; whilst at the metropolitan area, municipal and local levels it will be congestion, air quality and traffic safety.

D. Rationale for the private sector

21. Most of the investment in the transport sector in Asia and many of the actions required to reduce the climate change effects of on-road transport will be made by the private sector. Thus it is essential that a clear long-term signal is given of the way forward; with predictable and transparent regulations and policies. The analysis presented in this report indicates that policies and regulations for the transport sector in Asia can not be incremental in nature and that a paradigm shift is required in the thinking on mobility in Asia. Only by eliminating or reducing the risk associated with the paradigm shifts needed to systematically resolve all the problems associated with growing motorization will the private sector be in a position to invest and act in a timely manner and to the required extent.

II. TRENDS AND CHALLENGES IN ASIA

22. Emerging Asia is one of the most rapidly changing areas in the world and this directly impacts the global and local emissions from the region's on-road transportation.

A. Population growth and urbanization

1. Rapidly increasing growth in population and GDP in Asia

23. Of the approximately 6.5 billion people on the planet today, half live in emerging Asia (including India and China), compared with only about one-in-five that lives in the more developed regions[14]. By 2030 the world's population is projected to grow to around 8.2 billion people and the population of emerging Asia is expected to increase by more than 750 million (for a total of over 4 billion) (UN, 2004).

24. Economic and energy-demand growth (and GHG emissions) are tightly linked, so it is important to look at the region's expected growth in GDP. Emerging Asia's robust economic expansion is expected to continue with the rapidly expanding economies of China, India, Indonesia and Malaysia, leading emerging Asia to an average annual growth through 2030 of more than 5 percent. This will create a combined output that will approach that of Europe (IPCC, 2001). Such sustained high economic growth will be accompanied by rising incomes and

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[14] More developed regions comprise Europe plus Northern America, Australia/New Zealand and Japan (see UN definition of regions).

consumption[15]. The main engines of growth are expected to be China and India, which in 2006 are expected to have a growth of 9.2% and 6.6% respectively. India has been the second-fastest growing economy in the world over the last 15 years – after China -- and surpassed the US in 2005 to become the second most preferred economy in which to invest[16].

2. Population growth and uncontrolled urbanization

25. Whilst the population of China is expected to grow from 1.27 billion in year 2000 to 1.44 billion by 2025 (13% growth) its urban population is expected to increase from 35.8% (in 2000) to 57.2% (and combining the two effects gives an 81% growth in people living in cities). India's total population is expected to grow even more (37% from 1.02 to 1.40 billion) in the same period to almost match China and its urban population is expected to increase from 27.7% (in 2000) to 37.8% (combined 87% growth in people living in cities). The urban population of the other countries in emerging Asia is expected to double in the same time-span (UN, 2004). The future urban population growth in most Asian countries will drive increasing motorization and will have serious consequences for urban road congestion and air pollution as vehicle numbers continue to grow.

26. This overall urban expansion will be reflected in large city growth. Already, emerging Asia contains 10 of the world's 25 largest cities, and these are among the fastest growing[17]. Projected populations of the largest cities in emerging Asia in 2015 show four (Bombay, Shanghai, Jakarta and Karachi) in the 20-30 million range and a further nine cities with 10-20 million[18].

27. ADB has estimated that 80% of the region's new economic growth will be generated in its urban economies (Lohani, 2005a) since these provide the bulk of jobs and employment opportunities. A large number of their residents however will remain poor. About 70% (or 800 million) of the world's poor live in Asia and although poverty is widely considered to be a rural phenomenon, the incidence of urban and peri-urban poverty is significant and growing; about 240 to 260 million poor people in Asia reside in urban areas (Lohani, 2005b).

28. The rapid growth in urbanization in Asia has been to a large extent, poorly- or un-planned. Most Asian cities lack effective metropolitan-area land-use planning due to weak institutional capacity, lack of political will and overlapping or conflicting institutional mandates. They are inadequately prepared to design and achieve a city-wide urban development that reduces the travel demand whilst coping with this explosive growth. This has led to accelerating ad-hoc urban sprawl which together with the increase in purchasing power has generated a pressure for enhanced personal mobility which is being met by rapidly increasing motorization. In the case of emerging Asia this has often resulted in purchasing 2-wheelers, which provide cheap and readily-accessible personal mobility. These now dominate the vehicle fleet in terms of absolute numbers in almost all of the cities and countries in Asia.

29. With the historic emphasis on managing traffic growth rather than reducing travel demand, most Asian countries – with notable exceptions such as Singapore -- have not resolved how to internalize the externalities of personal transport – which is "subsidized" in the

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[15] Ifzal Ali, ADB's chief economist. Quoted on Sept 10 2005, Asia Times (2005).

[16] According to the AT Kearney FDI Confidence Index the ranking is 1-China, 2-India, 3-US. See: http://www.atkearney.com/main.taf?p=5,3,1,89

[17] WRI 1996

[18] World Bank 1998

sense that car owners (who are the minority in the population) do not pay the full cost of the resources they use or the congestion and pollution that they cause for the vast majority of passengers who have to travel by public transport. The impact of one person is small but when totaled across the population of vehicle-owners this presents considerable harm to society. This will only be resolved when urban growth is designed and managed in a way that promotes equity and improves access to goods and services whilst minimizing travel demand.

B. Transport Demand

30. Over the short term, the sensitivity of demand for vehicles to changes in GDP and in vehicle price is somewhat elastic as their purchase can often be delayed but in the long term it has low elasticity indicating that personal mobility is considered by many as essential to everyday living[19], and that it has few substitutes. In emerging Asia the price elasticity of demand for automotive fuel is slightly larger (in absolute value) than in the OECD countries, but even so, in the long-run it is inelastic (less than -0.6).In the short term, the sensitivity of gasoline demand to price tends to be very low (around -0.2) although in the longer term it may affect the decision of what size car to buy.

31. This indicates that fuel and vehicle taxation by themselves will have a less than direct impact on traffic demand (e.g.: a 10% increase in fuel prices may change the liters of fuel sold by less than 6% and vehicle-kilometers traveled by even less) and thus other measures are required as well to stem the tide of explosive growth in personal motorization and the externalities it produces.

32. There are several successful examples of transport demand management practices being enforced to shift at least part of the burden of pollution and congestion to those that produce it, but these have yet to be widely adopted.

33. The vehicle quota system in Singapore employs an open bidding process for certificates of entitlement (to own a vehicle); this is combined with a high initial registration cost (around 150% of the vehicles market value), annual road tax that increases with engine capacity and has a surcharge for older vehicles, and Electronic Road Pricing based on a spatial and temporal pay-as-you-use principle to control the movement of vehicles and ensure that congestion does not worsen. In other cities, road and congestion pricing programs, park and ride schemes and even parking fees may be used to control the movement of private motor vehicles to areas with high vehicle concentration like business districts to address congestion and access problems. At the same time this makes available an auxiliary source of funds for public transport improvements.

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[19] In developed economies the short-term price elasticity of demand for cars is around -1.2 to -1.5 whilst the long-term elasticity is around -0.2 and it is expected to be not very different in emerging Asian economies. Source: Lester D. Taylor, *Consumer Demand in the United States*, 1929-1970 (Cambridge: Harvard University Press, 1966,1970); Douglas R. Bohi, *Analyzing Demand Behavior* (Baltimore: Johns Hopkins University Press, 1981)

Shanghai's Comprehensive Transportation Plan[1]

Amongst major Chinese cities, Shanghai has one of the lowest ratios of cars to population even though it has one of the highest GDP per capita. This situation has been achieved through a deliberate effort by the municipal government to preserve the city's character and environment largely through the use of regulations, incentives, and fees. Under the current five-year plan, the policy to expand automobile ownership and use is coordinated at the national level and Shanghai is therefore in the process of adjusting its planning to allow for the implications of the expected population and motorization growth.

In 1992 a consortium of municipal organizations completed the Shanghai Comprehensive Transportation Planning system, SCTP1. Since then, the population and the state of motorization have changed as a result of the economic development policies. At the end of 2000 a revised plan, SCTP2, was announced, based on the second citywide transportation research survey in 1995 and a series of other commissioned studies.

These studies highlighted a series of specific problems with the current transportation system:

- The different travel modes within the public transportation system lack integration.
- Insufficient capacity of roads and rail network coverage.
- The public transport service level is low; because the roads are crowded, bus schedules lag (and compete ineffectually with bicycles and motorcycles) and the rail transportation system is not used efficiently.
- Traffic flow and environmental quality are not good. Pedestrians, bicycles, and autos are jammed together, resulting in high accident rates and worsening pollution, particularly from motorcycles.

SCTP2 will attempt to prepare Shanghai to meet the future challenges just described, and, in doing so, will adopt a focus that extends beyond the city center to the entire metropolitan area.

The passenger transport system will embrace four distinct public transport services. The rail system will be expanded, with a capacity ratio of rail transport to buses of 6:4. The road system will have three levels: city-wide freeway, town-wide artery, and interborough main streets. Traditional public ground transportation is expected to carry more than half of the passenger trips, serving short- and medium-distance passengers and those traveling to areas not covered by rail. Within the public ground transportation system, priority will be given to buses for parking, traffic flow, and passenger transfer nodes. To help limit congestion, the number of taxis will be controlled to reduce the vacancy rate from 50 percent to 30 percent. The role of ferries also will be reduced, with an emphasis on providing more service for bicycles. Finally, terminals will be built to facilitate passenger use of the multimodal system.

The road system is being designed specifically to increase the capacity of the downtown street area. New, radial arteries will serve the new suburban cities, airports, and industrial areas, with speed limits higher than on ring roads and internodal connectors, for both passengers and freight. Part of the road system will be designated for freight to expedite commercial activity without causing excess congestion of central areas. Bicycle lanes will be constructed, and an effective separation of motor vehicles and non-motorized vehicles will be maintained. Similarly, the pedestrian environment will be protected, with walk-signals and pedestrian malls in commercial areas. A new comprehensive parking system, with fees and space designed to limit auto traffic in the city center, will include public parking lots for the transportation nodes in the suburbs.

Perhaps most important, a traffic management system will be developed to manage the time distribution and space distribution of traffic flow, using methods such as land use management, toll fees, parking restrictions, information guidance for drivers, and restricted area policies. The goal will be to create a modern traffic environment suitable for an international metropolis. The Adaptive Signal Timing System will be expanded and improved. A major feature of the new system will be an Intelligent Transportation System (ITS) based on information technology. The main information resources of the ITS will include real-time traffic flow, socioeconomic information, parking availability, vehicular traffic, freight traffic, police status, and a basic geographic information system. The ITS will enable the Shanghai authorities to monitor and respond to changes in the vehicle population and patterns of use, to employ new roads and other facilities rapidly after they are placed in service, and to evaluate continually the effectiveness of the transportation management system to provide optimal service at all times.

Safety will be a primary goal of the traffic management system, and safeguards for pedestrians and bicycles will receive high priority. Among the measures being considered are designating exclusive lanes for buses in the downtown area, controlling the emissions and noise of motor vehicles, separating motor vehicles from non-motorized vehicles and pedestrians from vehicles, optimizing signal time slots to reduce the emissions caused by deceleration and low speed, reducing the traffic accident frequency, strengthening inspection requirements for vehicles and roads, and accelerating the replacement of old, poor, and damaged cars to improve the overall standard of Shanghai's road transportation system.

[1] Source: Lu Ximing Shanghai City Comprehensive Transportation Planning Institute, reported in "Personal Cars and China" Committee on the Future of Personal Transport Vehicles in China, National Research Council, National Academy of Engineering, Chinese Academy of Engineering, 2003

C. Motorization

34. As the per-capita income of urban dwellers in Asia increases in real terms, vehicle ownership likewise will increase and generally follow a similar path to that taken by developed countries except that Asia has a higher percentage of 2-wheelers than in most developed markets (see Figure 8). The ten countries in the world with the highest private-vehicle future demand index are in Asia including China, India, and Indonesia, three of the world's four most populous countries[20].

35. Consumer demand for personalized transportation – of which the 2-wheeler is providing an initial low-cost rung which in most Asian countries accounts for 50-80% of the vehicle fleet – will drive global sales as the ability to afford rises to match the desire to buy. Increasing individual mobility for the middle-class groups will make it particularly difficult to achieve the paradigm shift towards greater use of mass-transport without substantial governmental intervention. This highlights the danger that many countries in Asia will have difficulty in replicating the growth track in mobility that many European nations have been able to adopt which is more focused on well developed mass public transport systems whilst in other countries, such as the USA, Canada and Australia high-growth personal mobility is the norm. Singapore is a good benchmark for other Asian countries; it has demonstrated through an integrated and comprehensive approach the benefits of a long-term commitment to reducing the need for personal motorized transport.

36. International experience suggests that at the current and future income levels in emerging Asia, car and SUV ownership rates are likely to grow much faster than GDP and start to displace 2-wheelers[21]. Motorization in Asia is rising very rapidly with some countries' 4-wheeler[22] fleets doubling every 5 to 7 years. Emerging Asian countries are expected to integrate an additional thirty-five million vehicles (excluding 2- and 3-wheelers) into their fleets between 2006 and 2009 with China alone accounting for around 80% of that increase.

37. SUVs in Asia show an increasing market share, offering the key benefits of luxury cars – prestige/status, interior space and comfort, protection/safety through a combination of size and road presence not afforded by other vehicles. SUVs also offer practical benefits with the ability to handle poor road surface conditions. Unfortunately from an energy efficiency point of view, SUVs weigh more than cars and often have higher air and rolling resistance which all have a detrimental effect on fuel economy and hence GHG emissions. In the US, the market preference for SUVs has led to worsening fleet average fuel economies despite the fuel economy improvements made to individual vehicles.

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[20] This index measures the relationship between current ownership levels and future intentions to purchase a vehicle, highlighting countries of high future demand. The 10 highest in order were: China, Indonesia, India, Thailand, Korea, Hong Kong, Philippines, Malaysia, Singapore and Taiwan; Source: Asia Leads Global Car Ownership Aspirations, Midori Matsuoka, Director, ACNielsen International Research, ACNielsen online survey 2004 published 2005.

[21] Particularly between $3,000 and $10,000 of GDP per capita in PPP terms.(International Monetary Fund February 2006 IMF (India) Country Report No. 06/56)

[22] Cars and SUVs (plus pickups used as personal transport in the US)

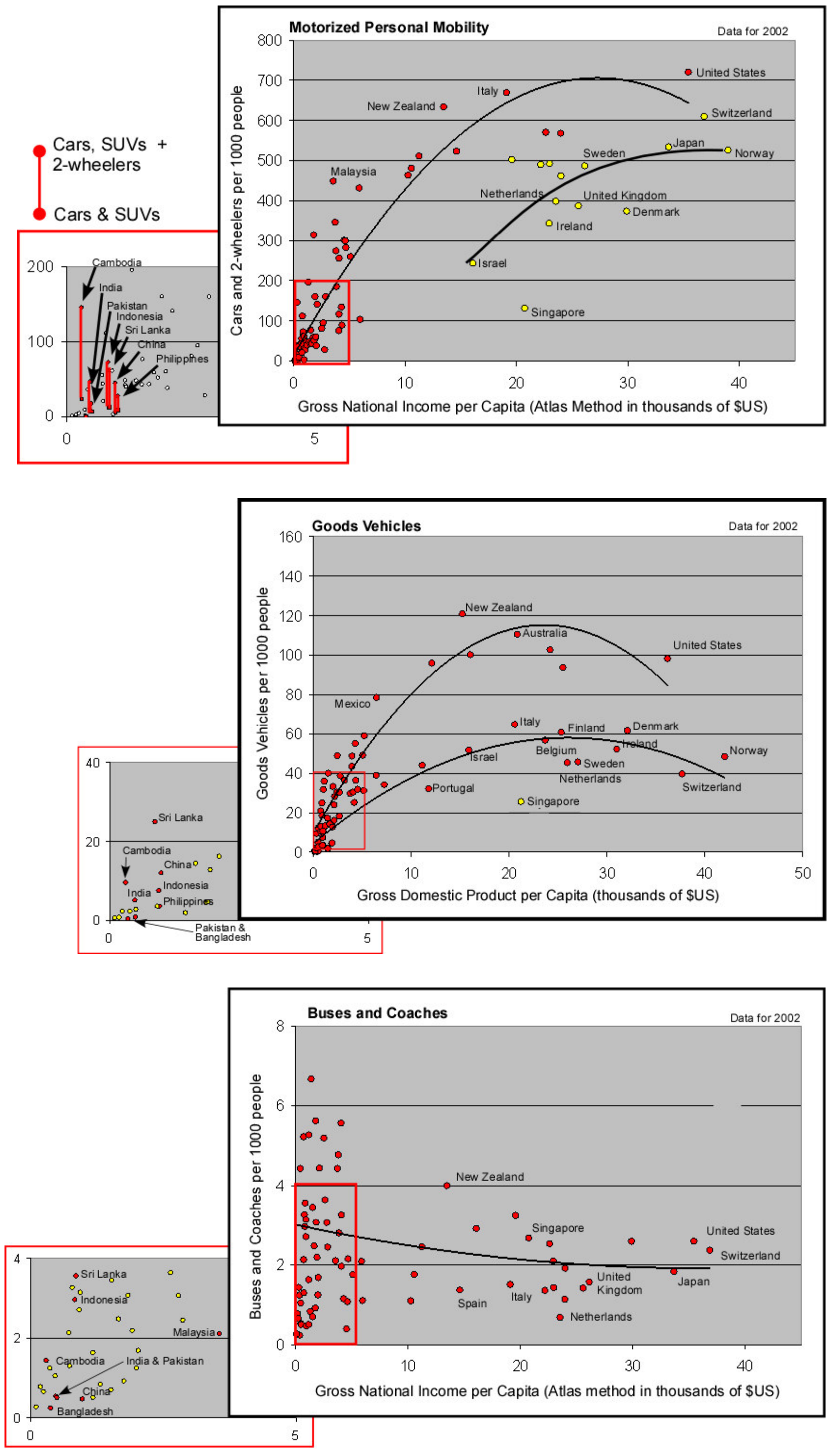

Figure 8[23] – Cars, SUVs and 2-wheelers, Goods vehicles and Buses per 1000 people

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[23] Country GDI, GDP, and population are from World Bank's World Development Indicators Database (2002), Total motor vehicles and passenger cars are from the International Road Federation database (2004) complemented by vehicle inventory data from individual countries

38. The number of personal vehicles for every 1000 people in Asia currently remains modest. For example, about 45 vehicles per 1000 persons in China (of which less than 10 are 4-wheelers) versus 530 per 1000 persons in Japan (of which 430 are 4-wheelers). The sheer size of Asian countries like China and India can however lead to a situation that in a relatively short period of time China and later also India will have vehicle fleet numbers comparable to those of the USA (see Figure 8). This combination of accelerating incomes, urban growth and accelerating vehicle ownership, if left unchecked runs the risk of severely constraining the future economic advancement of Asian cities and economies.

39. Diesel vehicles in Europe have grown from 14% of sales in 1990 and now account for 44 percent of all cars sold[24] and dominate the new luxury vehicle market with a similar tendency occurring with SUVs in emerging Asia. China and Malaysia are the only markets in emerging Asia where diesel currently has a noticeably lower penetration[25].

40. For goods vehicles (short plus long-haul) a similar situation exists; China and India report 12 and 5 goods vehicles per 1000 people respectively and run the risk of climbing the high-growth curve shown in Figure 8b. Freight in Europe has historically kept to the lower growth-rate curve mainly due to the modal share of rail and shorter distances, however this is now changing; rail's modal share in Europe is dropping, as supplier and distribution networks are increasing and the largest growth in fuel use for on-road transport is expected to be from trucks and by 2010 the fuel demand for trucks is forecast to exceed that of cars and motorcycles[26]. As before, Singapore is a benchmark. In emerging Asia, as GDP increases, supplier and distribution goods transport requirements will also increase to include greater geographical coverage, requiring a marked efficiency improvement from for-hire carriers and wholly-owned fleets. In many of these countries, legislative reforms and highway construction are accelerating, but need to accelerate further to promote the more efficient operation and lower GHG emissions – on a ton-km basis -- of larger, high capacity trucks and highway tractor-trailer combinations which historically have been absent from their goods-vehicle fleets to replace the standard 10-15 ton truck traditionally used in most of emerging Asia.

41. For buses and inter-city coaches, China and India both report less than 1 bus per 1000 people. The context for public transport in Asia is complicated by the large number of public transport vehicles which are specific for Asia and the developing countries. These include motorized 3-wheelers[27] of which there are hundreds of thousands in countries like India, Pakistan, and Philippines. In 2004, India had over 3 million 3-wheelers in service, mostly with gasoline 2-stroke (61%) followed by 4-stroke (24%) and diesel (15%) engines. The Philippines has over 1 million tricycles which are motorcycles equipped with a side car for the transport of passengers and goods. Figure 8 does not transmit the fragmented nature of mass transport in emerging nations; it does not include these motorized 3-wheelers or the custom build vehicles found throughout the region[28].

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[24] The Car Connection Website Auto News (www.thecarconnection.com)
[25] Keiko Hirota of the Japanese Automobile Research Institute
[26] DG Tren, 2003; "EU25 – Energy & Transport Outlook to 2030"
[27] Three-wheelers include small taxis such as autorickshaws in India, and Sri Lanka and baby taxis in Bangladesh – usually for carrying three passengers
[28] Such as the jeepneys in the Philippines, Tuk-Tuks in Thailand and Bemos in Indonesia

D. Impact on climate change and local emissions

1. Greenhouse Gases

42. From 1990 to 2002, the total combined CO2-equivalent emissions of China, India and emerging Asia grew from 37% to 48% of the OECD total, with the major growth component coming from China (see Figure 9).

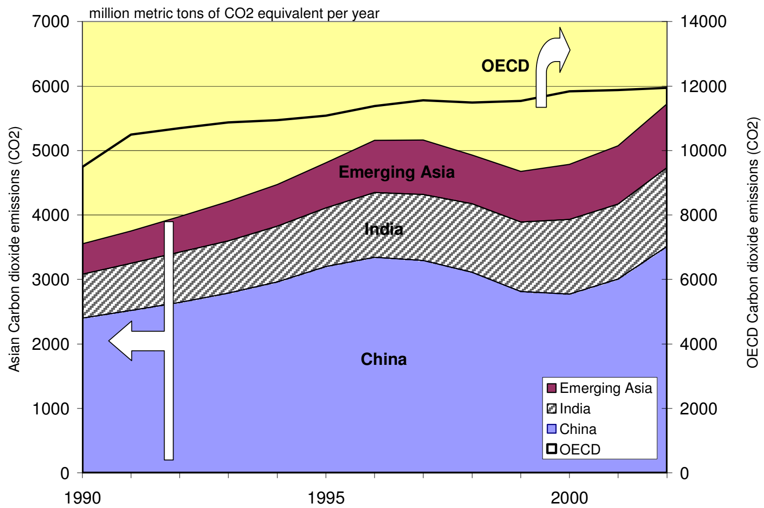

Figure 9 - Total energy sector CO_2-equivalent emissions of China, India and emerging Asia

(Note: China, India and emerging Asia relate to the scale on the left-hand side of the graph and OECD relates to the scale on the right-hand side)
Source: Millenium Indicators (CDIAC) 2005

43. Energy use in the transportation sector is currently dominated by petroleum product fuels and is growing fast. From 1990 to 2002, the combined CO_2-equivalent emissions from the transportation sector in emerging Asia grew faster than in developed economies going from 6% to 17% of the OECD total in only 12 years (see Figure 10).

44. This rate of growth is accelerating; if Asia were to follow the EU lead, and adopt similar improvements in car fuel economy as planned for the EU[29], it can be expected that with the emerging Asia fleet increasing in size more than five times by 2030, and assuming efficiency gains and favorable changes in fleet mix this would still result in a fuels and GHG emissions growth of at least three times the 2000 levels[30] . Such a decrease in the rate of growth might appear as a favorable development, but it needs to be realized that the tripling in 2000 levels does not compare well to the EU and the Japanese Kyoto commitment for the same period, which is to *reduce* GHG emissions to 1990 levels. However it is likely that the EU will not reach their target, citing as the overarching reason their high growth in GHG from transport.

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[29] It is expected that the fuel economy benchmark for 2012 is expected to be 27% better than 10 years earlier (European Federation for Transport and Environment, 2006))

[30] Source calculated from IEA/SMP Reference Case Projection, L. Fulton, IEA / G. Eads, CRA; July 2004, however current projections from China and India give higher numbers

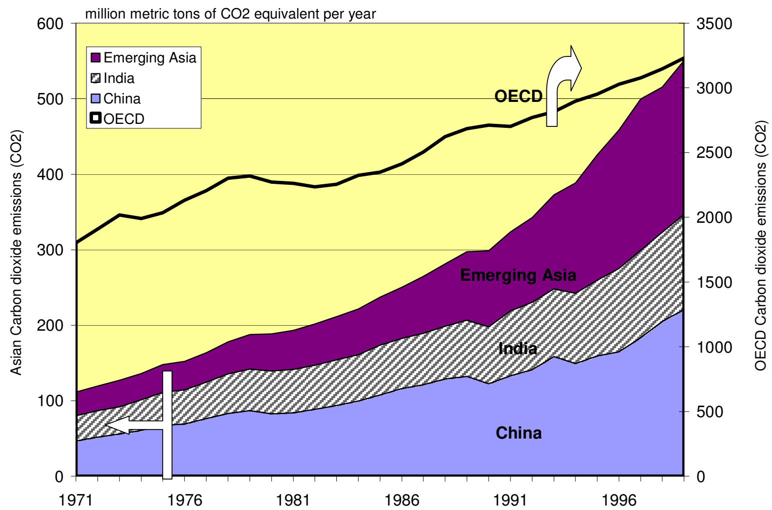

Figure 10 - CO_2-equivalent emissions from transportation in China, India and emerging Asia

(Note: China, India and emerging Asia relate to the scale on the left-hand side of the graph and OECD relates to the scale on the right-hand side)

Source: Energy Balances of OECD Countries (1960-1999) and Non-OECD Countries (1971-1999) Energy Statistics Division (ESD) of the International Energy Agency (IEA)

45. The growing number of private vehicles is a key determinant for fuel use and consequently GHG emissions. Some efforts have been made to improve the fuel economy by issuing fuel economy standards. In the EU a voluntary agreement with the association of vehicle manufacturers (ACEA) set a GHG standard for 2002 of 165 g/km CO2. This was achieved with diesel fuelled vehicles being on average10% lower in GHG emissions than gasoline (155 vs. 172 g/km CO2). The agreement set a standard of 140 g/km CO2 for 2008 with a possible extension to 120 g/km CO2 for 2012.

46. Japan also has already made a significant improvement in its fleet average fuel economy between 1995 and 2002 to tighter levels than the EU and is now in a process of proposing stricter fuel efficiency standards. Assuming no change in the vehicle mix, these targets imply a 23 percent improvement in 2010 in gasoline passenger vehicle fuel economy and a 14 percent improvement in diesel fuel economy compared with the 1995 fleet average of 14.6 km/L. According to the Japanese government, this improvement will result in an average fleet fuel economy of Japanese vehicles of 35.5 mpg by 2010.

47. In the US, the CAFE[31] program, which was established in1975 with the goal of reducing the country's dependence on foreign oil, maintains an important distinction between passenger cars and light trucks, with each having their own standard. This distinction was originally included when light trucks were a small percentage of the vehicle fleet but with the increasing popularity of SUVs this has changed. The CAFE standard for passenger cars has remained constant since 1985 at 27.5 mpg whilst the standard for light trucks has recently been increased from 20.7 mpg in 2004 to 21.0 mpg for 2005[32]. The law also allows special treatment of vehicle fuel economy calculations for certain groups of vehicles. The overall result has been a 7 percent

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[31] Combined Average Fuel Economy

[32] Further standards of 21.6 mpg for 2006, and 22.2 mpg for 2007 are also established

decrease in the light-duty fleet fuel economy since 1988, associated with the rapid growth of light trucks used as passenger vehicles (Feng et al., 2004),

48. Most of the emerging Asian nations, however, with the marked exception of China, have not implemented fuel economy standards and in many countries the increase in average vehicle weight due to the desirability of SUVs – and the move from 2-wheelers to cars -- increases the difficulty of improving economy

49. Despite its large and growing contribution to overall GHG emissions, transportation is a sector where the least progress has been made in addressing cost-effective reductions. It is one of the last major sectors considered under the Global Environment Facility (GEF) and only one transport project to date has sold carbon bonds through the UNFCCC Clean Development Mechanism (CDM)[33]. All incremental actions in these fields should help to improve (reduce) the high growth perspective currently envisaged.

2. Local pollutants

50. Many of the cities in Asia face problems with urban ambient air quality. In most cases, the transport sector is one of the most significant contributors to air pollution and tends to be geographically concentrated and particularly damaging at street level, where people live and work including the poor and vulnerable groups such as the young and elderly who have limited mobility (ADB, 2003).

51. Pollutants of main concern are particulate matter (PM), especially ultra-fine particles, nitrogen oxides (NOx), and hydrocarbons (HC). Increasing NOx levels contribute to an increase in ozone levels. An ongoing study[34] by the Clean Air Initiative for Asian Cities, summarizing air quality data from 20 cities in Asia shows that, on average, there has been a moderate to slight decrease in pollution levels for PM_{10} over the last decade (see Figure 11).

[33] This is the Mexico City BRT Pilot corridor where an Emissions Reduction Purchase Agreement (ERPA) was signed in 2005 with the Spanish Carbon Fund.

[34] See CAI-Asia, 2006 “Air Quality in Asian Cities” and “Ambient Concentrations of Pollutants and Trends of SPM, PM10 and SO2 in Selected Asian Cities”

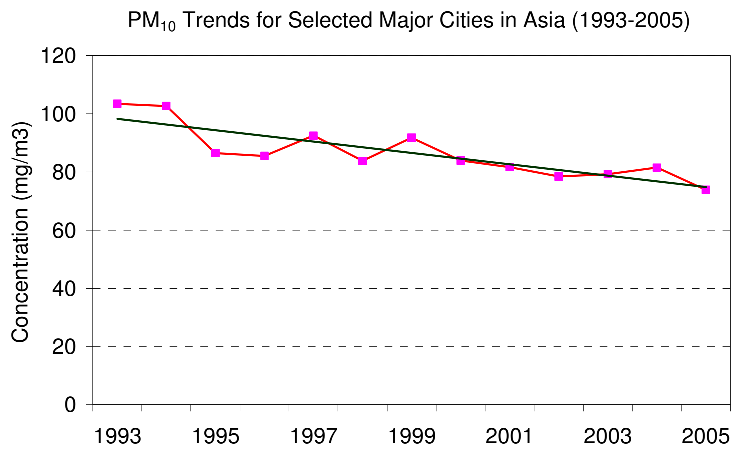

Figure 11 – PM_{10} Trends for Selected Major Cities in Asia (1993 – 2005)

52. There is an increasing burden of evidence that demonstrates the high impact of local pollution on the environment and human health. Ultra-fine particles, such as those emitted by un-controlled diesel vehicles, have been shown to have significant health impact costs and that there are insignificant differences between regions[35]. A pooled estimate of 39 studies (Borja-Aburto et.al. 2000) showed a weighted estimate of 1.01 percent increase in general, non-accidental mortality for each 10 µg/m3 increase in PM_{10}[36].

53. The costs of vehicle-generated air pollution are significant (Lohani, 2005b) and likely to increase if the growth in the vehicle fleet is faster than improvements in average in-use vehicle emissions.

3. Vehicle, engine and fuels technology

a. New vehicle technology

54. Vehicle, engine and fuels technologies are currently available to substantially reduce emissions and in many developed countries local emissions and air quality are not now considered as problems.

55. All the countries in emerging Asia now sell unleaded gasoline[37] which has enabled vehicle emissions technology changes (such as catalytic converters) to be implemented. This rapid elimination of leaded fuel is one of the success stories in Asia which demonstrates how rapidly effective policy changes can be brought about.

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[35] A review of Asian health impacts studies conducted as part of the CAI-Asia Public Health and Air Pollution in Asia Program concluded that the Asian response to air pollution in terms of health impacts are largely the same as in Europe and the USA. See Health Effects Institute special report # 15 and the Pan-American Health Organization's report found in Epidemiology: Volume 16(5) September 2005 p S111

[36] With a 95% confidence interval of 0.83-1.18 percent change for each 10 µg/m3 increase in PM_{10}

[37] Indonesia continues to sell both leaded and un-leaded fuel.

56. In gasoline vehicles there is a clear global consensus on how to obtain very low emissions levels (advanced three-way catalysts with sophisticated electronic controls for spark timing and air-fuel management) together with the elimination of 2-stroke engines. The EU is combining the move to ever-stricter emission limits with a voluntary agreement with vehicle manufacturers to improve the fuel economy of light duty vehicles, however the implementation of similar technology changes in many countries in emerging Asia is slow.

57. Several countries in emerging Asia Countries have no formal fuel quality or vehicle emissions road maps in place. These include Pakistan, Bhutan and Cambodia.[38] Others, like the Philippines, Indonesia and Viet Nam have developed road maps for EURO II[39] but have not yet finalized the way forward to EURO IV. China will move to EURO IV In 2010 and India will reach EURO III nationwide although both have prior introduction in major cities[40]. Thailand and Malaysia both reach EURO IV light duty standards in 2009. So far only Hong Kong has indicated that it is considering the adoption of Euro V standards. China is the only country in emerging Asia that has implemented fuel economy standards.

58. Diesel vehicles, which traditionally have been seen as part of the problem particularly due to visible exhaust smoke and high ultra-fine PM emissions, are rapidly becoming an integral part of the solution when advanced standards are introduced following the availability of ultra low sulfur diesel, which generate emission levels comparable to the best gasoline engines and with a higher fuel economy level. Diesel-powered cars and SUVs are achieving 20-40% better fuel economy with lower GHG emissions than their gasoline powered equivalents.

59. Many new vehicle technologies also contribute to improvements in GHG emissions; reducing vehicle weight and aerodynamic drag with new structure design and materials, smaller engines, light-duty hybrids, low rolling-resistance tires, low friction lubricants, idle-stop features and advanced air conditioning technology are all leading to improvements. The limits to the higher fuel economy performance of light duty vehicles in the EU (with fleet-average GHG emissions of less than 140 grams of CO2 per km[41]) is seen to be currently defined by the restricted acceptance amongst consumers of the smaller, lighter cars. Long-term innovations are envisaged such a hybrid heavy-duty vehicles, alternative fuels and the use of hydrogen fuel cells that will achieve important improvements in per-vehicle GHG emissions.

[38] Source: CAI-Asia, 2005
[39], The EU adopted EURO- II, III and IV standards for light duty vehicles in 1996, 2000 and 2005 respectively and will go to EURO V in 2008.
[40] Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad and Ahmedabad have EURO III standards since 2005 and Beijing will adopt EURO IV in 2007
[41] This is equivalent 18.8 km/L for a gasoline vehicle on the US Combined Average Fleet Économy (CAFÉ) test cycle

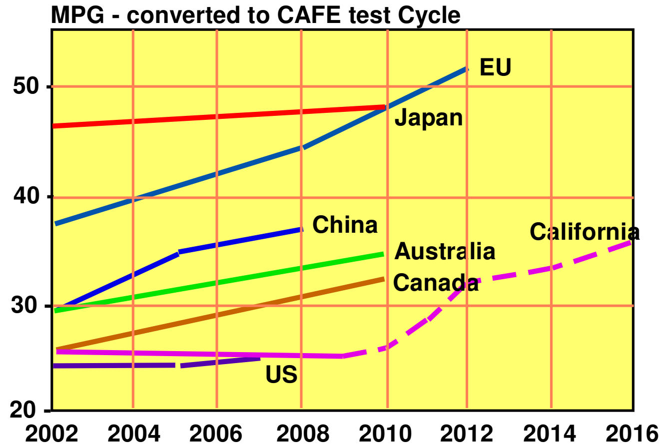

Figure 12 - Comparison of fuel economy and GHG emission standards normalized by CAFE-converted mpg

Source: Feng, et.al. 2004

60. This combination of engine and vehicle technology has allowed several countries to enact fuel economy and GHG emission standards. Figure 12 shows that the European Union (EU) and Japan have the most effective light vehicle fuel economy standards followed by the new PRC standards. The impact of these standards is relatively small at first but grows significantly as the new-technology vehicles replace older vehicles in the in-use fleet.

61. Air conditioning systems in vehicles are particularly prone to leakage and most use a hydrofluorocarbon called R-134a which has a GHG warming potential 1,300 times more potent than CO2. By 2010 the use of R-134a is expected to contribute more than 4% to total GHG emissions[42]. Recognizing this, the EU published a new regulation this year to phase out the use of R-134a in new cars beginning in 2011. It is likely to be replaced with other hydrofluorocarbon refrigerants with lower warming potentials or new technology, possibly employing CO2 as a refrigerant (Fairley, 2006).

62. The EU has not placed the same emphasis on reducing emissions from motorcycles[43]. As of 2006 all new motorcycles in the EU have to meet EURO III limits which can be achieved quite easily with current automotive technologies, such as fuel injection systems and catalytic converters. Even when these most stringent of currently agreed requirements are applied, motorcycles will be required to reach EURO III emission standards whilst passenger cars are already on the stricter EURO IV.

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[42] This impact rises to 7% if the extra fuel consumption due to the use of Air Conditioning is included.

[43] Although motorcycles are not a major means of transport in most of Europe, Global annual motorcycle production in 2003 was around 30 million units according to JAMA Motorcycle Industry New Year's Discussion, (JAMA, 2006.)

Vehicle Fuel Efficiency Standards in China[1]

In recent years, the fast economic (GDP) growth of China coupled with the need to activate internal consumption has fueled a rapid expansion of the Chinese vehicle fleet. In 2005, China had an active population of around 32 million vehicles (of 4 or more wheels) plus 57 million 2- and 3-wheelers. Over the coming 20 years the vehicle population is expected to grow by almost 5 times to 183 million plus 194 million 2- & 3-wheelers[2]. This growth will cause vehicle fuel consumption to increase substantially and cause major fuel security, traffic congestion and pollution concerns.

China is a country with scarce oil resources and became the net oil importer in 1993. The domestic supply of crude oil is stable at about 160 million metric tons per year but is expected to drop within this 20 year period whilst on-road transportation, by itself, could be expected to require around 300 million metric tons by 2025 unless a systematic control strategy is put in place to correct this tendency.

The government decided in 2002 to establish a framework including government cooperation, research team and international support to develop vehicle fuel efficiency standards and regulations. After two year of studies and negotiations, the first fuel efficiency standard – Fuel Consumption Limits for Light Duty Passenger Vehicles was published on September 2, 2004, for implementation as of July 2005. The main goal of this regulation was to help control the national total oil consumption to less than 400 million metric tons per year.

The components of the vehicle fuel efficiency standard were (i) the development of weight-class based maximum fuel consumption standard; (ii) An overall per-distance fuel consumption reduction of 15%; and (iii) a more stringent standard for heavier vehicle classes to prevent a shift to heavier vehicles and to encourage the use of economic compact cars. The first phase of the standard, targeting a reduction of 5% in per-distance fuel consumption was implemented in 2005, and a second phase, with a goal of 10 percent reduction in fuel consumption for each weight category in 2008. Figures 1 and 2 show the final standards for manual transmission (MT) and automatic transmission (AT) light duty vehicles respectively. This Chinese standard is more stringent than the US standard given that the limits are maximum values instead of average values and that the phase two standard is for 2008 model-year vehicles. However the technical requirements of this standard are not as stringent as those of the EU or Japanese standards.

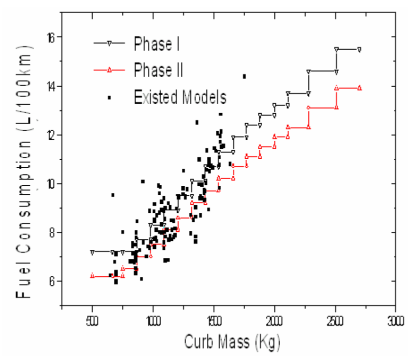

Figure 1 Fuel consumption standards for MT Cars

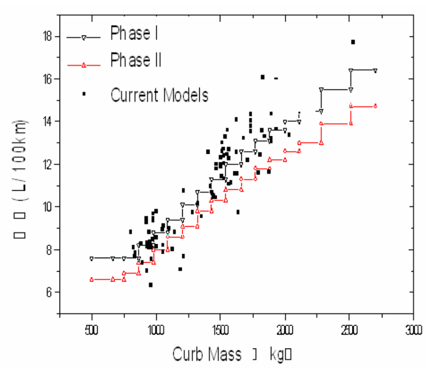

Figure 2 Fuel Consumption Standards – AT Cars, SUVs, and 3+ Rows Minivans

With the implementation of this fuel economy standard, it is forecast that 13 million tons of fuel will be saved in 2020 and 31 million tons in 2030. However more stringent fuel economy standards need to be put into force after 2009. A further reduction of 25% in vehicle fuel consumption to 5.6 L/100km (the European requirement for 2008) should be established by 2012 for light-duty passenger cars and a fuel consumption level of about 4.8 L/100 km should be developed to catch up with Europe and Japan by around 2016. If this were implemented, an additional 19 million tons oil would be saved in 2020 and 60 million tons in 2030.

[1] Sources: Chinese policy practice in developing vehicle fuel efficiency standard by Professor HE Kebin and Ms. LIU Huan, Ms. Zhang, and Mr. YAO Zhiliang, Tsinghua University, China
[2] Vehicle population forecast for 2025 developed by SegmentY plc (see www.segmenty.com)

63. Both China and India have adopted strict limits for motorcycles with 1.5 g/km (HC + NO_x)[44]. These limits are causing 2-stroke engines to phase out due to difficulty in meeting the standard without a catalytic converter. In 2003, 91% of the production of motorcycles in China was already 4-stroke[45]. India will go to a limit of 1.0 g/km (HC + NOx) in 2008/10 which will require further technological improvement[46]

64. The lower capacity motorcycles which dominate the Asian market have a clear advantage in GHG emissions which tend to be less than half those of small cars since substantial development has taken place focused on improving their fuel economy even though their emissions performance generally lags behind that of the EU (BMF, 2003).

65. There has been substantial development of 3-wheeler engines towards gaseous fuels. Cities like Delhi and Dhaka have banned 2-stroke 3-wheelers giving substantial advantages both in local pollutant and GHG emissions[47].

66. The major lessons learnt from the past twenty-five years highlight the advantages of reducing the implementation lags in introducing tighter standards as much as possible. It can be seen that emerging Asia is catching up in terms of technology standards but still has a lag of 5 or more years in most countries and vehicle segments compared to the EU. Since improvements in emissions performance and fuel economy are being developed in parallel particularly in the EU and Japan, local air quality and climate change both can benefit from a rapid incorporation of new technology and from other measures that promote fleet renewal. The expected high growth in light duty Asian fleets assists in this per-vehicle improvement although the near-term vision is not so clear for heavy-duty fleets.

b. Diesel

67. As diesel emission standards ramp-up to technologically demanding levels the sulfur concentration in the fuel needs to be progressively reduced. The EURO III and IV intermediate standards require better than 500 ppm and 50 ppm sulfur content respectively. The major emissions advances occur however with the introduction of ultra-low sulfur fuel (<10 ppm) which allows advanced exhaust after-treatment devices to be used that can reduce emissions by up to 95%.[48]

68. It is argued by many[49] that the considerable investment required to equip refineries and fuel distribution systems to be able to deliver diesel with these low levels of sulfur can be reduced by leapfrogging directly to the ultra-low levels. Even though the required investment is high, in the USA context and following US accounting practices, the ratio of benefits to costs ranged from 5:1 to 40:1. In China a ratio of benefits to costs ranged from 7:1 to 22:1 over a time frame of 2020-2030 with small positive net benefits even in 2010[50].

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[44] However the drive cycle is different between the two countries. The limits as of 2005 for 3-wheelers in China is 1.9 g/km (HC + NO_x)

[45] Dr. Prof Fu, Lixin, Tsinghua University, Beijing China, May 2004, Hanoi

[46] N.V. Iyer, Adviser (Technical), Bajaj Auto Ltd, Pune, India

[47] Approximately 16% of the Indian 3-wheeler market consists of 4-stroke CNG fuelled units.

[48] Europe (EURO V) has chosen slightly less stringent emissions standards than the US and by using mainly selective catalytic reduction (SCR) techniques are further improving diesel fuel economy and GHG emissions.

[49] M. P. Walsh, ICCT and Enstrat, 2003 (Cost of Diesel Fuel Desulphurisation for Different Refinery Structures Typical of the Asian Refining Industry),

[50] Sources: Cost Benefit Analysis of Low Sulfur Fuels, Katherine Blumberg, ICCT, Partnership for Clean Fuels and Vehicles, November, 2005

c. Biofuels

69. Internal combustion engines will continue to be the dominant on-road transport power source in 2030, using mostly liquid fuels. Within the range of liquid fuels, biofuels provide the best option to reduce the GHG footprint of transport fuels by replacing a significant share of these fossil fuels[51].

70. The principal biomass-derived liquid fuels commercially available today and suitable for road transport are ethanol -- for spark ignition (gasoline) engines -- and vegetable oil-based diesel substitutes for compression ignition (diesel) engines. Ethanol is derived primarily from corn (United States) and sugar (Brazil), but can also be produced from sugar beets and wheat. The diesel substitutes are made from a wide range of vegetable oils (e.g., rapeseed, soy, palm, coconut and jatropha) to fuels that are completely compatible with fossil diesel fuel, both as a mixture of any fraction and in pure (neat) form[52]. Fuel additives are also produced from biomass; Bio-ETBE (Ethyl-tertio-butyl-ether) produced from bioethanol and Bio-MTBE (Methyl-tertio-butyl-ether) produced from biomethanol are used as additives to increase octane rating of gasoline and to reduce knocking.

71. Whilst biofuel programs started over 3 decades ago in a few countries, it is only recently that they gained broad based interest, this mainly due to the increase in oil prices and governmental incentives making investments profitable and to address national foreign exchange, fuel diversification and security concerns. In 2004, 33 billion liters of ethanol were produced accounting for about 2% gasoline production worldwide[53]. 2.2 billion liters of biodiesel (accounting for around a third of one percent of worldwide diesel production) were also produced that year principally in Germany, France, and Italy with small amounts in the Philippines and Malaysia[54].

72. “Second generation” biofuels are now being developed from a wider range of feedstock that increase the fraction and reduce the cost of the avoided CO_2 by utilizing biomass fractions that are presently discarded and making the best use of the whole plant. Figure 13 and 14 show the current and next generation of liquid biofuels for substituting gasoline and diesel as transport fuels, together with their principal feedstocks and conversion processes, net energy balances, and GHG emissions reductions. Since different amounts of energy are used in producing a bio-fuel to a petroleum based fuel, a life cycle analysis (LCA) must be used to compare the net GHG emissions performance of different fuels.

73. The present production of ethanol from corn in the US yields limited GHG savings[55], but these savings could be increased if biomass residues from corn production are used for heat

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[51] Source: “Biofuels in the European Union a vision for 2030 and beyond”; Final draft report of the EU Biofuels Research Advisory Council

[52] These are principally vegetable methyl esters (VME); in some countries (e.g., UK), waste oils and greases are used to produce biodiesel fuel.

[53] 15 billion liters of ethanol from sugar cane in Brazil, 13 billion liters from corn in the United States, 2 billion liters from China, 0.2 billion liters from Thailand and the rest from other countries compared to gasoline worldwide production in 2004 of 1,200 billion liters.

[54] Respectively from coconut oil and palm oil

[55] Up to about 13% according (Farrel , 2006)

and power generation in the ethanol production process[56]. Prof. Eric Larson of Princeton University in the GET STAP report concluded "Very broadly, grain or seed-based biofuels (e.g., corn ethanol or RME) might give 20-30% GHG reductions per vehicle-km relative to petroleum fuels, sugar beets might give 40-50% reductions, sugarcane (average SE Brazil) gives 90% reductions, future advanced cellulosic conversion (to ethanol, FT, or DME) from perennial energy crops might give 80-90+% reductions. Biofuels production with carbon capture and storage (a longer-term option) will give >100% reductions."

74. In Asia there is increasing investment in new biodiesel production capacity with coconut oil, palm oil, and jatropha as feedstock. The Philippines has a commercial coco biodiesel (coco methyl ester) industry producing the equivalent of about 1% of diesel fuel use (Karunungan, et.al. 2005), and Malaysia is gearing up for increased production of palm oil and the development of a palm oil biodiesel production capacity. However, it is likely to be several decades before a strategically important share of liquid fuels for road transport can come from biofuels, and that assumes that the economic and policy signals are supportive of production and use of these fuels.

Figure 13 - Bioethanol for replacing petrol: a Climate Change Perspective

Feedstock	Production Status and Regions	Current life cycle GHG Emissions reduction relative to gasoline	Biofuels yield per hectare	Costs	Net energy balance
Grains (wheat, maize)	Large-scale & commercial (US, Europe, China)	None to moderate with maize but improvements possible	Moderate	Moderate	Currently low
Sugar beets	Large-scale & commercial (Europe)	Up to 50%	Moderate	Moderate	Currently low
Sugar cane	Large-scale & commercial (Brazil, India, Thailand)	Brazilian ethanol has highest GHG reduction (92%) and lowest cost. Biomass energy used in the production process.	High	Low	Medium
Ligno-cellulosic biomass	"Next Generation" bio-fuel. Pilot plants in Sweden, Spain, Denmark	High; 70 – 90% estimated; can be close to 100% in principle	High	High	High (expected)

Source: IEA, 2004

[56] The reduction achieved by using corn-based E85 is only moderate because (1) significant amounts of GHG emissions are generated during corn farming and in corn ethanol production plants; (2) diesel fuel, LPG, and other fossil fuels are consumed during corn farming; (3) a large amount of nitrogen fertilizer is also used for corn farming, and manufacture of nitrogen fertilizer and its nitrification and denitrification in cornfields produce a large amount of GHG emissions; and (4) usually, NG or coal is used in corn ethanol plants to generate steam.
Source: Norman Brinkman, Michael Wang, Trudy Weber and Thomas Darlington. "Well-to-Wheels Analysis of Advanced Fuel/Vehicle Systems — A North American Study of Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions". (May 2005).

Figure 14- Biodiesel fuels for replacing diesel: a Climate Change Perspective

Feedstock	Production Status and Regions	Current GHG Emissions reduction relative to petrodiesel	Biofuels yield per hectare	Costs	Net energy balance
Oil seeds (rape, soy)	Medium-scale, mature and evolving (US, Europe)	78% reduction (soybean base), 40 – 60% for rape	Low	Moderate	3.2 for soy biodiesel vs. 0.8 for petrodiesel
Coconut oil to CME	Medium commercial (Philippines)	No LCA has been conducted yet (Expected to be moderate)	Moderate to High	Low-moderate	LCA needed
Palm oil	Small-scale, commercial (Malaysia, Indonesia)	No LCA has been conducted yet (Expected to be moderate)	Moderate to High	Low-moderate	LCA needed
Jatropha	Pilot-scale, pre-commercial (China, India)	No LCA has been conducted yet (Expected to be moderate to high)	Moderate to High	Low-moderate	LCA needed
Biomass to liquids	"Next Generation" bio-fuel. Fischer-Tropsch biodiesel pre commercial (Demo plants in Germany and Sweden)	High (IEA)	High	High	LCA needed For many combinations

Source: IEA, 2004

d. CNG and LPG

75. **Natural gas** is a mixture of hydrocarbons, mainly methane (ca. 90% CH_4), with smaller amounts of ethane, propane and CO_2. It is collected from gas wells and produced as a co-product in refining petroleum oil. Compressed natural gas (CNG) is used to run buses and light duty vehicles, including 3 wheelers mainly in urban environments, propelled by energy security concerns and air quality consideration with the goal of minimizing tailpipe particulate emissions to negligible levels.

76. Several studies suggest that at current engine and vehicle technology levels, the use of CNG reduces CO_2 emissions up to 20% compared to gasoline and has the potential to reduce CO_2 emissions by up to 5–10% compared to diesel, but this is strongly dependent on fuel system design and conversion quality and actual emissions in some cases will be higher than before conversion. Methane has a global warming potential 21 times greater than CO_2 and any

methane leakages, especially in refilling and end-use, can potentially negate all GHG savings from using CNG as fuel.

77. As of 2005, approximately 4.75 million natural gas vehicles are estimated to be in use worldwide with over 1 million in emerging Asia[57]. Growth in CNG vehicle populations has been very rapid over the last 2 years in Bangladesh, China, Malaysia, and Thailand. The Thai government is aiming to convert half a million vehicles to run on compressed natural gas (CNG) by 2010, to help reduce the country's dependence on oil[58].

78. In India, The Supreme Court ruling in 1998 mandated CNG as the fuel for public transport in Delhi to control pollution. In 2002 a further ruling directed the Union government to give priority to the transport sector for CNG and a further 4 cities have implemented programs for urban transport[59].

79. **Liquid Petroleum Gas** (LPG) consists mainly of propane with propylene, butane, and butylenes in various proportions according to its origin. The components of LPG are gases at normal temperatures and pressures and the fuel is easily stored in a steel cylinder as a liquid. Its ease of transport and storage makes it applicable even in smaller vehicles and LPG presents an opportunity as a vehicle fuel for cities that do not have pipeline or sea access to CNG.

80. In 2004 there were approximately 10 million LPG vehicles in use worldwide concentrated in few countries. It is widely used in Europe and in 5 countries, LPG accounts for more than 10% of the total automotive fuel demand[60]. Fuel diversity and security issues have enticed governments to offer attractive incentives for its use; in South Korea more than 10% of all registered vehicles are fuelled by LPG, in Japan over 90% of the taxi fleet uses this fuel, Thailand introduced this fuel to the Tuk-Tuk 3-wheeler segment and Hong Kong is replacing 18,000 diesel taxis to achieve important reductions in PM and NOx emissions[61].

81. Whilst these gaseous fuels do impact local emissions, their contribution towards meet the combined energy policy targets of enhanced long-term supply security and significant CO_2 emission mitigation in Asia is limited now and will continue to be limited in the future[62].

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[57] Of which Pakistan has 700,000; India, 220,000; China, 97,000; Bangladesh, 23,000, Malaysia, 18,000 and Thailand about 9,000 vehicles. Source: Asian NGV Communications (February 2006). Vol 1, #3

[58] Source: just-auto.com Editorial Team, 15 March 2006

[59] These are Ahmedabad, Lucknow, Kanpur and Hyderabad. If the national gas grid is implemented, 22 cities will be enabled.

[60] South Korea is followed by Japan, Poland, Turkey and Australia account for more than half the world on-road transport consumption however in South Korea, Bulgaria, Turkey and Lithuania LPG represents more than 10% of the total vehicle fuel consumption. (WLPG)

[61] Sources: M.P. Walsh, "Sustainable Transport, a source-book for policy makers in developing cities" GTZ; Alternative Fuel use, US Department of Energy, Vol 6 #2; Kong Ha Hong Kong Environmental Protection Department, CSE conference New Delhi 2004.

[62] In light duty vehicles a fuel economy improvement of between 3.5% and 12.6%[62] was reported in Arizona USA due to the implementation of a vehicle inspection and maintenance program when their vehicle fleet had a technology level similar to that found today in many parts of emerging Asia. Since it can be expected that the vehicles in Arizona were on the whole better maintained than their counterparts in emerging Asia, similar or larger gains should be possible today in Asia (Gielen, et.al., 2005)

e. Need to Control in-use vehicle emissions

82. Proper maintenance is important to control emissions over the life of the vehicle, however in most parts of Asia, owners generally do not give much consideration to maintenance. It has been shown that a fully implemented and enforced inspection and certification (I&C) program supported by adequate maintenance can bring about reductions in NOx emissions of 2-5%, PM_{10} emissions of 2-15%, and fuel consumption and GHG emissions by around the same amount (2-17%) with the higher numbers being for the less advanced vehicle fleets as commonly found in Asia.

83. In Bangkok, privately owned urban bus fleets have de-rated their engines to avoid fines for visible smoke, which combined with driver training and a driver incentive scheme to use less fuel has improved their fuel economy by over 30%[63]. In India's "golden triangle" traffic police empowerment has virtually eliminated the smoky diesel problem. B.E.S.T, the Mumbai bus operator has also reported substantially improved fuel consumption through better maintenance and driver training originally incorporated due to pressure to eliminate visible smoke.

84. Studies performed in Jakarta indicated that the wide scale adoption of preventive Inspection and Maintenance programs for in-use vehicles can help improve overall fleet fuel efficiency by 3-4 per cent and substantially reduce exhaust emissions (Pramono, et.al., 2001). Under a separate Swisscontact program in Jakarta - 5245 buses from 9 companies were subjected to I&C testing and an improved maintenance regime over a two year period resulting in a 5.5% improvement in fuel efficiency and SIAM, in India reported a fuel economy improvement of up to 17% from their 2-wheeler voluntary clinics[64].

85. All these examples illustrate the fact that well-managed I&C programs can have a considerable positive impact on vehicle fuel efficiency if implemented across the entire in-use vehicle fleet. However the majority of I&C programs in Asia have been of an ad-hoc nature. Few of the countries in Asia have been able to implement a structured and well-enforced I&C program which targets large numbers of gross polluting in-use vehicles on a regular basis. Effective I&C programs require setting in-use emission standards that are achievable by a majority of vehicles with good maintenance, and tightened them over time with the objective of removing gross polluting vehicles from the road. Such programs can lead to the replacement of damaged catalytic converters, and can be used (with the corresponding regulatory measures) as a low cost means of preventing the import of grossly polluting used vehicles into the country.

86. Many cities and countries are now actively promoting the retrofitting of high urban usage diesel vehicles with particulate filters. Though costly, the impact on emissions appears to be very favorable but such retrofits do not have a positive impact on fuel economy. Other retrofit programs that are piloted at present in the Philippines can have regional importance by installing direct injection systems to in-use 2-stroke 2- and 3-wheelers. In this case both emissions and CO2 emissions may improve greatly.

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[63] Interviews with owners of privately operated buses running on routes concessioned from the Bangkok Mass Transit Authority, April 2003

[64] See "Sustainable Transport: A Sourcebook for Policy-Makers in Developing Cities, Module 4c Two- and Three-Wheelers; GTZ, Main contributors: Jitendra Shah (The World Bank) and N. V. Iyer (Bajaj Auto Ltd)

E. Congestion and road safety

87. The substantial growth in vehicle populations is clearly evident in the urban areas throughout the region in the form of increased congestion, and road safety concerns particularly for the poor.

88. Many of Asia's megacities have now realized that it is physically impossible to build road infrastructure capacity faster than the growth rate in vehicle ownership and thus to reduce congestion. The recently adopted Urban Transport policy in India calls for a more equitable road space focusing on people rather than vehicles (GOI-MUD, 2006). Other more innovative and equitable solutions are required. The UN (1999) and Allport (1996) amongst others have also recognized that simply providing more road space, even if the associated land and capital could be made available, is not a solution. Given the substantial private-vehicle future demand and ever-increasing space requirement caused by the move from 2- to 4-wheelers, any attempt to increase road space will quickly be absorbed by higher car ownership and use, with no long-term improvement in traffic speeds, air quality or GHG emissions[65].

89. Ten years ago the peak-hour average speed for Asian cities was estimated to be 16 km/h, with much lower speeds in many cities[66]. Evidently, cars in many Asian cities spend much of their time stationary in traffic jams and this is worsening rapidly over time. As travel time per km increases, the fuel consumption per km increases substantially (as illustrated in Figure 15) with attendant increases in air pollution and GHG emissions[67].

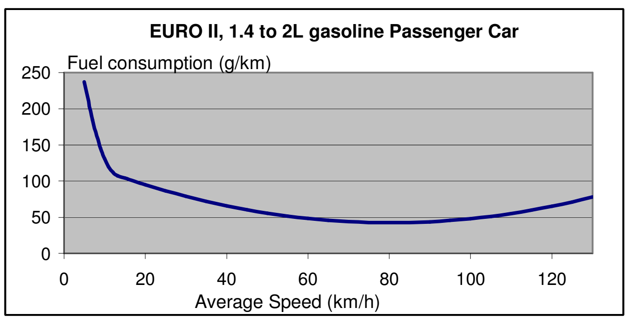

Figure 15 - Relationship between average speed and fuel consumption for a EURO II 1.4 – 2.0 liter displacement gasoline passenger car[68]

90. In Southeast Asia inadequate road safety will cause 385,000 road deaths and 24 million injuries in the next five years, incurring more than US$88 billion in economic losses, according to ADB sponsored studies. Some 75,000 persons were killed and more than 4.7 million were injured in road crashes in Southeast Asian countries during 2003, with annual economic losses estimated to be around $15 billion, or 2.2% of the region's total gross domestic product[69]. Such huge recurring losses are not socially acceptable and whilst great strides have been made to improve the safety of occupants in new vehicles, little attention – and funding – has been given

[65] Source: Car travel: "Asia cannot follow Australia's path" Road & Transport Research, Jun 2000 by Moriarty, P
[66] Kubota 1996; World Bank 1998
[67] World Bank 1998
[68] using the EEA, COPERT II formulae
[69] Road Crashes Costing Southeast Asian Countries US$15 Billion Per Year, Charles Melhuish, Lead Transport Sector Specialist ADB see http://www.adb.org/Documents/News/2004/nr2004155.asp

in emerging Asia to improving road safety for pedestrians together with NMT and 2- and 3-wheeler users.

F. Public Transport and Non Motorized Transport

1. Public Transport

91. Most cities in emerging Asia can be characterized as having large-scale and growing urbanization with high-density inner city areas and inadequate road space with a large part of the growth taking place at the edges of the cities resulting in a decrease in overall density. They typically still have a high modal share of public transport which is used by all of the population that does not own a car or 2-wheeler and the rapid growth in motorization in most cities is causing the relative share of public transport to decline.

92. Although there are shining exceptions, most of the cities in emerging Asia offer a low quality of service in their public transport which although low cost and relatively fast, is overcrowded, often dirty and highly polluting and with important personal security and safety issues. Accessibility issues are often evident, where high entrance deck height on buses, for example, effectively barring entry to women with small children and the elderly.

93. Whilst most of the cities in emerging Asia have formal bus services, a greater percentage of the passenger trips are conducted on informal buses and para-transit vehicles. These provide a service to the traveler that is cheap and convenient with a large number of vehicles – far more than would be needed if they were all full size buses – that are willing to pickup and drop passengers at any point along the route. However these large numbers of informally-operated and often inadequately maintained vehicles, competing for passengers, obstruct the flow of traffic and are a substantial source of criteria and GHG emissions.

94. Over the last years several cities in the region have put in place rail based public transport systems, either in the form of light rail, (e.g. Bangkok, Manila, Shanghai) and metro (e.g. Delhi, Beijing, Shanghai, Nanjing) and many cities have planned to put in place such systems. Rail based public transport systems tend to have a high public profile, but they are responsible for a relatively low numbers of the overall number of trips (usually less than 10%) while in all cases requiring large subsidies for construction and operation. These are supported by taxis and 2- and 3-wheelers; motorbikes in Thailand, motorbikes with sidecar in the Philippines, autorickshaws, Bajaj in India, Tuk-Tuks, and of course human-powered rickshaws etc that are also informally operated.

95. A current trend in many cities is towards Bus Rapid Transit (BRT) which consists of high capacity (usually articulated) buses operating on exclusive segregated bus lanes with rapid loading and un-loading of passengers at stations that provide electronic fare pre-payment and obstacle-free waiting areas and level access to the buses. The System includes centralized coordinated fleet control providing monitoring and communications to schedule services and real-time response to contingencies and is usually accompanied by traffic-flow improvement measures including bus-priority traffic lights, elimination of left turns, continuity given to right-turns, and improved sign-posting. These ground-level modern, high-quality bus corridors are often the result of a public-private partnership (PPP), in which the public sector is responsible

for the investment to deploy the required infrastructure and have been demonstrated to supply carrying capacities rivaling metro[70] without the need for subsidized operation.

96. Informal public transport is characterized by many owner-operators or small to medium size operations where staff is employed mostly on the boundary system without health benefits and avoiding tax. The vehicles typically operate all day (independent of the demand) with ad-hoc scheduling and informal maintenance that stretches the operational life of each vehicle. They compete for passengers, occupy multiple road lanes and are a major cause of congestion and air pollution. They are usually a major source of employment and actively defend the status quo.

97. Although some cities (such a Hanoi and Bangalore) report increasing bus ridership (after having lost almost all bus services after the large scale introduction of 2 wheelers), generally in emerging Asia, mass transit is not an attractive option for anybody that has access to personal transport (car SUV or 2-wheeler). Many modern routes (for example the Skytrain in Bangkok or the metro in Delhi) lose attractiveness when the journey end-points are far from stations. Modernization of the transport system, preferably as a door to door solution, to attract passengers that own vehicles is substantially more difficult when the majority of mass transit vehicles are in the informal sector.

98. The informal sector is generally not interested in promoting or accepting long-term transport policies and severally hampers the mobilization of additional capital. Whilst it is now realized that mass transit systems need to be improved[71], in any move forward (i.e. the introduction of BRT) the emphasis needs to be on shifting operators from the informal to the formal sector and on public-private partnerships (PPP). BRT (as in Beijing, Kunming, and Xi'an in China[72] and Jakarta, Indonesia) is seen as a valid option for improving bus operation at high flow levels without the need for continuous external subsidies; something that rail, light-rail and metro cannot live without. Currently there are more cities in Asia that are planning BRT systems than rail-based solutions.

99. The largely informal nature of public transport in emerging Asia restricts modernization in other ways; most cities do not have any mechanism in place to monitor the performance of the transport system (modal split, passenger- and vehicle-kilometer-traveled, activity data by sub-sector and routes, environmental performance, safety and access etc) and there is often no clear guidance on the role of public versus private transport and associated with this, the incentives/disincentives to develop public- versus private-transport.

100. When strong governmental action is taken as in Delhi and Dhaka[73] the externalities of public transport can be substantially improved. Modern buses can generate orders-of-magnitude less emissions per passenger-km than private cars, and substantially reduce congestion if car usage within the metropolitan areas is inhibited and modal shift is induced.

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[70] The Transmilenio system in Bogotá, Colombia has demonstrated the ability to carry a peak flow of up to 36,000 passengers per hour per direction

[71] The Hon. S. Jaipal Reddy, India's Union Minister of Urban Development, stated in his opening remarks at the Conference on Alternative Technologies for Public Transport held in New Delhi, India, from March 21-23, 2006; "There is no escape from Bus Rapid Transit" when authorities at the national and local level must make choices to improve urban transport. The Minister also emphasized the need to reduce private car use.

[72] The Energy Foundation a partnership launched in 1991 by major foundations has initiated a sustainable transportation project in China. See "Promoting Bus Rapid Transit in China" at www.ef.org

[73] see 3a and 3c above

101. In Sept, 2005 the PRC State Council Office issued a nationwide "Suggestions on giving the highest priority to urban public transportation development"[74] that assigns top-priority to developing urban public transportation as an important measure to increase energy efficiency in the transport sector and alleviate congestion, These guidelines directly promote the development of multi-mode intelligent public transportation systems (including BRT) with priority treatment being given to public transport, over private vehicles. The need to modify laws, regulations and standards is emphasized to promote well-regulated development and reform the investment and financing support for privately operated, government supervised urban public transport systems.

2. Non-motorized transport (NMT)

102. Walking and non-motorized transport are traditionally the main means of transport in emerging Asia but these are becoming more difficult and less socially acceptable in many Asian cities. Many bicycle lanes built in China and Vietnam in the 1960s and 1970s are now being taken over by cars or are being systematically removed. Bike and becak lanes were also built in several Indonesian cities, such as Surabaya, in the 1970s, and have subsequently been removed. In Hanoi it is currently commonly accepted that only students use bicycles and these change to motorized 2-wheelers as soon as it is financially feasible. In many cities, rickshaws are restricted to certain streets because they slow the traffic for cars and SUVs. Recently, however there has been resurgence with Bangkok, Kuala Lumpur, and Manila all constructing new separated bicycle facilities in the 1990s. In India in recent years modern human-powered rickshaws have been introduced in several cities such as Agra, Delhi, Lucknow, Jaipur, and Vrindavan. The 2006 India Urban Transport policy makes specific reference to the need to maintain and expand the share of NMT in urban transport.

103. Urban walking in most Asian cities involves threading one's way along narrow, uneven (or nonexistent) pavements through street vendors, urban furniture and parked cars in a noisy polluted environment where it is difficult to advance at a steady speed. The revival of walking and NMT as effective mobility options is necessary but will require a change in vision for many Asian cities to actively build pro-pedestrian zones and pavements free of obstructions and promote segregated walk- and bike-ways to provide the safety and user-friendliness that these activities require.

When increased pedestrian areas and non-motorized vehicles are bundled with high speed public transport it is possible to reduce GHG and local emissions and provide a more enticing urban environment and economy as in the Dongshan District government in Guangzhou where the street was raised to a single flat pedestrian level giving people, not cars, the intrinsic right of way (Lohani, 2005b). An elevated pedestrian network in Bangkok, underneath the Skytrain stations, shields pedestrians from traffic and noise and links shopping centers in the nearby buildings, generating income both for the stores and for Skytrain. This is similar to the elevated network of pedestrian walkways at the Ayala Center in Makati City, Metro Manila which is linked to the MRT station, providing better access and comfort to commuters.

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[74] Submitted by the Ministry of Construction, the National Development and Reform Committee, The Ministry of Public Security, the Ministry of Finance, and the Ministry of National Land and Resource as summarized and translated by Li Shuang, Apr.25, 2006

Application of ASIF framework in South Asian cities

Three South Asian cities - Bangalore, Dhaka and Colombo - were selected as case study sites to analyze the transportation, energy demand and emissions scenarios over the next fifteen years (to 2020) using the ASIF analytical framework. Although the types of data available in the three cities vary widely and there are deficiencies and inconsistencies in the available data, analysis of the results show in each city roughly doubling of motor vehicle populations due to the forecast rise in income levels in the business-as-usual scenario, and tripling of fuel use and CO2 emissions between 2005 and 2020. Analysis of the city data shows further strengthening and augmenting bus services, with commensurate increases in ridership, will provide multiple benefits – reduction in traffic congestion, fuel savings, pollution reduction and CO2 mitigation.

- An increase in public transport share from 62% to 80% in Bangalore leads to a fuel saving of 765,320 tonnes of oil equivalent, which is equivalent to about 21% of the fuel consumed in the baseline (BL) case. The other advantages that ensue are a 23% reduction in total vehicles (642,328) and creating a road space (equivalent to 418,210 cars off the road) and reduce traffic congestion. Air pollution in the city drops significantly -- 40% drop in CO, 46% HC, 6% NOx, and 29% PM. The total CO2 mitigation potential over the next 15-year period would be 13%.

- An increase in public transport share from 24% to 60% in Dhaka leads to a fuel saving of 106,360 tonnes of oil equivalent, which is equivalent to about 15% of the fuel consumed in the BL case. The other advantages that ensue are a 39% reduction in total vehicles (99,294) and creating a road space (equivalent to 78,718 cars off the road) and reduce traffic congestion. Air pollution in the city drops significantly -- 24% drop in CO, 26% HC, <1% NOx, and 13% PM. The total CO2 mitigation potential over the next 15-year period would be 9%.

- A marginal increase in public transport share from 76% to 80% in Colombo leads to a fuel saving of 104,720 tonnes of oil equivalent, which is equivalent to about 3% of the fuel consumed in the BL case. The other advantages that ensue are a 5% reduction in total vehicles (47,716) and creating a road space (equivalent to 62,152 cars off the road) and reduce traffic congestion. However, air pollution in the city does not drop much as the city already depends heavily on public transport and the CO2 mitigation potential is around 2%.

G. Conclusion

104. The trends and challenges presented in this chapter, are each by themselves already serious, taken together they show the lack of sustainability of the mobility model that has been followed in Asian cities in the last few decades and which unless a paradigm shift occurs will prevail in the years to come. Emerging Asia is faced with these challenges that need to be resolved for high economic growth to continue and improvements in quality of life to be sustainable. The growth of GHG emissions is directly related to GDP-inspired increases in passenger and freight inter-city transport and increasing personal mobility which also cause other national concerns – in terms of energy security and imports – and local problems such as congestion, pollution and road safety, that together seriously risk restricting the high economic growth that originally caused them. Many of these challenges, even in the most optimistic scenarios will get worse. A series of policy interventions that have co-benefits in each of these areas need to be urgently implemented for emerging Asia to reach its true potential.

105. Any vision on economic development, urbanization and motorization for the period to 2025 involves a “post-Kyoto” view in which countries in emerging Asia will have to buy into the facts of climate change. Within this timeframe the largest countries will be solidly established

amongst the largest worldwide emitters of GHG and will have to face the paradigm shift that is presented here. Delaying action and doing so at considerably higher levels of personal mobility (as currently forecast based on historic tendencies will cause a greater cultural and economic shock than taking action today. Any delay in generating this paradigm shift will have severe long term implications for the social and economic development of Emerging Asia.

Greenhouse Gas Scenarios from Road Transportation in Delhi

Delhi is a rapidly expending mega city which had over 13 million people in 2001 and is expected to surpass 22 million by 2020. It had about 2.6 million motor vehicles on-road – 200 for every 1,000 inhabitants in the year 2000, a rate far higher than most cities with similar incomes. Rising incomes, combined with demand for greater personal mobility and inadequate public transport, will inevitably result in continuing increase in personal vehicle utilization and ownership, especially inexpensive scooters and motorcycles, but also cars.

In Delhi, GHG emissions from road transportation are expected to soar.

Two GHG scenarios were created to characterize what is likely and what is possible. First (high-GHG) scenario is an extrapolation of trends in Delhi, modified to reflect policies and commitments, but without taking into account the Supreme Court directives.

Second (low-GHG) scenario is an extrapolation of trends in Delhi taking into account the Supreme Court directives and is premised on strong political and institutional leadership to enhance the economic, social, and environmental performance of Delhi's transportation system. In this scenario, conventional-sized cars drop from 30 to 19 percent of motorized travel between 2000 and 2020, and mass transit increases its share from 49 to 53 percent. More efficient scooters and mini-cars account for most of the remaining motorized travel, and bicycling becomes more important, especially for the poor.

Following important observations stand out:

- Greenhouse gas emissions is expected to go up more than four-fold in the high-GHG, or business-as-usual, scenario; but only double in the low-GHG scenario.
- Transportation policies are readily available that will not only slow emissions growth, but also significantly improve local environmental, economic, and social conditions.
- Improved technology would maximize the efficiency of automobiles, buses, and other modes of transportation and could play a key role in reducing emission increases.

Keeping many travel mode options available—including small compact cars and new efficient scooters and motorcycles—will help individuals at various income levels meet their mobility needs.

In summary, GHGs associated with road transportation will increase dramatically in Delhi in the coming decades, but many opportunities to slow the growth in vehicle use, pollution, GHGs, and traffic congestion are at hand at modest cost. Stong leadership is needed.

Source: Bose and Sperling, 2001

III. VISION AND POLICY FRAMEWORK

A. The Vision

106. Asia has to promote economic growth -- necessary for poverty reduction and improving the quality of life -- and account for a rapidly growing transport demand within the overall context of social development with improved equity and zero environmental impacts.

107. This will require accelerated urban reform together with innovative transport-demand management and access-and-mobility planning (travel demand management) that respects the differences between countries, cultures and cities and integrates a specific vision and action plan for each one. Faster implementation of new technology is needed, both regionally developed and adopted, with improved sharing of knowledge on a regular basis both North-South and South-South.

108. Future efforts in urban planning (to reduce the need to travel and promote NMT) combined with structural changes to the transportation system and improvements in the fuel economy of vehicles, could cause the accelerating growth-rate of GHG emissions in Asia to slow. It must be assumed, however, that GHGs from the transport sector in Asia continue to grow. This means that overall global climate goals can only be accomplished if absolute reductions are achieved either in other sectors in Asia or in other parts of the world.

B. Barriers

109. Accomplishing a reduction in the growth of GHGs in the transport sector will require that substantial barriers to change are overcome. Availability of congruent and consistent knowledge of international best practices on climate change and sustainable transport for national, state and local government planners and decision makers is one of the greatest barriers to change.

110. The currently weak empowerment and linkages in many metropolitan areas between urban planning, transport planning, traffic management and enforcement of planning, environmental and other transport related regulations provide a substantial barrier to effective changes that are focused, amongst other things, on reducing the climate change effects from transportation.

111. Inadequate accounting tools that fail to take into consideration the true cost of the externalities of on-road transport (congestion, pollution, climate change, travel cost and time etc) severely limit corrective actions. Charging the externalities of private motorized transport and achieving modal shift to public transport will require restraint of private transport demand and in many cases legislative reform that may be opposed by many current or potential private vehicle owners unless consultation and awareness programs are implemented with positive outcomes.

112. The lack of information to the consumer of the true per-km cost of private transport (including the components of vehicle depreciation and replacement, interest value of capital, insurance, taxes, maintenance, parking etc) restricts his/her ability to make rational choices. Awareness among different stakeholders on the need for urban reform and a paradigm shift in transportation planning contributes to a lack of grass-roots support for urban and transport reform which can negate its inclusion in the political agenda at the highest level.

113. Access to capital is also a barrier particularly where different administrative areas need to collaborate within the same transport development program. Lack of incentives to invest in better transport systems and new technology delay the adoption of new technologies and contribute to a continued lagging behind of certain countries in emerging Asia compared to Europe and other parts of the world. Difficulties in developing an optimum investment framework for more climate friendly transport systems are augmented by the currently limited relevance of the clean development mechanisms (CDM) for transport-related projects.

C. Principal policy interventions to reduce GHG emissions

114. If policy interventions to reduce GHG emissions from on-road transport were adopted these would improve access to goods and services whilst requiring fewer passenger- or freight-kilometers, reduce fuel consumption per passenger- or freight-kilometer traveled increase the distance traveled per unit of fuel for individual vehicles and adopt fuels with lower GHG emissions. This requires that the DMCs recognize the GHG emissions are a problem and strengthen their effective planning to mitigate them.

115. To accomplish this vision an integrated set of policy interventions need to be implemented. Policy interventions are required at the long, medium and short term as shown in Figure 16. The principal policy approaches can be divided in four categories:

(i) Promote Urban Reform and Land Use Planning to ensure Urban design that reduces the need to travel, requiring fewer passenger- or freight-kilometers;
(ii) Adopt Integrated Transportation Planning to ensure Modal shift that promotes lower fuel consumption per passenger- or freight-kilometer traveled;
(iii) Improve Vehicle Engines and Fuel Technology to improve the energy efficiency of individual vehicles, to increase the distance traveled per unit of fuel
(iv) Introduce Biofuels with lower GHG emissions

116. It is only if all of these policy interventions are implemented that Asia will be able to reduce the growth in GHGs from the transport sector. In other words decision makers do not have the luxury of choice but rather they need to develop the support and capacity to take on all the policy interventions outlined below.

117. Whilst the policies need to be all adopted within the short term the time required for successful implementation and that impacts start to materialize in a sizable manner varies between the policy options identified. Changing the urban design is the most challenging and will take the longest while the improvement of maintenance of in-use vehicles can be introduced immediately with a measurable impact.

118. There is also the need to strengthen the interventions by emphasizing the co-benefits of linked programs to facilitate the buy-in of (i) national governments, (ii) local governments and (iii) civil society even though each has different priorities including energy security, congestion, air quality and equality of access.

119. An important contribution of the development community in the adoption and implementation of these four policy approaches would be the strengthening of a continually-updated shared knowledge base as input into these decision processes and the development of

common tools that allow surrogate regional default parameters to be evaluated for hard- or costly-to-measure variables and for inter-comparison and accumulation of cities and countries. The development community also has an important role to play in the accelerated implementation of new technology (closing the gap) by encouraging technology development by areas and the adoption of leading worldwide standards. It can assist the DMCs to share technology development, and knowledge on a regular basis both N-S and S-S.

1. Urban Reform and Land-Use Planning

120. .The greatest GHG mitigation can be achieved in the long term through travel demand management linking urban development and land use with transportation planning to improve access to goods and services whilst minimizing the need to travel. The village concept of high-density urban planning within the region's mega-cities can, by integrating residential, business, commercial and light industrial areas, improve the quality of life and substantially reduce the need to travel. Linking villages with fast public transport and promoting electronic communities can enhance economic and social development while reducing consumption of transport fuels. Long-term, inter-sectoral regional policy frameworks need to be established for this to happen.

121. Within the framework of an exploding urban population, Asia needs to more actively promote the development of livable and sustainable, community- and health-centric, green cities that reduce the demand for personal motorized transport. Many inner cities would benefit from being revitalized to create a livable mixed-land-use environment that focuses on reducing emissions (including GHG), facilitating the new economy, saving landscapes and rebuilding communities through equity of access to goods and services, education and environmental empowerment. Electronic, networked communities that alleviate the need to travel should also be further promoted

2. Transportation Planning

a. Integrate Urban Transportation Planning with Land Use Planning

122. Urban transportation planning has to be well integrated with land use planning, community and educational development to promote increased mobility and a reduced demand for cars through a greater use of intelligent transport systems and the use of market instruments that equitably internalize the cost of public infrastructure usage (e.g.: roads and parking), pollution and congestion. These may include tax reform and deregulation, road and congestion pricing, active traffic management with car-free zones and cities, modal shift and the promotion of car sharing.

123. This is the component that can generate the largest GHG mitigation in the medium term. It involves charging the true cost of externalities such as congestion, pollution, climate change and use of public infrastructure – roads and parking – to the use of private motorized transportation (cars and motorcycles). It involves providing efficient and high quality public mass- and non-motorized alternative transport. Reducing subsidies to the private vehicle provides an important incentive to promote change and offsets some of the costs of improvements to public transport (rolling stock and infrastructure).

b. Charge the externalities of private motorized transport

124. Traffic demand management with a fiscal package that combines, increased fuel tax, carbon-based annual road charge (where low powered, low-emissions, hybrid and newer vehicles pay less than the higher powered, higher emissions and older vehicles), parking charges together with variable road-use pricing (congestion charging) are all tools that can charge the private vehicle owner for the climate change, local emissions, congestion and infrastructure externalities that his vehicle's operation creates or uses. Additional up-front private vehicle registration fees coupled with purchase limitations (such as the publicly managed open-bid Vehicle Quota System operating in Singapore) can further entice a market-priced efficient use of public road space. The creation of an urban transport fund can ensure that these charges and fees collected are used to improve public transport which considerably enhances the public acceptance of the policies and accelerates the change process.

c. Improve public transport

125. Safe, secure, rapid and user-friendly public transport systems (including para-transit, buses, metro, rail and new alternatives such as BRT) need to be further developed to promote modal shift from private transport and integrate with pedestrian and non-motorized transport to equitably provide efficient door-to-door connectivity.

126. Bus, metro and elevated light rail have traditionally been seen as the public transport option to private transport but increasingly the low-investment, low-operating-cost alternative provided by BRT operating on segregated roadways is gaining adherents. BRT can offer substantially higher-speed user-friendly mass transit at high carrying capacities[75] than traditional buses but with a considerable reduction in per-km investment vs. metro or light rail that allows substantially more routes to be developed for subsidy-free operation within a politically accessible timeframe[76].

127. The significant GHG and emissions reductions that can be achieved through modal shift from private vehicles to high occupancy public transport vehicles can in many cities in Asia be incremented substantially from improved traffic flow for the other private vehicles on the main route due to the elimination of interference from local bus or para-transit operation. Not only is travel time important to users; accessibility, reliability, safety and security issues need to be addressed. Where effective mass public transport crosses political jurisdictions, a regional policy framework is essential for development to occur.

128. Public transport systems need to provide door-to-door solutions for end users thus the feeder bus and para-transit routes into the main mass transit routes are equally important components of the overall system and need to receive the same attention to detail.

d. Maintain or increase Non motorized transport

129. Safe, secure, user-friendly modern rickshaws, together with pedestrian zones and walkways, segregated cycle paths and park-and-ride car and bike parks need to be created as

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[75] 36,000 peak passengers per hour per direction has been achieved on a two-lane-per-direction corridor in Bogotá, Colombia

[76] A study for Bangkok showed that an investment of one billion US dollars could buy 7 km of subway or metro; 14 km of elevated rail or 426 km of BRT (Wright, et.al. 2006).

an integral part of the transport system to cater to both rich and poor although each has different needs.

e. Address increased Freight transport

130. Economic growth generates, and requires, greater long-distance connectivity in the supplier and distribution chains which should be further promoted through improved intra- and inter-city infrastructure (roads and depots) for efficient larger-capacity long-distance carriers. Modal shift to proficient, less-GHG-intensive transport channels (such as railways) should be actively encouraged by fiscal measures and fine-tuned freight transport management policies. More control needs to be imposed in urban areas with well-defined trucking routes and spatial and temporal truck restrictions in other zones.

f. Integrate Inter-city road passenger transport with urban transport systems

131. Long-distance passenger travel needs to be closely integrated into the urban environment facilitating fast traveler-friendly mass-transport access to well-located terminals and airports. Carefully planned highway system improvements are required to reduce travel times for goods and passengers whilst improving road safety, congestion, fuel consumption and emissions.

3. Vehicle, Engine and Fuels Technology

132. Vehicles that are sold today will contribute local and GHG emissions to the atmosphere during the next 10 – 15 or more years. Asia would benefit by minimizing the implementation lags in achieving the "world-standard" automotive fuel specifications[77] to accelerate the incorporation of clean vehicle technologies into the active fleet.

a. Improve Energy Efficiency

133. GHG emissions reductions would benefit if energy efficiency standards were implemented (or improved) throughout emerging Asia for all forms of motorized personal transport following China's lead[78]. The implementation timetable and cost structure of the technical changes could be optimized if country-specific development were not required from the vehicle manufacturers and their supply chains. There is a powerful logic to adopting uniform "worldwide" standards even though the implementation schedule may differ on a per-country basis due to limitations in fuel supply. As can be seen in Figure 8, the fleet averaged fuel economy of EU vehicles is now approaching 60+ percent improvement over US fleets.

b. Fuel and Emissions standards

134. Synergy is achieved when the introduction of fuel economy standards is directly linked with vehicle and engine emissions standards. Emerging Asia would do well to issue vehicle technological requirements in line with the EURO specifications with implementation timeframes

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[77] With ultra-low sulfur content as specified for US-EPA and EURO emissions standards

[78] China has fuel economy standards in place for light duty vehicles, and standards for light duty trucks will come later this year or early 2007 closely followed by fuel efficiency standards for heavy duty vehicles and agricultural vehicles

that depend on fuel availability amongst other considerations. It is important that the "world-wide" standards are adopted completely, including any durability requirements etc, so as not to provide a perverse incentive to manufacturers to cut cost and deliver a sub-standard product in terms of emissions. A medium-term objective for emerging Asia would be to reduce the implementation gap to zero.

135. Vehicle energy efficiency and emissions standards are intrinsically linked to fuel standards. Introducing tighter energy efficiency and emissions standards requires sufficient unleaded and low sulfur fuel to supply new vehicle consumption (i.e.: for the growth component of automotive fuel sales) accompanied by a fiscal policy that does not promote cross-fuelling[79]. It is important the policies be established to influence fuel use on differential pricing terms and environmental grounds.

136. If emerging Asia were to adopt EURO energy efficiency and emissions standards for light and heavy duty vehicles it would benefit directly from the worldwide automotive industry's research and development efforts, minimizing both development costs and implementation timeframes whilst improving its competitive position as a manufacturing base in the international vehicle market.

137. Since emerging Asia is the largest producer and consumer of motorcycles of less than 150 cc engine displacement and 3-wheelers, further promotion of research and development through advanced energy efficiency and emissions standards that drive technology could increase its leadership in these market segments.

c. Inspection, certification and maintenance

138. If in-use vehicles do not receive adequate maintenance (in quality and frequency) their emissions – both local and global – will suffer. Most emerging Asia does not have a solid maintenance ethic. In many countries, formal workshops staffed with trained mechanics equipped with diagnostics equipment are hard to find for out-of-warranty vehicles and a wide variety of replacement parts that are readily available for their repair do not meet OEM specifications.

139. Strict visual-smoke rules empower traffic police to issue fines to smoking gross emitters and have catalyzed fuel economy improvements in many fleets in developing countries.

140. Vehicle inspection programs that are correctly implemented and rigorously enforced can detect the gross emitters and ensure that they are repaired. Such Inspection and certification programs are particularly well suited to include fitness and safety inspection of the older vehicle with a resultant reduction in road accidents. Such programs can be beneficially linked to accelerated scrap page programs that remove older, less-efficient, contaminating and/or unsafe vehicles from the fleet and promote their substitution with new technology vehicles.

[79] If "dirty" fuel is cheaper than clean fuel it provides a perverse incentive for users of new vehicles to permanently damage their vehicles by using an inadequate fuel. On the other hand if the "clean" fuel is cheaper demand can outstrip supply.

141. These benefits can be accompanied by substantially reduced local emissions, especially from older diesel and gasoline-fuelled, carbureted vehicles. It is important to incorporate used vehicles that are imported into this framework.

d. Retrofit

142. Tightened emissions, safety and fuel economy control on older vehicles also provides an important incentive to fleet renewal. Modern heavy duty trucks are substantially more fuel efficient than units produced 15 years ago. Operators in Mexico have reported that the fuel saved is sufficient to cover the cost of the monthly interest payments on the new truck[80]. Particularly for heavy duty vehicles, retrofitting a new engine into an existing vehicle can provide important fuel consumption -- and emissions -- benefits. Direct-injection retrofit options are being developed for 2-stroke 2- and 3-wheelers that provide substantial fuel economy benefits.

143. These fuel economy improvements from in-use vehicles will not occur without government providing incentives, establishing inspection requirements and empowering enforcement.

4. Biofuels

144. Unless there is a paradigm shift in current tendencies, the transport sector in emerging Asia is forecast to demonstrate almost unmanageable growth over the next 25 years in private vehicle populations, fuel consumption and GHG emissions. Even in Europe with relatively stable vehicle fleets, it is expected that 90% of the increase in GHG emissions between 1990 and 2010 will be attributable to transport and one of the main reasons that EU is failing to meet their Kyoto targets[81].

145. An ambitious, congruent and realistic vision in emerging Asia to convert a substantial portion of on-road transport to clean and CO_2 efficient biofuel provided by competitive private industry would assuage part of the fuel security and GHG pressures. However, the required scale of production to make a significant difference is far greater than that proposed in other continents. The EU vision[82] of providing 25% of their transport fuel needs by 2030 from biofuels requiring 4-13% of the total agricultural land to be dedicated to this use, pales in comparison to the long-term GDP-growth driven increase in personal mobility in emerging Asia and its accompanying fuel requirements. Co-benefits such as additional rural employment need to be balanced against potential competition with food production, sustainable forestry, and the impact on the environment of substantial crop changes.

146. For biofuels to supply a significant proportion of fuel for on-road transport, government needs to provide a clearly marked roadmap driven by market incentives and assurances in which a premium is established for those feedstock/process combinations that generate the largest life cycle analysis GHG emissions reductions relative to conventional fuels. It is important that the policies do not limit development to one crop and process type, but create an environment in which diversity in crops and technologies can evolve.

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[80] Interview with Joaquin Montiel, Managing Director of Transportadora Estrella, Mexico 2003

[81] Source: Biofuels in the European Union – a vision for 2030 and beyond by the Biofuels Research Advisory Council 2006

[82] as provided for in EU Directive 2003/30/EC

D. The co-benefits of climate change mitigation

147. In moving towards this vision, most of the development, and poverty alleviation goals directly impact on-road transportation and hence GHG emissions from this sector. Adding to the complexity is the reality of a highly dynamic moving baseline powered by population and economic growth placing heavier burdens on the road-transport system. This sector currently uses around 21% of the world's total energy consumption; over the short and medium term is the most tied to petroleum products and emerging Asia by itself is expected to account for 45 percent of the total world increase in oil use through to 2025. Despite this, the GHG potential of on-road transport in emerging Asia is yet to be seen by many as a priority area, within itself, for sectoral reform and development.

148. An effective and sustainable transport system for people and goods is a prerequisite for consistent long-term economic growth. Equity and poverty alleviation both require such a sustainable system. Asian countries and cities urgently need a policy reorientation that develops new institutional capacities and bridges between sectors to improve land-use planning and promote integrated transport infrastructure schemes based on affordable, environmentally-friendly public transport and non-motorized transport. There are many co-benefit linkages within this framework however that inextricably relate economic, efficiency and quality-of-life enhancements to improvements in GHG emissions.

149. All of the policy interventions shown in Figure 16 that are required to mitigate climate change have important co-benefits at the regional and local level. Improvements in air quality and health, traffic and congestion, quality of life, economic development, road safety and transport efficiency will be generated to a greater or lesser degree by most of the climate change interventions and these provide an important opportunity to tailor the proposals to each stakeholder's constituents and interests.

150. Policy changes in urban development and awareness campaigns are needed for longer term benefits to be seen. Most of these changes will be instigated based on this series of co-benefits relating to equity and quality of life; very few will be based solely on global environmental concerns. The DMCs would benefit from a strengthening of common modeling tools using continually updated and shared knowledge bases in their decision-making processes to optimize their climate change mitigation efforts from on-road transport.

Figure 16 - Co-benefits and principal stakeholders

Effectiveness	Policies	Co-benefits							Principal Stakeholders					Investments by the international development community
		Climate Change	Air Quality and Health	Traffic and Congestion	Quality of life	Economic Development	Road Safety	Transport Efficiency	Int. Development Community	National, State, Provincial Gov't	Local, City , Municipal Gov't	Community Groups & NGOs	Private Enterprise and Investors	
Continuous	Strengthening continually-updated shared knowledge bases and common tools to assist DMCs in optimizing their climate change decisions for urban development, transport systems and biofuels	★★★	★★★	★★★	★★★	★★★	★★★	★★★	✓	✓				Non-lending regional assistance to develop and maintain a climate-change focused shared knowledge base and tools (models) for optimizing option selection in urban development, transport systems and biofuels.
Long Term	Improving access to goods and services through integrated urban planning and travel demand management	★★★	★★★	★★★	★★★	★★★	★★★	★★★	✓	✓	✓	✓	✓	TAs to strengthen and promote governance, legal, structural and institutional reform and awareness building. Strengthen administrative and functional linkages at city and municipal levels. Develop standards and sustainable indicators. Large investment requirement in urban development and transport systems
Medium Term	Reducing the fuel consumed per passenger- or freight-kilometer traveled through traffic demand management 1. Charge the externalities of private motorized transport 2. Mass-transit improvements 3. Non motorized transport	★★★	★★★	★★★	★★★	★★★	★★★	★★★	✓	✓	✓	✓	✓	

Effectiveness	Policies	Co-benefits							Principal Stakeholders					Investments by the international development community
		Climate Change	Air Quality and Health	Traffic and Congestion	Quality of life	Economic Development	Road Safety	Transport Efficiency	Int. Development Community	National, State, Provincial Gov't	Local, City , Municipal Gov't	Community Groups & NGOs	Private Enterprise and Investors	
Medium Term	Fuel efficiency standards for new vehicles 1. Energy Efficiency standards 2. Emissions standards 3. Fuel standards 4. Research and Development	★★★	★★★		★★	★★	★★	★★	✓	✓		✓	✓	TAs to advance the technological automotive roadmap and promote the development of new vehicle energy efficiency, emissions and fuel standards. Reinforce research and development in technology for 2-wheelers and to use non-carbon-based fuels (hydrogen etc). Large investment requirement in clean-fuel production capacity
Medium Term	Provide a substantial part of on-road transport's fuel requirements with clean and GHG efficient biofuels.	★★★	★★★		★★	★★			✓	✓	✓		✓	Technical, policy, and focused financial assistance to promote the large scale production, distribution, and use of biofuels and biofuel-compatible vehicles. Support for research and development to create an environment in which diversity in crops and technologies can evolve to large-scale biofuel production
Short Term	Improving Fuel Efficiency in existing vehicles 1. Inspection, certification and maintenance 2. Retrofit	★★★	★★★		★★	★	★★	★★	✓	✓	✓	✓	✓	TAs to promote governance, capacity and awareness building and to establish and effectively enforce in-use vehicle emissions standards. TA support for pilot demonstration projects.

E. Stakeholders

151. The accelerated growth in Asia of urban population, motorization, congestion, road safety concerns and pollution – including the GHG component – urgently require a change in focus for most Asian metropolises in their approach to urban and transportation planning and the actions required to face these problems are the same actions required to reduce the accelerated impact of Asian on-road transport on climate change.

152. The major stakeholders in this process are:

- *The international development community*: whose overriding interest is poverty alleviation and social development through sustainable economic growth with a reduced carbon footprint
- *National, state and provincial governments*: who share the international development community's concerns of poverty alleviation and social and economic development combined with concerns of energy security in the light of increasing demand and costs with an ever greater imported component.
- *Local, City and Municipal governments*: faced with unfettered urban growth and sprawl with growing congestion, pollution and safety concerns that restrict their ability to attract business and improve the quality of life.
- *NGOs and Community Groups*: that will be faced with a lowering of expectations towards the common "good" unless paradigm shifts are achieved.
- *Private Enterprise*: depending on the availability of well functioning and affordable transport systems to generate further economic growth and
- *Investors*: in need of clearly defined regulations and long-term policies to reduce the risk and enable the paradigm shift changes that they must promote.

153. Of these, the development community and some NGOs are most likely to buy in to the proposed action plans purely because of their climate change implications, however the identified co-benefits of all the proposed action plans directly impact major problem areas that countries and cities in Asia are currently facing.

154. Public awareness-raising to improve the understanding and knowledge of the different stakeholders is very important for climate change in general and transport-related climate change in particular and this needs to be promoted by the development community as well as by national and local stakeholders. Separate strategies are required for each different stakeholder to inform and promote the co-benefits associated with each policy intervention.

155. An area of special concern needs to be the limited capacity among all stakeholders in analyzing current trends, developing integrated policies for transport and climate change and effectively implementing and monitoring the policy approaches outlined in this report. Establishing priorities for climate and transport is still relatively new for both the development community and Asian countries and cities. In those few cases where such priorities have been established it has been within units with an environmental mandate rather than urban development or transport. This implies that before large training programs are initiated, the institutional mandates of different governmental agencies at both the national and the local level need to be adjusted. Since this is a new topic it is also important that sufficient capacity is created in the private sector both to guide decision making in the private sector and to act as a consultant to the government and the international development community. For a regional

approach to be promoted it is important that such capacity is not limited to individual cities or countries but is also consistent at the regional level.

156. In order for the stakeholders to engage in a productive dialogue and implement common programs and projects it is important to develop a better set of tools and instruments that can be used to identify and analyze trends and plan for the future. The development of the policy recommendations in this report was hampered by the lack of comparative data for Asian countries (for example modal split) and the overall absence of reliable data in specific areas such as the number of different vehicle types in use and the number of people making use of NMT.

F. Investment

157. Urban development and expansion of the transport systems in emerging Asian countries will require large amounts of funding. A joint ADB - JBIC - World Bank study in 2005 estimated that the creation of additionally required infrastructure for Asia at $165 billion per year for the next five years (2006-10), out of which $37 billion comprises investments required for roads and rails subsectors.

158. Investments are required for short, medium and long term. In general most of these investments would be needed in any case (e.g. for urban expansion, infrastructure generation, public transport and fuel supply). Ensuring the right type of investments so that GHG emissions are minimized can prevent economic damages through health impacts, congestion and road accidents. Since all these investments have important co-benefits including air quality and health, traffic and congestion, quality of life, road safety, transport efficiency and economic development, over the long-term, similar investments would probably be required even if the climate change component were not considered. It is encouraging that key components of the policy approaches identified as being more climate friendly also are less-costly to implement. For example a BRT is in many cities a more appropriate solution than a metro and is far less expensive to construct and to operate and maintain.

159. The economic benefits of investments in reducing air pollution from the transport sector or improving road safety have been well established. The limited financial returns often prevent the quick adoption of cleaner technologies such as low sulfur fuels. In order for such measures to be taken it is important to promote a willingness–to-pay attitude among the general public by undertaking extensive awareness raising campaigns. This will help to increase the possibility for consumer financing. At the same time it is important to ensure that the externalities of transport are well understood and reflected in any type of incentives and disincentives used in the transport sector. China recently modified the sales tax on light duty vehicles and introduced a system of 6 classes whereby cars with a small engine displacement (and low GHG emissions) are lightly taxed relative to cars with larger engine displacement.

160. To develop a medium to long term investment plan for transport in Asian cities will require addressing the status of the informal sector. As described in this report in many cities the informal sector is currently providing a large part of the public transport. The time perspective of this sector is limited. The sector does not generate enough cash internally to modernize fleets and it does not have established linkages with formal external sources of capital. Without regulating and formalizing this sector it will be difficult to develop integrated investment strategies and plans.

161. Introducing a climate change priority requires re-focusing many investment components and this demands an additional effort from the development community to build awareness, develop capacities and technical expertise, strengthen linkages, and promote inter-sectoral collaboration and technology development. It requires an increased knowledge base to encourage enlightened decision making that proactively evaluates the GHG implications of co-related projects.

162. Close monitoring of the results from research and development conducted by internationally or commercially supported efforts outside of emerging Asia can allow the countries in emerging Asia and the development community to optimize their funding within the region as a whole and within individual countries to catalyze investments in areas that remain behind and threaten to undermine the overall success of implementation of the action plan. Informed decision-making when selecting future action plans to mitigate climate change from this sector will thus require a knowledge base that closely monitors worldwide technological pathways and best-practices.

163. To catalyze investment to support the policy approaches proposed in this paper it is important to have dedicated funds available, this in addition to regular funding for urban development and transport described above. Such funds can help in overcoming the institutional, technological and knowledge related barriers and help finance pilot projects. It is not expected that such special funds will be able to take over the role of regular financing of urban development and transport as stated is in many cases undertaken by the private sector. Such dedicated funds could be financed from a range of sources, including:

i) Earmarked funds from special user charges such as a congestion charge. The London congestion charge has helped to fund the expansion and modernization of the bus fleet and has resulted in a modest modal shift away from private cars towards public transport. Other possibilities which can be introduced quicker and more widely include road user charges and fuel taxes. Both are already fairly widely used and can be redirected, most likely in part, towards providing incentives for more sustainable transport systems. This would require that governments, especially the Ministries of Finance, no longer regard such charges as instruments to raise the general revenues but as targeted policy instruments which both aim to restrain private car use and at the same time promote integrated land use and transport planning and the expansion and improvement of public transport. Another instrument which is not yet widely used in Asian countries is parking charges. Parking policies at present are in most cases ad-hoc and as in the case of other user charges do not have a transport related policy objective ;

ii) Linkages to GEF and CDM mechanisms could help raise interest. Currently there are no dedicated funding windows available for financing energy efficiency in transport unlike other areas where there are a range of special funds. If the global community is serious about moving forward with energy efficiency in the transport sector it will have to create similar funds to catalyze knowledge management, capacity building and policy development.

iii) Development agencies have over the last years either formally or informally adopted targets on for example renewable energy or water and sanitation. Embracing such targets, which are usually the outcome of international discussions have helped to prioritize funding in development agencies. It could be considered to encourage the adoption of targets on urban development and transport, e.g. improving share of trips undertaken by public transport and/or

NMT. At present less than 10% of transport related lending in ADB is for the development of urban transport systems and the large majority of funding is for road construction.

164. The danger of dedicated funding is that a dependency develops which prevents a wide scale replication and dissemination of successful sustainable transport solutions. A financial model whereby IFI financing is required as bridge financing might be attractive in the short term but needs to be avoided for the medium and long term.

165. It is important for those stakeholders who will be expected to take the lead in formulating and implementing transport programs and projects what the support is that will be provided by the national government. Few countries in emerging Asia have come out with a clear policy in this respect. A notable exception is the recent National Urban Transport Policy in India in which the national government formulated clear criteria for the support to be provided: (i) 50% of the cost of preparing comprehensive city transport plans and detailed project reports; (ii) equity participation and/or viability gap funding to the extent of 20% of the capital cost of public transport systems; and (iii) 50% of the cost of project development whenever such projects are sought to be taken up through public-private partnerships, so that a sound basis for attracting private partners can be established, whereby the remaining funds would have to come from the city development authority.

166. Most of the investment requirement for the international development community and to a lesser extent the governments in Asia is in institutional development and knowledge management. The private sector will be the source of the greater proportion of implementation investment, and for this to occur in the timeframe and to the required extent, very clear and transparent regulations and long-term policies need to be established. It can be expected that public private partnerships will increase especially with respect to the provision of urban public transport. This will require the establishment or improvement of a regulatory institutional framework. Currently few of the countries in Emerging Asia have effective independent regulators for public transport in place.

IV. ACTION PLAN

167. A multi-sectoral action plan needs to be developed as a roadmap for GHG reduction and co-benefit improvements on a regional – emerging Asia – level and for each individual country and city. The action plan presented in Figure 17 to Figure 21 can guide the individual countries and cities but countries and cities will have to ensure that their action plans reflect their particular situation.

168. The following action plans, as previously discussed, are presented below:

A. *To improve access to goods and services through an integrated urban plan*
The greatest GHG mitigation can be achieved in the medium to long term through linking urban development with transportation planning to improve access to goods and services whilst minimizing the need to travel.

B. *To reduce the fuel consumed per passenger- or freight-kilometer traveled through modal shift*
This is the component that can generate the largest GHG mitigation in the medium term. It involves modal shift; promoted by charging the true cost of externalities such as congestion, pollution, climate change and use of public infrastructure – roads and parking – to the use of private motorized transportation (cars and motorcycles) and providing efficient mass-transit and non-motorized alternative transport.

C. *To establish and implement fuel efficiency standards for new vehic*les
Energy efficiency standards need be implemented throughout emerging Asia for all forms of motorized transport.

D. *To massively increase the use of GHG-friendly biofuels for on-road transport*
Changing to fuels that have a lower carbon footprint in sufficient quantities would have a major impact in GHG emissions from on-road transport.

E. *To improve Fuel Efficiency in existing vehicles*
Improving the maintenance condition of in-use vehicles (in terms of quality and frequency) can generate an improvement in the short term for both their global and local emissions.

169. These action plans must be updated on a regular periodic basis as part of a continually improving multi-faceted process that respects the social and economic differences between countries and cities but maintains regional congruence and consistency. To support this process there is a need to establish an institutional mechanism in each country and city to discuss, evaluate and apply an action plan to address GHG emissions.

170. Similarly members of the international development community should formulate their own action plan to outline steps that will be taken by them to assist in Asian countries and cities to move away from the current mobility paradigm and replace it with one which takes into account the impact of transport on climate change.

Figure 17 - To improve access to goods and services through an integrated urban plan

Effectiveness	Institutional development	Investment and financing	Operation
A. To improve access to goods and services through an integrated urban plan			
Most of these actions will generate visible results in GHG mitigation in the ***medium to long term.*** *The short-term targets of capacity and awareness building and institutional integration and reinforcement should be identifiable within a shorter term political timeframe.* *The international development community together with national governments is key in catalyzing climate-change-friendly sustainable improvement of urban and transport development programs at the state, provincial and metropolitan-area levels*	• Support the formulation of metropolitan area development strategies that integrate all cities or municipalities within the area. • Promote via training and best-practice definition the development of a long term urban and transport structure plan for each major Asian metropolitan area and ensure that all short and medium term projects are on meeting these long term goals. • Strengthen the linkages at city and municipal levels between urban planning, transport planning, traffic management and enforcement to minimize functional and jurisdictional impediments to policy integration. • Charge the externalities of private motorized transport to improve NMT and mass-transport by actively promoting private transport demand restraint via spatial and time-variant pricing and non-financial measures. • Promote the involvement of local community groups and NGOs in the strategy design and project implementation via well-informed, opportune consultation. • Promote the application of consistent sustainable development indicators at the national, state and provincial levels to evaluate the urban and transport progress at city and municipal levels towards meeting these long term goals for each major Asian metropolitan area. • Promote GHG reduction as a “sine qua non” basis for all traffic management and urban and transport development projects	• Actively promote investment in infrastructure, safety and security, capacity and awareness building that develops NMT via a network of segregated routes and integrated areas in the urban environment. • Promote private sector investment that is consistent with the strategic framework. Provide capacity and awareness building to the private sector. • Promote multi-agency financing packages and programmatic lending to cities where different administrative areas need to collaborate within the same transport development program. • Ensure that all bank lending for urban development and road infrastructure projects have a long-term energy efficiency improvement component.	• Promote private sector operation of public transport. Provide technical assistance in the design of franchised, route-based urban transport concession contracts and controlling regulations. • Ensure that all urban development that is a high trip generator (such as shopping malls) has optimized public transport access with special attention to the modal interchanges (e.g.: private to public). • Evaluate bank investment projects on the basis of how they improve access and mobility of persons to goods and services, not on the basis of traffic improvements. • Strengthen sustainable urban development and transport planning training institutions and promote the retention of skilled professionals in evangelistic centers of excellence

Figure 18 - To reduce the fuel consumed per passenger- or freight-kilometer traveled

Effectiveness	Institutional development	Investment and financing	Operation
B. To reduce the fuel consumed per passenger- or freight-kilometer traveled through modal shift			
These actions can generate visible results in GHG mitigation in the short to ***medium term****. The deployment of BRT is achievable within a* ***shorter political timeframe****.* *The international development community together with national, state and provincial governments is key in catalyzing climate-change-friendly sustainable improvement of urban and transport development programs at the metropolitan-area and city or municipal levels*	As above plus: • Promote mass transport developments that work towards meeting a goal of improved door-to-door connectivity. Stand-alone routes will never substantially change the number of vehicles per 1000 population. • Promote collaboration between different administrative functions within the metropolitan area to create transport systems that integrate and cross administrative barriers. Provide education and guidelines to ensure that all the local agencies involved (land transport, urban development, traffic police etc) work towards a common vision and goal. • Develop technical expertise at the local levels of government to facilitate improved transport integration within a city-wide and regional development framework particularly for NMT to mass-transport interfaces. Promote best-practice development. • Assign responsibility at the highest level for traffic safety and for safety and security in all mass transport, and associated pedestrian and NMT development. • Strengthen the focus for access of the urban poor and mobility-impaired to transportation systems. • Reinforce traffic management and enforcement skills at the local level. • Develop metropolitan-area-wide policies that favor mass transport over private transport	• Focus and give preference to investments in transport programs that reduce the fuel consumed per passenger- or freight-kilometer traveled. • Procure investment for mass-transit projects and instigate policies that promote modal shift from private personal transport. Seriously consider low investment options that allow extensive coverage such as BRT operating on segregated roadways. • Consider public-private partnerships where the infrastructure investment for mass transit is provided by the government and the rolling stock is operated by well-regulated franchised private operators. (a franchised bus route can generate notable less GHG emissions (direct and indirect) than free competition between individual bus operators). Most urban transport systems can benefit from private operation. • Place emphasis on sufficient investment on infrastructure and improvements for pedestrians and NMT in all urban transport and development programs.	• Place emphasis on the development of financially sustainable transport systems which allow the system operator to invest in growth and continual system maintenance and rolling stock replacement. • To enable efficient and sustainable transport operations, it is desirable that subsidies to meet other sectoral objectives (health, education, etc) be financed directly through the budgets of these other sectors. • Since fares must be affordable, a well regulated mass transport system may require the franchised operator to internally subsidize a less profitable low cost service with a higher fare service on the same route (for example by operating seat-only A/C and higher passenger density non-A/C buses on the same route at regulated frequencies).

Figure 19 - To establish and implement fuel efficiency standards for new vehicles

Effectiveness	Institutional development	Investment and financing	Operation
C. To establish and implement fuel efficiency standards for new vehicles			
*These actions can generate noticeable results in GHG mitigation in the **medium term**. Whilst changes in standards, if implemented, can bring about considerable changes to fuel efficiency, their impact in overall results depend on the speed of incorporation into the in-use vehicle fleet.* *The international development community together with national governments is key in catalyzing climate-change-friendly sustainable improvement of fuels and vehicle technology*	• Promote the evaluation and open discussion of the health cost associated with automotive emissions and the participation of private and mass-transport in criteria- and GHG-emissions inventories at the local -- metropolitan area – and regional levels. • Promote the development of future scenarios of motorization based on population and urban growth and determine its expected impact on criteria- and GHG-emissions. Provide technical assistance with capacity and awareness building. • Develop a national technological automotive roadmap that defines and regulates the availability of no-lead and low sulfur fuels together with advanced engine and vehicle technology to mitigate the health cost and climate change impacts of road transportation.. • Establish the energy efficiency and vehicle emissions standards together will their associated fuel standards reducing the technology implementation gap for vehicle and fuels with a goal of reaching current "world-wide" standards in the shortest feasible timeframe (closing the gap). • Promote research and development. Assume a leadership position for 2- and 3-wheel vehicles and for the future use of non-carbon-fuels (e.g.: hydrogen). • Promote the involvement of local community groups and NGOs in the strategy design and roadmap implementation via well-informed, opportune consultation. .	• Promote an investment strategy that allows these standards to be implemented whilst reinforcing the international competitiveness of private sector stakeholders. Promote the accelerated substitution of old vehicles in the fleet with new cleaner, higher efficiency vehicles.	• Promote the involvement of local community groups and NGOs in the strategy design and roadmap implementation via well-informed, opportune consultation the future use of non-carbon-fuels (e.g.: hydrogen). • Actions need to be taken by private enterprise;- refineries, engine and vehicle manufacturers • Support the formulation of energy efficiency and vehicle emissions standards and their accelerated implementation. • Promote the accelerated replacement of old vehicles in the fleet with new cleaner and more efficient vehicles • Optimize the international competitiveness of refineries and manufacturing plants in Asia • Promote professional vehicle maintenance through training, parts availability and diagnostics

Figure 20 - To massively increase the use of GHG-friendly biofuels for on-road transport

Effectiveness	Institutional development	Investment and financing	Operation
D. To massively increase the use of GHG-friendly biofuels for on-road transport			
These actions can generate noticeable results in GHG mitigation in the ***long term****.* *The short-term targets of capacity and awareness building should be identified.* *The international development community together with national governments is key in creating a harmonized environment that promotes development and large scale production of biofuels within an evolving framework of diverse feedstocks and processes.*	• Promote via training and best-practice definition the development of a long term policy that creates a regional framework and incentivize GHG-friendly biofuel production for each major Asian economy. • Promote the development of regionally harmonized biodiesel quality standards and tariff policies congruent with international developments and standards that stimulate investments in large-scale production and facilitate international trade in biofuels, both within Asia and with markets outside the region. • Establish the appropriate legal framework at national and state levels to minimize functional and jurisdictional impediments to policy integration. • Promote GHG reduction as a "sine qua non" basis for all biofuels development projects.	• Actively promote the research and development of innovative feedstock and processes including integrated refining schemes. • Promote private sector investment that is consistent with the strategic framework of providing a substantial substitution of fossil fuels for on-road transport. • Provide capacity and awareness building to the private sector. • Promote multi-agency financing packages and programmatic lending to DMCs for the development of biofuels programs.	• Promote private sector operation of all phases of biofuel feedstock and production processes. • Evaluate bank investment projects on the basis of how they contribute to a mitigation of GHG emissions. • Strengthen sustainable fuels training institutions and promote the retention of skilled professionals in evangelistic centers of excellence. • Strengthen biofuels and raw materials trading on regional and world markets.

Figure 21 - To improve Fuel Efficiency in existing vehicles

Effectiveness	Institutional development	Investment and financing	Operation
E. To improve Fuel Efficiency in existing vehicles			
These actions can generate noticeable results in GHG mitigation in the short term. *The international development community together with national governments is key in catalyzing the political will-power required to get these programs off the ground.*	• Promote extensive capacity and awareness building on the health cost and additional fuel costs associated with inadequately tuned and repaired vehicles. • Promote and incentivize the political will-power in local – city and metropolitan area – governments to establish and effectively enforce in-use vehicle emissions standards. • Establish the appropriate legal framework that allows sanctions to be applied for failure to correctly perform the mandatory testing protocols and strengthen the linkages at city and municipal levels between environment and traffic enforcement to minimize functional and jurisdictional impediments to effective implementation. • Develop and establish a mandatory and well-enforced inspection and certification program focused on improving the emissions and fuel economy performance of older and intensively used vehicles in the fleet. Develop priority programs for municipal and urban bus fleets. • Evaluate the inclusion of mandatory vehicle fitness and safety inspection on older and intensively used vehicles in the fleet to directly promote increased road safety. • Evaluate retrofit as an option to achieve improved emissions and fuel economy performance from existing heavy vehicles at a lower cost and in a shorter timeframe than would be achievable through vehicle replacement.		• Promote improved vehicle maintenance through training, parts availability and diagnostics.

V. NEXT STEPS

171. This study presents one of the first comprehensive efforts to analyze the relationship between the transport sector and climate change in Asia over the next 25 years. The results of the analysis make it clear that even the most optimistic scenarios, integrating all expected technological improvements, will lead to a tripling of CO2 emissions over this period. At the same time the growth model for the transport sector on which these estimates are based will also result in an increase in air pollution from the transport sector, increase congestion to levels which seriously hamper the ability to move people and goods in an effective manner. In short, any continuation of historic tendencies or variations thereof, are not sustainable and should not be used as the basis for policy making and investments in urban development and transport.

172. A paradigm shift will be required which should result in a new Asian consensus on economic development mobility which can guide policy making and investment decisions. The international development community plays a key role in placing energy efficiency and climate change from transportation on the agenda. It needs to promote this change in vision together with the co-benefits of the proposed action plans that directly impact several of the major problem areas that the countries in emerging Asia are currently facing. The international development community through its assistance can help to get buy-in to the need for a paradigm shift by presenting and discussing the policy recommendations of this study in the continuation the deliberations on the G8 Gleneagles' Action Plan on Climate Change, Clean Energy and Sustainable Development as well as in regional meetings such as the upcoming second Regional Environmentally Sustainable Transport Forum in September 2006 in Indonesia, and the First Governmental Meeting on Urban Air Quality also in September 2006 in Indonesia. The ADB Regional and Sustainable Development workshop on "Energy Efficiency and Climate Change Considerations for On-road Transportation in Asia" in May 2006 is an important initial step for awareness-raising.

173. To promote the discussion at the national and local level it is important that the recommendations are in parallel also discussed at the regional level. The future of urban development and transport is being shaped now. In this context it will be helpful if multilateral development organizations make the topic of transport and climate change a more substantive part of their policy dialogues which they conduct on a regular basis in support of the development of their assistance and lending programs.

174. Whilst the development community should continue to provide advice on all modes of transport, greater importance should be given in future lending to programs that work towards integrally planned urban development and mass transport systems that increase mobility and access to goods and services whilst reducing vehicle-kilometers-traveled.

175. The international development community has a leading role to play in reducing the knowledge gap for developing countries by strengthening a continually-updated shared knowledge base on urban development and transport planning towards sustainable climate-friendly access to goods and services.

176. The international development community also has a leading role to play in the development of common tools that allow surrogate regional default parameters to be evaluated for hard- or costly-to-measure variables and for inter-comparison and accumulation of cities and countries.

177. A core set of monitoring parameters for the climate change components of on-road transport and associated co-benefits needs to be agreed between participating stakeholders to enable progress to be measured and reported – both at the local and regional levels – for each distinct action plan. This will most certainly require some field measurements to populate the baseline data where this is currently absent, and the development of supplementary parameter sets to cover specific local requirements.

178. Additional analysis needs to be performed with individual countries with particular reference to inclusion as a pilot case study in a few major metropolises and medium-sized cities. Here the international community should assist in the development of a strategic urban development and transportation plan, with selective support of small bus and para-transit operators, the development of private-public partnerships in mass transit and reducing the negative consequences of private motorization. The pilot cities should be chosen based on the individual countries interest and ability in undertaking the needed institutional reforms and building the required inter-sectoral linkages.

179. The international development community should also extensively reinforce research and development on the incorporation of bio- and non-carbon-based fuels (e.g.: hydrogen) for future use in on-road transportation.

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APPENDIX I

CURRENT PROJECTIONS

A. Greenhouse Gas Emissions

1. All energy sector Total GHG emissions

Country/Region	1990	1995	2000	2002	2002/1990
	Million metric tons of CO2 equivalent per annum				
China	2,403	3,203	2,772	3,513	146%
India	679	909	1,161	1,221	180%
Other emerging Asia	471	698	851	990	210%
Emerging Asia (EA)	3,553	4,810	4,783	5,724	161%
EA as % of OECD	37%	43%	40%	48%	
OECD (for reference)	9,489	11,088	11,839	11,944	126%

Source:United Nations Statistical division. Millennium Indicator: 'Carbon dioxide emissions (CO2), million metric tons of CO2 (CDIAC)'

2. Transport sector GHG emissions

Country/Region	1980	1990	1995	1999	1999/1990
	Million metric tons of CO2 (CDIAC) per annum				
China	83	122	159	221	180%
India	57	76	101	126	167%
Other emerging Asia	49	100	166	204	203%
Emerging Asia (EA)	189	299	425	550	184%
EA as % of OECD	8%	11%	14%	17%	
OECD (for reference)	2,272	2,711	2,953	3,230	119%

Source: International Energy Agency (IEA) Energy Balances of OECD Countries (1960-1999) and Non-OECD Countries (1971-1999)

3. Total CO_2 Emissions directly from on-road vehicles

Country/Region	2000	2005	2015	2025	2025/2000
Million metric tons of CO2 per annum					
China	141	181	300	455	321%
India	114	135	200	280	246%
Other emerging Asia	237	274	378	496	210%
Emerging Asia (EA)	492	591	879	1,231	250%
EA as % of OECD	18%	20%	27%	36%	
OECD (for reference)	2,783	2,919	3,268	3,466	125%
EA as % of World	18%	20%	27%	36%	
World Total	2,783	2,919	3,268	3,466	125%

Source: IEA-SMP transport model reference case projections (see http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

4. Total CO_2 Emissions directly from on-road vehicles in 2005 by type of vehicle

Country/Region	China	India	Other emerging Asia	Emerging Asia (EA)
Million metric tons of CO2 per annum				
Light Duty Vehicle	64.1	28.6	63.7	156.4
Medium Freight Truck	30.1	19.8	44.1	94.1
Heavy Freight Truck	28.9	36.6	85.5	151.0
2-wheelers	13.4	10.8	17.7	41.8
3-wheelers	7.1	4.9	6.6	18.6
Buses	16.3	18.8	30.7	65.8
Minibuses & paratransit	21.2	15.9	25.7	62.8
Total	181.1	135.4	274.0	590.5
Percent of EA	31%	23%	46%	100%

Country/Region	China	India	Other emerging Asia	Emerging Asia (EA)	OECD
Percent					
Light Duty Vehicle	35%	21%	23%	26%	69%
Medium Freight Truck	17%	15%	16%	16%	7%
Heavy Freight Truck	16%	27%	31%	26%	18%
2-wheelers	7%	8%	6%	7%	1%
3-wheelers	4%	4%	2%	3%	0%
Buses	9%	14%	11%	11%	4%
Minibuses & paratransit	12%	12%	9%	11%	0%
Total	100%	100%	100%	100%	100%

Source: IEA-SMP transport model reference case projections (see http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

5. Total CO_2 Emissions from on-road vehicles including upstream emissions (well-to-wheel)

Country/Region	2000	2005	2015	2025	2025/2000
Million metric tons of CO2 per annum					
China	169	216	359	543	322%
India	132	157	230	322	243%
Other emerging Asia	278	322	445	584	210%
Emerging Asia (EA)	579	696	1,034	1,449	250%
EA as % of OECD	18%	20%	27%	36%	
OECD (for reference)	3,278	3,430	3,818	4,050	124%
EA as % of World	18%	20%	27%	36%	
World Total	3,278	3,430	3,818	4,050	124%

Source: IEA-SMP transport model reference case projections (see http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

B. Energy

1. All sector, total energy consumption

Country/Region	1985	1990	1995	2000	2003	2003/1985
	Mtoe (million metric tons oil equivalent)					
China	559	680	886	978	1,146	205%
India	149	202	290	340	354	238%
Other emerging Asia	125	178	267	332	384	307%
Emerging Asia (EA)	833	1,060	1,443	1,650	1,884	226%
EA as % of OECD	20%	23%	27%	28%	32%	
OECD (for reference)	4,069	4,527	5,376	5,833	5,932	146%

International Energy Annual 2003, Energy Information Administration

2. All sector, total energy consumption per capita

Country/Region	2000	2001	2002	2002/2000
kg of oil equivalent per capita				
China	903	894	960	106%
India	509	508	513	101%
Other emerging Asia	573	585	598	104%
Emerging Asia (EA)	688	686	718	104%
EA as % of OECD	13%	13%	13%	
OECD Average	5,465	5,414	5,426	99%
EA as % of World	41%	41%	42%	
World Average	1,692	1,682	1,699	100%

World Bank's World Development Indicators Database

3. Fuel consumption of on-road vehicles (all fuels)

Country/Region	2005	2010	2015	2020	2025	2025/2005
	Mtoe (million metric tons oil equivalent)					
China	63	81	104	132	157	251%
India	47	57	69	84	97	209%
Other emerging Asia	95	112	132	154	173	182%
Emerging Asia (EA)	204	251	305	370	427	209%
EA as % of OECD	20%	23%	27%	32%	36%	
OECD (for reference)	1,009	1,069	1,127	1,169	1,196	119%
EA as % of World	13%	15%	17%	18%	20%	
World total	1,514	1,666	1,831	2,001	2,135	141%

Source: IEA-SMP transport model reference case projections (see http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

4. Diesel fuel consumption of on-road vehicles as percentage of all fuels

Country/Region	2005	2010	2015	2020	2025
	percent				
China	32%	31%	29%	28%	27%
India	64%	63%	60%	58%	57%
Other emerging Asia	55%	55%	54%	53%	53%
Emerging Asia (EA)	51%	50%	49%	47%	45%
OECD (for reference)	33%	34%	35%	36%	36%
World total	36%	37%	38%	38%	38%

Source: IEA-SMP transport model reference case projections (see http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

C. Population

1. Total Population

Country/Region	1985	1995	2005	2015	2025	2025/1985
			million people			
China	1,070	1,219	1,316	1,393	1,441	135%
India	766	936	1,103	1,260	1,395	182%
Other emerging Asia	580	717	849	981	1,100	190%
Emerging Asia (EA)	2,416	2,872	3,269	3,634	3,937	163%
EA as % of MDN	217%	245%	270%	294%	315%	
More developed nations (MDN)	1,115	1,174	1,211	1,237	1,249	112%
EA as % of World	50%	50%	51%	50%	50%	
World Total	4,844	5,692	6,465	7,219	7,905	163%

Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2004 Revision and World Urbanization Prospects: The 2003 Revision, http://esa.un.org/unpp

2. Urban Population as a percentage of total population

Country/Region	1985	1995	2005	2015	2025	2025/1985
				percent		
China	23%	31%	41%	50%	57%	249%
India	24%	27%	29%	32%	38%	156%
Other emerging Asia	26%	32%	38%	44%	50%	193%
Emerging Asia (EA)	24%	30%	36%	42%	48%	200%
More developed nations (MDN)	41%	45%	49%	54%	58%	142%
World Total	71%	73%	75%	77%	80%	114%

Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2004 Revision and World Urbanization Prospects: The 2003 Revision, http://esa.un.org/unpp

3. Urban Population

Country/Region	1985	1995	2005	2015	2025	2025/1985
			million people			
China	246	383	533	690	824	335%
India	186	249	317	406	527	283%
Other emerging Asia	150	226	322	431	551	367%
Emerging Asia (EA)	582	858	1,171	1,527	1,903	327%
EA as % of MDN	127%	162%	197%	230%	261%	
More developed nations (MDN)	458	529	596	663	728	159%
EA as % of World	17%	21%	24%	27%	30%	
World Total	3,415	4,155	4,842	5,581	6,340	186%

Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2004 Revision and World Urbanization Prospects: The 2003 Revision, http://esa.un.org/unpp

4. 10 of the 25 largest metropolitan areas in the world are in emerging Asia

Country	City	Population
China	Shanghai	18,150,000
	Beijing	12,100,000
	Shenzhen	10,700,000
India	Mumbai	19,850,000
	Delhi	19,700,000
	Kolkata	15,650,000
Bangladesh	Dhaka	13,250,000
Indonesia	Jakarta	16,550,000
Pakistan	Karāchi	14,300,000
Philippines	Manila	14,950,000

Source: The Principal Agglomerations of the World (2006-01-28)

D. Economy

1. Gross Domestic Product (GDP) per capita

Country/Region	2000	2001	2002	2003	2004	2004/2000
GDP per capita, Atlas method (current US$)						
China	856	924	992	1,099	1,272	149%
India	450	463	485	564	641	142%
Other emerging Asia	815	784	850	944	1,036	127%
Emerging Asia (EA)	711	735	786	880	998	141%
EA as % of OECD	3%	3%	3%	3%	3%	
OECD Average	27,246	26,731	27,750	31,023	34,173	125%
EA as % of World	14%	14%	15%	15%	15%	
World Average	5,217	5,110	5,245	5,822	6,444	124%

World Bank's World Development Indicators Database

2. Gross National Income (GNI) per capita

Country/Region	2000	2001	2002	2003	2004	2004/2000
GNI per capita, Atlas method (current US$)						
China	840	900	970	1,100	1,290	154%
India	450	460	470	540	620	138%
Other emerging Asia	742	772	812	886	1,030	139%
Emerging Asia (EA)	685	720	762	857	997	145%
EA as % of OECD	2%	3%	3%	3%	3%	
OECD Average	27,530	27,390	27,220	29,360	33,470	122%
EA as % of World	13%	14%	15%	16%	16%	
World Average	5,220	5,180	5,140	5,520	6,280	120%

World Bank's World Development Indicators Database

E. Vehicle Population

1. In-use vehicle population (2002)

Country/Region	Motorcycles & Mopeds	Passenger Cars	Buses & Coaches	Goods Vehicles	Total 4 or more wheels
	thousands of vehicles				
China	49,000	6,238	600	15,372	22,210
India	41,581	7,613	559	5,322	13,494
Other emerging Asia	51,636	21,653	3,281	10,959	35,893
Emerging Asia (EA)	142,217	35,504	4,440	31,653	71,597
EA as % of OECD	311%	7%	122%	35%	12%
OECD	45,685	506,470	3,627	90,079	600,175

2. Vehicles per 1000 people (2002)

Country / Region	Motorcycles & Mopeds	Passenger Cars	Buses & Coaches	Goods Vehicles	4 or more wheels
	vehicles per 1000 population				
China	38.0	4.8	0.5	11.9	17.2
India	39.5	7.2	0.5	5.0	12.8
Other emerging Asia	63.7	26.7	4.0	13.5	44.3
Emerging Asia (EA)	45.1	11.3	1.4	10.0	22.7
EA as % of OECD	114%	3%	45%	13%	4%
OECD	40	440	3	78	521

Total motor vehicles and passenger cars are from International Road Federation (mainly 2002 but earlier years where no data available);

Additional Sources

India:	<http://www.adb.org/Documents/Books/Key_Indicators/2005/pdf/IND.pdf>
Thailand	pop - http://www.library.uu.nl/wesp/populstat/Asia/thailanc.htm from 1 Jul - http://www.adb.org/Documents/Books/Key_Indicators/2005/pdf/THA.pdf
Phillippines	Department of Transportation and Communication, Philippines pop - http://www.library.uu.nl/wesp/populstat/Asia/philippc.htm http://www.adb.org/Documents/Books/Key_Indicators/2005/pdf/PHI.pdf
Nepal	Department of Transport Management, Nepal; 2002 onwards from Anil K. Raut pop - http://www.library.uu.nl/wesp/populstat/Asia/nepalc.htm & unctad.org http://www.adb.org/Documents/Books/Key_Indicators/2005/pdf/NEP.pdf
Indonesia	pop - http://www.library.uu.nl/wesp/populstat/Asia/indonesc.htm
China	pop: http://www.adb.org/Documents/Books/Key_Indicators/2005/pdf/PRC.pdf National Bureau of Statistics of China. China Statistical Yearbook 2004: Segment Y
Pakistan	pop: http://www.adb.org/Documents/Books/Key_Indicators/2005/pdf/PAK.pdf

F. Road Network

1. Kilometers of road, Total Road Network

Country/Region	2003
China	1,351,691
India	2,456,647
Other emerging Asia	1,295,429
Emerging Asia (EA)	5103767
EA as % of OECD	35%
OECD (for reference)	14,594,838

Source: RSDD, ADB

2. Number of vehicles per 1000 km of road

Country/Region	1999
China	42,274
India	23,961
Other emerging Asia	66,059
Emerging Asia (EA)	39,496
EA as % of OECD	89%
OECD (for reference)	44,253

Source: RSDD, ADB 2003

3. Average urban traffic speed

Country/City		Residential	Arterial	Highway
			km/h	
China				
	Beijing	16.4	19.5	38.8
	Shanghai	17.8	16.5	39.9
India				
	Pune	26.6	30.8	45.2

Source: International Vehivle Emissions Model Applications, College of Engineering Center for Environmental Research and Technology, University of California, Riverside

G. Road Safety

1. Deaths in road accidents

	Reported		Estimated	
Country/Region	Killed	Injured *	Killed	Injured *
				People
China	109,381	562,074	237,042	14,959,721
India	80,000	382,700	136,800	8,633,448
Other emerging Asia	58,510	341,646	101,457	6,444,633
Emerging Asia (EA)	247,891	1,286,420	475,299	30,037,802

Source: Estimated casualties and reported toad safety statistics in 2003, ADB

2. Estimated Death and Serious Injury Indicators

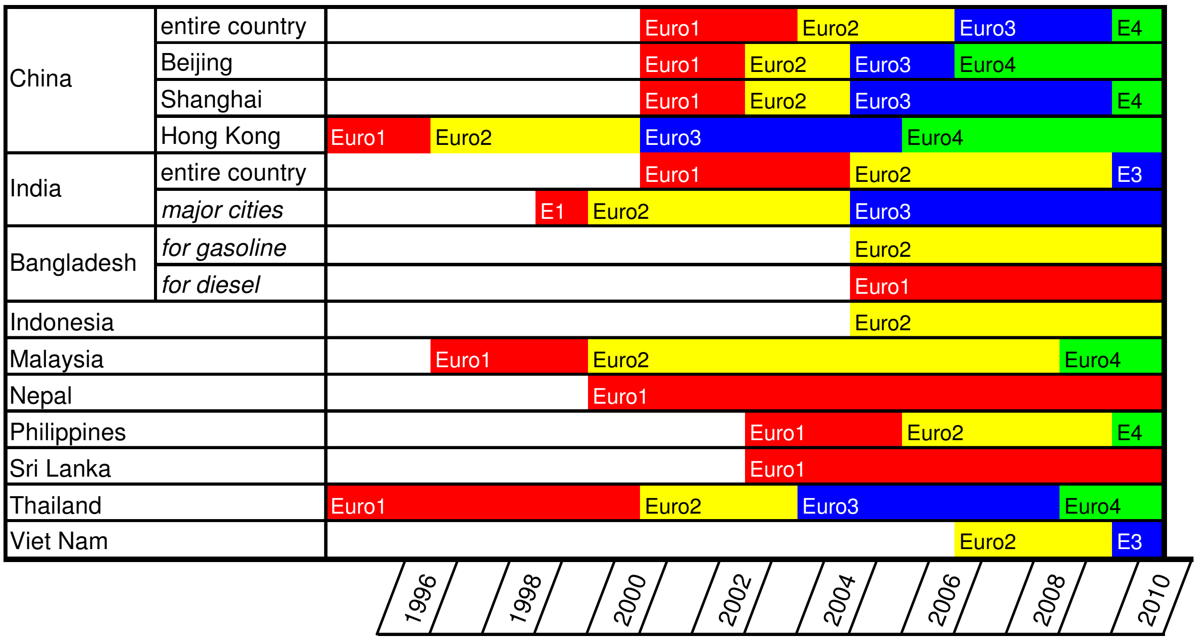
	Killed and Seriously Injured		
Indonesia	per 1000 vehicles*	per 1000 km road	per 1000 population
Bangladesh			
China	266	11,243	12
India	149	3,570	8
Other emerging Asia	76	5,053	8
Emerging Asia (EA)	151	5,979	10

* Includes 2 wheelers

Source: Estimated casualties and reported toad safety statistics in 2003, ADB

H. New-vehicle emissions standards

1. Light Duty Vehicles



2. 2-wheelers

Country/Region	Year	Type	CO	HC	HC + NOx
units in g/km, or as specified					
PRC	2003	2S	4%	4,000 ppm	-
		4S	4%	1,000 ppm	-
India	2000	2&4S	2	-	2
	2005		1.5	-	1.5
	2008/ 2010		1	-	1
Other emerging Asia					
Bangladesh	current	2&4S	3.5	-	2
Cambodia	current	2S	4%	3000 ppm	-
		4S	4%	2400 ppm	-
Indonesia	2001	2&4S	12	-	10
	2004		8	-	5
	2007		5	-	3
Malaysia	current	2S	8	4	0.1 (NOx)
		4S	13	3	0.3 (NOx)
Philippines	2002	2&4S	6%	-	-
	current		4.5%	-	-
Sri Lanka	current		6	-	-
Thailand	2002	2&4S	4.5	3	-
	2004		3.5	-	1.8
Viet Nam	2004	2&4S	4.5	-	3
	2007		3.5	-	2

I. Emissions

1. Total PM Emissions from on-road vehicles

Country/Region	2000	2005	2015	2025	2025/2000
	Thousand Metric Tons of PM				
China	183	203	219	135	74%
India	206	201	192	124	60%
Other emerging Asia	372	368	340	188	50%
Emerging Asia (EA)	761	772	751	446	59%
EA as % of OECD	69%	86%	154%	338%	
OECD (for reference)	1,099	893	489	132	12%
EA as % of World	28%	31%	37%	45%	
World Total	2,671	2,468	2,017	1,001	37%

Source: IEA-SMP transport model reference case projections (see http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

2. Total PM emissions from on-road vehicles in 2005 by type of vehicle

Country/Region	China	India	Other emerging Asia	Emerging Asia (EA)
Thousand Metric Tons of PM				
Light Duty Vehicle	37.1	20.3	38.1	95.5
Medium Freight Truck	22.9	20.3	45.8	89.0
Heavy Freight Truck	36.2	44.8	112.8	193.8
2-wheelers	61.9	49.6	83.0	194.5
3-wheelers	0.0	16.2	17.7	33.9
Buses	19.6	25.5	38.7	83.7
Minibuses & paratransit	24.9	24.3	32.5	81.7
Total	202.7	200.9	368.5	772.1
Percent of EA	26%	26%	48%	100%

Country/Region	China	India	Other emerging Asia	Emerging Asia (EA)	OECD
Percent					
Light Duty Vehicle	18%	10%	10%	12%	63%
Medium Freight Truck	11%	10%	12%	12%	6%
Heavy Freight Truck	18%	22%	31%	25%	22%
2-wheelers	31%	25%	23%	25%	3%
3-wheelers	0%	8%	5%	4%	0%
Buses	10%	13%	11%	11%	5%
Minibuses & paratransit	12%	12%	9%	11%	0%
Total	100%	100%	100%	100%	100%

Source: IEA-SMP transport model reference case projections (see http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

3. Total NO_X Emissions from on-road vehicles

Country/Region	2000	2005	2015	2025	2025/2000
	Thousand Metric Tons of NOx				
China	1,529	1,657	2,050	1,425	93%
India	1,594	1,665	1,948	1,362	85%
Other emerging Asia	3,253	3,395	3,769	2,561	79%
Emerging Asia (EA)	6,376	6,716	7,767	5,348	84%
EA as % of OECD	43%	57%	137%	311%	
OECD (for reference)	14,947	11,688	5,655	1,719	12%
EA as % of World	11%	13%	18%	22%	
World Total	59,076	53,044	43,039	24,649	42%

Source: IEA-SMP transport model reference case projections (see http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

4. Total NO_X emissions from on-road vehicles in 2005 by type of vehicle

Country/Region	China	India	Other emerging Asia	Emerging Asia (EA)
	Thousand Metric Tons of NOx			
Light Duty Vehicle	175.4	84.5	213.0	472.9
Medium Freight Truck	285.8	229.1	534.0	1,048.9
Heavy Freight Truck	483.2	597.7	1,503.5	2,584.4
2-wheelers	120.7	94.5	174.2	389.4
3-wheelers	0.0	30.8	37.1	67.9
Buses	260.8	339.5	516.1	1,116.4
Minibuses & paratransit	330.8	288.7	416.9	1,036.4
Total	1,656.6	1,664.8	3,394.9	6,716.2
Percent of EA	25%	25%	51%	100%

Country/Region	China	India	Other emerging Asia	Emerging Asia (EA)	OECD
	Percent				
Light Duty Vehicle	11%	5%	6%	7%	43%
Medium Freight Truck	17%	14%	16%	16%	11%
Heavy Freight Truck	29%	36%	44%	38%	37%
2-wheelers	7%	6%	5%	6%	1%
3-wheelers	0%	2%	1%	1%	0%
Buses	16%	20%	15%	17%	8%
Minibuses & paratransit	20%	17%	12%	15%	1%
Total	100%	100%	100%	100%	100%

Source: IEA-SMP transport model reference case projections (see http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

5. Total VOC Emissions from on-road vehicles

Country/Region	2000	2005	2015	2025	2025/2000
	Thousand Metric Tons of VOC				
China	2,841	2,717	2,206	902	32%
India	2,590	2,248	1,742	664	26%
Other emerging Asia	4,850	4,173	2,745	1,012	21%
Emerging Asia (EA)	10,280	9,138	6,693	2,578	25%
EA as % of OECD	48%	69%	291%	234%	
OECD (for reference)	21,326	13,219	2,297	1,101	5%
EA as % of World	24%	30%	52%	45%	
World Total	42,259	30,371	12,786	5,688	13%

Source: IEA-SMP transport model reference case projections (see http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

6. Total VOC Emissions from on-road vehicles in 2005 by type of vehicle

Country/Region	China	India	Other emerging Asia	Emerging Asia (EA)
Thousand Metric Tons of VOC				
Light Duty Vehicle	461.5	143.6	694.5	1,299.6
Medium Freight Truck	175.2	41.6	178.2	395.0
Heavy Freight Truck	55.8	69.1	173.7	298.6
2-wheelers	1,728.9	1,397.5	2,287.7	5,414.1
3-wheelers	0.0	455.8	487.4	943.2
Buses	74.6	40.2	110.1	224.9
Minibuses & paratransit	221.6	99.9	240.8	562.4
Total	2,717.5	2,247.7	4,172.5	9,137.7
Percent of EA	30%	25%	46%	100%

Country/Region	China	India	Other emerging Asia	Emerging Asia (EA)	OECD
Percent					
Light Duty Vehicle	17%	6%	17%	14%	87%
Medium Freight Truck	6%	2%	4%	4%	2%
Heavy Freight Truck	2%	3%	4%	3%	2%
2-wheelers	64%	62%	55%	59%	8%
3-wheelers	0%	20%	12%	10%	0%
Buses	3%	2%	3%	2%	1%
Minibuses & paratransit	8%	4%	6%	6%	0%
Total	100%	100%	100%	100%	100%

Source: IEA-SMP transport model reference case projections (see http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

7. Total CO Emissions from on-road vehicles

Country/Region	2000	2005	2015	2025	2025/2000
	Thousand Metric Tons of CO				
China	15,334	14,856	13,608	5,858	38%
India	11,661	10,722	9,637	3,794	33%
Other emerging Asia	24,242	21,711	16,325	6,421	26%
Emerging Asia (EA)	51,237	47,289	39,570	16,074	31%
EA as % of OECD	32%	47%	156%	106%	
OECD (for reference)	158,176	101,202	25,287	15,101	10%
EA as % of World	19%	24%	43%	35%	
World Total	271,955	196,460	91,573	46,249	17%

Source: IEA-SMP transport model reference case projections (see http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

8. Total CO Emissions from on-road vehicles in 2005 by type of vehicle

Country/Region	China	India	Other emerging Asia	Emerging Asia (EA)
Thousand Metric Tons of CO				
Light Duty Vehicle	2,672.8	747.4	4,073.1	7,493.3
Medium Freight Truck	1,266.0	177.8	1,102.5	2,546.3
Heavy Freight Truck	255.8	316.5	796.1	1,368.4
2-wheelers	7,779.8	6,288.6	10,294.8	24,363.3
3-wheelers	0.0	2,050.9	2,193.4	4,244.3
Buses	550.0	256.3	785.6	1,592.0
Minibuses & paratransit	2,331.9	884.1	2,465.4	5,681.5
Total	14,856.5	10,721.6	21,710.8	47,289.0
Percent of EA	163%	117%	238%	518%

Country/Region	China	India	Other emerging Asia	Emerging Asia (EA)	OECD
Percent					
Light Duty Vehicle	18%	7%	19%	16%	89%
Medium Freight Truck	9%	2%	5%	5%	2%
Heavy Freight Truck	2%	3%	4%	3%	2%
2-wheelers	52%	59%	47%	52%	6%
3-wheelers	0%	19%	10%	9%	0%
Buses	4%	2%	4%	3%	1%
Minibuses & paratransit	16%	8%	11%	12%	0%
Total	100%	100%	100%	100%	100%

Source: IEA-SMP transport model reference case projections (see http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

9. Total Lead (Pb) Emissions from on-road vehicles

Country/Region	2000	2005	2015	2025	2025/2000
	Thousand Metric Tons of Pb				
China	1.17	0.25	0.00	0.00	0.0%
India	0.48	0.10	0.00	0.00	0.0%
Other emerging Asia	3.33	0.64	0.00	0.00	0.0%
Emerging Asia (EA)	5	1	0	0	0.0%
EA as % of OECD	162%	199%	23%	324%	
OECD (for reference)	3	0	0	0	0%
EA as % of World	12%	5%	0%	43%	
World Total	42	21	1	0	0%

Source: IEA-SMP transport model reference case projections (see
http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

Source: IEA-SMP transport model reference case projections (see
http://library.iea.org/Textbase/subjectqueries/keyresult.asp?KEYWORD_ID=4121)

J. Fuel Standards

1. Gasoline Specifications

Country		Lead	Sulfur	Benzene	Aromatics	Olefins	Oxygen	RVP
			ppm	% v/v, max	%	%	% m/m, max	kPa, max
China	nationwide	Lead free	500	2.5	40	35	-	74
	Hong Kong	Lead free	50	1	42	18	2.7	60
India	nationwide	Lead free	500	5	-	-	2.7	35-60
	Major Cities	Lead free	150	1 & 3b				
Bangladesh		Lead free	1000	-	-	-	-	68
Cambodia		Lead free	-	3.5	-	-	-	-
Indonesia		0.30 g/l	2000	-	-	-	2.0 (premix	62
Malaysia		Lead free	1500	5	40	18	-	70
Pakistan		Lead free	10000	5	40	-	-	62-69
Philippines		Lead free	1000	2	35	-	2.7	62
Sri Lanka		Lead free	1000	4	45	-	2.7	35-60
Thailand		Lead free	500	3%	35	-	1-2%	-
Viet Nam		Lead free	5000-10000	5	-	-	-	-

[b]Benzene – 3% in metros and 1% in National Capital Region

Source: CAI-Asia, 2005

2. Sulfur levels in Diesel

Country	Region	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
China	nationwide	5000						2000			*500 - widely used*						
	Beijing	5000						2000		500	350						
	Hong Kong		500					50					*10 - under consideration*				
India	nationwide	5000				2500					500					350	
	major cities	5000				2500	500				*350*					*50*	
Bangladesh								5000									
Cambodia						2000											
Indonesia		5000															
Malaysia		5000		3000				*500 - marketed*			500					*50*	
Pakistan		10000						5000									
Philippines		5000					2000			500							
Sri Lanka		10000							5000	3000/ 500			500				
Thailand		2500			500					350						50	
Viet Nam		10000							2500			500					

Legend: > 500 | 51 – 500 | < 50 | < 10

Source: CAI-Asia, 2005

K. Fuel prices

1. Gasoline

Country/Region	1995	1998	2000	2002	2004	2004/1995
	in US Cent per litre (last survey 17-20 Nov 2004)					
China	27	28	40	42	48	178%
India	48	56	60	66	87	138%
Other emerging Asia						
High	75	84	66	66	79	88%
Low	34	16	17	27	27	79%
Reference						
United States	34	32	47	40	54	159%
Europe						
France	117	111	99	105	142	121%
Germany	112	96	91	103	146	130%
Spain	89	84	73	83	121	136%
United Kingdom	92	111	117	118	156	170%

Source:Dr Gerhard P. Metschies, GTZ, International Fuel Prices 2005, 4th Edition

2. Diesel

Country/Region	1995	1998	2000	2002	2004	2004/1995
	in US Cent per litre (last survey 17-20 Nov 2004)					
China	24	25	45	37	43	179%
India	19	21	39	41	62	216%
Other emerging Asia						
High	31	30	44	44	61	142%
Low	20	7	6	19	18	95%
Reference						
United States	33	27	48	39	57	173%
Europe						
France	78	77	82	80	125	160%
Germany	77	69	78	82	129	168%
Spain	70	70	65	72	110	157%
United Kingdom	85	111	122	120	160	188%

Source:Dr Gerhard P. Metschies, GTZ, International Fuel Prices 2005, 4th Edition

APPENDIX II

THE CASE OF CHINA: TRANSPORT, ENERGY EFFICIENCY AND CLIMATE CHANGE IN THE PEOPLE'S REPUBLIC OF CHINA

A. INTRODUCTION

1. With the economic development in China, energy consumption and greenhouse gas emissions are being taking more and more into consideration. As a main energy consumption component, transportation is been paid a great deal of attention. This paper illustrates the status and challenges of transportation energy consumption in China. Also, the potential of oil savings and greenhouse gas reductions under different visions are discussed.

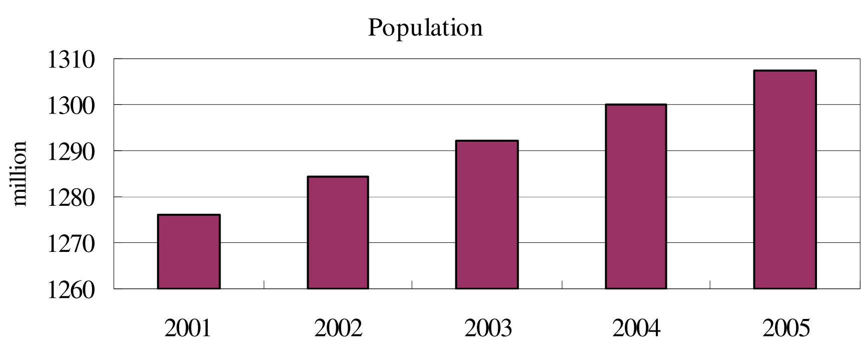
B. TRENDS AND CHALLENGES IN CHINA

1. Urbanization

a. Rapidly increasing growth in Population and GDP in China

2. Figure 1 shows the population growth in the 10th Five Year Plan. The average annual rate of increase is about 2.5% per year [1].

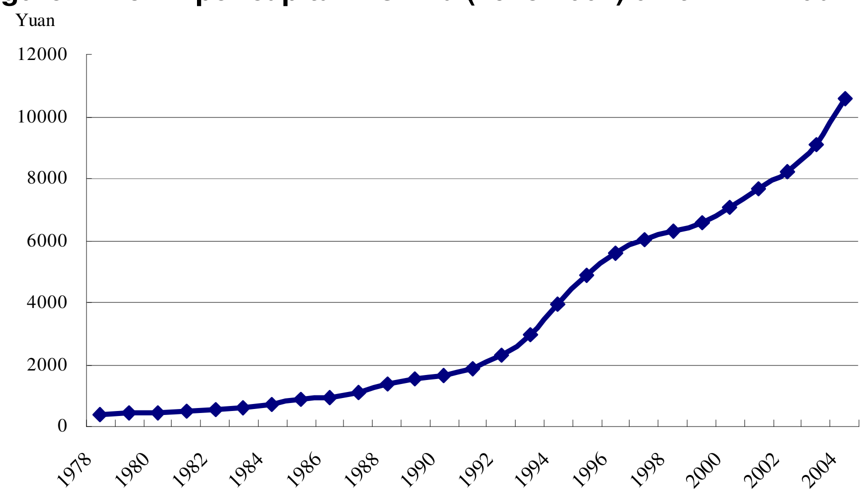
Figure 13: Population (2001 - 2005) in China



(Source: China statistic yearbook)

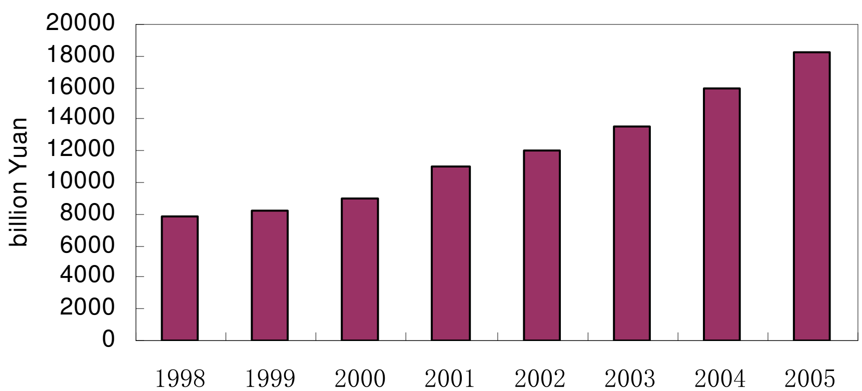
3. According to statistical data, China's GDP in 2005 was RMB 18,232 billion Yuan[83] and GDP growth rate was 9.9%. In 2004, the average disposable income of urban residents was RMB 9,422 Yuan per capita while the average net income of agriculture population was RMB 2,936 Yuan per capita. The income ratio between urban and suburban residents was 3.2:1 (Figures 2 and 3).

Figure 14: GDP per capita in China (1978-2004) unit: RMB Yuan



Source: China statistic yearbook

Figure 15: GDP in China (1998-2005)



Source: China statistic yearbook

[83] There are approximately 8 Chinese Yuan per 1 USD

b. Uncontrolled urban growth has lead to urban sprawl

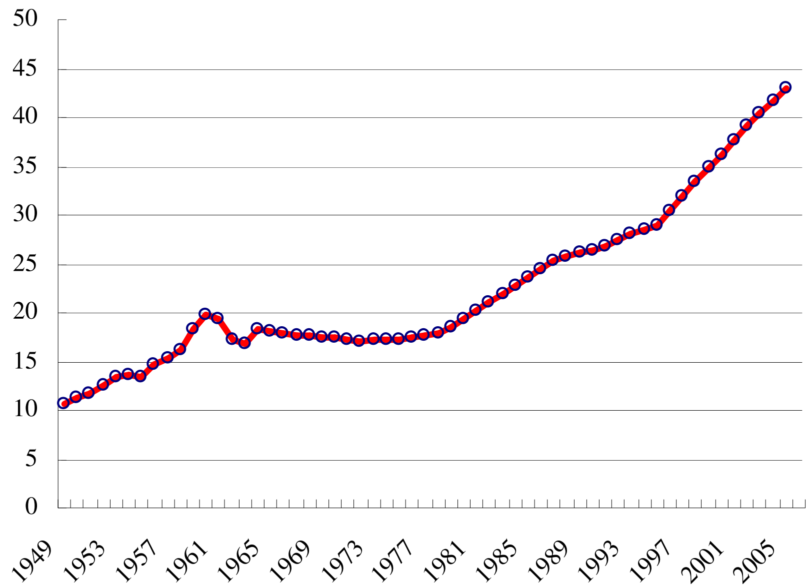
4. China's modern industrialization and urbanization started after the Opium War (1840-1842). When the People's Republic was founded in 1949, the urban population accounted for only 10.6% of the total population in the country. The urban population reached 19.4% in 1980, 26.23% in 1990 and 41.76% in 2004 (the current average urbanization level in developing countries is about 40%) [2]. According to the statistics released at the end of 2004, the number of cities increased from 136 in 1949 to 661 in 2004, amongst which are 4 municipalities directly under the Central Government, 15 cities at the sub-provincial level (cities whose economic planning power is directly under the Central Government), 268 cities at prefecture level, and 374 cities at county level.

5. In 1949, China had over 5,000 towns; the number dropped to 2,173 in 1978, and reached 19,883 in 2004. The non-agricultural population was about 50 million in 1949, and by 2004 has grown to 543 million (which ranks as the highest in the world and is double the urban population in India which is in second place). Both the urban area and the urbanization level in China have increased considerably, especially in eastern China (Figures 4, 5 & 6).

Figure 16: China's urban area in 1982, 1995 and 2002

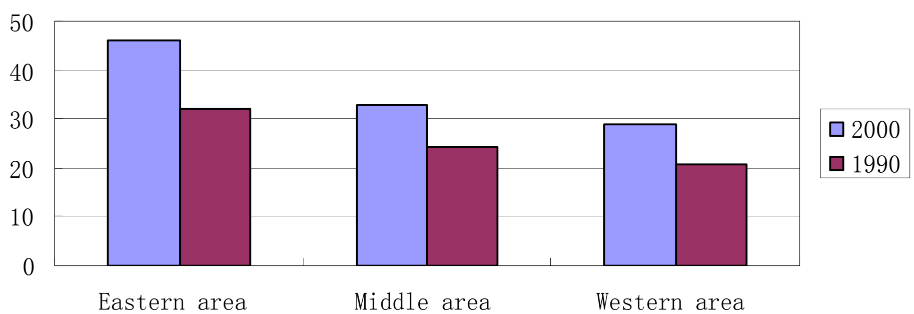
Source: Report of China cities' development in 2004

Figure 17: Urbanization Process in China Between 1949-2004



Source: Urban Planning for Sustainable Urban Mobility)

Figure 18 - Urbanization level in different areas of China in the year 2000 and 1990



(Source: Report of China cities' development in 2004)

6. The 11th Five Year Plan specifically mentions urbanization. It includes plans to: improve the level of urbanization; develop clusters of cities and strengthen urban planning and management [3]. As a result, urbanization will continue to develop.

7. This rapid increase in urbanization causes great challenges in land use. Without stringent land use control, developers will try to use any land they can for profit, as a result, urban areas sprawl rather than grow in an orderly manner. For example, in Beijing during the past 30 years, the urban areas have sprawled from within the second ring road to beyond the fifth ring road in almost every direction. The total urban core increased from 20 km^2 to about 1500 km^2, this urban structure,

which consists of one single high density urban core with gradually lower density sprawl in every direction causes serious urban logistics and transportation problems.

c. Land-use planning and travel demand

8. The configuration and continual modifications of the urban functional zones have changed the primary passenger and freight movement distribution characteristics. The transportation network and public transit routes need continual adjustments. The growth of urban space and the lengthening trip distances require increasing the transit speed of all transportation modes. High-intensity land use exploitation causes passenger and freight flow-rates to exceed the road capacity. Also, the improvement in residents' living standards increases their expectations for travel and level of service. This in turn requires constructing multi-mode urban transportation systems of a new type

9. The linkage between urban transportation and urban development has not been made due to the lack of effective policy guarantees. Due to this, the economic activity within the central area continues to increase in many big cities as does population and employment density. Central agglomerations are continuously exceeding planned capacity, leading to a severe deterioration in transportation within these central areas.

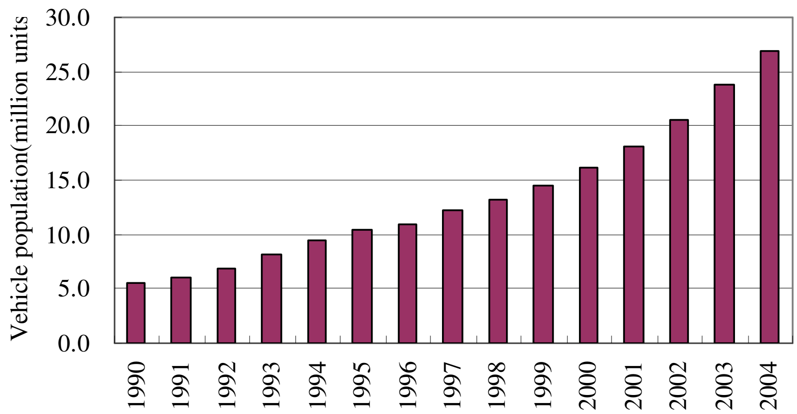
10. Highway corridors (that are mainly for the cars) have been established which have stimulated the rapidly increase of car traffic. Centripetal transportation characteristics and tide-pattern traffic flows are apparent. The transportation situation is getting worse. For example: The travel volume within the third ring road in Beijing accounts for 60% of the total travel volume in the city and that within the second ring road represents 47% of the city's total. Motor vehicle travel intensity in the city area is 3.6 times higher than that in the suburban area. In the past eight years, vehicle travel intensity in the old city area has increased by a factor of 1.6.

2. Rapidly increasing motorization

a. Population of motor vehicles in China

11. In recent years, the population of motor vehicles in China has increased rapidly. Figure 7 shows the growth of vehicle ownership; from the early 1990s to today, China has maintained a high annual growth rate of 13% in vehicle ownership. By the end of 2004, the total number of registered vehicles was close to 26 million and the total number of motorcycles was over 45 million.

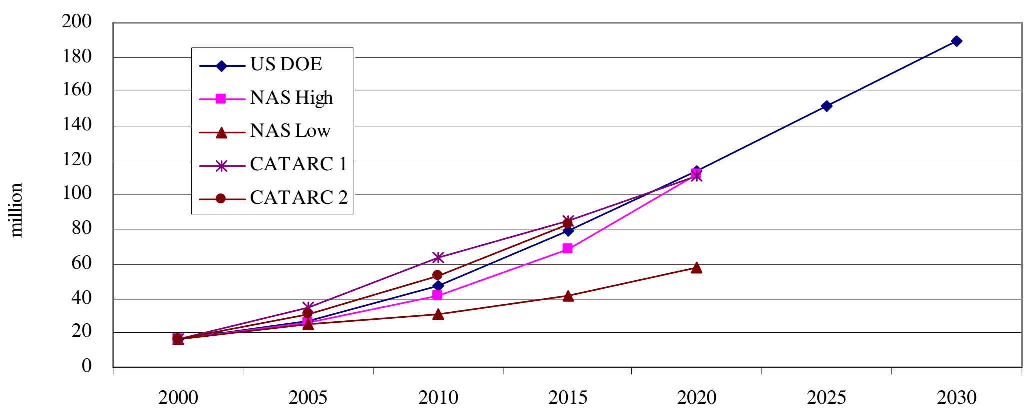
Figure 19: Growth of the motor vehicle population in China [1]



Source: China statistic yearbook

12. Motorization will continue to grow rapidly over the next 10~20 years, yet the vehicle ownership in China is still much lower than in developed countries. International experience shows that there will be a vehicle purchase peak when the country's per capita GDP reaches $3000~4000 USD, which China will happen within 20 years. Thus vehicle ownership -- as an important indicator of the standard of living -- will continue to rise. Figure 8 illustrates various forecasts of the Chinese vehicle population from Chinese and international researchers. Although forecasts invariably show considerable uncertainty, it is generally acknowledged that, around 2020, the total number of motor vehicles will be between 100 and 130 million. The rapid growth of the number of motor vehicles will bring greater challenges to the urban transportation systems, energy and environment.

Figure 20: Vehicle population forecast [4]

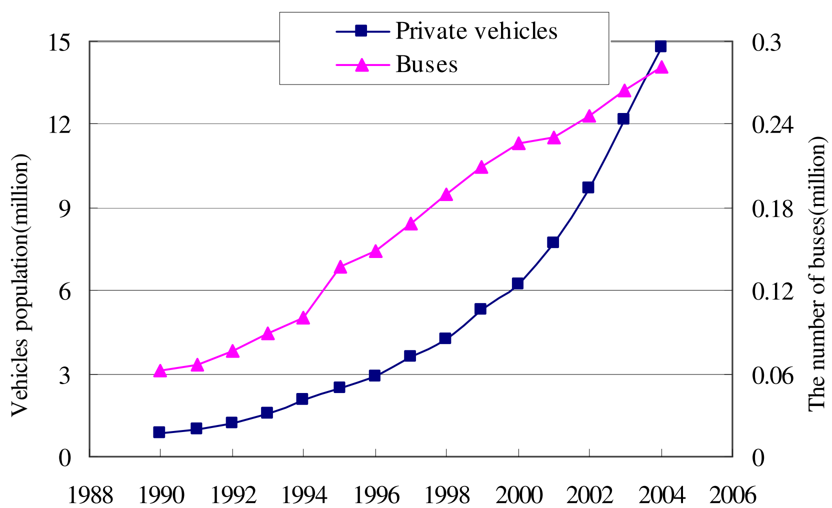


Source: Energy, Environment and transportation in China

b. Disproportionate growth in private car ownership

13. Based on vehicle registration data, ownership of private vehicles has experienced an annual growth rate of 23%. By the end of 2004, the number of the private vehicles in China had increased to 14.8 million, which accounted for 55% of the total number of vehicles. In recent years, although government has increased investment on the development of public transportation, the growth rate of buses was still slower than that of private vehicles. The rapid growth of private vehicles has brought a lot of problems to cities, such as serious traffic congestion, accidents and air pollution. It is urgently needed that new policies be adopted to alleviate the pressure caused by the rapid growth of private vehicles in China (Figure 9).

Figure 21: The growth of private vehicles and buses in China [5]



Source: Yearbook of China transportation & communications

c. Dieselization Trends

14. Diesel is playing an increasingly important role in the on-road transportation sector in China. The China Automotive Technology and Research Center (CATARC) estimated the diesel consumption of road transportation sector for commercial and other vehicles. The results are shown in Table 1. Whilst gasoline consumption for vehicles in China has increased from 19.8 to 38.1 million tons during 1990-2002; with an average annual growth rate of 5.6%; diesel consumption for vehicles has increased from 4.5 to 17.1 million tons, with an average annual growth rate of 11.8%.

15. By the end of 2002, diesel consumption for vehicles accounted for 31% of the total fuel consumption for vehicles. There is a clear dieselization trend.

Table 1: Vehicular gasoline and diesel consumption (x 104 tons)[6]

Year	Vehicle gasoline consumption	Vehicle Diesel consumption	Total consumption	Diesel consumption/Total consumption (%)
1990	1984.5	452.5	2437.0	18.6
1991	2188.8	512.1	2700.9	19.0
1992	2522.8	630.7	3153.5	20.0
1993	2722.5	705.6	3428.1	20.6
1994	2580.1	711.0	3291.1	21.6
1995	2685.8	725.2	3411.0	21.3
1996	2818.5	809.1	3627.6	22.3
1997	2976.1	873.0	3849.1	22.7
1998	2945.6	922.5	3868.1	23.8
1999	3198.8	1285.7	4484.5	28.7
2000	3554.4	1451.3	5005.7	29.0
2001	3588.6	1555.0	5143.6	30.2
2002	3811.4	1709.6	5521.0	31.0

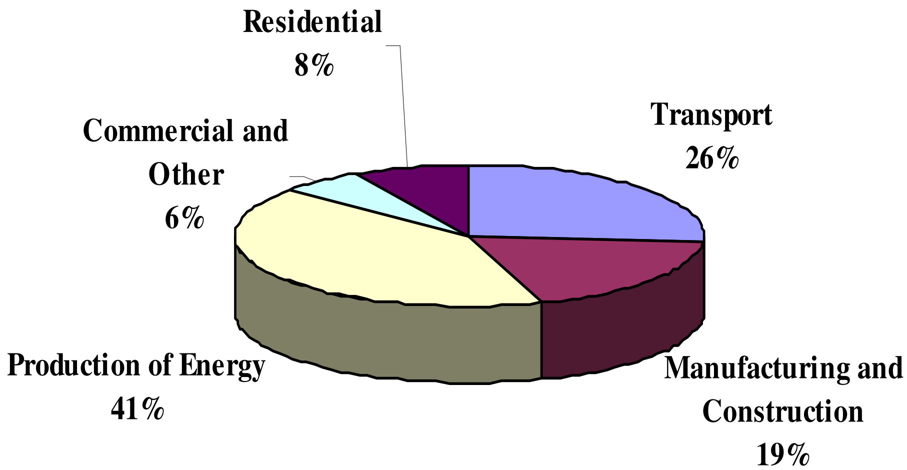
3. Rapidly increasing GHG and local emissions

a. Greenhouse Gases (GHG)

16. China is currently the second largest greenhouse gas emitter in the world (The USA is the largest). If these trends continue, the China's carbon emissions will reach 1940 million tons in 2020 and China will become the largest GHG emitter by 2030. This will place China under formidable international pressure [7].

17. GHG emissions will have long term environmental, health and economic impacts. GHG emissions from transportation accounts for about 26% of the global all-sector total (see Figure 10).

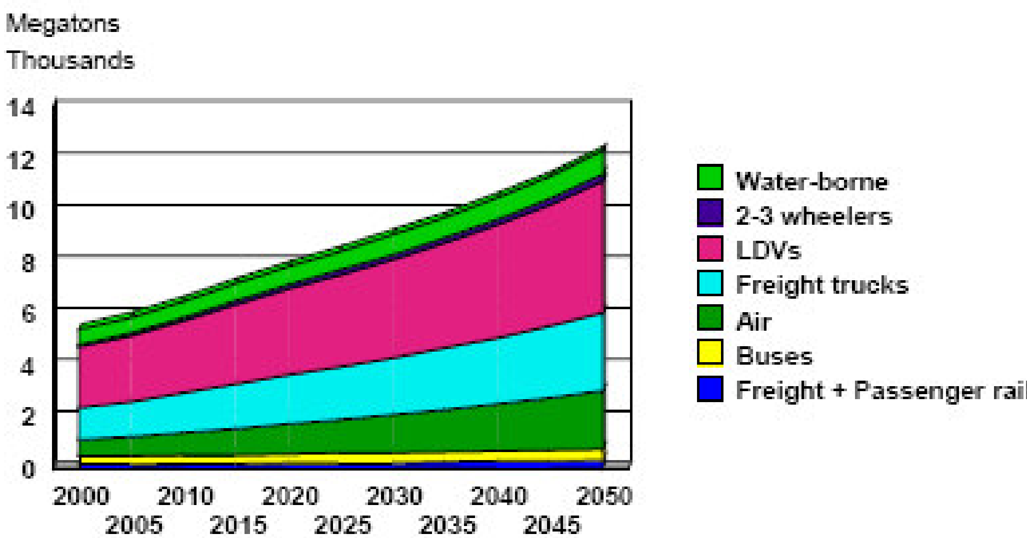
Figure 22 - Share of worldwide C02 emissions from the combustion of fuel [8]



Source: International Experience in Improving Fuel Efficiency and Reducing Greenhouse Gases

18. Figure 11 shows the GHG emissions of different transport modes. It can be seen that light-duty vehicles account for the largest source.

Figure 23 - World Transport Vehicle CO_2 Emissions By Mode[8]



Source: International Experience in Improving Fuel Efficiency and Reducing Greenhouse Gases

19. Table 2 also shows that GHG emissions have grown almost as rapidly as vehicle fuel consumption.

Table 2: Vehicle CO2 emission [1]

(Million tons)

	1997	1998	1999	2000	2001	2002
Car	6.10	6.81	7.71	8.58	9.99	11.73
Motorcycle	4.03	5.02	5.67	6.76	7.76	9.14
CO2 emissions	147.77	160.88	175.22	184.48	198.36	229.04

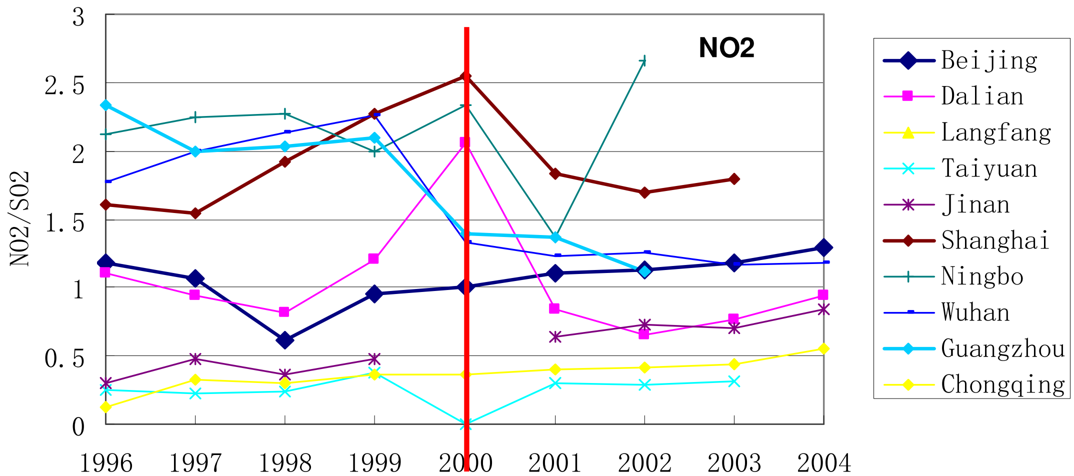
4. Local pollutant

a. Main pollutants

20. Serious air pollution is caused by the fast growth of the vehicle population and kilometers traveled. From 2001, many amendments have been added to the emission standards to better control vehicle pollution. Although all new cars do meet the published emissions standards, the high vehicle population growth will certainly cause the total emissions from on-road transport to increase.

21. General speaking, the major source of SO_2 is coal burning while NO_2 is emitted both from coal burning and vehicles. In cities, vehicle emissions are the largest contributor to NO_2 emissions. The ratio of NOx/SO_2 can directly reflect the air pollution type. A high ratio of NO_2 to SO_2 indicates a high vehicle emission contribution. From an analysis of monitored urban air quality data over the last ten years (Figure 12), an increasing trend of NO_2/SO_2 can be found in 10 cities, particularly in the largest cities, such as Beijing, Chongqing, Jinan etc. In Figure 14, NOx was monitored prior to 2000 and NO_2 after that date.

Figure 24: NO2/SO2 ratio



Source: China urban statistic yearbook

22. The vehicle population in China will be 45~50 million in 2010 and 100~130 million in 2020. The CO and NOx released by vehicles will represent 85% and 45%~50% of the total pollutant emissions respectively in 2010. In some large cities, such as Beijing, Shanghai, and Guangzhou, vehicles have become the main source of noise and air pollutants. Vehicle emissions occupy a larger and larger percentage of the total amount (Table 4).

Table 4: Vehicle emission contribution (%)

	CO	HC	NOx	PM10
Beijing	80.3	79.1	54.8	8.1
Dalian	40	30	20	
Taiyuan	50	50	40	5
Jinan	70	60	40	
Shanghai	86	96	81	
Ninbo	3.15t/h	0.34t/h	3.56t/h	
Guangzhou	88.8	91	79.3	
Chongqing	85.8	36.6	86.3	

Source: Environment Considerations for Sustainable Urban Mobility

Emission inventory [9]

Table 5: 2001 Pollutant emission inventory in China (Gg)

	SO2	*NOx*	*VOC*	*CO*	*NH3*	*TSP*	*PM10*	*PM2.5*	*BC*	*OC*
Beijing	247.5	263.7	463.5	3123.4	65.8	183.8	124.7	89.4	18.5	22.6
Tianjin	361.2	226.6	300.2	1919.2	42.2	305.8	152.5	98.8	14.4	17.8
Hebei	1579.4	929.7	1260.8	12112.3	840.4	1895.7	1259.7	892.3	134.4	211.1
Shanxi	1241.5	658.1	560.3	5783.5	208.3	1451.2	1012.8	711.9	191.2	181.2
Neimenggu	830.3	593.1	668.9	5196.1	320.9	822.1	548.2	402.4	49.6	154.0
Liaoning	824.9	672.5	876.4	7353.8	398.5	1123.5	701.2	497.7	63.1	115.6
Jilin	357.0	384.0	558.8	4124.6	331.9	684.5	444.3	304.7	44.9	100.0
Heilongjiang	224.8	560.5	966.3	5839.4	378.0	904.2	652.2	491.3	55.0	219.4
Shanghai	591.2	424.4	432.9	1908.2	77.4	220.7	128.2	83.6	11.0	9.4
Jiangsu	1253.3	826.7	1330.1	8901.3	1006.8	1879.6	1147.9	823.1	77.7	182.7
Zhejiang	1529.1	547.4	834.2	5087.5	418.1	1308.8	787.7	530.9	39.5	80.4
Anhui	586.8	487.7	782.7	7483.2	670.5	1234.7	765.7	543.8	79.7	180.2
Fujian	326.8	228.8	586.8	3669.6	334.4	648.6	433.7	325.4	40.9	125.5
Jiangxi	377.2	232.8	461.8	3747.0	461.0	665.5	430.4	285.8	36.6	91.3
Shandong	1925.3	917.6	1757.2	12976.7	1093.0	2208.3	1471.8	1048.9	114.7	233.4
Henan	1007.1	717.2	1091.4	9289.5	1134.6	1687.9	1107.7	768.4	104.0	178.5
Hubei	1915.8	460.5	860.7	7931.3	797.8	1284.6	807.5	578.3	82.0	182.7
Hunan	542.5	296.7	722.3	6107.9	721.7	1112.9	709.1	509.0	69.5	166.5
Guangdong	1024.6	831.1	1583.1	8823.4	712.2	1631.2	1041.3	729.1	57.8	139.9
Guangxi	718.5	216.4	574.8	4158.1	519.9	707.9	483.8	350.8	37.5	112.6
Hainan	39.7	43.6	159.8	1278.1	78.0	142.1	115.5	97.7	12.6	44.9
Chongqing	1065.0	189.1	310.0	2758.9	370.5	644.6	402.8	283.9	36.2	82.7
Sichuan	1809.0	420.9	1015.5	8157.4	741.0	1347.4	851.6	619.8	90.2	210.2
Guizhou	1017.7	274.1	363.8	3253.2	349.8	636.4	442.4	320.5	64.9	102.9
Yunnan	256.0	259.1	579.8	4122.3	487.4	715.3	503.4	373.0	50.0	132.8
Xizang	5.5	89.1	166.3	1087.8	93.4	146.1	100.3	82.3	7.7	50.8
Shanxi	611.1	243.7	422.3	3235.0	303.7	571.2	376.3	265.7	36.8	73.4
Gansu	223.9	210.7	310.6	2934.6	209.6	425.0	295.9	221.3	35.2	66.5
Qinghai	37.7	98.5	141.9	1065.1	89.6	157.9	108.7	87.0	10.8	36.7
Ningxia	193.2	79.9	88.4	753.7	54.6	152.5	87.2	60.0	7.6	11.3
Xinjiang	173.4	284.3	392.2	3004.3	253.4	449.6	291.7	212.4	31.6	63.2
Total	22897.2	12668.8	20623.9	157186.2	13564.5	27349.4	17786.2	12689.0	1705.3	3580.0

4. Vehicle, Engine and Fuels Technology

a. New vehicle technology

(i) New vehicle emission standards

180. The new vehicle emission standards in China are similar to the European vehicle emission standards. Stage I entered in force in 2001. Stage II was implemented in 2004. Beijing, Shanghai and Guangzhou are ahead of the national scheme in implementing the standards. The regulations for new vehicle emission control are shown in Table 6.

Table 6: China new vehicle emission standards

Code of standard	Name of standard	Instead of	Implement data
GB18352.1-2001	Limits and measurement methods for emissions from light-duty vehicles (Ⅰ)	GWPB 1 -1999 HJ/ T 26. 1□26. 5 -1999 GB 14761 -1999 HJ/ T 26. 1□26. 5 -1999 GB 14761 -2001	2001-04-16
GB17691 -2001	Limits and measurement methods for exhaust pollutants from compression ignition engines of vehicles	GWPB 6 -2000 HJ 54 -2000 GB 17691 -1999	2001-04-16
GB18352.2-2001	Limits and measurement methods for emissions from light-duty vehicles (Ⅱ)	GWPB 1 -1999	2004-07-01
GB18352.3-2005	Limits and measurement methods for emissions from light-duty vehicles□Ⅲ□Ⅳ□		2007-07-01 2010-07-01
GB17691□2005	Limits and measurement methods for exhaust pollutants from compression ignition and gas fuelled positive ignition engines of vehicles	GB 17691□2001 GB 14762□2002	2007-01-01 2010-01-01 2012-01-01

181. The newest regulation covering in-use vehicle emissions is GB 18285-2005, ‘Limits and measurement methods for exhaust pollutants from vehicles equipped spark-ignition engine under two-speed idle conditions and simple driving-mode conditions.

(ii) Development of advanced electric-drive vehicles

182. In the 1980s, China began research on electric-drive vehicles. In the ‘Tenth five year plan’, electric-drive vehicles is one of the main research directions.

183. In the pure battery passenger vehicle research, some institutes have finished the stabilization of Miyun electronic vehicle production center. Shown in Figure 13 is the EV Bus.

Figure 25: Electric Bus

184. Hybrid vehicle technology is considered one of the most useful vehicle power technologies; it's also an important bridge between traditional vehicles and future fuel cell vehicles. The government, companies and research institutes have focused activities in this field. In the 'tenth five year plan', hybrid vehicle research had the largest number of projects.

185. Fuel cell vehicle research is now carried out by universities, institutes and vehicle producers together. Tsinghua University developed a fuel cell bus and Tongji University developed a fuel cell car which has a top speed of 122km/h and a hydrogen consumption of 1.1kg per hundred kilometers.

(iii) Alternative Fuels and their implementation

Ethanol

186. Ethanol can be used directly or mixed with gasoline as the fuel for engines, and can also be mixed with diesel. But ethanol has lower heating value than gasoline thus driving the same distance will consume about 6%~7% more liters than undiluted gasoline, it will also increase the cost.

187. China is not producing ethanol fuel for the whole country. China is currently using E10 gasoline, the total amount of ethanol produced for fuel is about 1 million metric tons from corn, which makes about 10 million metric tons of E10 gasoline (gasoline with 10 percent ethanol in volume blend). This is not a major program however since corn – used as feedstock – is not sufficiently plentiful to smooth-out the energy shortage.

Bio-diesel

188. Bio-diesel has a higher cetane number and oxygen content, it can burn more completely and lower emissions of CO, HC and PM. Bio-diesel has very low sulfur and aromatic content, so SO_2 and PAH emissions will be very low, and it will be a good clean substitute fuel.

iv Need to Control in-use vehicle emissions

189. China has an Inspection and Maintenance program (I/M) for in-use, on-road vehicles whose emissions test component has been recently tightened in the newly issued 'criterion of vehicle maintenance, inspection and diagnostic technology', The program requires all vehicles to be periodically inspected and maintained / repaired as required.

190. Under this program high emission vehicles that are detected must be repaired. Using the BASM5024 driving cycle as an example, the reduction in CO emissions for these vehicles is up to 84.7% and the reductions in HC and NOx emissions are 64.8% and 64.7% respectively.

5. Growing congestion and safety concerns

191. Even though all the big cities are accelerate the constructing of urban roads, the contradiction between transportation supply and demand is still serious. The phenomenon of congestion presents a trend the getting worse. The travel speed in the central-area of most metropolis is around twenty kilometers per hour. Traffic congestion presents an extending trend both in the scale of time and space. For example, the average saturation rate on the trunk network of Shanghai reaches 90% in peak hours and 12.5% of the trunk roads in Guangzhou have travel speeds of less than twenty five kilometers per hour.

192. Studies in Beijing have indicated that when the average travel speed of buses drops by one kilometer per hour, the loss of transport capacity is equal to the carrying power of 200 buses which is as high as 100 million Yuan[10]. The loss of efficiency caused by transportation congestion has increased the cost of traffic management, and at the same time seriously restricts the healthy development of the urban economy.

193. The number of traffic accidents grew at a rate of 12.96% per year between 1992 and 2002. The average annual mortality rate is increasing by 42%. China's ordinary road accident rate and mortality rate were 0.238 cases/km and 0.059 cases/km respectively. The highway accident rate and the mortality rate have reached 1.894 cases / km and 0.248 cases / km (Table 7) [11].

Table 7: Road accident rate statistics in China [12-14]

Year	No. of	Death toll	person injured	Death proportion per thd. vehicles	Death proportion per million. person
1970	55437	9654	37128	22.763	11.6
1975	91606	16862	71776	18.386	18.2
1980	116692	21818	80824	10.447	22.1
1985	202394	40906	136829	6.239	38.9
1990	250297	49271	155072	3.338	43.1
1995	271843	71494	159308	2.248	59
1998	346129	78067	222721	1.730	62.5
1999	412860	83529	286080		
2000				1.535	70.8
2001	773306	115266			
2002	785837	118193			
2003	660839	103394	487940		
2004	517888	107076	480865		
2005	450254	98738	819911		

Source: Traffic accident statistic by month in 2003, 2004 and 2005 etc.

6. Rapidly increasing of transportation energy consumption

a. Energy consumption status in China

194. During the last two decades, China's energy consumption has increased rapidly together with marked economic growth. As GDP continues to rise, China's vehicle industry has developed rapidly, particularly in the 10th Five Year plan. Because of the increasing vehicle population, the need to increase fuel economy and reduce emissions is becoming more important. The fuel economy of domestic vehicles is often 20%-30% lower than for the same type of vehicle in developed countries.

195. China has very low oil resource per capita. The population of China is 21% of the world's while the oil resource is only 3%. During the past twenty years, GDP has increased by 8-9% every year. Along with the economic growth, energy consumption has also increased rapidly. In 1978, China's primary energy consumption was 571 million ton standard coal, by 2000 this had more than doubled to 1280 million ton standard coal. By the end of 20th century, China had become the second largest energy consumption nation in the world, behind the USA.

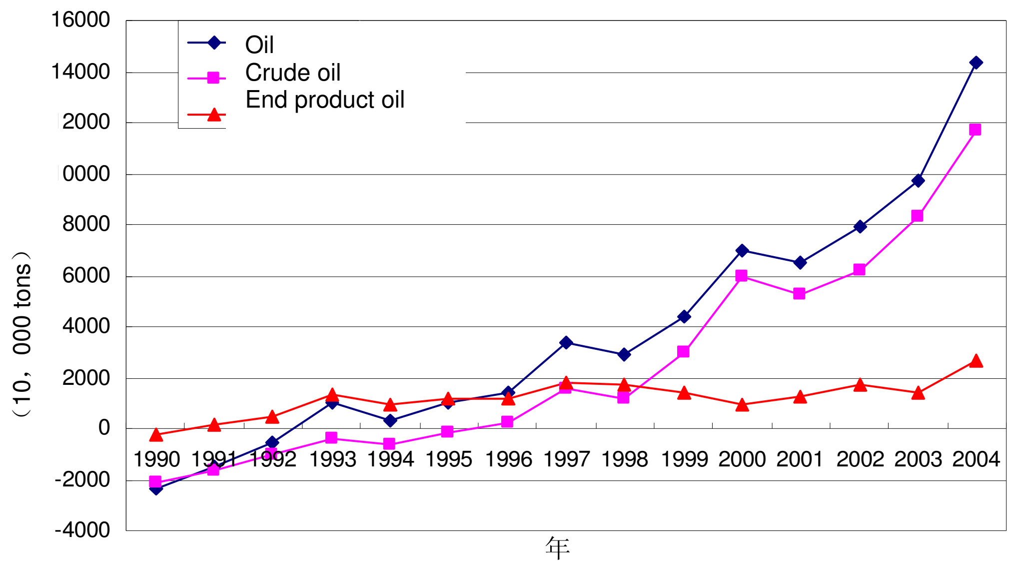
196. Over the last 20 years, 19% of China's primary energy consumption came from oil. In the 9th five-year period, 10.16 million tons of oil was consumed per year; in 2000, China's oil consumption reached 210 million tons, becoming the third largest economy in terms of oil consumption behind the USA (890 million tons) and Japan (250 million tons). Table 8 shows the historic trends of China's oil supply and demand, identifying the country's oil imports and Figure 14 shows the historic tendency of the imports of crude oil and refined petroleum products.

197. In 1993, China became a net oil importer. By 2000, the annual oil imports reached 70 million tons, accounting for 32% of oil consumption.

Table 8: China Oil imports（million tons)

	1994	1995	1996	1997	1998	1999	2000	2002	2003	2004
Domestic demand	130	160	170	196	200	210	230	240	252	309
Domestic supply	150	160	180	200	190	210	190	180	170	175
Import	30	40	50	68	60	64	70	70	91	150

Figure 26 - Net imports of crude oil and refined oil



b. Energy consumption trends in China

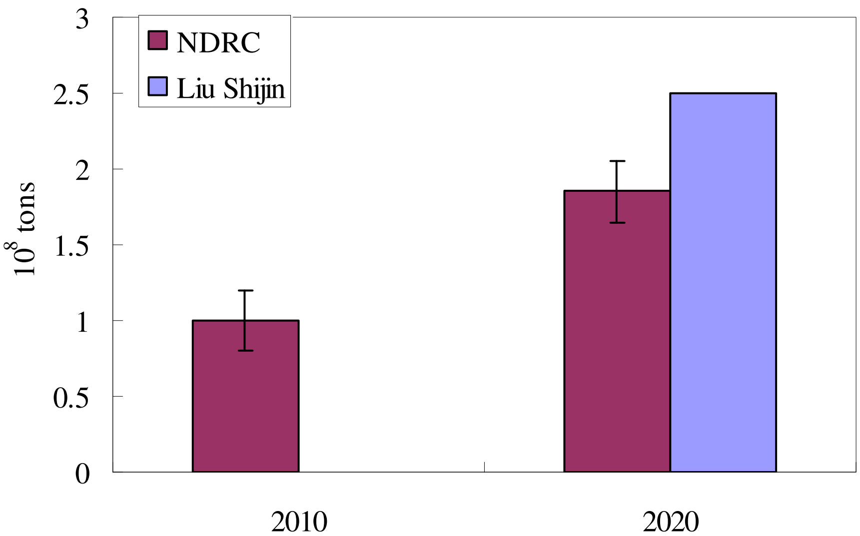
198. According to the National Development and Reform Commission's (NDRC) forecast, in 2010, oil net imports to China will reach 80-120 million tons and in 2020 will reach 150-220 million tons. By 2020, more than 50% of the oil consumption will be met by imports. This

increase in oil imports will seriously threaten Chinese energy security and affect economical development.

199. China's energy requirements will exceed 3.3 billion standard tons of coal for the first time in 2020, this includes 2.8 billion tons of coal, and 600 million tons of crude oil. The energy consumption in 2020 will be more than 2.5 times that of 2000, the GHG emissions will reach 1.94 billion tons [7].

200. The cost of the national energy consumption was 125 billion Yuan in 2001, accounting for 13% of GDP, whilst in the USA it only accounts for 7%. According to the NDRC, between 2000 and 2020 the elasticity coefficient of China's energy expense is 0.65. Energy demand grows at 4.8% per year. The growth of electric power demand is greater than primary energy. This growth in energy demand places great pressure on resources, the environment, GHG emissions and energy supply. It is a serious challenge to China's energy development [15]. This forecast is shown in Figure 15.

Figure 15 - China's net oil imports



c. Energy consumption of Transportation

201. In 1999, researchers of Tsinghua University calculated the energy consumption of the Chinese traffic departments in 1995 (including vehicle transportation, water transportation, railway transportation and air transportation). The result of this analysis indicates that in 1995 the oil consumption of vehicle transportation was 43.8 million tons, accounting for 70% of the oil consumption of the entire transportation system, and 32% of the national oil consumption that year.

202. In 2000, the economical technical research institute (Sinopec) estimated national vehicle fuel oil consumption (including commercial vehicles, motorcycles and agricultural vehicles) for 1997. The results indicated that vehicle oil consumption was 50.3 million tons in 1997, accounting for 30% of the national oil consumption. This research also forecasted, to 2005, the national vehicle fuel oil consumption to be 50% greater than that of 1997.

203. Also in 2000, CATARC estimated the fuel consumption for the national vehicle population (including commercial vehicles, motorcycles and agricultural vehicles) for 1998. This research showed that total nation vehicle oil consumption was about 42.9 to 71.6 million tons, which is between 21.7% and 36.1% of the total national oil consumption.

204. In 2004, researchers in Tsinghua University again calculated the energy consumption of Chinese traffic department between 1997 and 2002. In 2002 the vehicle oil consumption reached 72.5 million tons, which was 33% of total national oil consumption. The vehicle diesel consumption occupied 42.2% of national diesel consumption.

Gasoline
205. 21% percent of the total crude oil input in China is used to produce gasoline. In recent years, vehicle and gasoline production has increased rapidly and gasoline quality has also improved greatly in China.

206. Table 9 shows China's gasoline production. Cars accounted for 89%-90% of total gasoline consumption and motorcycles 8%-9% of the total; agricultural and industrial machines accounting for the rest.

Table 9: Domestic gasoline production and vehicular gasoline consumption (million tons)

Year	Crude Oil	Gasoline		
		Production(A)	Vehicle consumption(B)	B/A（%）
1990	138.3	21.6	19.8	92.0
1991	141.0	24.0	21.9	91.1
1992	141.7	27.3	25.2	92.5
1993	144.9	31.4	27.2	86.5
1994	147.6	28.5	25.8	90.4
1995	149.8	30.5	26.9	88.0
1996	157.3	32.8	28.2	85.9
1997	160.7	35.2	29.8	84.6
1998	161.0	34.7	29.5	85.0
1999	160.0	37.4	32.0	85.5
2000	163.0	41.3	35.5	86.0
2001	164.0	41.5	35.9	86.4
2002	167.0	43.4	38.1	87.9

Diesel
207. The diesel output of 1998 in China was 45.5 million tons and occupied 30% of crude oil. In recent years, #0 diesel occupied the largest proportion due to the geographic and climatic characteristics; for instance, #0 light diesel output in 1997 occupied 71.3% of the total amount. Light diesel output in China during recent years is shown in Table 10.

T able 10: Domestic diesel production and vehicular diesel consumption (million tons)

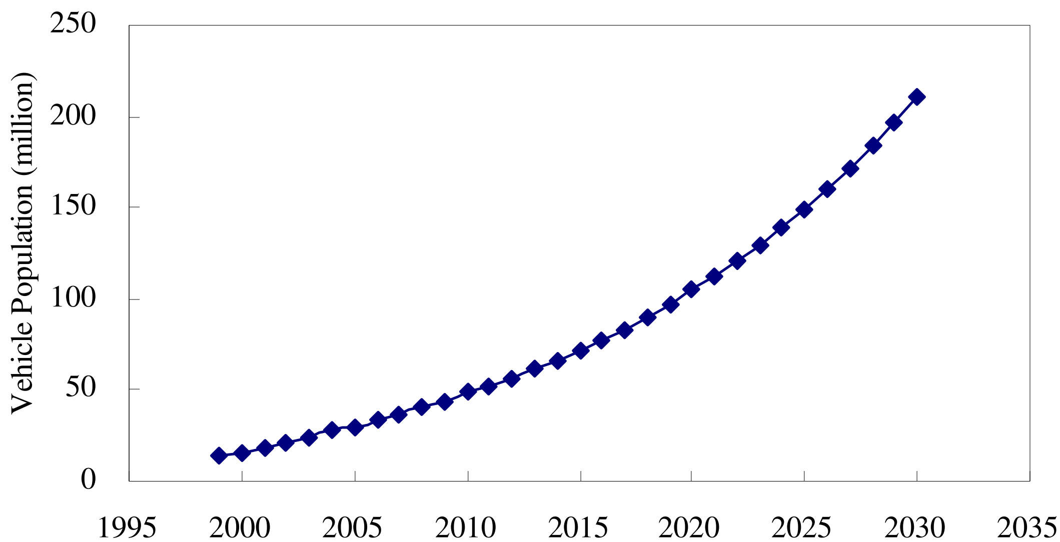
Year	Crude oil	Diesel		
		Production(C)	Vehicle consumption(D)	D/C （%）
1990	138.3	26.1	4.5	17.3
1991	141.0	28.5	5.1	18.3
1992	141.7	31.7	6.3	19.9
1993	144.9	34.7	7.1	20.3
1994	147.6	34.8	7.1	20.4
1995	149.8	39.7	7.3	18.3
1996	157.3	44.2	8.1	18.3
1997	160.7	49.2	8.7	17.7
1998	161.0	48.8	9.2	18.9
1999	160.0	63.0	12.9	20.4
2000	163.0	70.8	14.5	20.5
2001	164.0	74.9	15.6	20.8
2002	167.0	77.4	17.1	22.1

d. Challenges of transportation energy consumption in China

i. Vehicle population and fuel consumption in the future 30 years in China

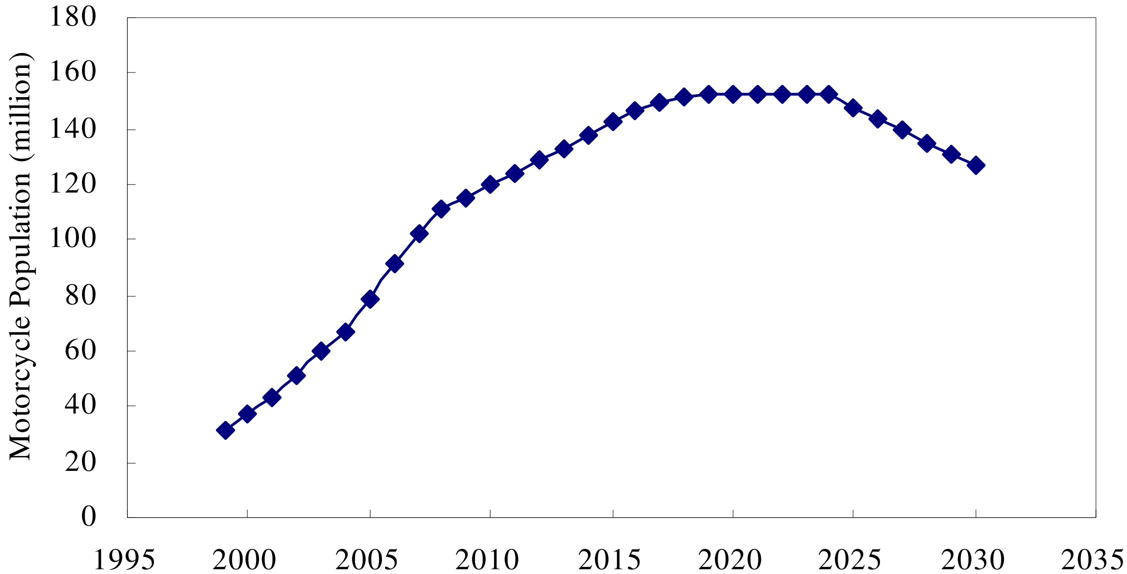
208. Based on historic trends and expected GDP, the total vehicle population (without motorcycles) in China is estimated to be 211 million in 2030; a growth factor of nearly 6 times compared with vehicle population in 2005 (Figure 16).

Figure 27: China's vehicle population forecast 1999-2030



209. The motorcycle population will also increase over the next 20 years. Because of the policy to encourage the use of economical cars, it is expected that a proportion of the motorcycle users will become car owners. The motorcycle population is forecast to be 130 million in 2030 (see Figure 17).

Figure 28: China's motorcycle population forecast 1999-2030



210. If vehicle fuel efficiency does not improve, the total fuel consumption of vehicles will be about 500 million tons in 2030, which is 6 times the vehicle fuel consumption in 2000 (Figure 18). As a result, in the business as usual scenario CO2 emissions from vehicles will be 1,600 billion tons in 2030 (Figure 19).

Figure 29: Total fuel consumption 2000-2030

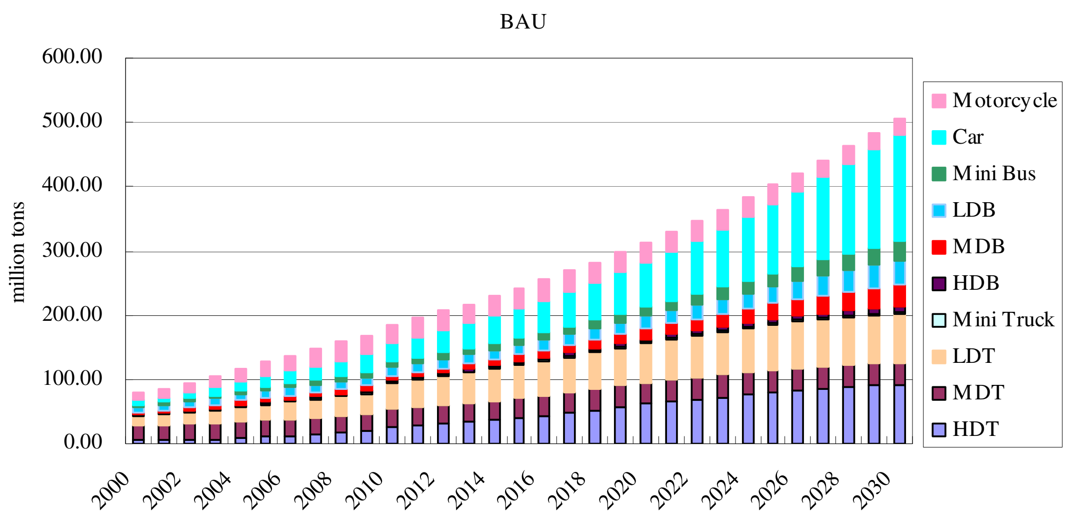
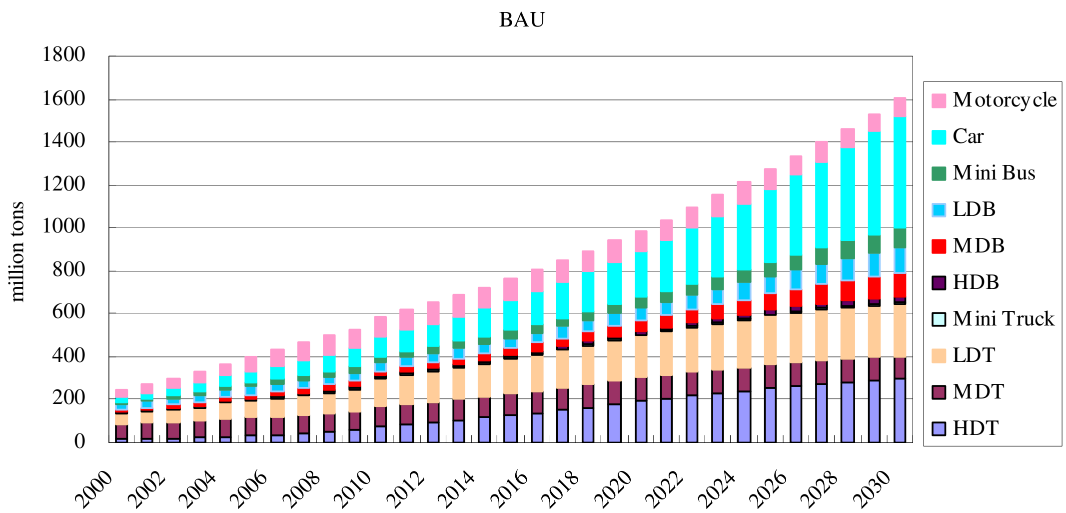


Figure 30 - CO2 emission from vehicles 2000-2030



ii. Other forecasts of transportation energy consumption in China

211. With the rapid development of China's economy and degree of motorization, in the future 30 years, the percent of total fuel oil that is consumed by vehicles will increase rapidly. Table 11 shows forecasts made by NDRC and the development research center of State Council's for China's oil consumption in the next 30 years. As can be seen, the Chinese road department's oil demand will reach 57% of the total oil demand in 2020. In 2030, this proportion is expected to reach 87.3%. This clearly shows that on-road transport is expected to be the main cause of the growth in China's oil demand. From 2020, on-road transportation will become the biggest oil consumer in China. As the forecasts made by the Development research center of State Council show, unless there are effective measures to reduce on-road fuel consumption, it will reach 256 million tons in 2020 with serious implications for the national economic development, national energy security and GHG emissions.

Table 11: Vehicle oil demand and total oil demand —2030(million tons)

	Year	1995	2000	2010	2020	2025	2030
NDRC, 2000	Vehicle oil demand		65.64	119.02	208.29	282.89	378.58
	Total oil demand		200	278.05	364.7	402.66	433.78
	percent		32.8%	42.8%	57.1%	70.3%	87.3%
Development research center of State Council	Vehicle oil demand	28.64	55.09	138	256		
	percent	17.8%	24.6%	43.0%	57.0%		

212. All other research efforts (based on 2004 data) show that the transport oil consumption will be 200 ~ 300 million tons in 2020 and 400 ~ 500 million tons in 2030.

e. Problems and challenges

213. Many institutes have forecast China's energy supply and demand. Most of the results show that the domestic oil production will be less than 200 million tons in 2020. 60% of the total oil demand will rely on imports. Table 12 shows NDRC's forecast.

Table 12: China long-term energy demand and supply (Million tons)

Year	2000	2010	2020	2050
Domestic production	160	170	180~200	100
Domestic demand	200	300	400	500
Import	40	130	220	400

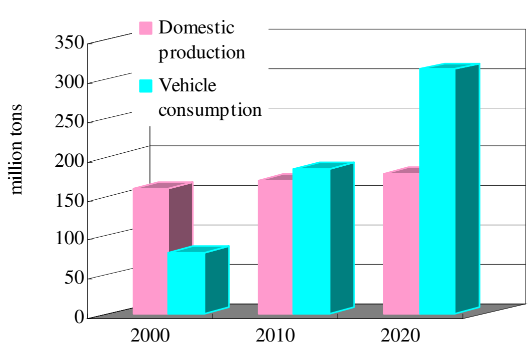
Source: China middle and long term energy strategy

214. Comparing transportation fuel consumption requirement with the total fuel supply over the next 20 years identifies a large gap that will need to be covered via imports. In the BAU scenario, 300 million tons of fuel will be required annually for road transportation in 2020. This huge increase in vehicle fuel consumption will bring many problems. The national government will face great pressure due to energy security concerns and residents will pay more for gasoline and diesel. This number of vehicles will lead to severe congestion with increased air pollution and GHG emissions from vehicles.

215. According to the different researchers, road transportation will cover 50%~60% of the national oil demand in 2020 (source: DRC; ERI of NDRC). 500~600 million tons oil will be needed in 2020. Domestic oil production is 180 million tons (Source: China middle and long term energy strategy). So the gap will be 320~420 million tons between the domestic supply and demand. It means the reliance on imported oil will rise to 64%~70% which is a great challenge to the state (Figure 21) (Source: Analysis of State energy strategy and policy, Development Research Center of State Council, 2003,11; An Energy-Conserving Society and Sustainable Development, Zhou Dadi, Energy Research Institute, National Development and Reform Commission).

216. If the oil import dependency could be reduced to 50%, it would be a great help. It means that the total oil demand should be held at 360~400 million tons. As mentioned before, transportation oil consumption is 50%~60% in total oil consumption. The transportation oil consumption should be controlled below 180~240 million tons in 2020.

Figure 31: Gap between vehicle consumption and domestic production in China



C. POLICY AND VISION FRAMEWORK

217. In general terms, there are four ways to limit vehicle GHG emissions: restricting the total vehicle population; enhancing fuel efficiency per vehicle; reducing Vehicle Kilometers Traveled (VKT) and using alternative, less carbon intensive, fuels. This chapter will discuss different measures. The scenario analysis, policy demand and co-benefits analysis will be made for different measures.

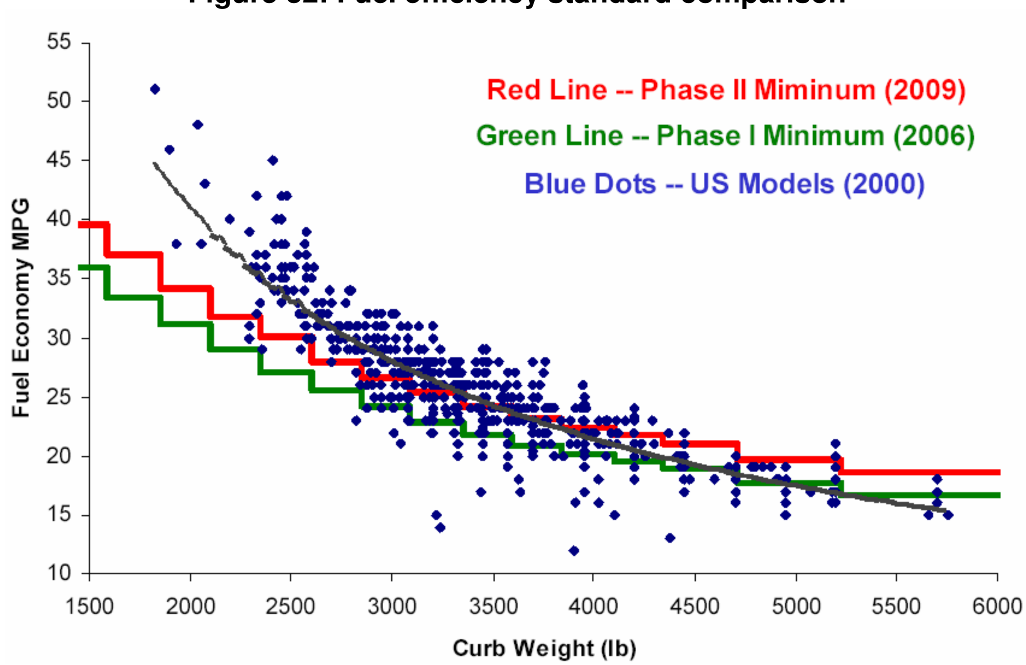
1. The Vision

a. Fuel economy standards

218. The Chinese government has been considering the adoption of vehicle fuel efficiency standards and other polices to regulate vehicle fuel economy since 2000, to deal with the rising energy pressures. Maximum fuel consumption limits for passenger vehicles were published on September 20th 2004, with an implementation date of July 1st 2006. These are maximum values that vary by the weight of the vehicle; they are not average fleet economy figures. A second phase with more stringent fuel economy standards will be enforced as from January 2009.

219. Fuel economy standards for light passenger vehicles are expected to reduce per-distance vehicle fuel consumption by 5%~10% between 2005 and 2008, as compared with present vehicles. Per-distance vehicle fuel consumption will be further reduced by 15% after 2008. Figure 22 shows the comparison of Chinese and US standards.

Figure 32: Fuel efficiency standard comparison



220. With the implementation of this fuel economy standard, 13 million tons fuel in 2020 and 31 million tons in 2030 will be saved (Figure 23). About 100 million tons CO2 emission will be reduced in 2030 (Figure 24).

Figure 33: Fuel saving with fuel economy standard

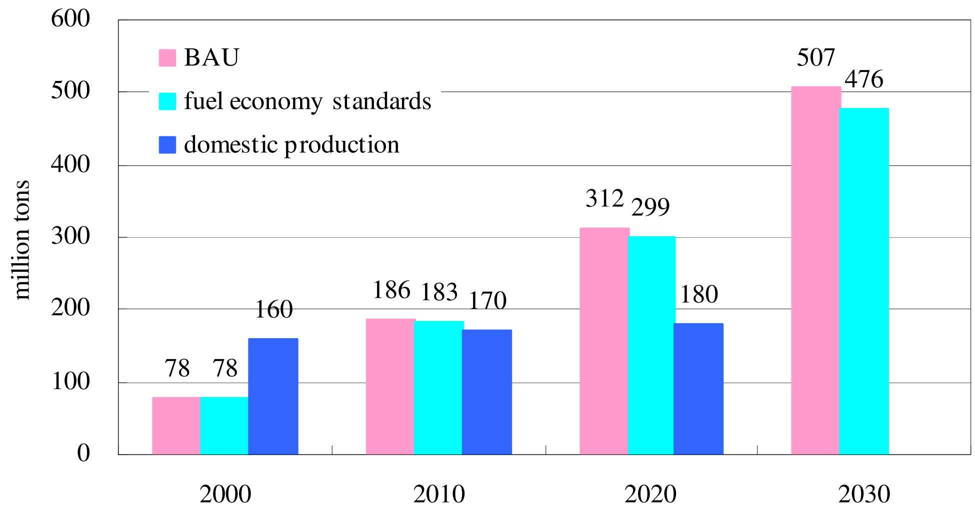
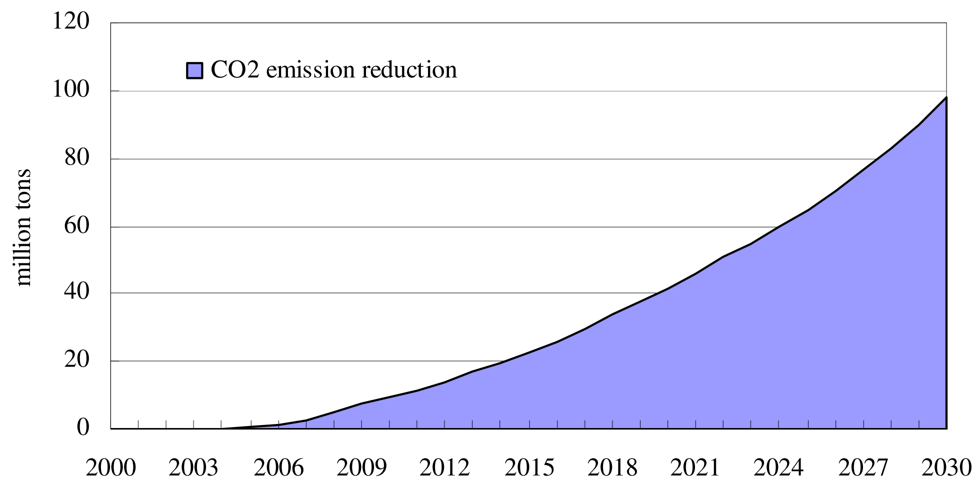


Figure 34: CO2 emission reduction with fuel economy standard



221. The fuel economy standards are expected to save 31 million tons of fuel in 2030, but it's not enough. Fuel economy standards for other vehicle types, not only passenger cars, need to be implemented. Also, more stringent fuel economy standards should be put into force after 2009.

b. Further improvement of fuel efficiency of light-duty passenger cars

222. A further reduction of 25% in vehicle fuel consumption to 5.6 L/100km (the European requirement for 2008) should be established by 2012 for light-duty passenger cars. In addition, the fuel consumption level of about 4.8 L/100 km should be developed to catch up with Europe and Japan by around 2016.

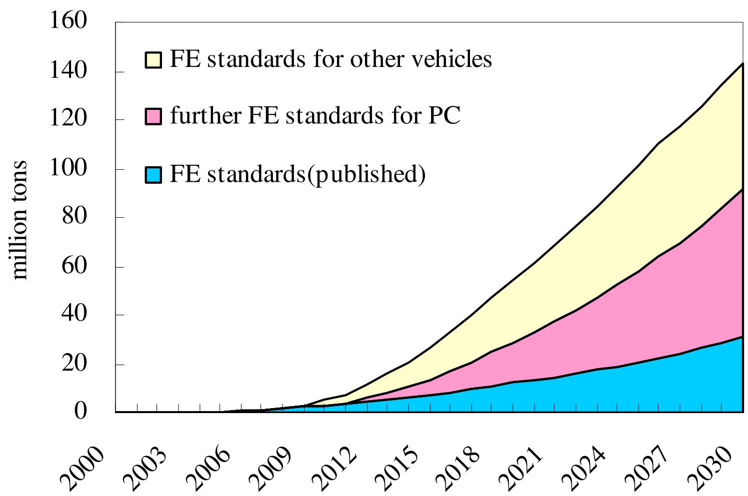
223. If this were implemented, an additional 19 million tons oil would be saved in 2020 and 60 million tons in 2030 (Figure 25). This would also reduce CO_2 emissions by 61 million tons in 2020 and 189 million tons in 2030.

c. Improving the fuel efficiency of heavy-duty vehicles

224. Compared to light-duty vehicles, the technology gap for heavy duty vehicles between China and developed countries is larger. Therefore, there should be a greater potential to improve the technical level of Chinese heavy duty vehicles. In order to reach this total oil saving target, the fuel economy of heavy duty vehicles should be improved by 20% around 2010, an additional 25% around 2012, and reach the level of fuel economy for heavy duty vehicles of developed countries in 2016.

225. Some research has showed that the effect of the fuel efficiency standard for heavy-duty vehicles and light-duty trucks will be about 25 million tons oil in 2020. Also, the calculation result shows that 52 million tons oil would be saved in 2030 by this measure (Figure 25). The CO_2 emission reduction (compared to BAU) would be 166 million tons in 2030.

Figure 35 - Fuel saving of different measures



d. Urban reform and transportation planning

226. With the development of cities leading to people choosing and buying their own housing, the traditional pattern that people live close to their work has been broken and the average trip distance has increased. For example, the average trip distance in Beijing in 1993 was 6.4 kilometers/person/trip. By 2003, this number had increased to 8 kilometers/person/trip (Source: Transportation Planning for Sustainable Urban Mobility). The increase of trip distance leads to the motorization. The proportion of walking in the total trip mode has been greatly replaced by motorized travel.

227. According to the 11th five-year plan of the national economy and social development of P.R. China, the size and layout of urban development should be consistent with local economic

development and employment space, infrastructure and public services supply capabilities. The various transport modes should interface well with each other and improve the overall efficiency of the system. The goal is to build convenient, open, efficient, safe and integrated transport systems.

228. Quantitative research of the effect of these measures' is rare in China. Most of the research assumes a VKT reduction in the future. Further research should be made to evaluate the co-benefit of urban reform and transportation planning.

e. Trip mode shift

229. In recent years, the government began to realize the importance of modifying the transport system. Some cities have begun to reinforce the construction of their public transportation systems and improve the public transport structure. Vehicle usage tax and insurance premiums will relate directly to vehicle efficiency and miles driven. Thus consumers may choose vehicles with higher energy efficiency and reduce their driving mileage to lower the rates. Government will encourage the use of public transportation and limit the use of private vehicles.

230. Some additional measures should be taken, such as: charging during the rush hour and downtown; high parking costs; convenient and comfortable subway systems and BRT systems. Also, bicycle is traditionally a main transportation instrument in China. A problem is that the combined road-use of bicycles and vehicles lead to congestion so with the development of motorization, the bicycle users need to shift to buses and walking.

231. One researcher has showed that in the next ten years, if half of the growth in vehicle trips can be displaced by public transportation, especially using effective public transit systems such as bus rapid transit (BRT) or urban rail transportation, then 60% of urban trips will be taken by public transportation systems, and 14 million tons of oil can be saved.

f. Alternative fuels and advanced vehicle technologies

232. China has already produced 1 million tons of ethanol fuel. Coal-based alternative fuels such as methanol, dimethyl ether (DME) and natural gas will also be used in the transportation sector. However, because the development of alternative fuels involves such questions as the overall efficiency of fuel production pathways and the total social cost, etc., the pathways of producing alternative fuels must be carefully studied.

233. Fuel cell technology could play an important role in the long-tern (after 2050) for sustainable transportation energy development. However, the technology may not have great influence on oil saving in the next 20 years. On the other hand hybrid technology that is being developed quickly now may have an important influence on the oil saving in the Chinese transportation sector in the next twenty years because of its technical maturity and market competitiveness.

234. In order to establish a high energy-efficiency society, some large cities such as Shanghai proposed that HEVs should have 10% market penetration by 2010. In the mid and long term technology development plans, the Chinese government has decided to increase the market penetration of HEVs to 3 millions units in China by then (Japan's goal is 10 millions in 2020) with government's strong policy and economic support.

2. Diesel vehicles

235. Because of the high efficiency of the diesel engine, diesel vehicles have been paid a great deal of attention in many countries. With advanced diesel engine technology, the efficiency can be improved further and emissions reduced.
236. In Europe, because of the wide use of diesel vehicles, the average fuel consumption has changed from 10.2 liters per 100 kilometers in 1980 to 8 liters per 100 kilometers in 2000. At the same time, the fuel efficiency change in the USA is only from 10.4 liters per 100 kilometers to 10 liters per kilometer [17].

237. At present, 23.7% of all vehicles are diesel but only 0.2% of cars are diesel. Some researchers suggest that diesel penetration in passenger vehicles should increase to 5%, 15% and 30% in 2010, 2015 and 2020 respectively. If 20% of passenger vehicles were diesel, 30 million tons oil would be saved which is 5% of the total oil demand in 2020 [17].

D. Policy Co-benefits

1. Effectiveness of different polices

238. The effectiveness of the policies recommended in this study are listed in Table 13.

Table 13 - The effectiveness of polices

Policy Effectiveness	Climate change	Energy saving	Air pollution	Congestion	Quality of life/economic development	Road safety
Introduction of fuel economy standards(including light-duty vehicles and heavy-duty vehicles)	★★★★★	★★★★★	★★★★★		★★	
Urban reform& transportation planning	★★★	★★★	★★★	★★★	★★★	★★
Traffic mode shift	★★★	★★★	★★★	★★★	★★	★★★
Alternative fuels	★★★		★★★		★★	
Advanced vehicle technology	★★★	★★★	★★★	★	★★★	★★
Diesel vehicles	★★★	★★★	★		★★	

2. Stakeholders

239. The major stakeholders in this process are shown in Table 14.

Table 14: The effectiveness of policies

Policy Effectiveness	Stake-holders: The international development community development community	National and provincial government	Local, City and Municipal government	NGOs and Community Groups	Private Enterprise and Investors
Introduction of fuel economy standards(including light-duty vehicles and heavy-duty vehicles)	✓	✓		✓	✓
Urban reform& transportation planning	✓	✓	✓	✓	✓
Traffic mode shift	✓	✓	✓	✓	✓
Alternative fuels	✓	✓	✓	✓	✓
Advanced vehicle technology	✓	✓	✓	✓	✓
Diesel vehicles	✓	✓		✓	✓

E. FURTHER RESEARCH IS NEEDED

240. Due to the time, database and methodology limitations, this research could not evaluate all the measures mentioned in this study. The following research is needed for the next phase of the study:

1. Develop a trend analysis of transport behavior and demand characteristics
2. Methodology study and analysis of the transportation demand properties under different land use characteristics
3. Co-benefit research of integrated transportation networks
4. Further research of the fuel and GHG saving effects brought by alternative fuels and dieselization.

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Appendix III

THE CASE OF INDIA: ENERGY EFFICIENCY AND CLIMATE CHANGE CONSIDERATIONS FOR ON-ROAD TRANSPORTATION IN INDIA

A. INTRODUCTION

1. GHG emissions in developing countries are increasing most rapidly in the transportation sector. A major issue of global concern at present is the increasing contribution of the transport sector to carbon dioxide (CO_2)—the main greenhouse gas (GHG) produced from the use of fossil fuels—and its consequences on global warming and climate change. Even people with low incomes are meeting their need for mobility, and projected income growth over the next two decades suggests that many more will acquire personal modes of transportation. How this will affect the earth's climate is a great concern.

2. In India, roads have dominated land transport system since 1985, and it is clear that their dominance will continue, if not increase. In the last three decades, owing to easy accessibility, flexibility and reliability the share of both freight and passenger traffic has experienced a rapid shift from rail to road, however the capacity of the road has not been able to keep pace with the increasing demand. In terms of rail-road modal mixes, the freight traffic carried by road transport is estimated to have increased from roughly 35% in 1970/71 to 70% in 2003/04 whereas the passenger traffic has increased from 67% to 85% during the same period (TERI, 2005a).

3. Current transportation activity is overwhelmingly driven by internal combustion engines powered by petroleum fuels. The total transport sector (which includes road, rail, aviation and water navigation) energy consumption in India was 31.14 million tones of oil equivalent (mtoe) in 2003/04 with share of petroleum fuels 98% and electricity 2% (MoPNG, 2005). Of the total petroleum products consumed, share of high-speed diesel (HSD) was the highest 71%, gasoline 27%, and all other fuels less than 1%. Demand for gasoline and HSD has grown at 7.4% and 5.7% per year respectively between 1980/81 and 2003/04. As a consequence, transport energy use and CO_2 emissions closely track the growth of transportation activity. The total CO_2 emissions from the transport sector in the country in 1994 were 79.88 million tonne (mt) (MoEF, 2004). The transport sector contributed around 12% of the country's total CO_2 emissions as a part of its total energy activities (i.e., 679.47 mt of CO_2 in 1994). Among the transport sub-sectors, road transport is the main source of CO_2 emissions and accounted for nearly 90 per of the total transport sector emissions in 1994.

4. Further, the rapid pace of urbanization and an even faster pace of motorization—measured as the growth in ownership and use of motor vehicles—have exerted heavy pressure on the urban transport system, especially in the large metropolitan cities. One noticeable feature about the growth of vehicles is the explosion in the number of two wheelers (namely, scooters, motor cycles, and mopeds), cars and auto rickshaws, in absence of a good mass public transport system.

5. The importance of transport energy use and emissions, within the overall energy scene, has grown substantially in recent decades in response to a series of public policy objectives such as energy security, human health, safety, local environment and climate change. There are policy and technology choices that could significantly lower the emissions growth rate while increasing mobility, improving air quality, reducing traffic congestion, and lowering transport and energy costs. These can be attenuated by sensitive design of new infrastructure and introduction of best practice operating technology. But technology is not enough, and measures are required to restrain road traffic growth by better-directed land use

planning, stricter demand management, and greater use of public transport. These measures would require policy changes in urban planning and development for long-term benefits. These objectives can be achieved by regulatory and market instruments: both of which require improved administrative capability. Most of the changes will be driven by a series of co-benefits relating to equity and quality of life; very few will be based solely on global environmental concerns.

6. This paper is an abridged version of the draft final policy document prepared by the author as a part of ADB's Regional Technical Assistance (TA No. 6261) during the period 28 February – 31 May 2006 (Bose, 2006). The primary objective is to present transport, energy efficiency and climate change impacts in India over the period to 2030. The paper has examined options for reducing vehicle emissions and avoiding lock-in problems associated with high carbon intensity in this sector; keeping in view the rapid expansion of urban populations, high rates of economic growth, increasing real incomes and the corresponding steep increases in vehicle fleets and vehicle use. It also examines the co-benefits from the perspective of both global climate change as well as local air pollution. This will have benefits during the implementation phase since local issues will be easier to adopt compared to global issues and the co-linkage of mitigating issues could provide solutions to local as well as global concerns. The paper concludes with policy measures that require immediate attention to initiate actions.

B. TRENDS AND CHALLENGES IN INDIA

1. Rapidly increasing urbanization

a. Rapidly increasing growth in population and GDP

7. The population of India stood at 1.027 billion comprising of 0.531 billion males and 0.496 billion females as on 1st March 2001 (GoI 2001). While the decadal growth of the country as a whole has declined from 23.86% during 1981-1991 to 21.34 during 1991-2001, the pace of urbanization in India has been increasing rapidly owing largely to policies driving economic growth. Currently, the contribution of urban sector to national GDP is expected to be in the range of 50-60%. This implies that Indian cities hold tremendous potential as engines of economic and social development, creating jobs and generating wealth through economies of scale. Rising incomes and higher population growth in urban areas is leading to growth in city size and subsequently increasing sub-urbanization.

b. Uncontrolled urban growth

8. The share of urban population has risen from 25.7% in 1991 to 27.8% in 2001. It is expected that by 2031, about 40% of its total population in the country estimated to be 1.42 billion would reside in urban areas (GoI, 2001). There is skewness in the distribution of population among different urban centers with a high concentration of population in a few large-sized cities. According to the 2001 census, 35 metropolitan cities had populations exceeding one million, almost twice as many as in 1991(GoI, 2001). The total population of these metropolitan cities accounted for nearly one-third of the total urban population. In addition, there are over 300 cities with a population between 1,00,000 and one million and over 3,784 cities having population between 5,000 and 1,00,000. Thus, increasing population coupled with continued urbanization is likely to result in the emergence of 60-70 cities with population of more than a million by 2021(Planning Commission, 2002b).

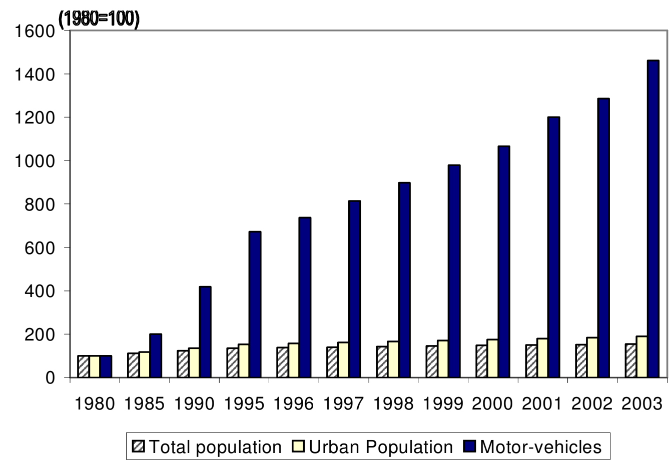
2. Rapidly increasing motorization

9. India has experienced high levels of motorization, which is inextricably linked to urbanization. Rapid motorization in India can be attributed to numerous factors such as rising per-capita incomes, higher aspiration levels of customers, price reductions and new models/variants launched by auto manufacturers, lower monthly installments due to stable interest rates and higher tenures, and the recent excise duty cuts in small-sized cars.

a. Heavy dependence on personalized motor vehicles

10. While total population and urban population have almost doubled during the period 1980-2003, the number of registered motor vehicles has risen by 15 times (Figure 1). The two-wheeler happens to be the dominant mode of road transport amongst all modes of road transport in the country. They account for more than three-fourth of the total registered vehicle population and have exhibited the highest average annual growth rate of 14.5% between 1980 and 2003. Cars, jeeps and taxis taken together have grown at an average annual growth rate of 9.5% during the period, whereas population of registered buses have increased at an average annual growth rate of 7.5% in the same period.

Figure 1: Growth of population, urban population and motor vehicles (1980 to 2003)



11. In 2003/04, the 23 out of 35 metropolitan cities—each with over one million population—accounted for about one-third of the total 62.7 million vehicles registered in the country. About 45% of the total cars in the country are confined to these metropolitan cities. The corresponding figures for other vehicular modes are shown in Figure 2.

12. In the five major metropolitan cities (namely, Greater Mumbai, Kolkata, Delhi, Chennai and Bangalore) the growth in registered motor vehicles has outpaced population growth. While the population in these cities has doubled during 1981-2001, the number of vehicle has gone up by six-and-a-half fold (Agarwal, 2006). These cities together accounted for over 31% of cars, 13% of two-wheelers, 12% of three-wheelers, 18% of buses and 13% of goods vehicles (MoRTH, 2005). In each of these five cities, two-wheelers are the dominant mode of transport (Figure 3).

b. Vehicle production, exports, and domestic sales

13. The Indian automobile sector can be said to have passed through three distinct phases:

- Tight government control and licensing until 1983.
- Partial liberalization in 1983 and 1984 that led to increased foreign investment and proliferation of two-wheelers and light commercial vehicles.
- Sweeping economic reforms through the 1990s that sustained foreign investment and increased vehicle sales.

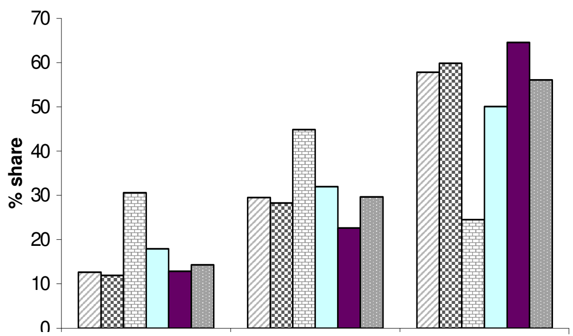


Figure 2: Vehicle composition in cities, 2003

2-wheelers 3-wheelers Cars Buses Goods All together

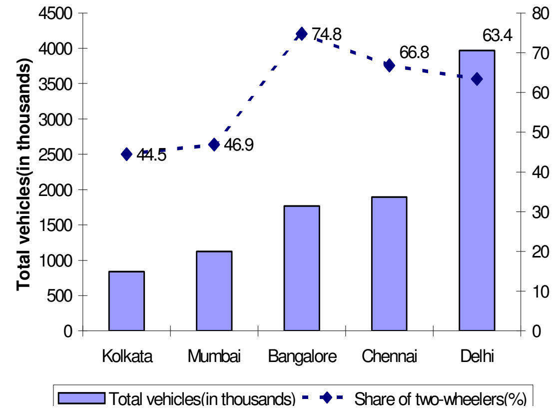


Figure 3: Growth of two-wheelers and total registered motor vehicles, 2003

14. The segment wise growth rates of automobiles sold given in Table 1 suggest that during post liberalization period the average annual growth rate for all vehicles were significantly higher as compared to the earlier years with the exception of light commercial vehicles (LCVs) & mopeds. In 1991 the New Industrial Policy swept away most of the hurdles relating to expansion and foreign investment. The car industry was also delicensed in 1993, as a result of which the passenger car & multi-utility vehicle segment have experienced a high average annual growth rate of 16% and 18% respectively during 1992/93 to 1999/2000 vis-à-vis 0.8% and 5.9% respectively, during government controlled regime (1972-1982).

Table 1: Domestic Sales growth rates in the country in different periods

Vehicles types	Govt control regime (1972-1982)	Partial liberalization (1982-1992)	Post liberalization (1992-1999)	Post liberalization (1992-2004)
Multi Utility Vehicle	5.9%	7.6%	18%	13.9%
Car	0.8%	14.3%	16%	11.7%
Light Commercial Vehicle	-4.2%	7.4%	-3.4%	1.9%
Medium and Heavy Commercial Vehicle	5.3%	3.2%	3.1%	4.7%
2-wheeler: Scooter	12.8%	12.4%	8.1%	-0.2%
2-wheeler: Motorcycle	6.3%	12.0%	21.0%	21.6%
2-wheeler: Moped	10.7%	3.4%	7.20%	-3.2%
Three-wheeler: Auto-rickshaw	10.6%	9.3%	15.5%	10.0%
Tractor	12.9%	6.3%	11.0%	-
All vehicles	8.2%	9.1%	12.4%	-

15. Deregulation of the two-wheeler industry brought about technology revolution as Japanese majors entered in technical and financial participation with Indian majors. Within the Indian two-wheeler industry, the motorcycle segment gradually increased its share at the

expense of scooters and mopeds and the three-wheeler and motorcycle segments have experienced a consistent and high growth over the years, with the motorcycle segment registering a high annual average of 21% during the period 1992/93 to 1999/2000. In 2000/01, the economy slumped into a recession and this affected the growth of the automobile industry as a whole. Most of the vehicles during this period experienced high negative growth in sales. With the revival of the economy in 2002 all vehicles except scooters and mopeds experienced double digit growth rates during the period 2002/03 to 2004/05.

c. Growth of motor vehicles and vehicle ownership levels

16. The total number of registered motor vehicles in India has increased from 1.86 million in 1971 to 62.7 million in 2003. Motorized two-wheelers (motorcycles, scooters, and mopeds) account for over 70% of the total registered fleet. During the same period, cars, jeeps, and taxis have grown from 0.68 million in 1971 to 8.69 million while the population of buses has increased from 0.09 million to 0.73 million. The population of the goods vehicles has increased from 0.343 million in 1971 to 3.5 million in 2003. A noteworthy feature is the reduced dependence on public transportation modes (the proportion of buses to the total registered fleet has fallen from 5% in 1971 to 1.1% in 2003). Correspondingly, the proportion of private vehicles (two-wheelers and cars) to the total number of registered vehicles in India has increased from 65% in 1971, to 84% in 2003.

17. Estimating the number of vehicles on road and its composition proves to be a major challenge because of the deficiencies and inconsistencies in the available data, and the fact that several past studies have been based upon estimates that are highly questionable. The fundamental difficulty is that while records of new vehicle registrations are kept to reasonable accuracy, there is no data on vehicle retirements or vehicles actually on road, which inevitably leads to the overestimation of the number of vehicles in the fleet. Another major problem occurs in correctly identifying the vehicle type by fuel category.

d. Establishing causal relationship for vehicle projections

18. Econometric relationships were established by analyzing the annual registration data for different category of vehicles with real per capita income (PCY) and total gross domestic product (GDP) over the 23-year period, from 1980 to 2003. Results of the econometric equations are given in Table 2. Per-capita income is found to be statistically significant in explaining the demand for personal modes of transportation (cars, jeeps & two wheelers). The private vehicle ownership level is highly income elastic with the elasticity coefficients of 1.7 and 1.87 for cars and two-wheelers respectively. This implies that if per capita income goes up by 1 per cent, cars on road would go up by 1.7 per cent and two-wheelers on road will increase by 1.87%. The high-income elasticity of car and two-wheeler ownership can be explained by the fact that during the period 1980 to 2000, the overall purchasing power of the average Indian measured by the per-capita income doubled from Rs.5,823 to Rs.11,786. This rise in income has contributed to increased levels of car and two-wheeler ownership in India. As regards to the public modes of transportation and commercial vehicles (bus, three wheelers, taxis, light and heavy commercial vehicles (LCVs and HCVs)), GDP was found to be a more appropriate variable explaining the demand over the years.

Table 2: Regression coefficients

Endogenous variable	Intercept	Explanatory variable			AR(1)***	R^2	Durbin Watson
		Log (GDP)	Log (PCY)	GDP			
Log (car)	-	-	1.7	-	0.94	0.99	1.42
			(44)**		(31)		
Log (2-wheeler)	-	-	1.87	-	0.90	0.99	1.65
			(129)		(57)		
Log (3-wheeler)	-	1.033	-	-	0.90	0.99	1.52
		(80)			(40)		
Log (Bus)	-3.05	1.16	-	-	0.5	0.99	2.10
		(32.4)			(3.17)		
Log (Taxi)	-	1.04	-	-	0.97	0.99	1.30
		(11.22)			(51)		
Log (HCV)	-	1.04	-	-	0.80	0.98	1.74
		(2.44)			(10.7)		
D(LCV)*	-82059	-	-	0.15	-	0.42	1.70
				(3.55)			

Note: The estimation period for all vehicle types is taken to be 1980-2003. However, disaggregated data for HCVs and LCVs is available till 2002.

*D(LCV) represents the first difference of the Light Commercial Vehicle registration data.

**t-values for respective coefficients are given in brackets.

***AR(1) denotes Auto Regressive term to correct first order autocorrelation.

e. Vehicle projections under low and high economic growth scenarios

19. Two economic growth scenarios—Low growth and High growth—are considered for projecting the number of registered vehicles using the regression coefficients given in Table 2. In the low growth scenario, it is assumed that GDP will grow at 6% per annum according to the growth trends observed between 1997/98 and 2003/04. While in the high growth scenario, it is assumed that GDP will grow at 8% per year during 2004-2030.The Tenth Five Year Plan covering the period 2002-2007 prepared by Planning Commission, Government of India, aims at achieving an average growth rate of real GDP of 8% per annum over the period 2002-07 (Planning Commission, 2002a). The rationale behind targeting 8% GDP growth rate is to aim doubling the per-capita incomes over the next decade with a more equitable regional distribution, thus bringing about substantial improvement in the welfare of the entire population. The GDP growth rate achieved by the Indian economy in the last three years clearly indicates that the economy has steered on a high-economic growth path. Growth of GDP at constant prices in excess of 8.0 per cent has been achieved by the economy in only five years of recorded history, and two out of these five happen to be the last three years. It is therefore assumed that in the high growth scenario, 8% growth rate of GDP can be sustained till 2030.

20. Unfortunately, there is no record of the number of cars and two-wheelers actually operating on Indian roads. These personal vehicles are registered only once, as new vehicles, for a 15-year period. Applying 15 years as the age factor to the projected figures of registered cars and 2-wheelers the number of cars and 2-wheelers operational on road is determined and presented in Table 3 under the low and high growth rate scenarios. For instance, the number of cars or 2-wheelers on road in 2000 would be equal to the difference between the extrapolated number of these vehicles in 2005 and the number in 1985. However, for all other categories of commercial vehicles (namely, 3-wheelers, taxis, buses, LCVs and HCVs) their projected registered numbers are taken to be the number of operational vehicles on road, as these vehicles are registered every year till they are found

to be road-worthy. Any commercial vehicle, which is unable to produce annual roadworthiness certificate, does not get a registration certificate and is automatically deregistered in the registration data.

Table 3 Estimated number of motor vehicles in use in India (in thousands)

Year	Car	2-wh	3-wh	Taxi	Bus	HCV	LCV	Total
2000	4,128	28,939	1,777	553	562	1,891	824	38,674
6% GDP growth rate per year								
2005	6,506	45,254	2,287	905	828	2,933	1,411	60,123
2010	10,477	71,722	3,251	1,378	1,163	3,978	2,479	94,449
2015	16,163	113,860	4,534	2,074	1,634	5,392	4,048	147,705
2020	24,779	178,955	6,248	3,090	2,296	7,306	6,286	228,959
2025	38,983	289,319	8,545	4,561	3,227	9,899	9,419	363,953
2030	62,041	424,973	11,635	6,675	4,534	13,411	13,751	537,020
8% GDP growth rate per year								
2005	7,100	49,452	2,377	941	865	3,050	1,425	65,208
2010	13,968	97,551	3,722	1,579	1,355	4,560	2,642	125,378
2015	26,241	191,347	5,718	2,621	2,123	6,812	4,623	239,485
2020	48,370	367,813	8,678	4,304	3,328	10,175	7,727	450,394
2025	89,014	410,785	13,073	7,003	5,216	15,195	12,480	552,766
2030	165,477	424,973	19,606	11,299	8,174	22,693	19,656	671,878

21. Of the total on road vehicles, currently about 75% are two-wheelers, 11% cars, 5% 3-wheelers, 1% taxis, 1% buses, 5% HCVs and 2% LCVs. If the present trend continues, the share of personal vehicles (cars and two-wheelers) will continue to be very high - roughly around 90%, intermediate public transport (IPT) modes, three-wheelers and taxis (4%) and HCV and LCV together around 6% by 2030, in both the scenarios.

22. The total number of vehicles is projected to increase at an average annual rate of 9% from 60 million in 2005 to 537 million in 2030 under the low growth scenario. Correspondingly for the high growth scenario, the total number of vehicles is estimated to rise at 10% per annum to reach 671 million in the same period.

- The car population is estimated to increase by 10 times under the low growth rate scenario and by 23 times under high growth rate scenario during the period 2005-2030.
- In case of two-wheelers, the projected numbers were very high which could not be justified. It has been assumed that the ownership levels would saturate at a point with 300 two-wheelers per thousand population. While with 6% GDP growth rate scenario this saturation sets in the year 2029, with 8% growth rate, the saturation arrives as early as 2021. The number of two-wheeler is projected to grow at 10% per annum under the low-growth scenario during the period 2005-2028 and at an average annual growth rate of 14% under the high growth scenario during the period 2005-2020.
- During the period 2005-30 while the per capita income increases by 3.2 times under low growth scenario and 5.3 times under the high growth scenario, personal vehicle ownership (car and two-wheeler together per thousand) is projected to increase about 7 times from 51 to 360 under the low growth scenario and about 8 times from 55 to 445 under the high growth scenario
- The share of buses is likely to fall further from 1.4% to 1% during the period 2005-2030.

- The proportion of personal vehicles (two-wheeler and cars) to the total number of vehicles is projected to increase from about 85% to about 90% during the period 2005-2030.

f. Personal motor vehicle ownership levels

23. Table 4 gives the change in ownership levels of personal modes of transportation in both developed and developing economies during 1990 to 2000. Countries with lower number of cars per capita have shown rapid rate of increase in their vehicle ownership. For example, in India, during 1990-1998 car ownership had more than doubled and that of China's had increased, fivefold. India and China had only 5.29 and 5.25 cars per thousand people in 1998. Till 1998 car ownership per thousand populations in India was higher than it was in China despite of much lower level of per capita income [on a purchasing power parity (PPP) basis] in India. In 2000 per capita car ownership in China was marginally higher than in India. It will take many years for both the countries to reach current levels in other Asian countries such as Malaysia and Republic of Korea. Car ownership in India is projected to go up to 116 by the year 2030/31 under the high 8% economic growth scenario.

24. In case of two-wheelers, India fares poorly vis-à-vis even most developing countries. In 1995, two–wheeler ownership In India and China was 22 and 7 respectively (Table 4). During the same year, Malaysia and Thailand had nearly 7 times higher number of two-wheelers per thousand population. While India's two-wheeler ownership increased only marginally from 22 in 1995 to 29 in 2000, Malaysia experienced a jump in its two-wheeler ownership from 175 to 228 during the same period. The two-wheeler ownership in India is higher than some developed countries like Australia, US and UK.

Table 4: Change in ownership levels of personal motor vehicles in different countries (1990-2000)

Country	Per capita Income#	Cars per thousand people				2-wheelers per thousand people			
		1990	1995	1998	2000	1990	1995	1998	2000
India	2,416	2	4	5	6	15	22	25	29
Sri Lanka	3,456	7	13	-	-	24	37	45	-
China	3,821	1	3	5	7	3	7	18	26
Philippines	3,985	7	9	10	10	6	10	14	16
Thailand	6,350	14	25	-	-	86	156	-	-
Brazil	7,366	-	120	-	-	-	-	24	28
Malaysia	8,952	101	127	-	-	167	175	212	228
Republic of Korea	15,202	48	133	163	171	32	50	56	-
New Zealand	20,010	436	451	-	578	24	15	20	-
United Kingdom	24,675	341	352	384	-	14	10	12	-
Italy	24,936	476	524	541	-	-	44	118	-
France	25,318	405	432	459	476	55	39	-	-
Hong Kong	25,784	42	56	56	-	4	5	5	-
Japan	25,974	283	356	395	413	146	124	115	110
Germany	26,075	386	495	508	-	18	28	56	-
Australia	26,181	450	478	-	-	18	16	18	-
Denmark	29,337	320	319	353	358	9	9	11	13
United States	34,114	573	485	486	-	17	14	14	-

#PPP International $ 2000
Source: World Bank, 2005

3. Analytical framework for transportation energy consumption and emissions

25. Energy policy makers need tools, which can illuminate the causes of rising emissions (of local pollutants and CO_2) in the transport sector and which can assign a balanced approach to mitigation strategies. Such tools need to take into account the critical role of energy demand and the links that exist between:

- Economic growth and transport activity (expressed as passenger, tonne and vehicle kilometers)
- Transport activity and modal energy intensity (expressed as energy use per passenger kilometer, freight tonne kilometer)
- Modal intensity and fuel mix

26. The link between economic growth and transport activity is complex and difficult to describe at the national level. This suggests that in the first instance a framework could be developed which takes the demand for mobility as its starting point (effectively endogenising the link between economic growth and mobility). It is therefore important to understand how activity (**A**), modal structure (**S**), energy intensity (**I**) and fuel choice (**F**) have varied in the past, how they are changing in the present, and how they are likely to change in the future. These will be based on various influences, including the influences of incomes, prices, technologies, modal shifts, and land use and transport planning policies. The ASIF methodology developed by IEA (International Energy Agency) offers an analytical framework to analyze the impact of growing automobiles on fuel demand and emissions trends, and evaluate mitigation potential of alternative policies.

27. **ASIF** method was first introduced and published in 1999 by the World Bank (Schipper & Marie-Lilliu, 1999). This method thus offers an analytical tool in which stakeholders can evaluate and debate the options for improving the environmental performance of transport. For example, interventions in **I** and **F** (technologies and utilization, respectively) have the largest promise of restraint, while policies that affect **A** and **S** through broader transport reform will also restrain emissions. The advantage with this methodology is that it allows for a number of interventions at **I**, **F** and **A** levels, with commensurate number of multiple scenarios each with a certain energy use and emission levels. Hence the policy makers have a spectrum of options to choose from and more importantly it makes the framework easily replicable.

28. **ASIF** method is applied on Indian road transport sector using the computerized Long Range Energy Alternatives Planning (LEAP) software developed by the Stockholm Environment Institute (SEI), Boston, USA (SEI, 1993) to analyze road transport energy demand and its resultant impact on emissions of CO_2 and local pollutants.

a. Database and Assumptions

i. Travel demand and modal split

29. The estimation of travel demand activity is a function of the following three variables: (1) Number of on road vehicles of different types and by fuel type. (2) Average effective distance moved by each vehicle. (3) Average occupancy levels in case of passenger vehicles and load levels in case of goods vehicles. The road based motorized passenger and freight travel demand in India is estimated by multiplying these three variables over the period to 2030 in five-yearly intervals with 2000 as the base year.

30. Travel demand estimates are obtained under low and high GDP growth rate scenarios as given in Table 5. Travel demand estimates show if GDP is to grow at 6% a year over the next 25 years, then the demand for road transport as per current trends will, in all likelihood, grow by at least 8.5% a year. Similarly, with 8% GDP growth, road transport demand is expected to be even higher at least 10.1% a year. But transport growth will materialize only if the level of services and capacity of supporting infrastructure are able to meet this demand. Otherwise, unmet demand will act as a constraint on economic growth, and impose high costs on business and households.

Table 5: Historical and forecasted travel demand and modal split under low and high growth scenarios

Year	Billion passenger-kilometers						Billion tonne-kilometers		
	Car	2-wh	3-wh	Taxi	Bus	Total	HCV	LCV	Total
2000	46.3	316.9	114.2	26.9	902.6	1406.9	476.3	61.4	537.6
	(3%)	(23%)	(8%)	(2%)	(64%)	(100%)	(89%)	(11%)	(100%)
				6% GDP growth rate per year					
2005	78.3	531.2	146.9	44.1	1329	2129.6	838.4	105.1	943.5
	(4%)	(25%)	(7%)	(2%)	(62%)	(100%)	(89%)	(11%)	(100%)
2010	135.1	902.5	208.9	67.1	1867.7	3181.3	1280.4	184.6	1465.0
	(4%)	(28%)	(7%)	(2%)	(59%)	(100%)	(87%)	(13%)	(100%)
2015	223.5	1535.9	291.3	101.0	2624.5	4776.1	1940.2	301.4	2241.6
	(5%)	(32%)	(6%)	(2%)	(55%)	(100%)	(87%)	(13%)	(100%)
2020	367.3	2587.7	401.4	150.5	3687.9	7194.8	2921.0	468.0	3389.1
	(5%)	(36%)	(6%)	(2%)	(51%)	(100%)	(86%)	(14%)	(100%)
2025	619.4	4484.8	548.9	222.1	5182.3	11057.5	4373.2	701.3	5074.5
	(6%)	(40%)	(5%)	(2%)	(47%)	(100%)	(86%)	(14%)	(100%)
2030	1056.7	7061.8	747.4	325.2	7282.2	16473.2	6514.8	1023.9	7538.7
	(6%)	(43%)	(5%)	(2%)	(44%)	(100%)	(86%)	(14%)	(100%)
				8% GDP growth rate per year					
2005	85.4	580.5	152.7	45.8	1388.4	2252.8	871.7	106.1	977.8
	(4%)	(25%)	(7%)	(2%)	(62%)	(100%)	(89%)	(11%)	(100%)
2010	180.2	1227.5	239.1	76.9	2176.0	3899.7	1467.4	196.7	1664.2
	(5%)	(31%)	(6%)	(2%)	(56%)	(100%)	(88%)	(12%)	(100%)
2015	362.8	2581.1	367.3	127.6	3410.2	6849.1	2451.1	344.3	2795.4
	(5%)	(38%)	(5%)	(2%)	(50%)	(100%)	(88%)	(12%)	(100%)
2020	716.9	5318.6	557.5	209.6	5344.6	12147.3	4067.9	575.4	4643.2
	(6%)	(43%)	(5%)	(2%)	(44%)	(100%)	(88%)	(12%)	(100%)
2025	1414.3	6367.6	839.8	341.1	8376.3	17339.2	6713.2	929.2	7642.5
	(8%)	(37%)	(5%)	(2%)	(48%)	(100%)	(88%)	(12%)	(100%)
2030	2818.5	7061.8	1259.5	550.4	13127.6	24817.7	11023.9	1463.6	12487.4
	(11%)	(28%)	(5%)	(2%)	(53%)	(100%)	(88%)	(12%)	(100%)

31. Table 5 also provides the changes in modal split, i.e., the share of total passenger and freight travel demand by different modes over the next 25 years. It is interesting to note that in 2005 inspire of an insignificant (1%) share of total number of buses in the total motor vehicle fleet on road, buses catered to a very high volume of travel demand of around 62%. However, in future, if the present growth of motor vehicles continue, in future, the share of travel demand to be met by buses is likely to decline to 44% in 2030 in the low growth scenario and to 52% in the high growth scenario.

ii. Characterization of automobile and fuel technologies and penetration levels

32. In absence of any data on number of vehicles broken down by fuel type, the penetration level of different types of vehicles and their technologies under alternative fuels (namely, petrol or gasoline, diesel, CNG and LPG) are assumed in the LEAP model over the reference period of the study based on the emerging changes due to auto fuel policy interventions combined with value judgment (Bose, 2006).

iii. Fuel efficiency and emission factors

33. The fuel efficiency values and emission factors of all vehicles considered in LEAP model is classified into the following four categories (Bose, 2006).

- Pre 2001 model vehicles
- 2001-2005 model vehicles
- 2006-2010 model vehicles
- Post 2010 model vehicles

4. Model results

a. Baseline case

34. The LEAP software is first run under baseline (BL) or a business-as usual (BAU) case using the database and assumptions presented in the main document (Bose, 2006). BL is defined as the best estimate of demand of alternative fuels in the future given current trends in travel demand of people and goods. BL case assumes a continued progression of growth of on road vehicles as per present trends, changes in modal split pattern, penetration of improved technologies and cleaner and alternative fuels with progressively stringent tailpipe emission standards of new vehicles as per the current set of policy measures. BL case however assumes no ‘dramatic’ or ‘significant’ changes in energy consumption or environmental policies. Here it is assumed that the following factors will change over the projection period (from 2005 to 2030).

- Number of on road vehicles of different types will continue to grow under low and high GDP growth scenarios
- Penetration of improved technologies and alternative fuels conforming to progressively stringent emission standards based on existing legislation
- Improvement in fuel efficiency of vehicles
- Increase in average effective distance moved especially by personal modes of vehicle

35. Table 6 presents the output of the LEAP model in terms of fuel demand estimates as well as emissions loading of CO_2 and local criteria pollutants (CO, HC, NO_x and PM) for the past, present and future in the BL case at five yearly intervals under low and high GDP growth scenarios.

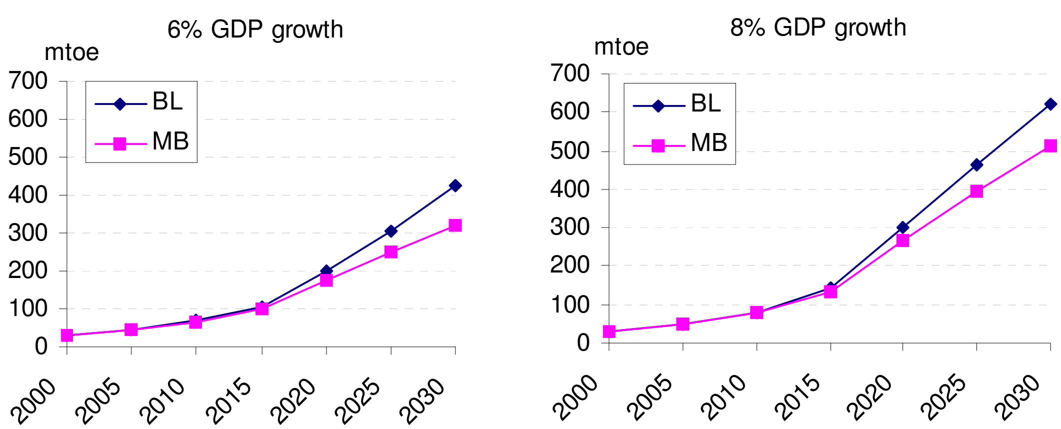
e. Rising fuel demand

36. Currently, energy use in the transportation sector is dominated by HSD and gasoline whereas the use of alternative fuels like CNG and LPG is expected to remain relatively modest over the projection period till 2030. The estimated demand of diesel and gasoline for road transportation from the LEAP model for the base year 2000 is quite close to the actual fuel sales data in 2000 (MoPNG, 2005).

37. Long-term projections for fuel demand depends on the assumptions of growth of the economy, growth of population, penetration of advanced automobile and fuel technologies as well as societal and lifestyle changes. No wonder the various available projections differ widely. Yet it is useful to have a set of consistent projections with clearly stated assumptions to outline the broad discussion of the challenges facing us in meeting energy needs and to provide a framework for policy formulation.

38. Figure 4 shows the fuel demand projections under low and high economic growth scenarios. With 6% GDP growth rate, total fuel demand for road transportation is likely to go up over 9 times over the projection period—from 45.93 million tones of oil equivalent (mtoe) in 2005 to 423.93 mtoe in 2030, an annual growth rate of 9.3% per year. However, with 8% GDP growth rate the total fuel demand during the same period is expected to increase nearly 13 times from 48.20 to 621.61 mtoe with an annual growth rate of 10.8%.

Figure 4: Total energy demand for on road vehicles in the BL and MB case (2000-2030)



39. The oil demand projections under the low economic growth scenario compared well with projections made by other agencies. According to Indian Planning Commission, the oil demand projections by the IEA and Energy Information Administration (EIA) are based on unrealistically low growth rate of GDP for India (Planning Commission, 2005). It may be seen that the oil demand for the year 2025 varies from 235 million tones (MMT) for the Best Case Scenario (BCS) of India Vision 2020 to 368 MMT of India Hydrocarbon Vision (IHV) 2025. The Integrated Research and Action for Development – Price Waterhouse Coopers (IRADe-PWC) projections exclude Naphtha and their projection of 347 MMT under high output growth (HOG) is comparable to 368 MMT of IHV (Planning Commission, 2005).

40. As far as the Indian gas market is concerned it is supply constrained. The future demand for gas appears to be strong. There are a number of estimates available for likely gas demand for the Tenth Five Year Plan (2002-07). However, there are a few long-term projections. Most of these projections have not taken into account the price sensitivity of gas. Natural gas can replace existing fuels in various sectors both for feedstock as well as for energy purposes. However, this substitution will depend upon the relative prices of gas with respect to other fuels. Therefore, the type of demand will depend upon the price of natural gas relative to that of alternatives, namely Naptha for fertilizer and petrochemicals, coal for power and oil for transport. The key challenge in terms of procuring adequate supplies of natural gas to meet the growing demand will be how the country's industry structure will

Table 6 Baseline case: Fuel demand and emissions under low and high GDP growth scenarios

Vehicles	Fuel type	Unit	Base year	Low Growth Scenario (6% GDP growth per year)						High Growth Scenario (8% GDP growth per year)					
			2000	2005	2010	2015	2020	2025	2030	2005	2010	2015	2020	2025	2030
Passenger	CNG	MT0E	0	1.16	2.89	4.02	7.70	11.73	16.10	1.21	3.37	5.28	11.67	20.12	31.05
Passenger	Gasoline	MT0E	7.16	9.79	14.37	27.62	62.85	112.06	177.65	10.60	19.03	45.29	92.73	142.36	189.27
Passenger	Diesel	MT0E	6.54	8.86	11.27	15.96	27.44	37.63	46.66	9.30	13.38	21.66	43.83	68.86	96.60
Passenger	LPG	MT0E	0	0.02	0.07	0.16	0.41	0.77	1.25	0.02	0.08	0.22	0.68	1.48	2.74
Passenger	Total	MT0E	13.71	19.83	28.60	47.77	98.40	162.19	241.66	21.14	35.85	72.45	148.90	232.82	319.66
Freight	Diesel	MT0E	15.26	26.10	39.16	58.50	102.03	143.28	182.27	27.07	44.51	72.96	153.44	229.76	301.94
All together	Total energy	MT0E	28.97	45.93	67.76	106.27	200.42	305.47	423.93	48.20	80.36	145.42	302.34	462.58	621.61
Passenger	CO_2	MT	37.95	53.66	75.90	127.13	261.71	431.33	642.86	57.19	95.31	193.35	396.16	616.79	842.23
Freight	CO_2	MT	43.30	74.04	111.10	165.97	289.43	406.48	517.09	76.78	126.28	206.99	435.28	651.81	856.58
All together	Total CO_2	MT	81.25	127.69	187.00	293.09	551.14	837.81	1159.95	133.98	221.58	400.34	831.44	1268.60	1698.82
Passenger	CO	MT	1.33	1.65	1.97	3.22	6.39	10.17	14.69	1.78	2.57	5.18	9.25	12.74	15.46
Freight	CO	MT	0.34	0.53	0.68	0.86	1.19	1.22	0.96	0.55	0.77	1.07	1.79	1.96	1.59
All together	Total CO	MT	1.67	2.19	2.65	4.07	7.58	11.40	15.65	2.33	3.34	6.24	11.04	14.70	17.06
Passenger	THC	10^3 T	622.90	642.64	774.33	1399.29	3044.75	5265.81	8177.23	694.90	1019.05	2285.84	4376.14	6407.93	8244.09
Freight	THC	10^3 T	67.20	102.41	144.44	184.04	264.61	288.18	254.58	106.21	164.17	229.53	397.94	462.12	421.72
All together	Total THC	10^3 T	690.10	745.06	918.77	1583.33	3309.36	5554.00	8431.81	801.11	1183.22	2515.37	4774.09	6870.06	8665.81
Passenger	NO_x	10^3 T	403.72	523.91	622.15	471.89	1888.18	2993.40	4360.58	550	770	1440	2750	4010	5510
Freight	NO_x	10^3 T	475.33	734.09	995.59	1444.31	2451.12	3342.67	4119.27	760	1130	1800	3690	5360	6820
All together	Total NO_x	10^3 T	879.05	1258.00	1617.74	2416.20	4339.29	6336.06	8479.84	1310	1900	3240	6440	9370	11930
Passenger	PM	10^3 T	63.87	72.16	82.16	129.85	255.15	409.38	603.33	76.77	103.67	201.33	371.58	518.76	626.03
Freight	PM	10^3 T	49.28	61.24	64.00	77.56	101.80	93.65	53.19	63.51	72.74	96.74	153.10	150.17	88.11
All together	Total PM	10^3 T	113.15	133.39	146.16	207.41	356.95	503.03	656.52	140.28	176.41	298.07	524.68	668.93	714.14

develop and what sustainable gas pricing mechanisms could be put in place to meet the requirements of both gas suppliers (inside and outside India) and consumers.

41. There seems little doubt that, in India, road transportation fuel demand with reference to baseline projection will continue to grow at a rapid pace for the foreseeable future. The shape of that demand and the means by which it will be satisfied depend on several factors.First, it is not clear that oil can continue to be the dominant feedstock of transport fuels in India that it has been for a century. There is no shortage of alternatives to oil, beginning with liquid fuels from so called unconventional oil (heavy oil, oil sands), manufactured from natural gas or coal, or produced from biomass (ethanol and bio diesel). Other alternatives include gaseous fuels (natural gas, hydrogen) and electricity (if battery operated vehicles is greatly successful). However, all of these alternatives are costly, and most will increase GHG emissions significantly without carbon sequestration.

42. Second, the growth rate and shape of economic development in India, the primary driver of transport demand, is uncertain. If India continues to rapidly urbanize, transport demand will grow with extreme rapidity over the next several decades. Although it is implausible that demand will not grow substantially, its growth could be slowed considerably if economic development is disrupted; thus, the range of prospects for future transport demand is quite wide.

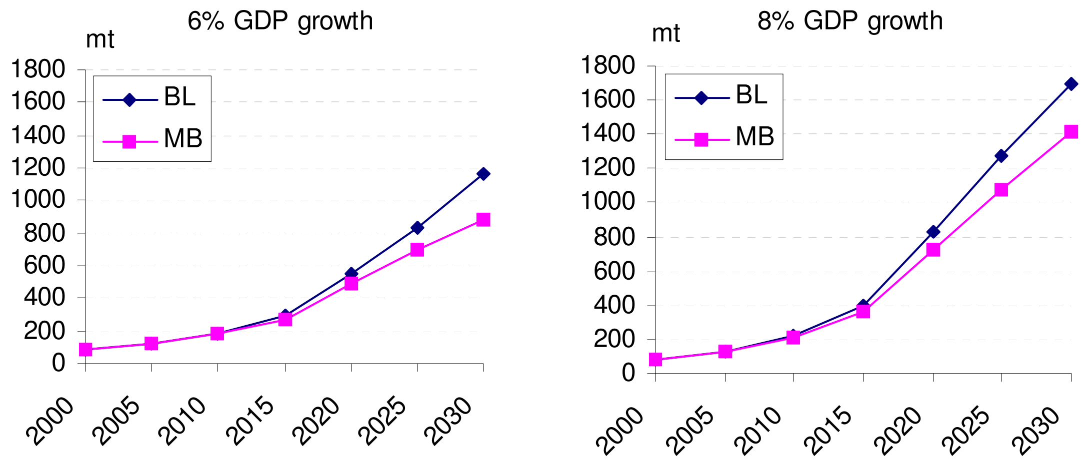
43. Third, transportation technology has been evolving rapidly, and the efficiency of the different modes and vehicle choices as well as their cost and thus desirability (and likely market share) will be strongly affected by technology developments in the future. For example, although hybrid electric drive trains have made a strong early showing in the Japanese and U.S. markets, their ultimate degree of market penetration in India will depend strongly on further (and uncertain) cost reductions and other factors like the future efficiency of those fleets. Similar uncertainty surrounds the migration to other markets of technologies with substantial penetration in limited markets, e.g. light-duty vehicles with clean diesel in Europe and alcohol fuels in Brazil.

44. Fourth, as incomes grow in India, transportation infrastructure will grow rapidly. Current trends point towards growing dependence on personal vehicles (cars and two-wheeled motor cycles and scooters), but other alternatives exist as demonstrated by Bus Rapid Transit (BRT) systems in Curitiba, Brazil; Bogota, Columbia; so on so forth. Also, as mentioned earlier the intensity of personal vehicle ownership varies widely around the world even when differences in income are accounted for, so different countries have made very different choices as they have developed. The future choices made by both governments and travelers will have huge implications for future transport energy demand and CO_2 emissions.

ii. Rising CO2 emissions

45. In India, GHG emissions from the road transport sector are expected to soar (Figure 5). The estimated CO_2 emissions from the use of petroleum products in the road transport sector in BL case for the period 2000 to 2030 under low and high GDP growth scenarios (Table 6). In 2000, nearly 81.25 mt of CO_2 was emitted from on road vehicles in India and in 2005 it went up to about 130 mt. Similar to the fuel demand growth rate, total CO_2 emissions is also likely to go up over nine-fold in the low GDP growth scenario (127.69 mt in 2005 to 1159.95 mt in 2030) and about thirteen-fold (133.98 mt to 1698.82 mt) in the high GDP growth over the next 25 year period between 2005 and 2030. This increase has been fuelled by the rising demand for mobility, as economies would continue to grow.

46. Despite the rapidly increasing contribution to CO_2 emissions growing at an average annual rate of 9.2% with GDP growth at 6% and 10.7% with GDP growth at 8%, there has been no initiative so far in addressing cost-effective emission reduction strategies in India. Although with advancement of automobile and fuel technologies, the fuel efficiency of transport vehicles will continue to improve but these improvements will be more than offset by a combination of



increases in the number of personal vehicles (with a shift towards vehicles with more powerful engines) and their increasing utilization levels. The use of urban planning that reduces the need to travel and promotes non motorized transport (NMT) and the improvement of public transport will be needed in reducing the energy intensive path of the road transport sector in India.

Figure 5 Total CO2 emissions from on road vehicles in the BL and MB case (2000-2030)

47. Further, in absence of fuel economy standards in automobiles in the country and with strong growth in family incomes, aspiration levels of customers have not only gone up but also people are moving from use of 2-wheelers to cars and to multi-utility vehicles (MUVs), which increases the difficulty of improving fuel economy. As far as in use vehicles are concerned, an effective vehicle inspection and maintenance programme need to be place in urban areas along with an improved traffic management measures.

iii. Emissions of criteria pollutants

48. The mix and the growth in automobile population determine the contribution of auto emissions of local pollutants namely, CO, HC, NO_x and PM in any city. Very little work has been done in India in the area of air pollution source inventory surveys and source apportionment. From the available studies, it is seen that although the contribution of auto exhaust emissions to the overall pollution load of CO is high, NO_x is moderately high but SO_2 is negligible. SPM or RSPM load is contributed by many sources, including industry, power generator sets, burning of fossil fuel, re-suspension of traffic dust, natural dust, building activities etc. (MoPNG, 2002).

49. The adoption of more effective abatement technologies (generally in response to stricter government-imposed emission standards) will lead to significant reductions in per vehicle emission rates. This will not, however, automatically translate into equivalent reductions in total vehicle related emissions. Emissions of all the four criteria pollutants are expected to go up significantly over the projection period in the BL case for both low and high growth GDP scenarios (Table 6).

b. Alternative case: Impact of increasing share of bus transport

50. In order to assess the impact of an increased penetration of public transport on energy demand and emissions, an alternative to the BL case is constructed. This alternative case is referred here as MB (more bus) case, which considers substitution of personalized motor vehicles with public transport in the future given an invigorated effort to promote energy efficiency through governmental policies and programmes and enhanced public-private sector participation. This scenario is optimistic but potentially feasible for achieving higher fuel efficiency based on more aggressive government policies, deployment programmes, and greater commitment to reduce emissions of local pollutants and CO_2.

51. In the BL case, the expected share of buses is likely to go down from 62% in 2005 to 44% in 2030 with 6% GDP growth rate; and 53% in 2030 with 8% GDP growth rate in the BL case (Table 5). This is due to the increasing share of personal modes (predominantly 2-wheelers and relatively low share of cars) from 29% to over 40% to meet the growing travel demand during the same period, whereas the share of 3-wheelers and taxis as IPT modes is expected to decline. However, to study the impact of more buses on roads in the coming years on fuel demand and emissions (GHG and local pollutants), in the MB case, the following assumptions are made.

- Total travel demand will be the same as presented in Table 5
- By 2010, the share of travel demand by alternative modes in both low and high GDP growth scenarios will be brought back to the same level as it was in 2000
- By 2030, while buses on road will significantly increase and meet 75% of the total road passenger travel demand, the share of 2-wheelers will significantly drop to 15%, 3-whellers drop moderately to 5%; cars drop marginally to around 3% and taxis continue to meet about 2% of the total travel demand.

52. It is interesting to note that with greater penetration of buses and lower utilization of personal motor vehicles there is expected to be a drop in the growth of energy demand and emissions of CO_2 (see Figures 4 and 5) and also local pollutants in both low and high GDP growth scenarios compared to BL case. Table 7 summarizes the benefits of strengthening bus transport compared to the BL case in terms of fuel savings and reduction in emissions over the projection period under both low and high GDP growth scenarios.

Table 7 Benefits of increasing the share of bus transport compared to the BL case

Fuel type	Low GDP growth (6%)					High GDP growth (8%)				
	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
Total fuel demand	3%	7%	13%	21%	31%	4%	11%	14%	18%	21%
Emissions										
CO_2	3%	7%	13%	21%	31%	4%	11%	14%	18%	20%
CO	10%	26%	51%	86%	139%	15%	40%	48%	58%	70%
THC	12%	35%	66%	109%	167%	20%	53%	62%	71%	81%
NO_x	0%	3%	8%	15%	27%	1%	5%	7%	9%	11%
PM	3%	13%	31%	64%	136%	5%	20%	29%	43%	67%

5. Strategies adopted in India to reduce vehicle emissions

53. In India, several steps have been taken to reduce level of vehicle emissions, particularly that of PM of critical concern, in a number of large-sized metropolitan cities. Generally, these actions have focused on reducing emissions per vehicle kilometer traveled by incorporating emission control standards and technologies at the production stage, changing the type and quality of fuels, and improving maintenance regimes. However, less attention has been paid to local area transport planning, including promotion of the use of demand management techniques such as taxation or road pricing, traffic management, and the use of public transport and non-motorized modes of transport, as a means of reducing vehicle use or reducing the total vehicle kilometers traveled.

54. The Environment Pollution [Prevention and Control] Authority (EPCA) set up by the Government of India in January 1998 recommended the following strategies that need to be adopted for improving air quality in cities grappling with critical levels of pollution, all of which were approved by the Supreme Court.

- Reduce emissions by setting standards for fuels and auto emissions in new vehicles
- Establish inspection and maintenance of in-use vehicles
- Reduce congestion levels and improve safety concerns
- Augment public transport
- Use clean alternative fuels

55. The following directives of Supreme Court in July 1998, regarding alternative fuel use in the city of Delhi was evaluated to study the impact on GHG emissions from the road transport sector.

- The number of buses must increase to 10,000 by April 2001 and must operate on CNG
- All pre-1990 taxis and autorickshaws (including those owned by individuals) must be replaced with new vehicles running on clean fuels by March 31, 2000.
- Local governments must provide financial incentives to replace all post-1990 autos and taxis with new vehicles that operate on clean fuels by March 31, 2001.
- All public sector buses older than 8 years must be scrapped by April 1, 2000 unless they operate on CNG or other clean fuels. The entire city bus fleet (public and private) must be steadily converted to CNG.
- The Gas Authority of India must create a network of 80 CNG refueling stations by March 31, 2000.

C. POLICY AND VISION FRAMEWORK

1. The Vision

56. Urbanization, economic liberalization, better incomes and higher aspirations in India have all led to individualization of lifestyles and a need for increased mobility. As a result transportation sector GHG emissions are expected to soar if it follows the path of the highly motorized nations without integrated land-use transport policies in place. This will require accelerated urban reform, improvement of urban structure (for example, to protect mass transit rights of way in the early stages of development) and urban road traffic (for example, to implement effective traffic restraint) together with innovative transport-demand management and access-and-mobility planning to support the main social and economic activities that take place in a city (MoUD, 2005).

2. Principal policy interventions for urban transport to reduce GHG emissions

a. Improving access and reducing passenger and freight-kilometers

57. The greatest GHG mitigation can be achieved in the medium to long term and that is through a proper integration of land use and transport planning to improve access to goods and services whilst minimizing the need to travel through innovative means without compromising economic growth. Travel demand is a function of population, the per capita trip rate and the average trip length. With rapid urbanization process in India, there is little possibility of reduction in the per capita trip rate. This is because a larger share of the population would be securing employment (especially women) and a larger share of children would be attending schools. Efforts to reducing travel demand have, therefore, to focus on reducing the average trip length. Small, self contained, clusters are considered desirable from a transport perspective, in mega-cities, as people are expected to move to residences that are closer to their place of work, or seek work closer to home. It is essential that the transport network guide the urban form, rather than the urban form guiding the transport system. Also, it would be equally important to link peri-urban and rural community with fast mass transit, and promoting use of information and communication technology (ICT) policies to enhance economic development.

b. Using less fuel per passenger- or freight-kilometers

58. The next exercise in developing a GHG mitigation strategy in the medium term would be to determine optimal modal preferences for meeting travel demand. Modal choices have to be made based on their relative congestion impacts, emission characteristics and energy efficiency if they are to lead to sustainable mobility. It is well known that non-motorized modes emit no pollutants and occupy least amount of road space. Hence they should be amongst the most preferred modes. Amongst the motorized modes, public transport occupies less road space, consumes less fuel and emits least pollutants per passenger-kilometer of travel compared to personal motor vehicles. There is therefore a need to encourage preference for public transport over personal vehicles. This can be achieved by a combination of fiscal and control measures.

i. Fiscal and control measures

59. Fiscal measures include charging of a fee for using certain congested parts of a city, levy of high parking fees, increasing vehicle registration charges and increasing the tax on fuel, carbon-based annual road tax (where low powered, low-emissions, hybrid and newer vehicles pay less road tax than the higher powered, higher emissions and poorly maintained old vehicles), etc. Such fiscal measures can help in reducing private vehicle operation leasing to reduced congestion and air pollution.

60. Control measures include physical restrictions on the use of personal vehicles on some corridors, limiting the availability of parking space in city centers, limiting the availability of road space for personal vehicles and restrictions on the ownership of vehicles etc to mitigate CO_2 emissions and local emissions. A good example of control measure is offered by the 'Congestion Charging' in operation in Singapore and more recently in London as well as the quota based 'Certificate of Entitlement' scheme for restricting vehicle ownership in Singapore. Both measures are forced measures to change the preferences of the people and promote the

public transport system. However, it may be noted that both cities had well-developed integrated public transport systems before these schemes were introduced.

ii. Priority to the use of public transport and its improvements

61. Significant reduction in GHG emissions can be achieved through modal shift from private vehicles to high occupancy public transport. There is a wide range of public transport technologies. At one end is high capacity, and high cost, for example technologies like underground metro systems and on the other hand, are low capacity bus systems running on a shared right of way, which costs far too less. Within these extremes is a range of intermediate possibilities, such as buses on dedicated rights of way, elevated sky bus and monorail systems, electric trolley buses etc. In India, so far high capacity rail systems and buses on shared rights of way are the only ones, which have been experimented. Electric trolley buses have been running in San Francisco, Beijing. Bus Rapid Transit (BRT) system operating on segregated roadways has become very popular in cities like Bogota in Columbia and Curitiba in Brazil. BRT can offer high-speed user-friendly mass transit at high carrying capacities but with a considerable cost reduction in per-kilometer investment versus metro or light rail system. BRT system also helps in improving substantially traffic flow for other private vehicles due to the elimination of interference from the conventional bus or paratransit operation.

62. So far, fares for public transport in India have been set on the premise that this mode of travel is used by poor, who have no other means of meeting their travel needs. As such, fares have been kept low as a measure of social equity. This has resulted in good public transport systems being unable to recover even its operating costs and deterioration of service quality. In view of this the following recommendations in the National Urban Transport Policy (NUTP) are important and needs to be taken note of (MoUD, 2005).

- Provisioning of different types of public transport services for different segment of commuters – a basic service, with subsidized fares and a premium service, with better quality but higher fares and no subsidy
- Setting up of a regulatory authority by the State Government to ensure that the fares charged are fair and reasonable by different types of public transport services.
- Basic principle in financing mass transit systems would be that the national government should provide the infrastructure but the users (direct and indirect beneficiaries within the city) must pay for the operating costs and the rolling stock.

iii. Promoting the use of non-motorized modes

63. Measures that discourage the use of personal motor vehicles would have to go hand in hand with measures that encourage the use of non-motorized modes, as they are 'greener' modes of travel. First of all, all safety concerns of cyclists and pedestrians have to be addressed by encouraging the construction of segregated rights of way for bicycles and pedestrians. This can be done by investing in a segregated right of way for bicycles and pedestrians, converting crowded areas like market places into no vehicle zones, bringing about improvements in bicycle technology, and providing safer parking facilities for bicycles at work places and finally promoting cycling and walking as healthy and exciting activities.

c. Fuel economy standards for new vehicles

64. Almost all industrialized countries use standards on new vehicles to reduce vehicle oil consumption and CO_2 emissions. Yet the three largest automobile markets, the United States, the European Union and Japan, approach these standards quite differently (TERI, 2006).

- The United States uses Corporate Average Fuel Economy (CAFÉ) standards, which require each manufacturer to meet, specified fleet average fuel economy levels for cars and light trucks. Canada's automobile industry has voluntarily agreed to follow the US CAFÉ standards in CAFÉ.
- In the European Union, the automobile industry has signed a voluntary agreement with the government to reach an overall fleet CO_2 emission level of 140 g CO_2/km by 2008. In Australia also, a similar voluntary agreement has been signed with the government.
- In Japan, as in China, fuel economy standards are based on a weight classification system where vehicles must comply with the standard for their weight class. Similarly, the fuel economy standards in Taiwan and South Korea are based on engine size classification system. China, however, is following the EU's testing procedures, and Taiwan and South Korea are following testing methods similar to US CAFÉ procedures. Japan maintains its own testing procedures.

i. Fuel efficiency standards

65. There is a clear difference between a regulatory and voluntary approach to fuel economy standards. While a regulatory target with sufficient enforcement and penalties for non-compliance can be more or less guaranteed in the future, a voluntary target is less certain. Till date, neither did the manufacturers come forward to declare the fuel efficiency of the vehicles nor did the government make such declaration mandatory. In view of the growing energy security concerns and environmental considerations, it has now become imperative for the Government of India to set mandatory targets for improvements in fuel efficiency for each type of motor vehicle. Such targets for improvement in fuel efficiency can be enforced through regulation with incentivizing of the auto industry.

ii. Emissions standards

66. With fuel and vehicle technology constantly evolving, it would logically appear more cost effective to upgrade newer vehicles now from Euro II to Euro IV instead of following a two-step approach of upgrading from Euro II to Euro III, and then to Euro IV as considerable savings in cost and time can be achieved. It is important the "world-wide" standard is adopted completely, including any durability requirements etc, so as not to provide a perverse incentive to manufacturers to cut cost and deliver a sub-standard product.

iii. Fuel standards

67. Fuel efficiency and emission standards are intrinsically linked to fuel standards. Experience, especially in Europe, has repeatedly demonstrated that economic instruments such as tax preferences can stimulate the early introduction of cleaner fuels (TERI, 2002). Because of which a number of refineries in Europe began to produce very low sulphur fuels that enabled advanced emissions technologies to significantly reduce tailpipe exhaust emissions. Similar tax incentives need to be considered by the Indian government to encourage oil companies in the country to produce ultra low sulphur fuels so that air quality in towns and cities could improve substantially, particularly with an increasing fleet of diesel vehicles.

b. Reducing emissions from in-use vehicles

68. Vehicle maintenance can play a role in efforts to reduce per kilometre emissions of local pollutants and GHGs. Although emission and fuel-efficiency performance deteriorate with age, good maintenance practices can greatly reduce the rate of this deterioration. Often, this maintenance involves simple, inexpensive periodic attention to aspects of motor vehicle operation that can significantly affect vehicle performance, such as oil and filter cleaning and replacement, spark plug replacement, spot checks for leaks in the fuel and other fluid delivery systems, and maintenance of correct tyre pressure. India, like many other emerging countries in Asia does not have a solid maintenance ethic. In India, vehicle owners do not get emission warranty benefits as in the developed countries. Although some automobile manufacturers have been offering emission warranty, there is no legal binding. There is a strong need to move towards the systems prevailing in the developed countries.

69. Further, in India, two- and three-wheeled vehicles constitute a majority of the road vehicle fleet. These vehicles are an essential source of affordable mobility for people in the country. But at present, they produce a greatly disproportionate share of transport-related conventional emissions. Several steps are underway to reduce emissions from these vehicles. The most important of these steps is to shift from two-stroke to four-stroke engines. Two-stroke engines are more polluting and less fuel-efficient than four-stroke engines. Such a shift will produce a significant improvement in fuel efficiency and in emissions performance.

i. Inspection and certification

70. Recognizing the need to address emissions from in-use vehicles to ensure that the on road vehicles are properly maintained so that they do not become emissions (both local and global) and safety hazards, the Ministry of Road Transport and Highways, Government of India, set up a committees to look at the various issues involved in introducing an effective inspection and certification (I&C) programme focusing on the policy issues and technical issues respectively (TERI, 2004a). The Committee made the following recommendations.

- A phased approach would be necessary to achieve the scope and coverage of the inspection regime outlined earlier.
- Significant investments, improvements in regulatory and management practices, increased capacity and capability would be prerequisites for the effectiveness of such regime.
- Prioritizing the I&C programme for transport (commercial) vehicles first and then moving on to the personal vehicles like cars and two-wheelers.
- Bringing in older vehicles under the inspection regime earlier as compared to new vehicles.
- I&C regime be introduced in cities with significant air quality concerns that can be attributed to the road transport sector.
- Begin with setting up of model inspection centers to demonstrate successfully the procedure for testing a vehicle for both emissions and safety
- I&C centers need to be correctly implemented and rigorously enforced to detect the gross emitters and ensure that they are repaired.

71. The benefits of an effective I&C programme would be enormous especially from older diesel, gasoline-fuelled, carbureted vehicles in terms of improving fuel efficiency, emissions and safety inspections with resultant reduction in road accidents.

ii. Retrofit programme

72. Not much work has been done in India on retrofitting a new engine into an existing vehicle or even refitting of emission control devices (ECDs) like diesel oxidation catalysts (DOCs), particle filters, continuous regenerating traps (CRTs), etc. Such measures can help in improving fuel efficiency and in reducing emissions from in-use vehicles as has been demonstrated in Mexico. A big challenge will be to equip “standard” road vehicles in India with advanced emission control equipment to function properly, and assure that vehicles thus equipped are fueled and maintained properly.

3. Non climate policies

a. Co-benefits

73. Policies for energy efficiency and environmental improvement in road-transport requires implementing a combination of technical measures that target individual vehicles and their fuels, and regulatory policy, standards, and those that are concerned with management of the urban transport, and institutional sector development of the complete transport system. In addition, policy changes are necessary in urban development and land use planning through awareness campaigns for longer-term benefits. The literature uses the term ancillary benefits when focusing primarily on one policy area, and recognizing there may be benefits with regard to other policy objectives. One speaks of co-benefits when looking from an integrated perspective.

74. This section is about ancillary benefits in the field of climate policy that come about when focusing on the policies to utilize synergy between the objectives of (i) improved equitable access to means of personal mobility, mobility infrastructure by designing effective land use and the provision of public transport, and inexpensive freight transportation, (ii) reduced level of congestion, transportation related accidents and air pollution to improve public health and cities’ image, and (iii) reduced demand of non-renewable transport energy, and carbon intensity (to reduce GHG emissions). These synergies and opportunities are particularly significant in India and have been the focus of an active dialogue over the last couple of years with respect to developing a sustainable urban transport programme. Most of the policy changes will be based on a series of co-benefits relating to clean energy and low carbon economy, equity and quality of life; and very few will be based solely on global environmental concerns.

75. Accounting for potential synergies of climate change policies and air pollution policies can be illustrated by the congestion-charging concept implemented in London in February 2003 to reduce traffic congestion. Simultaneously, investment in public transport increased to provide a good alternative. Since the introduction, congestion in the charging zone has reduced by 30% during the charging hours. The charge has had substantial ancillary benefits with respect to air quality and climate policy. An 18% reduction of traffic in the charging zone has led to reductions in CO_2 emissions of 20%. Primary emissions of NO_x and PM_{10} fell by 16% after one year of introduction (Transport for London, 2005).

76. While there are many synergies in emission controls for criteria pollutants and GHGs, there are also trade-offs. Direct injection diesel engines are about 35% more fuel efficient than conventional gasoline engines of comparable size. Thus, diesel engines have lower CO_2 emissions, but increase particle and nitrogen oxides emissions. Techniques that reduce nitrogen oxides from vehicles may increase nitrous emissions (Swart, 2004). Thus, capturing

synergies and avoiding trade-offs in addressing the above multiple objectives simultaneously offers potentially large cost reductions and reductions of health and ecosystem risks.

77. The above discussion highlights the need for identifying specific policy measures and opportunities in the road transport sector in India for addressing co-benefits in the near-to-medium-to-long term. India would significantly benefit if on a continuous basis through scientific research following areas are strengthened. (1) Regular updated knowledge bases on the linkages between air quality and climate change in policy development. (2) Development of common methodological tools and procedures, which can be easily implemented and can help decision makers in evaluating alternative policies and programmes. (3) Organize policy forms, discussions and workshops.

b. Privatization

78. Liberalization of the Indian economy in the early 1990s with increased privatization led to either contracting out specific services to private vendors, deregulation or attracting private financing for new infrastructure investment. The purpose was that competition enhanced by privatization would result in large efficient gains in the form of efficient transport services and minimal operational costs including for energy. Well-managed competition can result in manageable tariffs even by the poor but poorly managed deregulation can result in increased road congestion, and pollution and deteriorating safety and security. This is also a phenomenon of privatization in most of the developing economies' including India where deregulation has attracted small-mini buses (15-seater) replacing the previously state owned large buses (65-seater). With little enforcement of standards, deregulation of the urban road transport sector in particular has compromised energy intensity per passenger-kilometer and has caused congestion and pollution to the Indian cities/towns with implications for increased carbon intensity of providing road transport services. In India, intercity bus privatization looks strong. Private toll roads may find success in India and they may prohibit unnecessary trips and allow free flow of traffic as the roads are well maintained. There is hardly any data that links privatization to GHG reduction.

c. Transport and fuel subsidies

79. One of the most heavily subsidized forms of transport is public transport in India. Although public transport generally emits fewer GHG per passenger-kilometer, the net effect of these subsidies has not been quantified. It depends on the balance between increased GHG emissions due to higher demand due to lower subsidized fares and substitution of relatively less efficient transport modes. A quantitative appraisal of the effect of subsidies on GHG emissions is very complicated. Not only have shifts between fuels and transport modes to be taken into account, but the relation between transport and the production structure also needs to be analyzed.

80. Fuel subsidies can affect GHG emissions on two ways. First, they lower the cost of road transport, thereby increasing transport above the equilibrium in absence of the subsidy. Second, they decrease the incentive to economize on fuel, either by driving efficiently or by buying a fuel-efficient vehicle.

81. Price distortion in the auto fuels is commonly observed in India. A common example of such distortions is found in the relative prices of petrol and diesel, where the price of petrol is kept high with levies compared to that for diesel. Petrol carries a higher levy presumably on the ground that petrol vehicle owners have higher incomes and, therefore, a higher capacity to pay,

although the external cost of petrol vehicles is lower than those of diesel vehicles. Other examples of price distortions are subsidy on fuels such as kerosene and LPG used for cooking, and mandatory use of CNG in commercial vehicles in Delhi. Such distortions show themselves in higher use of diesel, leakage of LPG to the transport sector. The result is non-economic use of fuels, low fuel efficiency (higher GHG emissions), misuse of subsidy and last but not the least adulteration of diesel with kerosene.

82. Based on the National Sample Survey Organization (NSSO) data, TERI estimated that around 26% of the total kerosene consumed in India couldn't be accounted for (TERI, 2005b). In a recent study by the National Council of Applied Economic Research (NCAER), the corresponding figure is 40% (NCAER, 2005). It is believed that the kerosene that is siphoned off is used for adulterating diesel, used as a transportation fuel, and in pumpsets/gensets in rural areas. As sated earlier, a key reason for adulteration is the price different between diesel and kerosene. At present diesel is priced at 30.45 rupees/liter in Delhi and kerosene under Public Distribution System (PDS) network is priced at just 9.05 rupees/liter. This differential is a big incentive for retail sellers to adulterate.

83. Adulteration of low-sulphur diesel with higher-level kerosene can cause the fuel to exceed the sulphur maximum. This impacts unfavorably on the quality of ambient air as it affects the engine efficiency of vehicles and increases tailpipe emissions of HC, CO, NO_x and PM (ESMAP, 2002). The same study reports that according to available information adulteration generally occurs in three-wheelers and trucks, and often as much as 20%-30%. The adulteration of diesel by kerosene also negates the huge investments done by the refiners for improving fuel quality in India. Oil companies on their own are taking measures to prevent adulteration by ensuring product purity during transport. Independent fuel quality checks have also been established. These needs to be extended to all the oil companies and made more rigorous.

84. Though a number of studies suggest that fuel adulteration will increase the tail pipe emission, the exact quantification of emissions due to adulteration is limited. There is also a paucity of scientific studies on the impact of air pollution on health in developing countries, particularly in India.

4. Stakeholders

85. A wide range of sectors and institutions are involved in tackling emissions from on-road vehicles. Road transport and highways, petroleum and natural gas, environment, finance, urban development, and even agriculture (for biofuels) are the sectors involved. A number of groups are engaged to varying degrees in policy formulation and implementation, including the auto industry and oil and gas companies; goods delivery and passenger services firms; vehicle repair and service industries; manufacturers of emissions measurement equipment and emissions control devices; environmental non governmental organizations (NGOs); firms with their own fleets; private vehicle owners; municipal, state and national governments; and regional trade organizations. Apart from these the international development communities are likely to buy in to the proposed action plans purely because of their climate change implications. However, the co-benefits of all the proposed action plans directly impact major problem areas that India as a Developing Member Country (DMC) of ADB is currently facing. Thus, the major stakeholders in this process are:

- The international development community
- National and state governments
- Local, City and Municipal governments

- NGOs and Community Groups
- Private Enterprise and Investors

86. The international development communities need to promote public awareness raising for climate change in general and transport-related climate change in particular. While at the national level, due to the accelerated growth in India's urban population, motorization, congestion, road safety concerns and air pollution – including the GHG component – there is a need to change focus for urban areas in their approach to urban and transport planning and the actions required to reduce the accelerated impact of India on road-transport on climate change.

5. Emission trading

87. The Clean Development Mechanism (CDM) offers the possibility to increase funding for transportation projects; enhance local planning and project evaluation capacity; and expand technology transfer opportunities. However there are difficult challenges to overcome before these projects become more feasible to undertake. Despite emission reduction potential with several measures discussed above, projects in the transportation sector have been slower to develop than those in other sectors. Those projects that fit within the current CDM rules have limited impact on long-term emission trends. Projects that address fundamental structural change (e.g., BRT system, fuel economy standards, I&C test centers, etc.) offer major GHG reductions but do not fit well into the project based structure of the mechanism. Such projects, especially demand-side initiatives, face significant methodological and financial barriers.

88. One of the primary challenges with transportation projects under the CDM is 'additionality', i.e., how a project activity using the methodology can demonstrate that it is additional and different from the BL scenario. The purpose of the additionality tool is to check the claim of additionality and ensure that BL do not receive Certified Emission Reduction (CER) credits. A combination of high costs of transportation projects, low prices for CERs and low monetary value of co-benefits makes establishing addtionality very challenging for transportation projects.

89. Development of 'baselines' and 'verification' of emission reductions are further stumbling blocks. Baseline scenarios need to be established and must reflect actual circumstances, i.e., changes in technology and policy over time. Improvements in data collection; forecasting ability; incorporation of non-motorized trips; and consideration of policy impacts over time can all contribute to stronger methodologies.

90. Presently, CDMs are not in place for transport-related projects. Further guidance on additionality requirements for transportation projects and development of credible database that reflect the actual circumstances are key that would facilitate additional project development.

D ACTION PLAN

91. It will be a tremendous challenge to build sufficient institutional capacity—in both public and private spheres—to deal with the pace and direction of change in mobility systems. In a country like India—which faces the prospect of rapid motorization and potentially explosive growth in private ownership of automobiles—the lack of adequate road infrastructure poses an enormous problem. Government wants the economic development advantages of motorization, and increasing numbers of individuals desire and will be able to afford the personal freedom that vehicles provide. But the dangers of paralyzing congestion, local environmental degradation,

and high rates of GHG emissions that add to the threat of global change loom large. Institutional issues in the public sector include effective national decision-making that balances these considerations, as well as implementation capacity at the regional and metropolitan level. In the private sector, organizations with the competence to oversee large projects need to develop.

92. Adequate financing is another key institutional issue. Many priorities other than mobility—including enterprise investments as well as education and health—compete for limited private development capital and public resources. Access to international assistance is not likely to be sufficient for the full range of mobility needs in the developing world. These financing concerns will affect not only new facilities but also the maintenance of the existing ones. Equally important issue in financing is the problems of providing equitable mobility opportunities in low-income populations. The poor people frequently live in areas poorly served by public transportation, and may lack funds even for limited public transport options that do exist.

93. The opportunity to leapfrog the trajectory of technological development both for transportation and environmental technologies that developed nations have gone through is a potential advantage for a developing economy like India if the institutional capacity to adopt and implement these innovations can develop sufficiently.

94. Environmental and safety regulation is in its infancy in developing nations. Institutionally, there are issues not only of capacity but also of political will. Harmonization of regulation in this environment is not merely a matter of reconciling the relatively similar national schemes of regulation present in the developed countries; it is also a matter of making basic commitments to such regulation in international negotiations and national-level political decision-making.

95. Implementing action plans in India will require the creation of new skills and institutional capabilities—strategic planning, regulating unfair or non-competitive practices, contracting, performance monitoring, and enforcement—as well as implementation skills and capabilities. Implementation of plans would require investments, both via lending and non-lending operations. Since these activities have important co-benefits in terms of air quality and health, traffic and congestion, road safety, transport efficiency and economic development, over the long term, similar investments would probably be required even if the climate change components were not considered.

96. This section identifies list of priority areas in the country for developing action plans which broadly falls under integrated urban and transport planning, institutional development, capacity building, establishing regulatory framework, implementation of pilot demonstration projects, private sector participation, investment and financing opportunities, and associated timeframe for their implementation. It also identifies areas that require additional technical and economic assessment for continuous updating of knowledgebase.

1. Enhancement of knowledge base and capacity building

1. Develop an adequate and credible road transport database comprising city land use maps with road network, traffic flows and cost, which must be systematically collected and regularly updated. This would help in establishing credible baseline or the reference case scenario and would enable more informed decision-making, policy formulation, prioritizing policy options, planning and implementing projects both by the public and private sector, as well as academic and research work in the field.

2. Identify the training needs of the public officials and other public functionaries on a continuous basis within the states and support them with capacity building and training and skill development to develop a long term integrated urban and transport structure plan.

97. These actions would require continuous effort by the national or central government in building capacity and database for enabling informed decisions. The international development community together with national government is key in facilitating the transfer of technical know-how and build capacity among state and local government officials to be able to effectively design climate-change friendly sustainable improvement of urban and transport development programmes at the state, city/municipal levels.

2. Improve access to goods and services through an integrated urban plan

1. Support the formulation of Unified Metropolitan Transport Authorities (UMTA's) in all million plus cities in India as recommended by the NUTP. Such Authorities would facilitate more co-ordinated planning and implementation of urban transport programmes and projects and an integrated management of urban transport systems.

2. Encourage integrated urban and transport planning so that travel distances are minimized and access to livelihood, education, and other social needs, especially for the marginal segments of the urban population is improved. This is necessary to ensure safe, affordable, quick, comfortable, reliable and sustainable access for the growing number of city residents to jobs, education, recreation and such other needs within our cities. Further, improving NMT and bus systems modes of transport has been identified by many transportation studies to be the priority areas for development in India as these modes can more directly serve the poor as well as offset high-energy use and emissions associated with private motorized transport. Total transport demand can be restrained by urban planning oriented to public transport, by bringing policies, by parking control, and by direct restrains on traffic movement—all in the context of an integrated strategy. Implementation of such a strategy would help in reducing transport fuel consumption per passenger- or freight-kilometer and thereby mitigating GHG emissions.

3. Construct NMT lanes and pedestrian pathways that are secure, convenient, well maintained and managed can reduce the number of trips made on motorized vehicles. Pedestrian safety requires removal of encroachment of footpaths through strict enforcement coupled with public participation.

4. Promote private sector investment to improve public transport systems and their operation that is consistent with the strategic framework. Among the wide spectrum of public transport technologies available, while rail based systems seem to suit dense cities with limited sprawl and only a few spinal corridors, but high capacity bus raid transit (BRT) systems seem better where urban densities are lower and the city has spread over a large area. To enable proper evaluation of alternative public transport technologies, suitable for different size and shape of cities, government must create a knowledge center that would provide the necessary information required for taking the right cost-effective technological decisions.

5. Establish a clear and transparent legal and fiscal framework where large financial outlays are required to put in place an appropriate public transport system.

6. Support joint ventures and collaboration agreements between proven technologies of public transit and suitable Indian companies and institutions for better understanding of mobility patterns and mode choice criteria in metropolitan areas.

7. Encourage the adoption of measures that restrain the use of private motor vehicles through market mechanisms such as higher fuel taxes, higher parking fees, reduced availability of parking space, longer time taken in traveling by private motor vehicles vis-à-vis public transport.

8. Promote the involvement of local community groups and NGOs in designing need based strategies and projects for implementation through a consultative and participatory process.

9. Support public awareness programmes that educate people on the ill effects of growing transport problems in urban areas, especially on their health and well-being.

98. Most of these actions will generate visible results in GHG mitigation in the medium to long term. The international development community together with national government is key in facilitating climate-change friendly sustainable improvement of urban and transport development programmes at the state, city/municipal levels.

3. Establish fuel efficiency standards for new vehicles

1. Provide technical assistance and capacity building to evaluate the heath cost associated with automotive emissions and the contribution of emissions (local pollutants and GHG) from private and public transport at the city/metropolitan area level.

2. Develop past, present and future scenarios of level of motorization based on population growth, economic development and urbanization and estimate the impact on transport fuel demand by fuel type and its impact on criteria pollutants and GHG emissions.

3. Establish fuel efficiency standards for each category of motor vehicles in view of the auto-fuel policy road map that defines and regulates the fuel quality and emission standards and promote use of advanced engine and vehicle technology.

4. Promote the accelerated substitution of old vehicles in the fleet with new cleaner, higher efficiency vehicles.

5. Promote worldwide standards by leapfrogging to the state-of-the art vehicles and fuels. Since the upgradation of refineries is time consuming and capital-intensive, incentives to the oil companies can be graded across time if investments are made earlier.

6. Encourage the involvement of local community groups and NGOs in the strategy design and roadmap implementation through well-informed and consultative process.

99. Improvement in fuel efficiency can bring noticeable results in GHG mitigation in the medium term. The international development community together with national government is key in facilitating climate-change friendly sustainable improvement of fuels and vehicle technology.

4. Improve fuel efficiency in existing vehicles

1. Establish an effective institutional and regulatory framework for the inspection and certification regime in the country.

2. Promote and incentiviate the political will-power in local government (municipal/city) and governments to invest resources, staff, and effort in auditing and supervising the programme and effectively enforce in-use vehicle performance.

3. Raise public awareness of the ill effects (pollution and safety hazards) of poorly maintained vehicles.

4. Periodic requirement of undergoing an exhaust emission test of personal motor vehicles (cars and two-wheelers) like other commercial vehicles appears to be necessary.

5. Develop a well-enforced inspection and certification programme focused on improving emissions and fuel efficiency performance of existing vehicles. Initially, the focus should be on intensively used commercial vehicles (buses and three-wheelers).

6. Establish a legal framework to apply penalties to test centers found in violation of test protocols or engaging in fraudulent practices.

7. Mandate retrofitting of emission control devices (ECDs) in existing heavy-duty duty vehicles as a low cost option to achieve improved emissions and fuel economy performance.

100. These actions would bring noticeable results in GHG mitigation in the short term. The international development community together with national government is key in facilitating the Inspection and certification programme off the ground.

5. Demonstration of pilot projects

101. The national government together with state government must consider implementing the following kinds of pilot projects in the short tem, in a sample set of cities.

- Enhanced use of NMT modes on dedicated lanes
- Develop dedicated bus corridors with high capacity modern BRT system
- Reinforce TDM measures and enforcement skills
- Retrofit ECDs in heavy-duty diesel vehicles
- Setting up of I&C model test centers

102. Successful demonstration of pilot projects would need to consider public-private partnerships where the government provides the infrastructure investment and well-regulated franchised private operators operate the rolling stock. Apart from raising public awareness to wider application of sustainable transport measures, demonstrations can also help in the resolution of institutional issues associated with new technology, and with the development of maintenance and service infrastructure.

6. Investment and financing

1. Large capital investments are required for public transport oriented urban planning highlighted above whether they are for constructing highly capital intensive Rail Transit Systems or segregated right of way for cycles and pedestrians. The required resources are limited with most state governments and local bodies and therefore it is important that an alternative method of financing needs to be explored. Government recognizes that within the resource constraints, urban transport infrastructure development needs to be treated as a high priority area. Increasing participation of the private sector would be necessary to augment resource base and increase competitive efficiency. An appropriate mix of public funds and private capital can competitively deliver urban transport services. For example, private services that are currently provided by most of the states are incurring huge loss, could also be framed out to the private sector, through innovative public-private partnerships. In addition, the land available with public transports service providers can be put to use for commercial purposes and raise substantial resources in a manner that promote modal shift from private personal transport. Most State Transport Corporations own prime land in urban areas but such land is not being commercially exploited.

2. Huge investments are required for setting up of a number of modern inspection and certification centers for carrying out tests in existing vehicles. State governments because of their resource constraints would have to involve private sector for setting up of such modern facilities to attract investments and managing a large number of centers. There are other reasons for delegating the management of centers to the private sector, one of the most important of which is that it is more difficult for one government agency to apply sanctions, including license revocation, to another government agency, introducing the potential for compromising quality control. It is recommended that the State government specify the Inspection Fees and the bids are invited on the license fee (or the subsidy) that private operator wants. Wherever the volumes of traffic are not high to ensure viability of the centers, the state government could consider subsidizing these centers by providing land on lease.

3. Seek financial support under the Global Environmental Facility (GEF), Operational Programme (OP) number 11 on “Promoting Environmentally Sustainable Transport”, to improve NMT and bus systems together with transport and traffic management and land use planning.

4. Ensure that all multi-agency financing packages and bank lending for urban development and road infrastructure projects have a long-term energy efficiency improvement component.

7. Barriers to change

1. In metropolitan areas, the weak empowerment and linkages between urban planning, transport planning, traffic management and enforcement provide a substantial barrier to identify the priority measures and the broad level of resources that are required to initiate actions over short, medium and long-term on reducing the climate change effects from transportation.

2. Lack of public transport alternatives and political unwillingness to implement and enforce demand management measures to restrain growth of private transport demand

3. Access to huge capital to implement public transport systems and inspection and maintenance centers

4. Absence of a comprehensive framework to evaluate the true cost of externalities of road transport.

5. Knowledge of the cost and effectiveness of various measures to mitigate carbon emissions and that of criteria pollutants is inadequate.

6. CDM that are in place are not optimized for transport-related projects

8. Areas need additional technical and economic assessment

1. Develop a framework that estimates the number of vehicles on road in different sized towns and cities

2. Conduct mobility audits to understand travel behavior in large, medium and small sized cities

3. Design and operationalize large scale traffic and transportation surveys to develop a comprehensive integrated transport plan

4. Design a method that helps in understanding needs and preferences of commuters to promote public transport ridership and willingness to pay for better services

5. Develop a comprehensive framework for cost effectiveness analysis to control vehicle emissions related to advanced automobiles and fuel technologies, traffic management and fiscal instruments.

6. Determine the short and long-run price elasticity of transport demand

7. Examine the cost effectiveness of pilot demonstration projects on BRT system and NMT modes on dedicated corridors

8. Examine the cost effectiveness of a modern automated pilot inspection and certification center with respect to fuel efficiency improvement and emissions reduction potential

9. Conduct comparative cost effectiveness analysis of alternative public transport technologies

10. Examine the cost effectiveness of carefully designed and evaluated targeted incentive schemes for scrapping or replacement of high-mileage gross polluters.

11. Examine the cost effectiveness of moving to low fuel sulphur limits of 50 ppm or lower, taking into account maintenance capabilities and the concomitant investments in the necessary emission control technologies to exploit lower sulphur fuels

12. Estimate the cost of supplying alternative cleaner fuels to the transport sector under available resource and infrastructure conditions in a metropolitan region.

13. Develop transport-planning models that take into account market-driven choices of locations and not simply aim at improving existing traffic conditions.

14. Develop computerized land-use transport models that create an interface between land-use models and travel demand models, and are consistent with regional forecasts of population and employment.

15. Establish CO_2 baselines for the road transport sector

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Appendix IV

THE CASE FOR BIO-FUELS

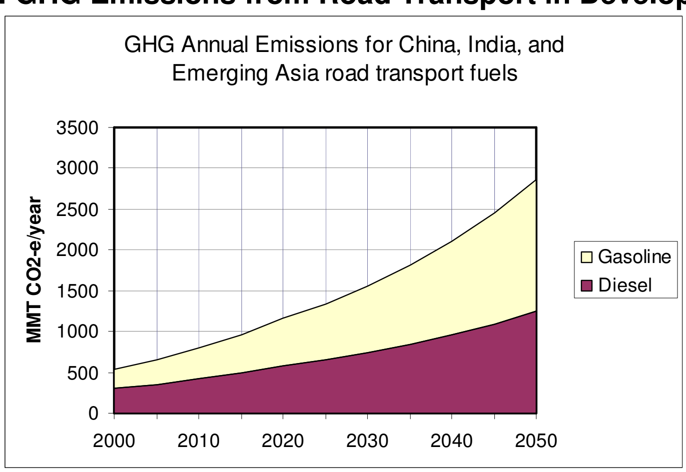
A INTRODUCTION AND OVERVIEW

1. The primary focus of this annex[84] is on the possible roles of liquid biofuels in reducing the rate of growth of greenhouse gas emissions in the Asian liquid transport fuels market over the coming several decades. Liquid biofuels produced for road transport are primarily ethanol for use with or in place of gasoline, and biodiesel, which is fully compatible with petroleum-based diesel fuel (petrodiesel). We emphasize that in the face of massive growth in road transport in Asia over the next several decades, the widespread use of biofuels is only one of the options that must be used in tandem if growth in GHG emissions from transport is to slow substantially.

2. About two-thirds of global greenhouse gas (GHG) emissions are from the energy sector. Emissions from the transport sector are about 14% of the total. Ten percent of global emissions originate with road transport and this is a growing sector world-wide, with the most rapid growth expected to be in Asia. Sixty percent of the growth in GHG emissions over the next several decades is expected to come from transport. Road transport, dominated by the use of gasoline and diesel fuel, is also a primary source of air pollution and the related negative impacts on human health and well being, and on the health of natural ecosystems as well. Figure 1 shows the expected increase in road transport GHG emissions under the reference scenario used for analysis in this Annex.

3. The developing countries of Asia are experiencing rapid economic growth and expansion of the transport sector. The Developing Asian economies considered in this report are China, India, and the economies of Emerging Asia, which are Bangladesh, Bhutan, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, and Viet Nam. These three regions are distinguished from OECD Asia, which includes Japan, Korea, and Singapore.

Figure 1: GHG Emissions from Road Transport in Developing Asia



[84] A more comprehensive and detailed report on the potential impact of biofuels on GHG emissions in the road transport sector of non-OECD Asia is in preparation. This Annex presents highlights of that report.

4. While the rate of growth in road transport fuel use in non-OECD Asia is dramatic in comparison with most other regions of the world, the total demand is just 15 % of world demand in 2005. However, it is anticipated to grow to 30 % of the total global in 2050 in this scenario. Consequently ADB is examining the potential policy and investment options that can result in significant reductions in the growth of GHG emissions in the transport sector in Asia; one of these options is the use of biofuels on a strategic scale in the region. To the extent that mobility and transport can become more efficient, the greater the contribution of biofuels can be at any specific biofuels production level. As with other renewable energy options, the relative contribution of renewables is enhanced as the end-use sectors become more efficient.

5. This Annex (a) briefly defines liquid biofuels and how and where they are produced, (b) assesses the potential impacts of biofuels on emissions of greenhouse gases relative to gasoline and diesel fuels for the region of developing Asia, (c) summarizes the results of life-cycle analyses of GHG emissions from biofuels production, (d) and discusses current and potential incentives for the production and use of biofuels, both in Asia and elsewhere.

6. Over the past few years there have been many expert publications on biofuels. These have been produced by agencies such as the International Energy Agency (IEA), the World Bank, the European Union, NGOs, the private sector, and government agencies at the national, provincial / state, and local levels. Key documents are referenced in this paper, and many of them are extensive and detailed. This Annex is complementary to those reports, and focuses primarily on biofuels activities and potentials for GHG offsets in the developing Asia region.

1. Growth in Transport Fuels and Implications for Greenhouse Gas Emissions

7. While road transport fuel use is expected to double world-wide by 2050, it is expected to increase more than 5-fold in China, India, and emerging Asia over that same time period. Expansion in the production and use of current generation liquid biofuels for road transport in Asia is one of several options with the potential to reduce the growth in greenhouse gas (GHG) emissions from road transport relative to emissions associated with petroleum-based fuels, to decrease unit vehicle emissions (both criteria pollutants and other chemicals, and to increase energy efficiency in this sector. This report examines the potential contributions of biomass-derived liquid fuels to overall liquid fuel demand for transport, to net lifecycle GHG emission offsets (if any), and to improvements in urban air quality.

8. A consistent model for developing scenarios for future fuel use is essential in order to explore the potential impacts of various measures on GHG emissions, pollutant emissions, and energy efficiency. This paper and the main report use the road transport fuel model developed[85] by L. Fulton and colleagues at the International Energy Agency. The model's scenarios for liquid fuels demands for the road transport sector are used as a framework for defining and assessing alternative scenarios for biofuels market penetration and for calculating associated impacts on GHG emissions. Scenarios are not predictions or forecasts; rather they provide a consistent framework for assessing the relative impacts of various interventions, in this case in the GHG emissions from the road transport sector in developing Asia. A biofuels market penetration model was developed for this annex, drawing on similar models developed to describe the time dynamics of competition between an "incumbent" product or service (e.g., liquid fuels from petroleum) and the new competitors (e.g., biofuels).

[85] Lew Fulton (2005). International Energy Agency IEA-SMP transport fuels model.

2. Liquid Fuels for Road Transport in Developing Asia

9. Figures 2 and 3 present reference case projections developed by the IEA-SMP model for liquid fuels for road transport for China, India, and Emerging Asia. Reference case projections or scenarios are shown for China, India, and Emerging Asia. In this projection the annual aggregate fuel demand for China, India, and emerging Asia grows by a factor of 5.5 over the period 2000 – 2050. This is the fastest growing region in the world in terms of liquid fuels for road transport. By contrast, the reference scenario for liquid transport fuels indicates a doubling globally between 2000 and 2050.

10. Use of both diesel fuel and gasoline will continue to grow throughout developing Asia, although different models and forecasts may vary somewhat in the growth rates. The GHG emissions consequences of the pattern described in Figure 3 are shown in Figure 1 above.

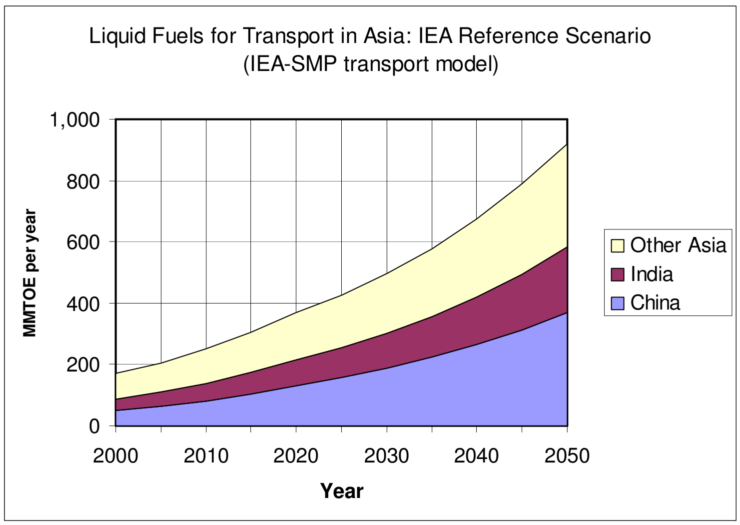


Figure 2: Growth in Liquid Fuels for Transport in Asia

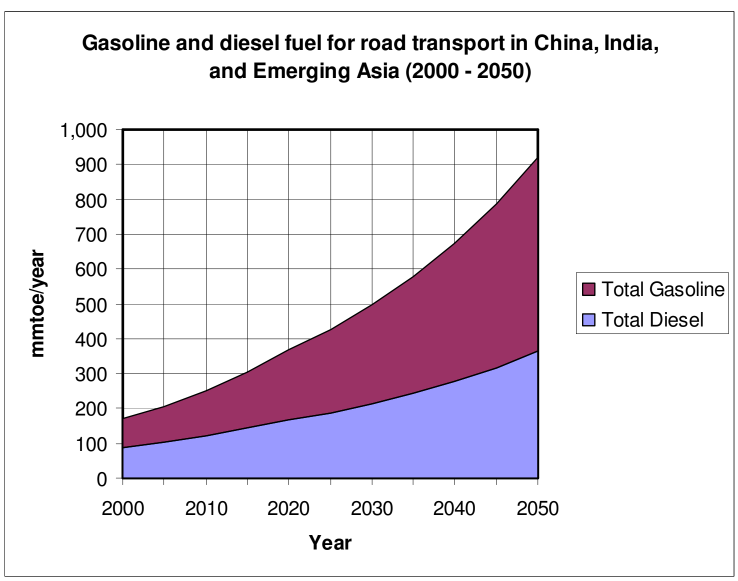


Figure 3: Gasoline and Diesel Fuel Scenario for Asia

B. BIOFUELS

1. Introduction

11. Internal combustion engines (ICEs) will continue to dominate road transport over the next several decades, using primarily liquid fuels. Biofuels in principle can reduce the GHG footprint of transport fuels by replacing a significant share of these fossil fuels. It will almost certainly require several decades for commercial biofuels to displace an important share (e.g., > 25%) of the growing fossil fuels markets, biomass-derived liquid fuels could become a strategic alternative to fossil-based liquid fuels by mid-century. This will require that issues of land use (and competition with food, forests, and fiber production), water resources, and environmental impacts of large-scale production of biofuels be successfully addressed; this is likely to be complex and challenging.

The biomass-derived liquid fuels commercially available today and suitable for road transport are ethanol -- for spark ignition (gasoline) engines -- and vegetable oil-based diesel substitutes for compression ignition (diesel) engines. Fuel ethanol is derived primarily from corn (United States) and sugar (Brazil), but is also produced on a smaller scale from sugar beets and wheat. Vegetable methyl esters (VME) are made from refined vegetable oils (e.g., rapeseed, soy, palm, coconut and jatropha) to a fuel that is completely compatible with fossil diesel fuel, both as a mixture of any fraction and in pure (neat) form86. Fuel additives are also produced from biomass; Bio-ETBE (Ethyl-tertio-butyl-ether) produced from bioethanol and Bio-MTBE (Methyl-tertio-butyl-ether) produced from biomethanol are used as additives to increase octane rating of gasoline and to reduce knocking.

12. While ethanol biofuel programs started over 3 decades ago in the US and Brazil, very high international interest in biofuels has emerged dramatically over the past several years. This reflects the enormous and rapid increases in oil prices, and government incentives making investments profitable and to address national foreign exchange, fuel diversification and security concerns. In 2004, 33 billion liters of ethanol were produced accounting for about 2% gasoline production worldwide87. 2.2 billion liters of biodiesel were also produced that year, principally in Germany, France, and Italy with small amounts in the Philippines (coconut biodiesel) and Malaysia (palm biodiesel).

13. “Second generation” biofuels are being developed from a wider range of feedstock that increase the fraction and reduce the cost of the avoided CO2 by utilizing biomass fractions that are presently discarded and making the best use of the whole plant. Table 1 shows the current and next generation of liquid biofuels for substituting gasoline and diesel as transport fuels. Later, tables 6 and 7 show principal bioethanol and biodiesel feedstocks and conversion processes, net energy balances, and GHG emissions reductions. Since different amounts of energy are used in producing a bio-fuel to a petroleum based fuel, a life cycle analysis (LCA) must be used to compare the net GHG emissions performance of different fuels.

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[86] In some countries (e.g., UK), waste oils and greases are used to produce biodiesel fuel.

[87] 15 billion liters of ethanol from sugar cane in Brazil, 13 billion liters from corn in the United States, 2 billion liters from China, 0.2 billion liters from Thailand and the rest from other countries compared to gasoline worldwide production in 2004 of 1,200 billion liters.

14. The present production of ethanol from corn in the US yields almost no GHG savings, but these savings could be increased if biomass residues from corn production were used for heat and power generation in the ethanol production process. The present Brazilian sugar cane crops, production, transport, and end-use cycle for bioethanol has a calculated 92% reduction in life-cycle GHG emissions relative to the production, transport, and use of gasoline.

15. Advances in bioethanol production, such as enzymatic conversion of ligno-cellulosic materials such as switch-grass, could provide ethanol with virtually no net GHG emissions for the entire life-cycle fuel production process. In Asia there is increasing investment in new biodiesel production capacity with coconut oil, palm oil, and jatropha as feedstock crops. The Philippines has a commercial cocobiodiesel (coco methyl ester) industry, and Malaysia is gearing up for increased production of palm oil and the development of a palm oil biodiesel production capacity. At current forecasts the contributions of these biodiesel industries will remain small (over the 2030 timeframe) when compared to the total market for transport diesel fuels.

Table 1: Biomass-derived Liquid Fuels for Transport

Biofuel	Feedstocks	Conversion Process
Current Generation Liquid Biofuels		
Biodiesel	Rape, canola, soy, sunflower, palm, coconut, Jatropha (vegetable methyl esters or VME)	Esterification
Biodiesel	Waste oils and greases	Esterification
Bioethanol	Grains and seeds (corn, wheat, potato)	Fermentation
Bioethanol	Sugar crops (sugar, sugar beets)	Fermentation
Current Generation Liquid Biofuel-derived Fuel Additives		
Bio-ETBE	Ethyl-Tertio-Butyl-Ether produced from bioethanol. ETBE is used as a fuel additive to increase octane rating and to reduce knocking. Percentage volume of bio-ETBE calculated as biofuel is 47%.	
Bio-MTBE	Methyl-Tertio-Butyl-Ether produced from biomethanol. MTBE is used as a fuel additive to increase octane rating and to reduce knocking. Percentage volume of bio-MTBE calculated as biofuel is 36%.	
Next Generation Liquid Biofuels		
Bioethanol	Cellulosic crops: wheat straw, switchgrass, short rotation woody crops	Hydrolysis + fermentation
Bioethanol	Cellulosic waste products: crop waste, forest residues, municipal wastes	Hydrolysis + fermentation
Fischer-Tropsch diesel	waste wood, short-rotation woody crops (poplar, willow), switchgrass	Fischer-Tropsch
Dimethyl ether (DME)	waste wood, short-rotation woody crops (poplar, willow), switchgrass	Gasification → synthesis → methanol → DME
Note: Biomass-derived gaseous fuels such as producer gas, biogas, bio-DME, and bio-hydrogen are not considered here.		

2. Commercially Available Biofuels

16. The principal biomass-derived liquid fuels commercially available today and suitable for road transport are ethanol and vegetable oil-derived diesel substitutes / fuel additives. Ethanol for transport use is currently derived primarily from corn (United States) and sugar (Brazil), and is also be produced from sugar beets and wheat (primarily in France).

17. "First generation" biofuels are ethanol made from corn and sugar and biodiesel fuels made from vegetable crops including soy, rape, and coconut oil. "Next generation" biofuels include bioethanol and biodiesel made from crops and / or using conversion processes that are not yet commercially available for large-scale production. The status of next generation biofuels ranges from basic research activities to laboratory-scale processes to pre-commercial pilot scale production. Table 1 shows the current and next generation of liquid biofuels for transport, together with principal feedstocks and conversion processes. Net energy balances, and GHG emissions characteristics of biofuels relative to petrodiesel and gasoline are shown in Tables 6 and 7 below.

a. Ethanol[88]

18. Ethanol is a clear, colorless, flammable oxygenated hydrocarbon, with the chemical formula C_2H_5OH. There is an important distinction between anhydrous and hydrous alcohol. Anhydrous alcohol is free of water and is at least 99% pure. Anhydrous ethanol is used in fuel blends. Hydrous alcohol contains some water and typically has a purity of 96%. In Brazil, hydrous ethanol is used as a 100% gasoline substitute in cars with dedicated engines. Ethyl alcohol as an automotive fuel replaces gasoline in dedicated internal combustion engines and is an effective octane enhancer when mixed with gasoline in blends of 5% to 30%. In this case no engine modifications are required. Ethanol easily blends with gasoline but not with diesel.
Ethanol was initially the fuel of choice for early automobiles, but was rapidly displaced when low-cost gasoline was developed as a commercial automotive fuel. Ethanol made a comeback as an automotive fuel in the early 1980s, when the Brazilian government launched the Proálcool program to produce fuel ethanol from sugar cane on an unprecedented scale.

b. Biodiesel[89]

19. Biodiesel fuels are *vegetable methyl esters* (VME) made through conversion (trans-esterification) of refined vegetable oils (e.g., rapeseed, canola, soy, palm, coconut, Jatropha, and even algae oils) to a fuel that is fully compatible with fossil diesel fuel, both as a mixture of any fraction and in pure (neat) form. The trans-esterification process removes the glycerine in the vegetable oil. In some countries (e.g., UK), waste oils and greases are also used as feedstocks for producing biodiesel fuels.

20. In 2000, biodiesel became the only alternative fuel in the country to have successfully completed the EPA-required Tier I and Tier II health effects testing under the Clean Air Act. These tests demonstrated biodiesel's significant reduction of virtually all regulated emissions, and showed that biodiesel is not a health threat. Biodiesel contains no sulfur or aromatics, and use of biodiesel in a conventional diesel engine results in substantial reductions of unburned hydrocarbons, carbon monoxide and particulate matter.

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[88] This section is adapted in part from C. Berg (April 2004). World Fuel Ethanol Analysis and Outlook. F.O. Licht, UK and Germany. www.fo-licht.com
[89] This section draws on: The US Biodiesel Board www.biodiesel.org

21. Vehicle emissions will vary with engine design. The following numbers[90] reflect the potential reductions offered by a biodiesel blend of 20% biodiesel and 80% petrodiesel (B20) and pure biodiesel (B100), relative to conventional diesel, in engines designed to take full advantage of biodiesel properties. Figure 4 below (IEA 2004a) presents potential emissions reductions from biodiesel blends over the full range (0% to 100% biodiesel).

- Reductions in carbon monoxide emissions of 10 percent (B20) and 50 percent (B100).
- Reductions in particulate emissions of 15 percent (B20) and 70 percent (B100).
- Reductions in total hydrocarbon emissions of 10 percent (B20) and 40 percent (B100).
- Reductions in sulfate emissions of 20 percent (B20) and 100 percent (B100).
- Increases in nitrogen oxide emissions of 2 percent (B20) and 9 percent (B100).
- No change in methane emissions using either B20 or B100.

3. Factors Driving the Growth in Biofuels Production

22. Driving the growth in interest and investment in biofuels production and use are several factors. The relative importance of these factors varies significantly among the EU / OECD countries and the emerging regions of Asia. Some of the concerns and drivers are the following:

- Environmental concerns (local, regional, and global), especially the increasingly severe levels of air pollution in most cities in developing Asia, the impacts of transboundary air pollution, and concerns about the need to reduce the rate of growth in greenhouse gas (GHG) emissions would seem to be important factors for development of the biofuels industry. *However, reducing GHG emissions is not a major driver for biofuels development in many Asian countries*; rather it is the potential for product diversification and increased incomes in the palm, sugar, and coconut industries and the opportunity for increasing rural incomes for families that work in these industries. With both the sugar and coconut industries worldwide suffering from low commodity prices, it now makes sense for those industries to consider using sugar as a feedstock for ethanol production and coconuts (refined coconut oil) as a feedstock for CME (coco methyl ester – a true biodiesel fuel) production and also for use as a fuel directly in certain situations.

- For some countries the reduction of tailpipe emissions through use of biofuels is a driver for biofuels development. There *are* serious concerns about air pollution in many of Asia's major cities, but this alone is not the principal justification for establishing or expanding biofuels industries. There are many ways to reduce criteria pollutant emissions from vehicles, and the use of biofuels may not have a significant advantage over other approaches, especially if the latter are developed by the automotive industry for emissions reductions and efficiency increases.

- Biofuels promotion policies have been established in many countries including Brazil, Canada, China, Colombia, Dominican Republic, Pacific Island nations such as Fiji, Marshall Islands, Samoa, Vanuatu, India, Philippines Indonesia, Malaysia, Canada, the US, and many of the countries of the European Union. For many developing countries, the objectives of expanded biofuels production are to reduce petroleum imports, improve the balance of payments condition, and increase and diversify rural incomes.

[90] US Environmental Protection Agency (2002)

4. Potential Costs and Benefits of Biofuels for Road Transport

23. With increasing production and use of liquid biofuels for transport, specific benefits accrue. Since the benefits and the negative impacts are both proportional to the scale of biofuels production and domestic use, both will be small for a few decades.

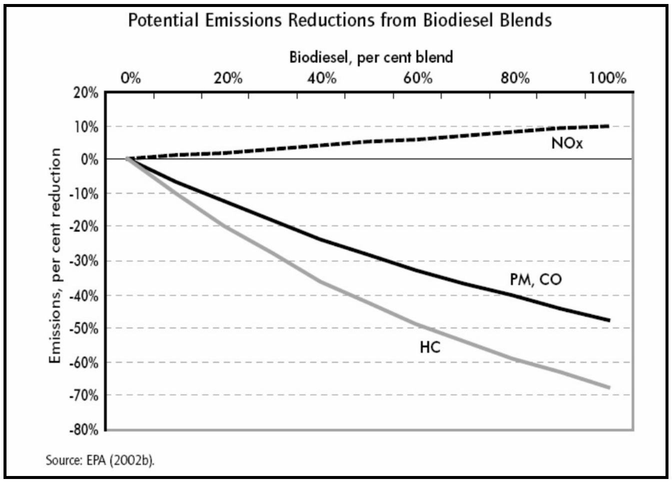
a. Potential Advantages

- Over the long term (several decades or more), a successful large-scale domestic biofuels industry will offset petroleum imports and improve the balance of payments position of developing countries. The experience with sugar cane-based fuel ethanol in Brazil has demonstrated this potential.
- Domestic biofuels production and use may improve energy security through diversification of supply and use of renewable domestic energy sources.
- Reduced greenhouse gas (GHG) reductions can be achieved *if low-GHG biofuels are used on a strategic scale (e.g., 25% or more of total land transport fuel requirements).*
- Decreased vehicle emissions, as discussed in this annex.
- Expansion and diversification of rural / agricultural employment and products. For China, India, and emerging Asia, development of substantial biofuels industries will provide additional employment and income to rural workers, and can diversify agricultural production.
- Waste management through conversion of biomass residues (forest products, wood waste), grease, and used oil into biodiesel fuels. This is valuable largely because of the environmental benefits rather than the production scale or final cost of the biodiesel produced.

b. Potential Costs and Liabilities

- The base costs of biofuels delivered to the end user may be higher than those for petroleum-based fuels. However, the Brazil experience suggests that for sugar cane-derived ethanol produced on an industrial scale, the cost to the user will be below present user prices for gasoline. The learning curves for both production costs and consumer prices for second generation bio-ethanol and biodiesel fuels will result in substantial reductions in these costs as a result of increased scale of production and ongoing technological advances.
- Large-scale use of ethanol as a road fuel will require expanded production of ethanol-compatible vehicles. However this does not appear to be a significant problem. For example, there are well over a million commercial vehicles in the United States that will operate on E85 (85% ethanol, 15% gasoline). Brazil has provided the model for development and production of dual-fuel and ethanol fueled vehicles.
- Increases in some pollutant emissions (modest increases of ca. 10% in NOx emissions relative to conventional diesel fuel)
- Environmental consequences of large-scale biofuels production are not yet fully understood. Impacts include negative changes in land use, such as conversion of tropical forests to palm oil monocrops, with attendant loss of biodiversity and habitat; expanded use of water, nutrient runoff, and loss of watersheds.

Figure 4: Potential Reductions in Emissions from Biodiesel Blends



Source: US Environmental Protection Agency (2002)

5. World-Wide Production of Biofuels: Ethanol

24. World-wide production of ethanol for vehicle fuel use exceeded 30 billion liters in 2004, equivalent in volume to about 3 percent of the 1,200 billion liters of gasoline consumed globally. Brazil produced half of the world's fuel ethanol (15 billion liters) in 2004. Almost all of the rest (13 billion liters) was produced by the United States. Ethanol provided 44 percent of all (non-diesel) motor vehicle fuel consumed in Brazil in 2004 and was being blended with 30 percent of all gasoline sold in the United States. Figure 5 shows global production of ethanol for fuel from 1980 through 2004. The principal markets for ethanol are (1) fuels, (2) industrial solvents, and (3) beverages. About 70% of global alcohol production is for fuel applications, and this is expected to grow somewhat to perhaps 80% by 2010. Agricultural feedstocks account for 95% of all ethanol production, and this percentage will grow with increasing demand for ethanol as a biofuel.

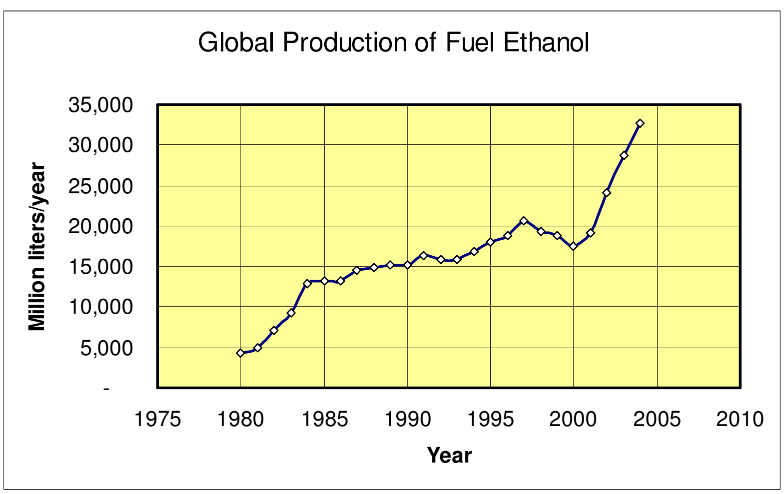


Figure 5: Global production fuel ethanol

Table 2: World-wide Ethanol Production in 2004 and 2005 (Asia shown in boldface)

Country	2004 Million Gallons	2004 Billion liters	2005 Million Gallons	2005 Billion liters	Increase 2004 to 2005
Brazil	3,989	15.10	4,227	16.00	1.06
United States	3,535	13.38	4,264	16.14	1.21
China	**964**	**3.65**	**1004**	**3.80**	**1.04**
India	**462**	**1.75**	**449**	**1.70**	**0.97**
France	219	0.83	240	0.91	1.10
Russia	198	0.75	198	0.75	1.00
South Africa	110	0.42	103	0.39	0.94
United Kingdom	106	0.40	92	0.35	0.87
Saudi Arabia	79	0.30	31	0.12	0.39
Spain	79	0.30	93	0.35	1.18
Thailand	**74**	**0.28**	**79**	**0.30**	**1.07**
Germany	71	0.27	114	0.43	1.61
Ukraine	66	0.25	65	0.25	0.98
Canada	61	0.23	61	0.23	1.00
Poland	53	0.20	58	0.22	1.09
Indonesia	**44**	**0.17**	**45**	**0.17**	**1.02**
Argentina	42	0.16	44	0.17	1.05
Italy	40	0.15	40	0.15	1.00
Australia	33	0.12	33	0.12	1.00
Japan	31	0.12	30	0.11	0.97
Pakistan	**26**	**0.10**	**24**	**0.09**	**0.92**
Sweden	26	0.10	29	0.11	1.12
Philippines	**22**	**0.08**	**22**	**0.08**	**1.00**
South Korea	22	0.08	17	0.06	0.77
Guatemala	17	0.06	17	0.06	1.00
Cuba	16	0.06	12	0.05	0.75
Ecuador	12	0.05	14	0.05	1.17
Mexico	9	0.03	12	0.05	1.33
Nicaragua	8	0.03	7	0.03	0.88
Mauritius	6	0.02	3	0.01	0.50
Zimbabwe	6	0.02	5	0.02	0.83
Kenya	3	0.01	4	0.02	1.33
Swaziland	3	0.01	3	0.01	1.00
Others	338	1.28	710	2.69	2.10
Total	**10,770**	**40.76**	**12,149**	**45.98**	**1.13**

6. World-Wide Production of Biofuels: Biodiesel

25. While biodiesel fuel production has been growing rapidly since 1998, tripling by 2003, global production is just 5% (in volume) of bio-ethanol production, with most biodiesel fuels produced in the EU, especially Germany.

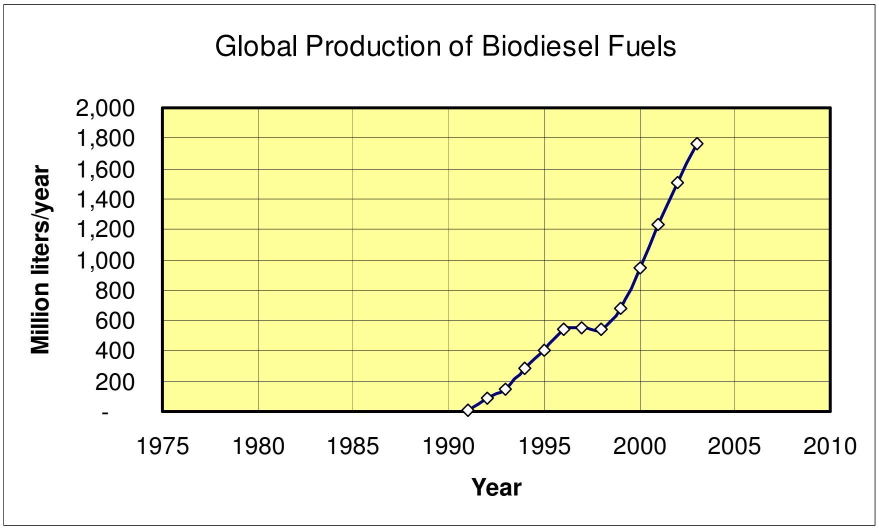


Figure 6: Global production of biodiesel fuels

7. Commercial Investments in Biodiesel Fuel Production

26. Biodiesel production has attracted commercial investment over the past few years. Examples include the investment by D1 Oils (UK) in biodiesel development from Jatropha in India, the Philippines, China, and India, and a new investment in US biodiesel production by Chevron Oil Company.

27. D1 Oils (UK): In India, D1 has established a joint venture with Mohan Breweries and distilleries and has initiated begun large-scale jatropha cultivation in the states of Tamil Nadu, Andhra Pradesh and Chattisgarh. The company plans to have five million hectares of land under jatropha cultivation and to produce 2.7 metric tons of oil per hectare within five years. D1 has established a partnership with Labland Biotech, a Mysore-based plant biotech firm, to produce some 100 million tissue culture-derived Jatropha plants. Labland Biotech joined with the Biotechnology Park, Lucknow for providing good-quality Jatropha seedlings for large-scale plantation with an assured buy-back arrangement for seeds.

28. Chevron Oil Company: Chevron, through its subsidiary, Chevron Technology Ventures LLC (CTV), has taken a 22% equity position in Galveston Bay Biodiesel LP (GBB). The Houston-based company is constructing a biodiesel production and distribution facility in Galveston, Texas, said to have the potential to produce about 380 million liters per year of biodiesel fuel derived from soybeans and other vegetable feedstocks. This facility can more than double the current US production volume of biodiesel. It is scheduled for completion by the end of 2006. Initial production will be about 80 million liters annually. GBB has the option to sell pure biodiesel or biodiesel blended with off-road or on-road diesel into marine, commercial, trucking and industrial markets in the Galveston and Houston metropolitan areas.

8. Production of Biofuels in Asia

29. Asian countries producing ethanol include China, India, Indonesia, Pakistan, the Philippines, and Thailand. Total ethanol production in these countries for years 2004 and 2005 are shown in Table3.

Table 3: Ethanol Production in Asia (billion liters per year)

Country	**World Rank**	**2004**	**2005**	**Growth 2004 to 2005**
China	**3**	**3.65**	**3.8**	**4%**
India	**4**	**1.75**	**1.70**	**-3%**
Thailand	**11**	**.28**	**.30**	**7%**
Indonesia	**16**	**.17**	**.17**	**2%**
Pakistan	**21**	**.10**	**.09**	**-8%**
Philippines	**23**	**.08**	**.08**	**0%**

Source: F.O. Licht, cited in Renewable Fuels Association (2005). *Homegrown for the Homeland: Industry Outlook 2005*

Table 4: Ethanol Production in Asia		
Location	**Feedstock**	**Ethanol Production**
China	Corn, cassava, wheat, potato-type products, and sugar cane.	China is the world's third largest ethanol producer, with 964 million gallons in 2004 and over 1 M tons in 2005. Since 2001, China has promoted ethanol-based fuel on a pilot basis in five cities in its central and northeastern regions (Zhengzhou, Luoyang and Nanyang in Henan and Harbin and Zhaodong in Heilongjiang province). The Jilin Tianhe Ethanol Distillery, the largest in the world, is producing 240 million gallons per year, and has a potential final capacity of 320 million gallons per year. China's ethanol industry has over 200 production facilities in 11 provinces, with a production capacity of more than 10 million tons annually. The bioethanol production capacity exceeded 1 million tons in 2005.
India	Sugarcane	Since 2003, India's government has mandated use of E5 in nine states and enacted an excise duty exemption for ethanol. Sugar producers are planning to build 20 new ethanol plants in addition to 10 existing plants, with most located in Uttar Pradesh, Maharashtra and Tamil Nadu. Estimated annual ethanol needs for an E5 blend is 98 million gallons, against actual production of 462 million gallons in 2004 and total capacity of 713 million gallons per year. India is the world's largest sugar consumer and a major importer. The country produces 1.5 billion liters of ethanol, although only a quarter of that is suitable for use as fuel. The rest is used for beverages or export. In January 2003, New Delhi directed oil companies in some parts of India to sell petrol made up of 5 percent ethanol. It planned to make this mandatory throughout the country later, but back-pedaled on the plan due to poor output and high costs. Oil companies had needed 363 million liters of ethanol in the 2003/04 year to satisfy the mandate, but only 196 million liters had been available due to declining sugarcane output. Ethanol production is projected to increase as sugar crops grow. India is initiating the use of ethanol as an automotive fuel. A move has been made by distilleries in India to use surplus alcohol as a blending agent or an oxygenate in gasoline. Based on experiments by the Indian Institute of Petroleum, a 10 percent ethanol blend with gasoline and a 15 percent ethanol blend with diesel are being considered for use in vehicles in at least one state.
Thailand	Cassava, sugarcane, rice	Thailand has mandated a 10 percent ethanol mix starting in 2007, which would boost production from 74 million gallons in 2004 to 396 million gallons. 18 new ethanol plants are being developed, and producers will enjoy several tax breaks. The government estimates that an E10 blend would be $0.04-0.08 cheaper per gallon than conventional gasoline. Since 2002, Thailand has been engaged in the development of ethanol as a transport fuel alternative. By late 2004 Thailand was using 5 to 10 percent ethanol blend in its gasoline. Thailand is the world's second largest sugar exporter after Brazil. the government plans to replace regular gasoline with a mix that includes 10 percent ethanol in 2007. One government projection is that Thailand's ethanol production capacity would increase to 1.5 billion liters a year in 2006 when all 24 ethanol plants are running.

Table 4: Ethanol Production in Asia		
Location	**Feedstock**	**Ethanol Production**
Philippines	Sugarcane	The Government of the Philippines and the country's sugar industry are exploring ways to convert part of the industry's output to ethanol for road fuel use. The Philippines and Thailand have forged an agreement (late 2004) to jointly formulate regional fuel standards for the use of agricultural by-product ethanol as a gasoline blend. The country decided last July to use a 1 percent blend of methyl ester made from coconuts in diesel for public transport. The government has pushed for bagasse for power generation. About 267,000 tons of raw sugar projected to fire power plants by 2007. Pending legislation would require ethanol use from 2007.
Conversions: 1 gallon = 3.785 liters; 1 acre = .4047 hectares; tons used here are metric tons.		

Table 5: Biodiesel Production in Asia		
Location	**Feedstock**	**Biodiesel Production**
China	Waste cooking oil, some plant oils Planned large-scale production of Jatropha oil-based biodiesel	Biodiesel specifications have not yet been issued, and there are no specific incentive policies for biodiesel production. A few small plants (5,000 – 20,000 tons per year) are operating. D1 Oils PLC (UK) has a joint venture agreement with a Chinese partner with access to 2 million ha in Sichuan Province for Jatropha cultivation. The goal is production of 500,000 tons of biodiesel per year. **Food vs. Biofuels: Soy and Rapeseed** China is the world's second largest importer of edible oils, after India. The country is a major producer, processor, and consumer of rapeseed. The planting area of rapeseed in China exceeds 7 million ha, with an annual production of 11 million tons. However, rapeseed is the source of edible oils, and production of biofuels from rape appears unlikely any time soon. China's soybean consumption outpaced domestic production over the last 25 years, primarily because of increases in consumption of soybean oil and meal induced by income and population growth, particularly in large urban areas. In 2003/04, according to USDA estimates, soybean consumption in China reached more than 34.4 million metric tons, four times the volume in 1980. In response to the rapid growth in demand, China now imports about half of its total soybean consumption. China's soybean imports accounted for about one-third of world soybean imports in 2003. Consequently soy is not seen as a potential source of biofuels for China.
India	Jatropha (pilot scale, with large-scale commercial production goals)	India is the world's largest importer of edible oils. Edible oil imports remained flat at ca. 4.8 million metric tons for 2005, due to a bumper harvest of oilseeds. Analysts estimate that another two years of similar oilseeds production could see China surpass India as the world's largest importer of edible oil. The high value of such oils for their importance in food makes it unlikely that India would produce biofuels from these oils. Consequently there has been a focus on alternatives to soy and rapeseed, which are the principal biofuels feedstocks in Europe. **Jatropha:** Jatropha, whose berries are poisonous, is being used on a small scale for production of biofuels, and there is considerable interest in expanding production. The Energy and Resources Institute (TERI) will demonstrate the feasibility of producing biodiesel from Jatropha in a project in Andhra Pradesh expected to take 10 years with funding from BP for $9.4 million. The project, which is scheduled to produce 9 million liters of biodiesel annually from Jatropha, calls for cultivation of ca. 8,000 hectares of land (currently designated as wasteland) with Jatropha, and to install all the equipment necessary for seed crushing, oil extraction and processing. TERI is to be responsible for the day-to-day management and execution of the project. **Pongamia:** The Pongamia tree is a nitrogen-fixing plant that grows well in tropical and subtropical climates in a variety of soils. The trees, which have a useful life of 40 – 50 years, produce non-edible oil seeds that have been used in India as a small-scale source of fuel for many years. (The properties and uses of Pongamia are discussed in some detail on the section describing biofuels sources, conversion processes, and commercial products).

Table 5: Biodiesel Production in Asia		
Location	**Feedstock**	**Biodiesel Production**
Indonesia	Palm oil	Indonesia, the world's second-biggest palm oil producer, is exploring the biodiesel market as world palm oil demand stagnates. It plans to double the palm oil area to 10 million hectares (25 million acres) over the next 30 years.
Malaysia	Palm oil	Malaysia is the world's leading producer and exporter of palm oil. Malaysian palm plantation company Golden Hope Plantations is partnering with the Malaysian Palm Oil Board to build the first biodiesel refinery in Malaysia. Expected to be completed in 2008, the plant will produce 60,000 MT of biodiesel annually. (Oct. 2005)
Philippines	Coconuts (copra oil) for CME, Jatropha (planned)	The Philippines is a leading producer of coco methyl ester (CME), a diesel substitute made from refined coconut oil. Current (2006) production capacity is 115 million liters per year. In July 2004 the Government mandated that a 1 percent blend of CME be used in diesel fuel for public transport, based on tests in Japan and the Philippines showing mileage increases and PM emission reductions from CME as a diesel fuel additive. The state-run Philippine National Oil Co. Energy Development Corp. (PNOC-EDC) has earmarked P1.6 million for the planting of Jatropha in its geothermal reservations. The Jatropha Propagation Project will determine the agronomic requirements of the Jatropha species in Philippine conditions. The Jatropha plants will be initially planted on a 5-hectare parcel of land in Kabankalan City, Negros Occidental.
Thailand	Jatropha (in initial pre-pilot development stage)	The Thai government requires that a 10% biodiesel blend is to be introduced nationally starting in 2012, and is considering increasing this target to 20%. The Thai Ministry of Energy is now actively investigating the creation of a national biodiesel industry. Thailand's Department of Alternative Energy Development and Efficiency (DEDE) and the UK's Department of Trade and Industry have jointly sponsored a five hectare pilot Jatropha plantation, to be planted and managed by D1 Oils PLC (UK). Seeds and growing medium for the project will be provided by D1, which will have the right to buy all the harvested seeds. The pilot project will raise awareness of Jatropha as part of Thailand's biofuels strategy. D1 will implement a second model farm at its own cost and is investigating joint ventures with some of Thailand's largest private companies to develop Jatropha plantations and install biodiesel refineries in Thailand and neighboring countries.
Conversions: 1 gallon = 3.785 liters; 1 acre = .4047 hectares; tons used here are metric tons.		

C. BIOFUELS GHG EMISSIONS CHARACTERISTICS

1. Introduction

30. The atmospheric carbon fixed by photosynthesis in crops and derived biofuels is recycled, with no net GHG burden to the atmosphere. However, the growing, harvesting, transport, and processing of crops to yield ethanol or biodiesel fuels require mechanical, thermal, and electrical energy, and to the extent to which fossil fuels are used in this process determines the net GHG offset benefits, if any, of the derived bioethanol or biodiesel fuels. Ethanol made from corn in the United States presently uses primarily fossil fuels for this overall process, so there is little in the way of reduced embedded GHG in this fuel. However, through use of crop wastes as a source of heat and electricity (and hence shaft power) production of biofuels can have dramatically reduced net lifecycle GHG relative to the production of the petrofuels that they replace. In Brazil, this approach has yielded reductions of 85% in the GHGs emitted in the process of producing bioethanol.

31. The current generation of liquid biofuels for transport offers some GHG offset benefits relative to petroleum-based fuels, and have other benefits including improved vehicle emission characteristics and positive net energy in the production processes.

32. Bioethanol**:** The present production of ethanol from corn in the US yields almost no GHG savings, but these savings could be increased if biomass residues from corn production were used for heat and power generation in the ethanol production process. In contrast, ethanol from sugar cane in Brazil has only one tenth the life-cycle GHG emissions of gasoline, due to the extensive use of sugar cane residues, especially bagasse, to provide thermal and electrical energy for the conversion process, along with the use of bioethanol as an energy input to this process. Advances in bioethanol production, such as enzymatic conversion of ligno-cellulosic materials such as switch grass and corn stover (agricultural residues) could provide ethanol with virtually no net GHG emissions for the entire life-cycle fuel production process. In Asia India is a leading producer (and the world's largest consumer) of sugar and is potentially a major producer of bioethanol.

33. Biodiesel**:** Most biodiesel fuels are produced now from rape seed and soy; they have life-cycle GHG reductions of ca. 50% for rape and 80% for soy, so they are climate-friendly as well as having attractive tailpipe emissions characteristics (except for a slight increase in NOx emissions compared with use of conventional diesel fuel). In Asia there is increasing investment in new biodiesel production capacity with coconut oil, palm oil, and Jatropha as feedstock.

Table 6: Bioethanol Production and GHG Offset Characteristics

Feedstock	Production Status and Regions	Current life cycle GHG Emissions reduction relative to gasoline	Ethanol yields per hectare	Costs	Net energy balance
Grains (wheat, maize)	Large-scale & commercial [US, Europe, China]	None to moderate with maize but significant improvements are possible	Moderate 2,500 to 3,000) l/ha	Moderate	Currently low
Sugar beets	Principally France	Up to 50%	High 6,800 l/ha	Moderate	Currently low
Sugar cane	Large-scale & commercial [Brazil, India, Thailand]	Brazilian ethanol has highest GHG reduction (92%) and lowest cost. Biomass energy used in the production process.	High 5,500 - 6,300 l/ha (Brazil)	Low	Medium
Ligno-cellulosic Biomass, including corn stover (crop residues) and switchgrass	"Next Generation" bio-fuel. Pilot plants in Sweden, Spain, Denmark, under development in Canada	High; 70 – 90% estimated; can be close to 100% in principle	High 4,000 l/ha (switchgrass)	High	High (expected)

Notes: The yields per hectare of biofuels reflect current practice and should be considered indicative rather than definitive, except where there are specific examples provided. The productivity of corn in the US (kg/ha) has increased five-fold since 1940, and the productivity of sugar-based ethanol in Brazil has grown from 2,000 liters/ha in 1975 to ca. 6,000 liters/ha in 2006.

The qualitative cost characteristics for the various biofuels are from the IEA (2005).

Table 7: Bioethanol Production and GHG Offset Characteristics

Feedstock	Production Status and Regions	Current GHG Emissions reduction relative to petrodiesel	Biodiesel fuels yield per hectare	Costs	Net energy balance
Oil seeds (rape, soy)	Medium-scale, mature and evolving (US, Europe)	78% reduction (soybean base), 40 – 60% for rape	Low 500 – 1,000 l/ha	Moderate	3.2 for soy biodiesel vs. 0.8 for petrodiesel
Coconut oil to CME	Medium commercial (Philippines)	No full LCA has been conducted yet (Expected to be moderate)	Moderate to High 2,000 l/ha	Low-moderate	LCA needed
Palm oil	Small-scale - commercial (Malaysia, Indonesia)	No LCA has been conducted yet (Expected to be moderate)	High 2,000 – 5,000 l/ha	Low-moderate	LCA needed
Jatropha	Pilot-scale, pre-commercial (China, India)	No LCA has been conducted yet (Expected to be moderate to high)	Moderate to High	Low-moderate	LCA needed
Biomass to liquids	"Next Generation" bio-fuel. Fischer-Tropsch biodiesel pre commercial (Demo plants in Germany and Sweden)	High (IEA)	High	High	LCA needed for many combinations

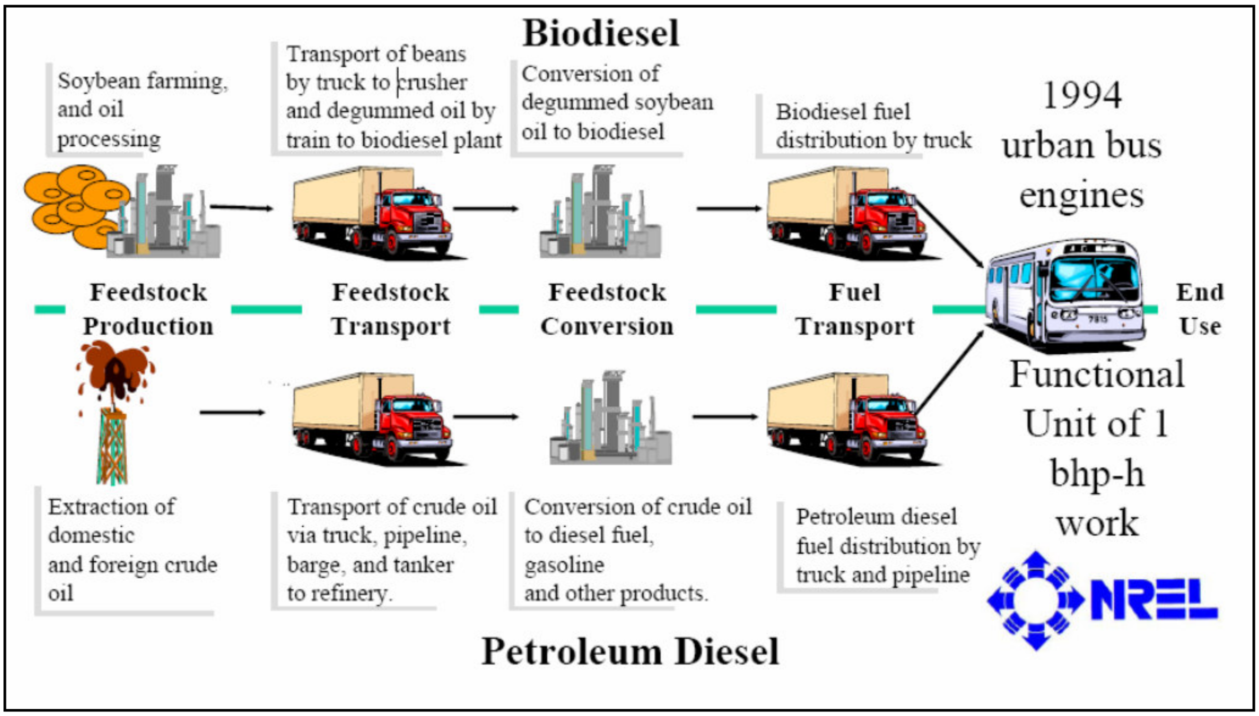
Note: The yields per hectare of biofuels reflect current practice and should be considered indicative rather than definitive. The qualitative cost characteristics for the various biofuels are from the IEA (2005).

D. LIFE-CYCLE ANALYSIS AND ASSESSMENT

1. Overview

34. Life-cycle Analysis (LCA) is a methodology designed to identify and quantify the inputs, processes, and outputs for a specific overall process, such as production, transport, and use of biodiesel produced from soybeans. New LCA developments and studies are typically reported in the International Journal of Life-cycle Assessment [91]. The International Standards Organization (ISO) [92] has established LCA standards for environmental assessments. A simplified representation of the production and use of biofuels and petrodiesel is shown[93] in Figure 7. Life-Cycle *Assessment* involves an assessment of the likely or potential impacts of the energy use and emissions associated with all of the steps in the life cycle of the process. It draws directly on the life-cycle analysis.

Figure 7: Schematic Life Cycle Representations for Biodiesel and Petrodiesel



35. As an analytical tool, LCA is used to quantify and *interpret* the flows of energy and materials to and from the environment. The inputs, outputs, and flows involved in a production process include air emissions, water effluents, solid waste production, and the consumption/depletion of energy and other resources, over the entire life cycle of a product or process. Inputs (e.g., for biofuels production) include elements such as land, nutrients, water, energy, and labor. Impact assessments use the resource flow data (both inputs and outputs), coupled with information on toxicity and other properties, to assess the potential *health and environmental impacts* of a process. Such impacts include global climate forcing resulting from

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[91] http://www.environmental-expert.com/magazine/ecomed/lca/
[92] www.iso.org ISO standards 14040 through 14049
[93] John Sheehan (31 July 2002). Biodiesel from soybeans; ethanol from corn stover. Biofuels briefing (PowerPoint presentation as PDF). US National Renewable Energy Laboratory www.nrel.gov

GHG emissions (including carbon dioxide, methane, and oxides of nitrogen) and local and regional air pollution and consequent health impacts from emissions of criteria pollutants and other chemicals.

36. LCAs can include production and extraction of raw materials, intermediate products manufacturing, transportation, distribution, use, and a final "end-of-life" stage, which often includes multiple parallel paths such as recycling, incineration, and use of land fills.

37. As the scale of biofuel production grows, the importance of the production requirements and inputs (e.g., water resource management, land use, nutrients, and environmental management) will grow disproportionately. Pilot scale biomass farming and biofuels production may have acceptably low impacts, but scaling up such operations by a factor of a hundred or a thousand may result in much larger impacts per liter of biofuels produced. Understanding the constraints affecting input requirements and environmental, ecological, social, and economic impacts of biofuels production and use at various scales is essential for informed policy making and investment decisions.

2. Life-cycle Greenhouse Gas Emissions for Various Biofuels

38. For the purposes of this annex we are concerned primarily with the life-cycle GHG emissions for bioethanol and biodiesel fuels produced from various feedstocks and by differing conversion processes.

39. For specific biofuels processes, life-cycle analyses have been conducted to calculate GHG emissions for all of the processes associated with farming, feedstock transport, feedstock conversion, and biofuels transport ("field to tank"). Other analysis for specific fuels, vehicles, and driving cycles provides data on the gross and net GHG tailpipe emissions ("tank to wheels"). Together, these analyses provide the total exbodied GHG emissions data.

40. Note on nomenclature: A recent report[94] to the Australian Greenhouse Office notes that "Life-cycle analysis has been used to determine the amount of upstream energy used to construct a particular object (or produce a liquid fuel). The term 'embodied energy' has achieved widespread use to denote such energy. However, the term 'embodied emissions', to cover the full fuel-cycle emissions of gases or pollutants, would be a misnomer, because emissions are emitted, not embodied. Thus we use the term *exbodied emissions* to refer to the cumulative life cycle of emissions (including combustion) associated with a fuel."

41. Comprehensive LCAs have been conducted for biofuels production processes including corn-derived ethanol in the US, sugar-derived ethanol in Brazil, and for production of ethanol from cellulosic materials. Larson[95] has reviewed many of the LCAs conducted for biofuels over the past decade. In his detailed review of biofuels life-cycle analyses Larson notes that "the most striking feature when comparing LCAs reported by different authors for the same biofuel and originating biomass source is the wide range of results in terms of net energy balances and net greenhouse gas emissions."

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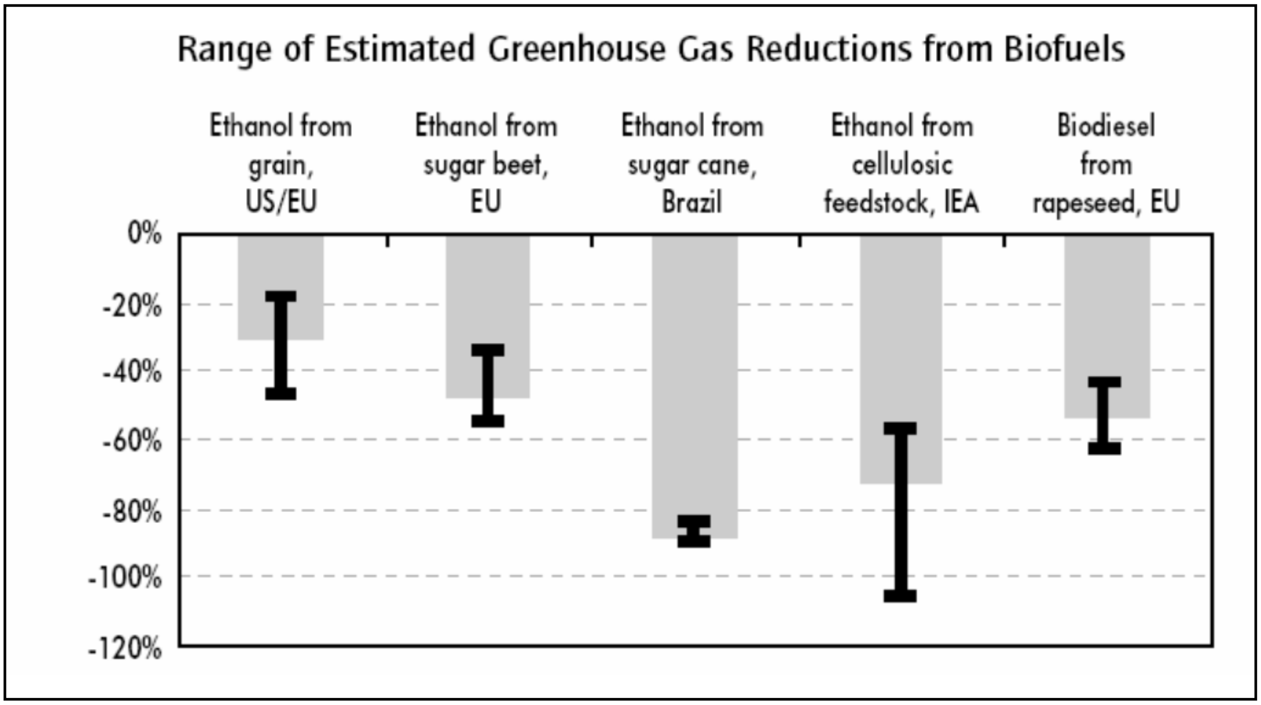
[94] Life-Cycle Emissions Analysis of Fuels for Light Vehicles (May 2004). Report to the Australian Greenhouse Office. http://www.greenhouse.gov.au/transport/publications/lightvehicles.html

[95] Eric D. Larson (6 August 2005). *Liquid Biofuel Systems for the Transport Sector: a Background Paper.* GEF/STAP Workshop on Liquid Biofuels. 29 August – 1 September 2005, New Delhi. 36 pages. This and other presentations at the workshop are available at www.unep.org/stapgef/home/index.htm

42. For purposes of this annex we have reproduced the simplified summary of relative GHG emissions developed by the IEA.

Figure 8: Simplified Overview of Biofuels Lifecycle GHG Reductions



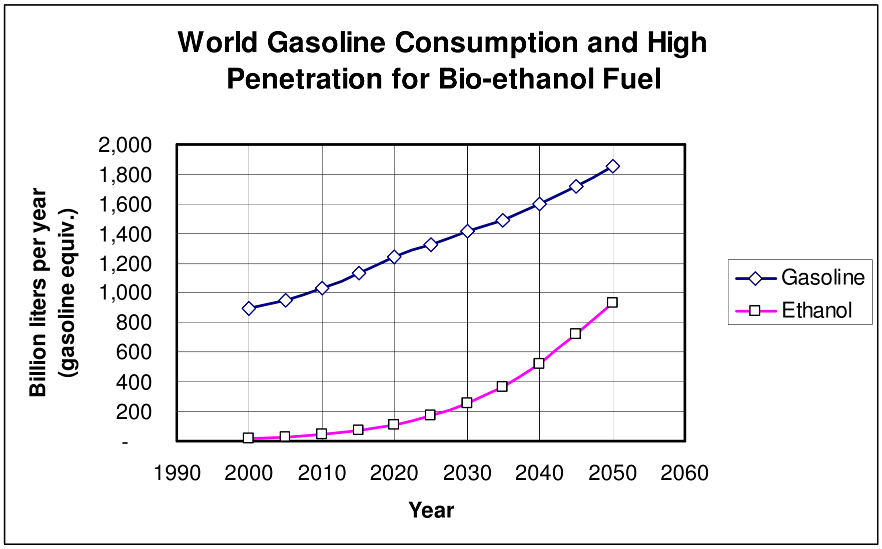
Source: International Energy Agency (2004). Biofuels for Transport: an International Perspective.

Note from the source document: Figure 8 shows reductions in well-to-wheels CO2-equivalent GHG emissions per kilometer from various biofuel / feedstock combinations, compared to conventional-fueled vehicles. Ethanol is compared to gasoline vehicles and biodiesel to diesel vehicles. Blends provide proportional reductions; e.g. a 10% ethanol blend would provide reductions one-tenth those shown here. Vertical black lines indicate range of estimates.

E. BIOFUELS MARKET PENETRATION SCENARIOS AND ASSOCIATED GHG EMISSIONS OFFSETS

1. Market Penetration Analysis

Figure 9: Results of a logistic curve fit to optimistic assumptions about the potential of biofuels to displace petrofuels for road transport globally



a. A Global Market Scenario for Bio-ethanol

43. A logistic fit was made to the historical growth of bio-ethanol and to three data points reflecting views of the ethanol industry and of the IEA, as noted in several IEA reports and presentations. These points correspond to bio-ethanol fuel comprising 4% of total gasoline production in year 2010, 6% in year 2020, and 50% in year 2050. This penetration of ethanol into the vehicle gasoline market corresponds to a logistic (s-shaped) curve with a 10% to 90% penetration time of 50 years. The scenario is shown in Table 8 (below) and Figure 9 above. The logistic projection also fits the year 2005 ethanol production (in gasoline equivalent terms) within 20%.

44. Global bioethanol production doubled in the period 1994 to 2005. The scenario shown here would have ethanol production grow by a factor of 35 from 2005 to 2050, which is roughly one doubling in production every decade for five decades. This scenario may be considered aggressive but plausible. Thus it may provide an upper limit to assessment of potential GHG offsets in the road transport market through the increased use of low “exbodied” GHG biofuels.

45. We emphasize that the bio-ethanol market penetration shown in Figure 9 is not a prediction. Rather it is a logistic curve fit to both historical growth in bio-ethanol and to informed “guesstimates” of some of the experts[96] in the field. We have chosen the ethanol / gasoline

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[96] Lew Fulton and Rick Sellers (2004, 2005) of the International Energy Agency, and Christopher Berg (2004) of F.O. Licht

market rather than the biodiesel / petrodiesel market because of (1) the much larger size of the ethanol fuel market, (2) the more detailed estimates of potential market capture by ethanol, and (3) the accomplishment in Brazil of production of bio-ethanol with very low GHG emissions and at costs that permit direct and attractive competition with gasoline at current market prices for oil.

Table 8: An optimistic market penetration scenario for ethanol fuel for the road transport market.

(Billion liters of gasoline equivalent per year)

Year	Gasoline	Ethanol	Ethanol fraction
2000	894	17	0.02
2005	954	27	0.03
2010	1,033	44	0.04
2015	1,135	70	0.06
2020	1,241	111	0.09
2025	1,324	169	0.13
2030	1,417	254	0.18
2035	1,491	367	0.25
2040	1,599	524	0.33
2045	1,720	724	0.42
2050	1,856	928	0.50

Gasoline and ethanol data are in billions of liters per year (gasoline equivalent). Vehicle gasoline projections from IEA/SMP model.

b. Biofuels Market Penetration Scenarios for Asia

46. We have used the resulting logistic penetration example as a basis for assessing a possible future for biofuels (both bio-ethanol and biodiesel) penetration of the combined gasoline and diesel road fuels market in developing Asia and for assessing the associated reductions in life-cycle GHG emissions. This scenario is one of many possible scenarios; this area and associated analyses are presented in much greater detail in the full report (forthcoming) being prepared for ADB on biofuels and GHG emissions management for the road transport sector of the Developing Asia region. Because the large-scale production of biodiesel fuels is not as advanced as it is for ethanol, this scenario pushes against the limits of plausibility, and indicates the potential for reductions in GHG emissions growth in the region.

47. Both experience and the results of detailed life-cycle analyses for biofuels indicates that we can expect to have biofuels with very low exbodied GHG emissions. “Exbodied” emissions are the sum of the pre-combustion emissions and the tailpipe emissions. The lower the embodied GHG emissions are for a specific fuel, the lower the emissions of fossil fuel-based GHGs per km of travel. With a fuel that has zero field-to-tank GHG emissions (possible with Brazilian sugar-based ethanol and in principle with enzymatic conversion of cellulosic materials to ethanol), all of the carbon dioxide emitted by the vehicles will be carbon originally fixed by photosynthesis in the fuel feedstock. For the extremely optimistic biofuels scenario for GHG

emissions reductions in the Asia road transport market we have assumed a reduction in field-to-wheels GHG emissions of 90% in the alternative fuels.

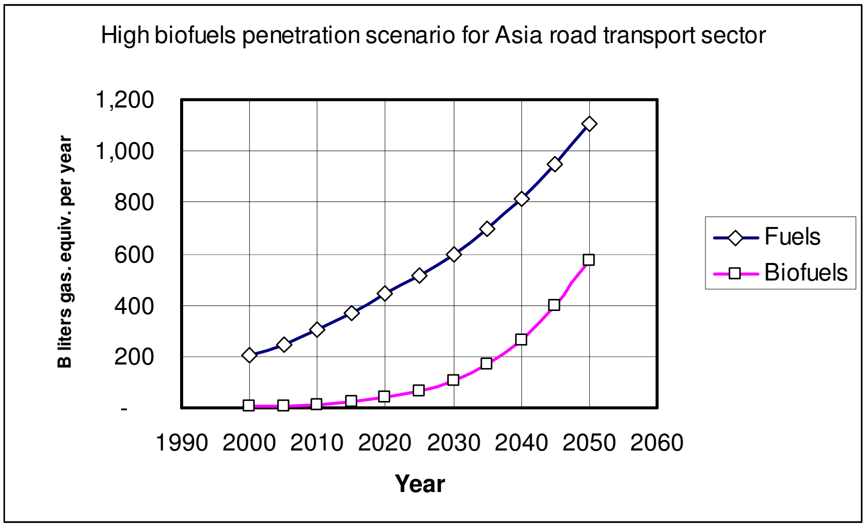

Figure 10

48. The biofuels market penetration shown in Figure 10 was derived using the identical penetration rate f(t) derived from a best fit to the global ethanol production projections for discreet years, as described above. To calculate the GHG emission reductions for this scenario, relative to the emissions associated with continued 100% use of petrodiesel and gasoline, a value of 0.1 for exbodied GHG emissions relative to fossil fuels was assumed. This scenario also assumes 100% use of ethanol and biodiesel in vehicles, which is unrealistic given that bio-ethanol is entering the Asian market as a 5 – 15% blend with gasoline and the same may happen with biodiesel. <u>The purpose here is to push against all of the boundaries to assess the impacts of the most optimistic biofuels scenario for Asia</u>.

49. \The analysis of the extremely optimistic scenario for biofuels in Asia included the parameters tabulated below in Table 9.

Table 9: Assumptions behind the extremely optimistic biofuels scenario		
Parameter	Value / assumption	Degree of realism
Biofuels market penetration fraction as function of time	10% to 90% penetration in a 50 year period, following a logistic or "S-shaped" penetration path.	Plausible only if the Asian experience can match the very optimistic market projections made by the IEA for global biofuels penetration.
Market fraction for biofuels	100% of the petrofuels transport market	Barely plausible: suggests that vehicles will operate on either 100% ethanol or 100% biodiesel and that biofuels will totally dominate the alternative fuels market
Biofuels exbodied GHGs	90% reduction in life-cycle GHG emissions relative to petrofuels	Highly optimistic: This presumes that the best of current practice (Brazil sugarcane to ethanol) and equivalent or better practices with second generation biofuels can be emulated and expanded to meet growing transport needs in Asia

c. GHG Emissions Reductions for Alternate Biofuels Scenarios in Asia

50. The GHG emissions results of this extreme biofuels market penetration scenario for combined China, India, and emerging Asia are shown in Figure11 below. Without external factors significantly reducing the rate of growth in land transport fuel demand, annual GHG emissions from the sector will triple by the year 2050 under the most extreme (and unrealistic) biofuels penetration scenario. Without biofuels, GHG emissions would increase almost 6-fold. Of course in the longer term, towards the end of the 21st century, GHGs from the sector would decline as low life-cycle GHG biofuels (or other comparably low GHG fuels) continued to penetrate and take over the transport fuels market.

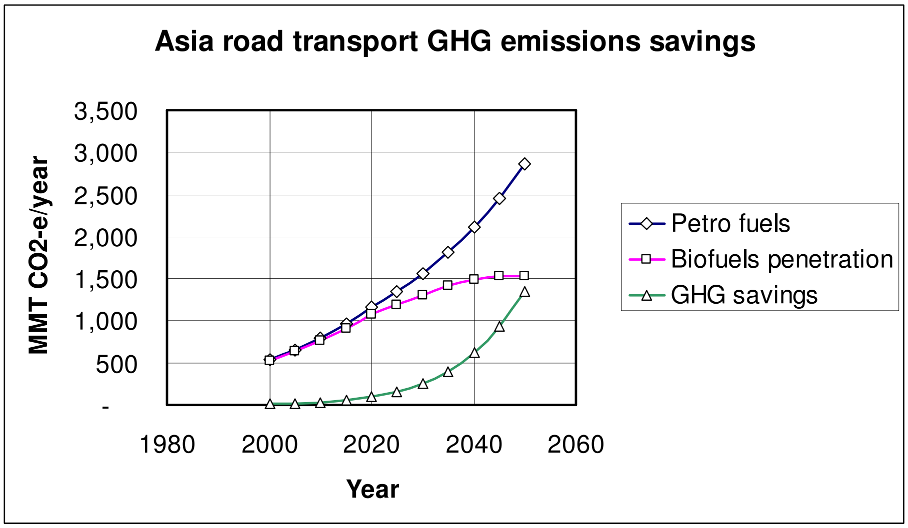

Figure 11: GHG savings in the extreme biofuels scenario for Asia

d. A "Moderate" Biofuels Scenario for Asia

51. The same analysis was conducted but with the following modifications in key assumptions:

- The market penetration curve remained the same
- The potential market for biofuels was taken as 50% of the total road transport fuels market through the year 2050
- The net reduction in exbodied GHG emissions was reduced from 90% to 75%

52. This can still be considered an optimistic scenario, but the results in terms of GHG emissions reductions are not attractive in the face of relentless growth in fuel demand by the sector. The results are shown in Figure 12 below. By year 2050 the savings in annual GHG emissions in the "moderate" biofuels penetration scenario are 500 MMT CO2-e. This is about 20% of the total emissions in the year 2050. Other measures that would reduce fuel consumption by 20% over the next 45 years might be accomplished without the use of biofuels.

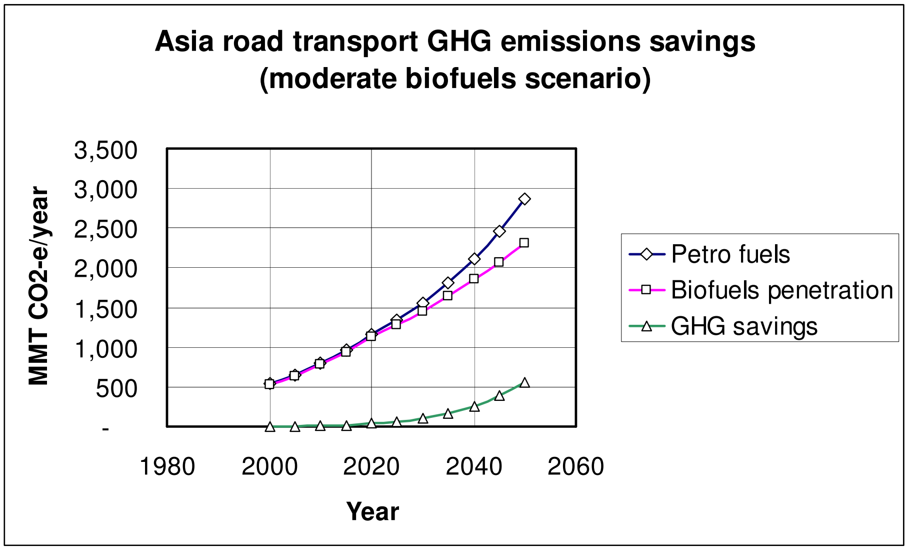

Figure 12: GHG savings in the "moderate" biofuels scenario for Asia

Source: data for the global biofuels logistic curve fit

53. Figure 13 below is from the IEA, in this case from a presentation by Sellers (2005). We used the gasoline and bioethanol production data for years 2005, 2010, and 2020, and also assumed that by the year 2050 half of the land transport fuel requirement could be taken up by biofuels. To be consistent, we assumed that half the global gasoline requirements could be taken up by bioethanol. The resulting logistic fit is shown in Figure 9 (above).

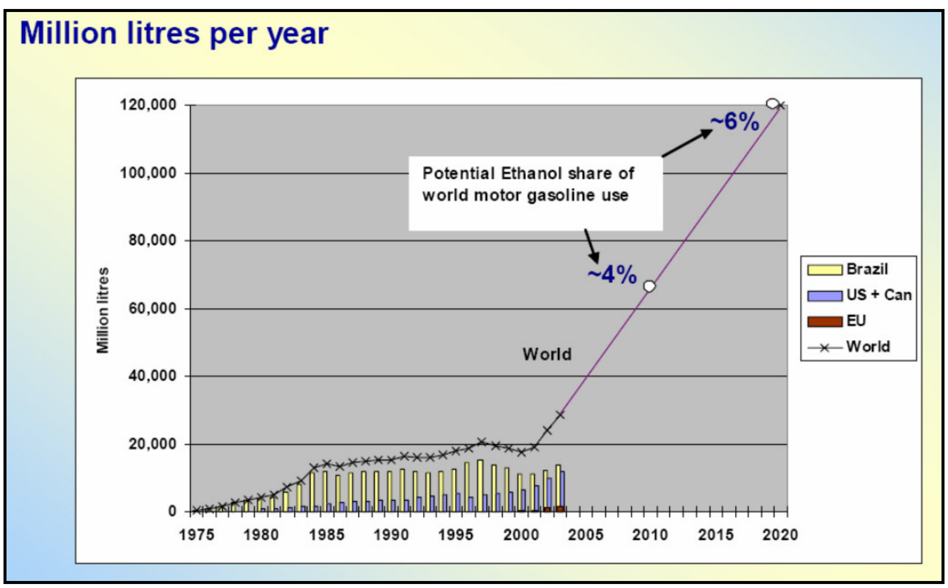

Figure 13: Potential Ethanol Share of World Motor Gasoline Use (IEA 2004)

F. LONG-TERM STRATEGIC IMPLICATIONS OF BIOFUELS FOR ASIA TRANSPORT

54. Over the long term (coming 100 years) the transition to 100% biofuels that have extremely low or even negative life-cycle GHG emissions would result in a net carbon-free road transport sector. While CO2 would still be emitted at the tailpipe, emissions of that carbon would represent a recycling of the atmospheric carbon fixed by the feedstock crops used to produce the biofuels and power the entire biofuels cycle.

55. The combination of rapid penetration of low-GHG fuels with rapidly decreasing fuel intensity in the transport sector (through modal shifts, improved vehicle technology, greater high-mileage vehicle choices, telecommuting, etc.) appears to be the means for dramatic reduction of GHG emissions from the sector by the year 2050.

56. In order to assess the potential impacts from large-scale production and use of biofuels on land use, water resources, nutrients, air quality, human health, and the global environment, each producing country will need to conduct the relevant life-cycle analyses and assessments. As the scale of biofuels production increases, some of the impacts are likely to increase more rapidly than production; these nonlinearities need to be understood and accounted for in the policy process and by both public and private sector investors.