Pricing and Infrastructure Costing

For Supply and Distribution of CNG and ULSD to the Transport Sector

Mumbai, India

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Prepared by

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Project Team

- R. K. Batra, Distinguished Fellow
- Ranjan K. Bose, Senior Fellow – Project Coordinator
- Pragya Jaswal, Research Associate
- S. Sundar, Distinguished Fellow

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Abbreviations

ADB	Asian Development Bank
AG	Arabian Gulf
APM	Administered Pricing Mechanism
bbl	Barrel
BCM	Billion Cubic Meters
BEST	Brihan Mumbai Electric Supply and Transport Undertaking
BG	British Gas
BL	Baseline
BMC	Brihan-Mumbai Municipal Corporation
BPCL	Bharat Petroleum Corporation Limited
BPKM	Billion Passenger Kilometer
BTKM	Billion Tonnes Kilometer
CARB	California Air Resources Board
C&F	Cost & Freight
CBD	Centralized Business District
CIF	Cost Insurance and Freight
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPCB	Central Pollution Control Board
CRT	Continuously Regenerating Technology
CST	Centistokes (unit for kinematics viscosity)
DHDS	Diesel Hydro-desulfurization
DOC	Diesel Oxidation Catalyst
DPC	Dabhol Power Company
DWT	Dead Weight
ECA	Essential Commodities Act
ECD	Emission Control Device
EDB	Environmental Database
EFP	Enhanced Fuel Proposition
EPCA	Environment Pollution (Prevention & Control) Authority
ESC	Empowered Standing Committee
FACTS	Fesharaki Associates Consulting and Technical Services
FDZ	Free Delivery Zone
FO	Fuel Oil
FOB	Free On Board
FSP	Freight Surcharge Pool
GAIL	Gas Authority of India Limited
GdF	Gaz de France
GJ	Giga Joules
GRI	Gas Research Institute
GVW	Gross Vehicle Weight
HBJ	Hazira-Bijapur-Jagdishpur
HC	Hydrocarbon
HCV	Heavy Commercial Vehicle
HDDV	Heavy Duty Diesel Vehicle
HPCL	Hindustan Petroleum Corporation Limited
HSD	High Speed Diesel
HSFO	High Sulfur Fuel Oil
HSU	Hartridge Smoke Unit

IDBI	Industrial Development Bank of India
IOC	Indian Oil Corporation
IPT	Intermediate Public Transport
JCC	Japanese Crude Cocktail
KL	Kiloliter
LACMTA	Los Angeles Country Metropolitan Transportation Authority
LBOS	Lube Base Oil Stocks
LCV	Light Commercial Vehicle
LEAP	Long-Range Energy Alternatives Planning
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LR	Large Range
LSD	Low Sulfur Diesel (500 ppm S)
LSHS	Low Sulfur Heavy Stock
MAPG	Multi-sectoral Advisory Group
MCGM	Municipal Corporation of Greater Mumbai
MECA	Manufacturers of Emissions Control Association
MGL	Mahanagar Gas Limited
MMBTU	Million British Thermal Unit
MMPTA	Million Tonnes Per Annum
MMR	Mumbai Metropolitan Region
MMRDA	Mumbai Metropolitan Region Development Authority
MMSCMD	Million Standard Cubic Meters
MMT	Million Tonne
MoE	Ministry of Environment
MoPNG	Ministry of Petroleum and Natural Gas
MoST	Ministry of Surface Transport
MPCB	Maharashtra Pollution Control Board
MR	Medium Range
MS	Motor Spirit
MSCM	Million Standard Cubic Meters
MSEB	Maharashtra State Electricity Board
MSRTC	Maharashtra State Road Transport Corporation
MT	Metric Tonne
MTA	Metro Transport Authority
MTOE	Million Tonnes of Oil Equivalent
MTPA	Metric Tonnes Per Annum
MTPD	Metric Tonnes Per Day
MTPM	Metric Tonnes Per Month
NAAQS	National Ambient Air Quality Standards
NCR	National Capital Region
NCT	National Capital Territory
NDP	Net Domestic Product
NGO	Non Government Organisation
NGV	Natural Gas Vehicle
NOIDA	New Okhla Industrial Development Authority
NO_x	Oxides of Nitrogen
NYC	New York City
NYCT	New York City Transit
NYCMTA	New York City Metropolitan Transitory Agency
OCC	Oil Co-ordination Committee
OMC	Oil Marketing Company
ONGC	Oil and Natural Gas Corporation Limited
OPEC	Organization of Petroleum Exporting Countries
PAH	Polynuclear Aromatic Hydrocarbons

Pb	Lead
PDS	Public Distribution System
PE	Polyethylene
PLL	Petronet LNG Limited
PM	Particulate Matter
PPA	Product Price Adjustment
PPM	Parts Per Million
PUC	Pollution Under Control
RPL	Reliance Petroleum Limited
RPO	Retail Pump Outlet
RSP	Respirable Suspended Particle
S	Sulfur
SBI	State Bank of India
SCM	Standard Cubic Meter
SCR	Selective Catalytic Reduction
SO_2	Sulfur dioxide
SPM	Suspended Particulate Matter
TERI	Tata Energy Research Institute
THC	Total Hydrocarbon
TOE	Tonnes of Oil Equivalent
TSP	Total Suspended Particle
ULG	Unleaded Gasoline
ULSD	Ultra Low Sulfur Diesel (50 ppm S)
US-AEP	United States Asia Environmental Partnership
USEPA	United States Environment Protection Agency
VKT	Vehicle Kilometer Travel
VOC	Volatile Organic Compound
WHO	World Health Organization

Executive Summary and Recommendations

Mumbai is a rapidly expanding mega-city and as in other mega cities in India and Asia air pollution is a serious problem. The city is characterized by high levels of particulate matter (PM) and nitrogen oxides (NO_x) concentrations, with PM being the greatest cause of concern. The annual average ambient concentration levels of PM have exceeded national ambient air quality standards at all monitoring sites in the city. The 1990 World Health Organization guidelines states, "the current time series epidemiological studies are unable to define a threshold below which no effects occur. Recent studies suggest that even at low levels of PM (less than 100 $\mu g/m^{3}$), short-term exposure is associated with health effects".[1]

Vehicular pollution contributes significantly to the air pollution problem in Mumbai. The city's population, number of motor vehicles, and traffic congestion have been growing rapidly, resulting in longer travel times, increased fuel consumption, increased air pollution, and degradation of the urban environment. Diesel vehicles (especially old buses) and two stroke engine, two and three wheeled vehicles are the primary source of PM emissions from the vehicle sector.

Internationally, clean fuels like compressed natural gas (CNG) and ultra low sulfur diesel (ULSD) with maximum sulfur level of 50 ppm or 0.005% have been promoted to combat vehicular pollution from all kinds of gasoline and diesel vehicles. When used with appropriate post combustion emissions control devices and engine technology, these fuels can significantly reduce PM and NO_x emission levels and are effective in pollution abatement.

The Asian Development Bank (ADB) is committed towards solving environmental problems like rising pollution levels in Asia's developing countries, and to address this issue it has initiated the development of action plans to reduce vehicle emissions in Asia.

Purpose

This study was undertaken by the Tata Energy Research Institute (TERI), New Delhi for the ADB, Manila as a part of their overall initiative to develop action plans for reducing vehicle emissions in Asia. The purpose of this study was as follows:

- To review international experience in reducing emissions through use of the clean fuels CNG and ULSD.
- To assess the potential benefits of using CNG and ULSD on a widespread scale in Mumbai.
- To assess the supply cost of CNG and ULSD in Mumbai at retail outlets, and cost-effectiveness of these fuels in the case of buses.
- To identify and address concerns, specific challenges and obstacles related to the use of the two fuels.
- To recommend a set of measures necessary to promote the use of the two clean fuels in Mumbai.

[1] (http://www.who.int/environmental information/Air/ Guidelines/Chapter3.htm).

Methodology

The methodology for carrying out the study was as follows:

1. Establishment of a multi-sectoral advisory group: Relevant stakeholders from government, oil and gas companies, NGOs and academia in Mumbai were identified and the group was set up to advise TERI in the study.
2. Literature review and collection of information using secondary sources.
3. Emissions impact assessment: A simple transport simulation model called LEAP (Long Range Energy Alternative Planning) was used to analyze the demand of compressed natural gas (CNG) and ultra low sulfur diesel (ULSD), and the resultant emissions of carbon dioxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x) and particulate matter (PM) in Mumbai, during the period 1993-2010. A baseline (BL) and two alternative cases were created in the model to characterize the current situation and possible future scenarios. The BL case is an extrapolation of present trends in Mumbai, modified to reflect existing policies and commitments. In the first alternative case, termed CNG, it is assumed that both CNG and ULSD will be used with an effort to maximize the use of CNG in a practical manner. In the second alternative case, termed ULSD, it is assumed that both ULSD and CNG will be used with an effort to maximize the use of ULSD in a practical manner. To study energy and environmental implications in Mumbai, the energy and emissions model results under the two alternative cases were compared with the BL case.
4. Cost analysis: The cost of CNG supply was estimated both through the domestic and import route (LNG import). For ULSD, the cost estimates were based on import parity price of the fuel and the likely import cost if the fuel is imported from Singapore. In addition, based on the current tax and duty structure, an indicative price build up was estimated for both fuels. The cost of operating a bus on CNG and ULSD on a per kilometer basis was calculated by taking into account the annualized capital, maintenance and fuel costs. Also, the PM abatement cost for an advanced bus was estimated by looking at the cost of introducing cleaner technology vis-à-vis the reduction in emissions that is achieved by the cleaner technology.
5. Identifying and addressing specific concerns raised by CNG and ULSD usage and recommendations for promoting the fuels: Various constraints in the use of ULSD and CNG were identified and measures to overcome these were recommended.

Conclusions

CNG and ULSD are both environmentally acceptable fuels and can bring about substantial pollution reductions, especially in the case of PM emission loading. The conclusions drawn from the transport model used in the study are as follows:

- Due to improvements in engine technology and use of cleaner fuels, the total energy demand from the transport sector in 2010 is expected to be 1.3% less in the CNG case compared to the BL case. The corresponding figure for the ULSD case is 6.4%;
- The CNG and ULSD use in increasing numbers of vehicles will bring about PM emissions reduction (over 30%) in both cases in 2010;
- The use of CNG can also reduce NO_x (3%) in 2010 whereas ULSD does not have an impact;
- While less important for Mumbai, small improvements in CO (10% in the CNG case and 11% in ULSD case) and reactive HC (1% in the CNG case and 5% in ULSD case) result from both fuels in 2010.

The advantages and disadvantages of both CNG and ULSD use are given below.

ULSD

- A very large proportion of commercial vehicles currently operate on diesel
- Infrastructure exists for diesel distribution.
- Adulteration of ULSD with lower priced products like kerosene would reduce its emissions reducing potential.
- Appropriate post-combustion emissions control devices (ECDs) must be carefully matched with vehicle operating characteristics.
- Good maintenance practices are critical to ensure efficient functioning of ECDs.
- Upgrading of refineries is required for domestic production

CNG

- A large percentage of taxis in Mumbai have already shifted to CNG fuel and there is some existing infrastructure for CNG distribution.
- Additional infrastructure is required to ensure speedy and efficient dispensation.
- Performance and reliability of converted heavy-duty diesel vehicles has not been established.
- Safety must receive greater attention.
- There is a shortage of available sites for stations and gas supply.
- High cost of converting/retrofitting existing vehicles to operate on CNG, especially in case of diesel vehicles.
- Good maintenance practices are critical to ensure efficient functioning of ECDs.
- Natural gas availability is likely to pose a problem in the short run with declining domestic reserves. However, the option of importing natural gas in the form of LNG would exist once the LNG terminals become operational.

ULSD was found to be a lower cost alternative than CNG (less taxes and duties).

- **Cost (less taxes).** At US$ 25/bbl crude oil price, cost of supplying ULSD up to a retail outlet (less taxes) in Mumbai is estimated as Rs 10.94/litre ($5.73/MMBTU). The corresponding cost for CNG is Rs 14.41/kg ($6.77/MMBTU) for domestic gas; Rs 16.12/kg ($7.58/MMBTU) via LNG ex-Dabhol and Rs 16.38/kg ($7.70/MMBTU) via LNG ex-Dahej.

- **Price Build–up.** The indicative price of ULSD inclusive of taxes and duties (if considered the same as 500 ppm S diesel supplied in Mumbai) is Rs 22.95 /l ($12.02/MMBTU) while that of CNG is Rs 22.15/kg ($10.42/MMBTU) through the import route and Rs 18.85/kg ($8.86/MMBTU) from the domestic route. The tax burden on ULSD is much higher (over 50%) compared to CNG (nearly 25%).

- **Cost of Operating a Bus on a per Kilometer Basis.** The cost of operating a Euro 2 compliant bus (minus tax) on a per kilometer basis on ULSD equipped with a PM filter (like, CRT) was estimated to be Rs 8.92/km ($0.19/km) while that for a CNG bus with a 3-way catalyst was Rs 11.11/km ($0.23/km) for CNG from the domestic route and Rs 11.59/km ($0.24/km) for CNG via the import route.

- **PM Abatement Cost for a Bus.** The PM abatement cost for a Euro 2 diesel bus operating on ULSD and equipped with a PM filter cost the least at $4,727/tonne, while a CNG bus with a 3-way catalyst lies in the range of $34,646 to $41,093 per tonne, depending upon whether CNG is indigenously supplied or imported. The abatement costs have been calculated for buses using CNG and ULSD compared to a pre-Euro 2 bus. The capital costs for a CNG bus is substantially high compared to a pre-Euro 2 bus. Also, the abatement cost calculated is based on the cost of operating a Euro 2 bus on ULSD and CNG bus without taking taxes into consideration.

The cost of operating a bus (minus taxes) on ULSD works out to be lower than that on CNG due to the following reasons:

- The fuel economy for a bus operating on ULSD is better than one operating on CNG.
- CNG buses are more expensive than diesel buses.
- The CNG infrastructure and distribution cost is higher than that for ULSD.

In carrying out this study, several methodological problems were identified which would benefit from further work and analysis, including:

- Absence of a reliable database on emission factors for all categories of vehicles using current fuels as well as the clean fuel alternatives.
- Inadequate data on vehicle numbers in actual use, by fuel type and vehicle category.
- Absence of field trials of buses with cleaner fuels and improved vehicle technologies and their close monitoring to establish fuel efficiency, costs and mass emissions data.
- Limited knowledge on commercial availability of emission control technologies and their costs. In this study, the type and size of the environmental problems facing Mumbai are assessed in terms of air quality, the possible solutions are evaluated in terms of their relative cost effectiveness, advanced vehicle technologies for emission controls and severe fuel reformulation have been treated as an integrated system. The Authors have identified areas that would benefit from further analysis, and would necessitate more basic information of better quality, in order to improve the precision of the conclusions of the study. Because of this lack of better information in some critical areas, there are uncertainties regarding some of the findings and the conclusions drawn from them, in particular, the quantitative calculation of the PM and NO_x emission reductions with the use of ULSD and CNG and the consequent calculation of the PM abatement costs. The expected environmental benefits of either ULSD or CNG may not have the same quantitative value predicted by the Study.

Recommendations

The results and conclusions of this study have given rise to the following major recommendations:

PROMOTE USE OF CNG/ULSD

Reducing vehicular emissions to improve air quality calls for interventions to improve both vehicle technology and fuel quality. Further, it is important to look at improvements in both conventional engine technologies and fuels, and the viability of alternative technologies. In India, the formal specification of vehicle emissions standards began only in 1991. Since then, the standards have become progressively stricter and thereby narrowed the gap between the standards applicable in the developed world and in India. Nevertheless, it is well recognized that India's current vehicle technologies are inferior to those in the developed world, especially for heavy-duty diesel vehicles. Diesel vehicles do not have particulate traps that help reduce PM emissions. Similarly, the sulfur content of diesel sold in India is higher than that sold in the developed world, and petroleum fuels sold in India have less stringent specifications compared to those sold in other parts of the world. Some recent developments have seen a tightening in fuel quality standards, particularly for the four Indian mega cities of Delhi, Mumbai, Kolkata and Chennai. The diesel fuel supplied to these cities today contains 0.05% or 500-ppm sulfur, which conforms to Euro 2 diesel quality.

Euro 1 and 2 vehicular emission norms were introduced in the then European Union countries in 1992 and 1996 respectively. Equivalent emission norms in India 2000 (equivalent to Euro 1) were introduced in India in 2000, while Bharat Stage II (equivalent to Euro 2) emission norms were introduced in the four metros of Delhi, Kolkata, Mumbai and Chennai in 2000-2001. Hence, the situation currently prevailing in India in 2002 is comparable to that in 1995 in the EU15 counties.

The Government's objective should be to move as close to Euro 4 norms as possible. International experience has shown that use of ULSD and CNG with appropriate emissions control devices and available vehicle technology gives emission results close to Euro 4 emission norms.

Both ULSD and CNG are considered environmentally clean fuels and are likely to reduce the total emissions loading in Mumbai if they replace conventional fuels substantially (as deduced from Chapter 5). Hence, there is a need to promote both these fuels. The Government can promote these fuels by mandating them or providing fiscal incentives, or a combination of these options. The introduction of cleaner fuels could also be used as a policy tool by the Government to promote the use of public transport.

In the deregulated scenario, the price of ULSD and CNG would be market-determined. Since the cost of producing the fuel cannot be changed, the appropriate government can use fiscal incentives to reduce the cost of producing cleaner fuels for the oil and gas companies. For example, sales tax is within the purview of the state government and import tax concessions are under the central government. Government can also influence the retail price, and hence demand, by adjusting the tax structure for the fuels since taxes form a major component of the fuel price. Taxation has been used as an instrument for influencing consumer's fuel choice in a number of countries and a similar approach can be used in India. The success of the CNG program in Delhi and Mumbai was because CNG prices were attractive in comparison to those of gasoline and diesel. The Government must ensure that the introduction of cleaner fuels does not result in raising the price of public transport use by adjusting the fuel taxes; public transport must remain affordable and accessible to the poor. High prices of CNG and ULSD might be counter-effective, shifting some public transport users to personal modes of transport.

The indicative prices that have been worked out for ULSD and CNG in Chapter 8 appear reasonable, and allow the government to price the fuels attractively. However, while promoting ULSD and CNG specific concerns such as adulteration of ULSD, infrastructure requirement for CNG, etc. will have to be addressed.

Hence, the Indian Government should promote the use of ULSD, CNG and other comparable fuels in vehicles equipped with appropriate post combustion emission control devices in public transport and intermediate public transport in Greater Mumbai. Since pollution is a critical issue in Delhi, Chennai, Kolkata and many other urban areas, CNG and ULSD should also be promoted in these cities if feasible and economically justifiable. This would also ensure that there are no volume problems for the refineries producing ULSD. As far as private vehicles are concerned, the emission norms can move according to the technological changes taking place in the rest of the country.

INCENTIVES FOR REFINERIES

At present ULSD is not produced or sold in the country but it can be imported. The Mashelkar Committee, appointed by the government to recommend an appropriate auto fuel policy, suggested a roadmap for introducing cleaner fuels. It suggested that Euro 2 quality fuel (500 ppm S diesel and gasoline) should be made available in the entire country by 2005 and Euro 3 fuels (350 ppm S diesel and 150 ppm S gasoline) by 2005 in the country's seven mega cities. With the Government's acceptance of the recommendations of the Mashelkar Committee, the oil companies will have to upgrade their refineries very soon.

Refineries can go a step further and produce ULSD, provided it is a financially attractive prospect. Since upgrading a refinery is capital-intensive, any concession given to the refineries or the consumer will help to promote the cleaner fuel by reducing the overall investment and/or lowering costs to the consumer. The capital investment can be reduced considerably by waiving the import duty on machinery required to set up the additional de-sulfurization capacity and refinery upgrade. Another option is to provide for accelerated depreciation, and while another is to give interest-free deferral of sales tax to refineries producing ULSD. Such measures introduced on capital investment will reduce the investments that refineries have to make to upgrade their facilities. Exemptions can be graded across time, with greater incentives if investments are made earlier. If the government decides to introduce ULSD within the next few years, it could consider limiting the incentives for that period so that the refineries are impelled to take immediate steps to upgrade and avail of the incentives to recover their investments.

INCENTIVES FOR GAS DISTRIBUTION COMPANY

The cost of the distribution infrastructure for gas is very high. Hence, incentives such as an import duty waiver on the plant and machinery (compressors, dispensers, etc.) can be given to gas companies. Accelerated depreciation is another available option. MGL has already been granted interest-free deferral of sales tax on CNG for a period of 13 years until 31 March 2009, by the Government of Maharashtra.

ONLY ULSD SHOULD BE AVAILABLE IN GREATER MUMBAI

To ensure that multiple grades of diesel are not used in diesel vehicles fitted with DOC or PM filters (which are very sensitive to higher levels of sulfur in diesel), only ULSD should be made available in Greater Mumbai and for some distance beyond the city limits. At present low sulfur diesel (LSD), i.e. 500-ppm sulfur diesel only, is available in Greater Mumbai.

PRICE ULSD ON A PAR WITH LOWER GRADES OF DIESEL

The price of ULSD should be at least equal, if not lower than that of low sulfur diesel to help ensure that there is no incentive for consumers or retail outlet owners to go and buy lower grade diesel from outside Mumbai. This can be done by adjusting the fuel taxes so that cleaner diesel is taxed at a lower level than other grades of diesel.

CHECKING AND ELIMINATING ULSD ADULTERATION

A main threat is the adulteration of ULSD with other petroleum products such as kerosene, which is available through the public distribution system (PDS) at Rs.9.01/litre, compared to diesel at Rs.23.75/litre in Mumbai.[2]

The following are specific recommendations to check and eliminate adulteration of ULSD:

- The Electronic Marker System (which was tested at two oil companies' installations) has given excellent results and extended field trials will now be conducted at six oil company terminals in Delhi. If the same results are obtained, the oil companies are expected to extend testing based on the marker system to retail outlets. As this marker system is a considerably improved option compared to earlier chemical markers, the development and propagation of the marker system needs to be accelerated.
- On a parallel basis, the 'Pure for Sure' campaign by BPCL needs to be extended within the organization and across the industry. In this system, physical adulteration of the fuel during transport from the oil companies' terminals to retail outlets is prevented, and if adulterated stocks are found in the dealers' tanks, the dealership is to be terminated. Monitoring is done by an external agency. An important feature is that BPCL as a company guarantees the quality of the fuel to the consumer.
- Though the Essential Commodities Act provides for penalties in cases of adulteration

[2] http://www.bharatpetroleum.com/general/gen_petroprices.asp as on 26 November 2002 as compared to diesel at Rs. 23.75/litre

and oil companies have also established guidelines and penalties, enforcement is weak and needs to be considerably strengthened.

- Public transport in Mumbai is provided by BEST and as far as BEST is concerned, adulteration is not an issue as their buses are fuelled by captive fuel storage facilities managed by BEST in their bus depots. It would perhaps be wisest to introduce ULSD for BEST buses initially, and then make ULSD available to the whole of Mumbai for all categories of diesel vehicles operating within the city limits.
- Under the APM, the kerosene subsidy was funded by a surcharge on motor spirit, but with the dismantling of the APM effective 1 April 2002, the subsidy is now provided directly by the Central Government. The Finance Minister has stated that the subsidy will be withdrawn in a period of three to five years. It is recommended that the subsidy be withdrawn at the earliest and not later than three years. It will also be necessary to rationalise the excise duties on kerosene and diesel to narrow the price gap further.
- In the meantime, if kerosene is available ex-storage point at import parity price and the subsidy is provided at the last point of sale (instead of first point of sale as at present) for the public distribution system, the incentive to adulterate diesel will be removed (due to a considerable narrowing of the price differential between diesel oil and kerosene ex-storage point).
- To check adulteration at the consumer level, it is necessary to launch extensive consumer awareness campaigns. The consumers should be apprised of the damage caused to the engine and emission control devices by adulterated fuel use. The inspection and maintenance system could detect damage to the engine and emission control devices caused by fuel adulteration. In addition, consumers could be informed that replacement of these emission control devices is expensive.
- The Government should introduce a roadside inspection system to catch users of adulterated fuel and punish them with high fines. Here again the enforcement mechanism has to be very effective.

The above recommendations need to be integrated in a manner that can check and eliminate fuel adulteration. This would be more easily achieved in a concentrated and developed market like Mumbai compared to up-country markets.

CRITERIA FOR SUPPLY OF CNG FOR TRANSPORT USE

MGL has faced substantial problems in extending its infrastructure in Mumbai. Due to spatial constraints in Mumbai city, MGL would find it hard to cater to demand were it to rise substantially.

The attractiveness of CNG as an option for all the concerned cities would have to be evaluated, as lack of infrastructure is likely to pose a problem. At present, the country's gas transmission and distribution network consists of the Hazira-Bijapur-Jagdishpur (HBJ) pipeline system and regional gas grids of varying sizes in Gujarat, Andhra Pradesh, Maharashtra, Rajasthan, Tamil Nadu and Tripura. The HBJ transmission system is the only major gas transmission line in India catering to customers in Madhya Pradesh, UP, Gujarat, Rajasthan, Haryana and Delhi. Even in these states where the main transmission system exists, for cities lying close to the main transmission line, regional grid lines would have to be established which would require substantial investment. Bringing CNG only for the transport sector, where there is no demand for natural gas by the industrial, domestic and commercial sectors, could not be justified economically. In places like Kolkata and Bangalore, which are not in the vicinity of a gas source and where infrastructure for gas supply is non-existent, CNG for the transport sector alone is not economically viable. In such cities, other options for reducing vehicular pollution should also be considered.

UPGRADING VEHICLES

There is a need to treat fuels and vehicles as an integrated system. Just as the cleaner environmentally friendly fuels need to be promoted, improved vehicle technologies should also be promoted. As for fuels, incentives can be offered to manufacturers to make additional investments to improve technology, for example, tax concessions for environmentally cleaner vehicles.

Various instruments can be used to subsidize the capital expenditure incurred by manufacturers, such as low interest loans, larger depreciation allowance, and lower tax rates for the purchase of plants and machinery. Soft loans and accelerated depreciation are incentives for manufacturers to incur the up-front cost at the earliest, and customs duty waivers for auto components used in cleaner vehicles is another option.

The emissions intensity of older vehicles is likely to be greater, other things remaining equal; so, specific measures are also required to discourage the use of older vehicles. The Government should specify age limits beyond which a vehicle must be scrapped. It should also give incentives for the replacement of old vehicles.

NEED FOR A CREDIBLE DATABASE

Based on the scope and limitations of this study, the following areas require special attention and support for further work.

- Better, more reliable emission factors for all categories of vehicles and fuels are needed.
- Carefully controlled demonstration projects in the region with both ULSD and CNG would help to develop cost and emissions data.
- Common methodologies for monitoring and evaluating fuel alternatives need to be developed.

NEED FOR AN INTEGRATED APPROACH

The introduction of CNG and ULSD will help to reduce emissions from the transport sector. However, these measures alone will be insufficient to bring about a marked improvement in air quality status. To achieve the required improvements and ensure efficient resource allocation, a coordinated action plan must be developed that would address transport sector concerns in an integrated manner. The goal of sustaining mobility must be linked with the goals of fostering economic development, improving the air quality, reducing energy consumption, promoting transportation-friendly development patterns, and encouraging fair and equitable access to transport for different socio-economic groups. Mechanisms for integrated transport planning strategies, urban and regional settlement strategies, land-use planning, traffic management, and implementing policies and transport programs that reduce reliance on private cars and encourage alternative forms of travel need to be put in place. In this regard, different forms of transport must be seen as parts of an integrated and interdependent whole.

CHAPTER 1

Introduction

Background

Mumbai is the industrial and commercial capital of the country and a rapidly expanding megacity. The population of Mumbai was 9.9 million in 1991 and around 12 million according to the 2001 population census. It covers an area of 437.71 square km (Census of India, 2001; WS Atkins International, 1994). Like any other metropolitan city in India, population and vehicle use continue to expand in Mumbai, with vehicles being the principal source of severe air pollution.

Measures to reduce air pollution in Mumbai focus primarily on the transport sector. In recent years a series of initiatives have been launched to reduce pollution in the city. In fact, most control directives call for a technical fix, such as altering the engine or fuel type. The introduction of low sulfur diesel (LSD), unleaded gasoline with a maximum of 1% benzene, and alternative fuels (mainly CNG) illustrates this technical fix approach. High speed diesel (HSD), which is normally used as a fuel in medium and high speed compression ignition engines (operating above 750 RPM) in vehicles, stationary diesel engines, locomotives and pumps etc., can be categorized according to its sulfur content. At present HSD with 0.25% sulfur content is available throughout India, except in the four metropolitan cities where LSD with 0.05% sulfur content is available. CNG is natural gas compressed at 250 bars stored in high-pressure cylinders used in transport vehicles.

Given the important role clean fuels play in improving air quality, the Asian Development Bank (ADB) organized a regional workshop on Fuel Quality and Alternative Fuels from 2 to 4 May 2001 in New Delhi, India, with the support of Tata Energy Research Institute (TERI) and the US Asia Environmental Partnership (US-AEP). This was part of ADB's initiative to develop action plans for reducing vehicle emissions in Asia. Senior government representatives from fourteen developing member countries, as well as representatives from the private sector and development agencies participated in the workshop. One major recommendation of the workshop emphasized the economics of fuel supply and determining the cost of environmentally acceptable fuels as measures to promote the use of such clean fuels.

On the subject of clean fuels, as per directions of the Honourable Supreme Court dated 26 March 2001 and 27 April 2001, the Environment Pollution (Prevention & Control) Authority (EPCA) of the National Capital Region submitted a report to the Supreme Court in July 2001 (EPCA, 2001). This report states that among the hydrocarbon fuels that are commonly used in automobiles, it is not possible to specify a "clean fuel" which does not cause pollution or is otherwise not injurious to health. Hydrocarbon fuels are polluting by nature because of their chemical composition, and their pollution potential depends on their ratio of carbon and hydrogen atoms. Gasoline and diesel are long-chain hydrocarbons with a large number of carbon atoms bonded to hydrogen atoms in the chain. Fuels such as CNG, liquefied petroleum gas (LPG) and propane belong to the group of short-chain hydrocarbons with fewer carbon atoms; their lower C:H ratio renders them less polluting. The C:H ratio together with the effects of fuel characteristics, fuel additives, exhaust treatment systems in automobiles, and secondary pollutants generated in atmospheric reactions all contribute to air pollution and its effects on health. Fuels that have less carbon in them also have less potential energy, and therefore more fuel is required to do the same work.

All over the world, initiatives have been taken to improve the quality of diesel and gasoline and make use of less polluting short-chain hydrocarbon fuels such as CNG, LPG and propane (EPCA, 2001). Improvements in fuel quality are also achieved through the removal or reduction of fuel constituents such as sulfur and polynuclear aromatic hydrocarbons (PAH) in diesel; and sulfur, lead, benzene and other aromatics in gasoline. Further emissions reductions are obtained by improving engine technology and exhaust treatment systems.

According to the EPCA report, CNG, LPG and propane have been categorized as environmentally acceptable in terms of their pollution potential. The report also says that ultra-low sulfur diesel (ULSD) with 0.001% (10 ppm) sulfur and a low PAH content will be significantly less polluting when used in combination with particulate traps and catalytic converters. In such a situation, ULSD can be regarded as an environmentally acceptable fuel. However, it is important and necessary to ensure that ULSD is not adulterated with low quality diesel or other adulterants. Currently, ULSD is not produced or sold in India. However, it can be imported or produced in the country by upgrading existing refineries.

Many European countries, particularly those in northern and western Europe, are already committed to ULSD that contains 0.005% or 50-ppm sulfur. ULSD is known as "city diesel" in Europe and was introduced in Finland and Sweden in 1993; since then it has captured 100% of the Scandinavian and UK diesel markets. ULSD is now available in Europe from several suppliers, including Shell, BP, Total, Neste and Greenergy, and the fuel is also imported by Hong Kong, China. ULSD is commercially available in the US but in limited areas, mostly in California and the north-eastern states of Massachusetts, Connecticut, New York, New Jersey, Pennsylvania and Maryland. Texas and the midwestern states (Ohio, Indiana, and Illinois) will also have ULSD supplied by British Petroleum.

Natural gas is being used as an automotive fuel in a number of countries. The greatest penetration of CNG in the fuels market is in Argentina. A number of European countries (including Italy, Germany, France, etc.), the US, Japan, and developing countries like Pakistan, People's Republic of China and India also have increasing natural gas vehicle fleets. Achieving the right balance between vehicle growth and fuelling station network expansion is a challenge; it must ensure that motorists do not wait for fuel at stations and that there are enough vehicles on the road to achieve the required natural gas throughput to keep the fuelling stations economical.

CNG is particularly suited to small, commercial high mileage vehicles such as taxis and autorickshaws, which are seldom used for long-haul travel or to carry heavy payloads. For heavy-duty vehicles such as buses, the choice between CNG and ULSD is far from clear, with each side citing experimental data to support its claims. It is, therefore, essential to test any new technology to find out whether it is suited to local driving conditions. The technical feasibility of improved heavy-duty vehicles, fuel technology and associated costs will have to be definitively established in India before any particular technology-fuel combination is recommended. Furthermore, the choice of CNG or ULSD vehicles will depend primarily on the availability of the relevant fuel.

As a result of air quality concerns, all types of vehicles in India have been subjected to increasingly stringent emissions standards and it is imperative that both fuel specifications and engine technology go hand in hand. Advances and improvements in technology and fuel quality now provide a choice of fuels that reduce particulate matter (PM) emissions, the main pollutant of concern in most Indian cities. The choice of better fuels such as ULSD and CNG, however, translate into high costs for vehicle manufacturers and refineries. The infrastructure required for natural gas, such as pipelines, gas filling (mother and daughter stations) and CNG engines is also expensive. The main issue with natural gas vehicles is that they must strictly conform to safety standards. Products manufactured for natural gas vehicles—from vehicle components, storage tanks to fuel-pump nozzles—need to be strictly governed by a wide variety of standards to ensure safety. In India, this will require more and better equipment, as well as extensive training of inspection staff. In the absence of better equipment, monitoring mechanisms for repair or modification of CNG vehicles would be weak.

COST CONSIDERATIONS

In a large but poor country such as India, to determine the most cost-effective solution, it is essential to evaluate the cost of different options, especially if they yield comparable results in air quality improvements. While CNG seems to be a good solution for improving Mumbai's air quality, the question is whether it is the only solution or other cost-effective solutions are available.

TECHNOLOGY CONSIDERATIONS

Compliance with Mumbai's existing programs to switch over to gaseous fuels in the transport sector may be expensive given the growing demand for fuel and the emerging market scenario. CNG is cheaper than gasoline and dependent on how much a vehicle is driven; the full lifecycle cost of owning and operating a CNG vehicle will be less than that of a comparable gasoline vehicle, although the initial cost of a CNG vehicle may be somewhat higher. In the case of buses however, the initial cost of a CNG bus is significantly higher compared to ULSD. Each CNG bus, for example, currently costs about 50% more than a diesel bus (or about $10,000 extra). This initial cost is so high that it outweighs the long-term cost benefits for many purchasers, even though the retail price of CNG and diesel (500 ppm S) in Mumbai is almost the same. As the technology matures, this cost differential is expected to diminish but not disappear, primarily because of the cost of high-pressure fuel storage tanks.

International experience shows that when compared to CNG buses fitted with emission-control devices, ULSD produces comparable results for all regulated pollutants except nitrogen oxides (NO_x) under the following conditions: when used in modern heavy-duty buses (Euro 2 or 3 compliant diesel buses) with exhaust fitments of post combustion emission control devices (ECD), such as continuously regenerating technology (CRT), and when tested on a city driving cycle.

Trials commissioned by the London Transport Board provide a concrete example. The tests mimicked a typical bus journey on city roads: a mix of fast and slow stretches, low average speeds, frequent stops at traffic intersections and to pick up and discharge passengers, extended idling times, and so on. Buses running on CNG and fitted with an oxidation catalyst were compared with Euro 2 buses running on ULSD and fitted with CRT, in terms of the amount of different pollutants they emitted for every kilometer of travel. ULSD-powered buses emitted less of every pollutant except NO_x. PM emissions were half of that produced by CNG buses (Barton, 1997). More recent trials conducted by the New York City Transit showed similar results. (Chatterjee et al. 2001; Lev-On et al. 2002*)*.

AVAILABILITY

Gas production in India was 28.4 billion cubic meters (BCM) in 1999/2000 (TERI, 2001). The three main gas producing basins in the country—the Western offshore region, the Cambay basin in Gujarat, and the Upper Assam region—are in the mature phase of exploration. As per the projections of the Sub-group on Utilization of Natural Gas constituted under the Hydrocarbon Vision 2025, the domestic gas availability is expected to decline to about 16 BCM by 2011/12. The country's rising gas demand will therefore have to be met largely by imported gas in all sectors. Until the late 1980s the supply of gas in India exceeded demand due to a lack of infrastructure, but in the 1990s demand exceeded supply. Currently, the registered gas allocation of 110 MMSCMD far exceeds the current supplies of 65 MMSCMD in the country. The overall demand-domestic supply scenario indicates that there are likely to be substantial deficits. In view of this, the government has directed efforts at enhancing domestic production of natural gas as well as exploring import options. Through the Government's forward looking exploration and licensing policy, there have been gas findings in the Cambay offshore region. Larger finds are expected in the Krishna Godavari basin[1]. However, it's too early to estimate the quantity of gas that would be available on a commercial basis.

As far as imports of gas through pipelines are concerned, there is continuing political uncertainty, as the pipelines would have to traverse international boundaries. The key issues in the case of imports via this route relate to reliable assurances on gas supply security to the recipient country, and acceptable transport costs considering the potential ability of transit countries to demand unreasonably high tariff charges or turn hostile. At present, there are proposals for gas exports from Bangladesh under consideration, however, these are at an initial stage. Thus, gas imports in the immediate future are likely to be in the form of liquefied natural gas (LNG).

Currently, the entire demand for CNG is met by domestic sources and the Indian government has had to resort to a system of gas allocations through the Inter-ministerial Gas Linkage Committee. The bulk of the gas is allocated to the power and fertilizer sectors. This allocation was based on studies carried out periodically by the Government to adjudge the best use of gas. Initially, these studies demonstrated that the use of gas for fertilizer production was its best application. Later the power sector became an equally preferred sector, and the transport sector was evaluated much later but received a very low rating at that stage. This evaluation, however, did not take into account the environmental and health impacts of the two fuels under analysis for transport sector, i.e. natural gas as CNG and diesel. There remains a need to evaluate the opportunity cost of gas after taking all these factors into consideration. So far, the debate over allocation of resources has been muted.

It emerges, therefore, that there is need to look at other clean fuels, such as ULSD, as it irrational to promote one particular fuel without examining comparable alternatives and their relative supply costs. Production of ULSD will require substantial investments for refinery upgrading and until this occurs, the availability of ULSD will depend on imports—as in the case of CNG.

In view of the growing demand for clean fuels in the transport sector, it is important to determine the cost of supplying CNG and ULSD to dispensing stations in Mumbai. The supply of CNG and ULSD for vehicles involves the following issues and this study addresses all of them in detail.

- Production and processing of fuels,
- Transportation of processed fuels to Mumbai and their storage, and
- Distribution of the fuel through retail outlets.
-

It is important to know how much it costs per kilometer to run a vehicle on clean fuels. This can be calculated by taking into account the capital, fuel and maintenance costs and the number of kilometers a vehicle moves. It is also crucial to understand the emission abatement cost and reduction in emissions when an improved vehicle technology and clean fuels are introduced.

[1] Reliance has very recently reported a very large find in deep waters in the Krishna Godavari basin of the coast of AP, the size of which is yet to be certified. It will take some time to bring this onshore.

Apart from determining the cost of fuel supply at the dispensing stations in Mumbai, it is also necessary to understand the duty, tax structure and dealer's profit margin to be able to understand the price build up, i.e. what is added to the cost. This helps to determine economic instruments such as tax preferences that can stimulate the early introduction of advanced vehicle and fuel technologies, as has been repeatedly demonstrated in the developed world, especially in Europe. This is essential to provide incentives to users and promote the adoption of clean fuels. At the same time, incentives are required for oil companies and refineries to produce ULSD.

In the current pricing policy, the landfall price of gas is linked to a basket of fuel oils. In 1999/2000, it was fixed at 75% of the import parity price. However, on account of the upward rally of oil prices in the year 2000, the government capped the gas price at the landfall point (at Rs 2850/thousand cubic meter)[2]. Until 31 March 2001 diesel pricing was under an Administered Pricing System (APM), which is now dismantled.

Ensuring the proper distribution of these clean fuels requires effective institutional arrangements and regulatory mechanisms for enforcement. There is a need to reduce the long customer queues at CNG dispensing stations and also to prevent adulteration of ULSD, as the entire purpose of introducing a clean fuel will be defeated if this is not checked. It is, therefore, important to involve relevant stakeholders in developing an effective institutional mechanism to formulate policies that ensure the safe and speedy delivery of CNG and to prevent adulteration of ULSD.

Coverage

During this nine-month study, TERI first analyzed the environmental impact of introducing CNG and ULSD (with 50-ppm sulfur) to Mumbai's road transport system, and then completed a detailed comparative analysis of the cost of fuel supply (production, transportation, and distribution) of these two fuels in Mumbai. Next, the cost of operating a bus on CNG and ULSD on a per kilometer basis was determined taking into account its capital, fuel and maintenance cost. The study also provides the cost of abatement of PM if advanced buses fuelled with CNG or ULSD are used. It analyzes the price-build-up of the diesel and CNG currently used in the transport sector, recommends measures to promote ULSD and CNG use, and addresses additional specific concerns (such as ULSD adulteration and infrastructure problems associated with CNG supply) which arise due to the use of these fuels. This approach will help relevant stakeholders in developing an action plan for reducing vehicle emissions in Mumbai. The results and recommendations of this study will be relevant to other cities in India and Asia.

Organization of the Report

The report is divided into eight chapters as follows:

Chapter 1 provides the rationale with key alternative fuels and environment policy/issues questions that motivated this study in Mumbai.

Chapter 2 gives the objectives of the study and the methodology used.

Chapter 3 details the status of air quality in Mumbai and identifies critical pollutants that frequently exceed permissible standards.

[2] http://petroleum.nic.in/ng.htm

Chapter 4 provides a policy review based on national and international experience on strategies promoting the two clean fuels—CNG and ULSD.

Chapter 5 analyzes the travel characteristics, vehicle ownership and growth to project the travel demand in the city for both passenger and goods vehicles in Mumbai. This chapter also presents a simple urban transport model, which is used for analyzing the past, present and future fuel demand in the road transport sector and resultant emissions loading of regulated pollutants, carbon monoxide (CO), hydrocarbon (HC), oxides of nitrogen (NO_x) and particulate matter (PM) in alternative scenarios. Each scenario is constructed assuming different levels of penetration of CNG vis-à-vis ULSD in the transport sector. This chapter also provides the emission benefits under alternative scenarios in the year 2005 and 2010 when each scenario's results are compared with the baseline or business-as-usual scenario.

Chapter 6 addresses the likely sources of ULSD—domestic refineries, import options—the distribution network in Mumbai and measures adopted by the oil companies to prevent adulteration.

Chapter 7 covers the CNG supply, sectoral allocation and the existing infrastructure network for the transport sector. This chapter also discusses the import option of natural gas in the near future through the LNG route and identifies possible LNG terminals around Mumbai.

Chapter 8 gives the detailed method for estimating the cost of supplying CNG and ULSD to the transport sector and also presents the estimated cost of supplying the two fuels in Mumbai. In addition, the cost of operating CNG and ULSD buses on a kilometer basis is determined. The chapter also provides the cost of abatement of PM if advanced buses fuelled with CNG or ULSD are used.

Finally, the recommendations arising from the results and conclusions are presented in the Executive Summary in the beginning of the report.

CHAPTER 2

Scope and Methodology

Scope

The scope of this study was to:
- Define the current air pollution problem in Mumbai;
- Estimate (a) the demand for CNG and ULSD (with maximum 50-ppm sulfur content) as road transport fuels over a ten year time frame (2000-2010) and identify supply sources, and, (b) the resultant emissions loading of the regulated pollutants CO, HC, NO_x and PM in a baseline and two alternative scenarios, based on increasing levels of penetration of CNG and ULSD;
- Determine the cost of supplying the two fuels to retail outlets (landed cost and network distribution cost);
- Estimate the cost of operating a bus on CNG and ULSD on a per kilometer basis;
- Estimate the PM abatement cost of introducing a CNG and a ULSD bus
- equipped with appropriate ECD;
- Recommend appropriate measures to promote the use of CNG and ULSD; and
- Identify and address concerns raised by the use of CNG and ULSD.

For the purposes of this study Mumbai refers to Brihanmumbai or Greater Mumbai.

Methodological Framework

The following steps were taken to address the scope of work.

ESTABLISHMENT OF A MULTI-SECTORAL ADVISORY GROUP

Relevant stakeholders in Mumbai were identified and a multi-sectoral advisory group (MAPG) was set up with representatives drawn from the government, oil and gas companies, NGOs and academia. The MAPG provided comments on the methodological framework, results and recommendations. Its members are listed below.

Co-Chairpersons

Mr. Utpal Mukhopadhyay
Principal Secretary to the Honourable Deputy Chief Minister of Maharashtra
Government of Maharashtra, Mumbai

Mr. S. Sundar
Distinguished Fellow
Tata Energy Research Institute, New Delhi
and Former Secretary Government of India

Members

Mr. Rahul Asthana
Former General Manager, Brihan Mumbai Electric Supply and Transport Undertaking (BEST), Mumbai
or his representative

Mr. Kavi Avari and Ms. Meher Rafaat
CLEAN-Air, Mumbai

Mr. S. Behuria
Director (Marketing), Bharat Petroleum Corporation Limited (BPCL), Mumbai
or his representative

Mr. Debi Goenka
Activist
Bombay Environmental Action Group, Mumbai

Mr. S. K. Kapoor
Director (Marketing), Hindustan Petroleum Corporation Limited (HPCL), Mumbai
or his representative

Ms. Zinnia Khajotia
Chairperson, Environment Committee
IMC – Ladies Wing, Mumbai

Mr. S. B. Sahasrabudhe
Deputy Transport Commissioner, Mumbai
or his representative

Mr. V. M. Lal
Principal Secretary (Energy & Environment), Mumbai
or his representative

Mr. U. P. S. Madan
Project Director, Mumbai Urban Transport Project, Mumbai Metropolitan Region Development Authority, Mumbai
or his representative

Mr. A. K. Purwaha
Managing Director, Mahanagar Gas Limited (MGL), Mumbai
or his representative

Prof. S. Sriraman
Professor of Transport Economics, Department of Economics, University of Mumbai, Mumbai

Project Co-ordinator

Dr. Ranjan Kumar Bose
Senior Fellow, Tata Energy Research Institute, New Delhi

LITERATURE REVIEW

A detailed literature review was carried out to assess the current status of ULSD and CNG use in various countries and India's experience in controlling vehicular emissions. It also focused on emission results of the field trials of CNG and ULSD powered buses equipped with ECDs in different countries.

INFORMATION COLLECTION USING SECONDARY SOURCES

The project team collected secondary information from the Environment Department on the current air quality status at major traffic junctions in Mumbai. It collected the following information to analyze the demand for CNG and ULSD, and estimated the cost of supplying these two fuels to the city over a ten-year time frame from 2000 to 2010.

- Socio-economic indicators,
- Air quality status and sectoral share in total emissions,
- Growth of in use motor vehicles,
- Gasoline, diesel and CNG sold in Mumbai by the oil and gas marketing companies,
- Production, transportation and infrastructure networks for CNG and ULSD distribution, and
- Cost of vehicle conversions.

The above information was analyzed to determine the following variables:

- Passenger and freight travel demand,
- Modal split by technology and fuel,
- Operating energy intensity,
- Fuel demand by mode: past, present and future (1993-2010),
- Extent of switch from gasoline/diesel to CNG, and
- The demand for CNG and diesel.

Further, to assess the transport sector's future demand potential for CNG and ULSD in Mumbai, the following issues were analyzed:

- The historical development of CNG infrastructure and CNG supply,
- An expansion plan for Mumbai by the Gas Authority of India Limited (GAIL) and Mahanagar Gas Limited (MGL), and
- Import options for natural gas and ULSD.

The project team interviewed representatives of the following associations to understand the people's perception about clean fuel use, problems related to adulteration, prompt supply of CNG, safety and efficiency of CNG vehicles, and the impact of CNG pricing on the public and intermediate public transport:

- Gasoline pump dealer's association,
- Taxi and autorickshaw owner's association,
- Bus owner's association, and
- NGOs.

EMISSIONS IMPACT ASSESSMENT

A transport simulation model was used to analyze the demand for CNG and ULSD and resultant emissions in Mumbai, during the period 1993-2010. The model includes the following variables: travel demand, modal split, penetration of vehicle technologies/fuels, number of vehicles of different vintage, vehicle space per passenger or per tonne of freight, energy intensity and emission factors of CO, HC, NO_x, PM. The model illustrates the effect of a baseline (BL) and two alternative cases on emissions loading from Mumbai's road transport system. The BL case is an extrapolation of present trends in Mumbai, modified to reflect existing policies and commitments. In the first alternative case, termed "CNG", it is assumed that both CNG and ULSD will be used with an effort to maximize the use of CNG in a practical manner. In the second alternative case, termed "ULSD", it is assumed that both ULSD and CNG will be used with an effort to maximize the use of ULSD in a practical manner. The energy and emissions model results under the two alternative cases were compared with the BL case, to study energy and environmental implications in Mumbai.

COST ANALYSIS OF CNG AND ULSD SUPPLY

The cost estimation of CNG supply was worked out for both domestic production as well as for the import option (through the LNG route). As ULSD is not produced or sold in India, the cost estimates were based on the import parity price of the fuel. The cost of supplying the two fuels—without taking into account taxes and duties—was determined by summing up the cost elements given in Table 2.1. The cost of supplying CNG at retail outlets is estimated in Rs/kg, whereas for ULSD it is expressed in Rs/litre to understand how they correspond to the retail prices of the two fuels.

Table 2.1
Cost Elements

Cost elements	CNG case	ULSD case
Landed cost	Two cases are considered. 1 LNG import: LNG CIF (cost insurance and freight) price at the nearest LNG terminal from Mumbai. 2 Domestic production: CNG cost based on fuel oil thermal parity.	ULSD CIF price imported from Singapore and delivered at Mumbai port, which is the import parity price.
Transportation cost	1 LNG import: Cost of transportation by pipeline from the LNG terminal to Mumbai City Gate station. 2 Domestic production: Does not apply.	Does not apply as refinery and storage locations are same in the case of Mumbai.
Distribution cost	Cost of gas distribution from City Gate Station to the dispensing stations which includes the cost of infrastructure.	Cost of distribution from the oil depot to the retail outlets (infrastructure for distribution of diesel already exists).

BUS OPERATION COSTS

The cost of operating a bus on CNG and ULSD on a per kilometer basis was estimated taking into account its capital, fuel and maintenance costs and the average annual utilization of a bus.

PM ABATEMENT COST OF AN ADVANCED BUS

The environmental impact of PM and NO_x emissions from current diesel engines is higher than that of emissions from gasoline/CNG engines equipped with catalysts. Also, it is well known that the most serious health risks arise from exposure to PM, a critical concern in Mumbai. Diesel buses currently comprise around 1% of the total number of motorized vehicles in Mumbai but meet over 60% of travel needs. It is, therefore, important to understand the cost of PM abatement if buses equipped with ECDs and powered by CNG and ULSD are introduced.

The abatement cost of PM emissions was computed for improved bus technology and powered with CNG and ULSD, separately. To calculate the cost per tonne of PM abated, CNG and ULSD buses which had lower PM emissions were compared to the baseline option. The BL option considered is a conventional (pre-Euro 2) diesel bus without any ECD running on 500-ppm sulfur diesel.

USE OF MARKET INCENTIVES TO PROMOTE THE USE OF CNG AND ULSD

Economic instruments such as tax preferences can stimulate the introduction of improved fuel quality and alternative fuels such as ULSD and CNG. The prevailing price build up structure of CNG and 500-ppm low sulfur diesel (LSD) was analyzed and related to the estimated cost of supplying CNG and ULSD. Measures to promote the use of the two clean fuels were recommended.

ADDRESSING ISSUES OF ADULTERATION OF ULSD

The report examines extensively the main cause of diesel adulteration. This includes the various steps taken in the past by both oil companies and the government to check adulteration, and the new practices and technologies which hold great promise to effectively check and eliminate adulteration during the transportation process and storage at retail outlets. The key issue of eliminating the subsidy on kerosene—which is the main incentive for adulteration—is also addressed.

CHAPTER 3

Status of Air Quality in Mumbai

Mumbai's population grew by 38% between 1971-1981, by 20% in the period 1981-1991 and by another 21% in the last decade to reach its present figure of 12 million (Census of India, 2001). The per capita net domestic product (NDP) of the city has also grown rapidly; at current prices it went up from Rs 19270 in 1991 to Rs 32439 in 1994-95, an increase of 68% in three years (Centre for Research and Development, 2001). Rising incomes combined with demand for greater personal mobility has resulted in a continued increase in personal vehicle use and ownership. The substantial increase in the city's vehicle fleet has resulted in the growing severity of air pollution. Air quality has emerged as a principal motivation for improving Mumbai's transport system.

In response to a writ petition filed by the Smoke Affected Residents forum, the Mumbai High Court recognized the deteriorating quality of ambient air in the city. Its order stated that "it would be necessary to have environment-friendly vehicles/engines, environment-friendly oils and above all, an environment-friendly approach." In an order dated 15 December 1999, the Court constituted an expert committee under Mr. V. M. Lal, the then Transport Commissioner, to examine the entire matter. The Expert Committee made several recommendations as listed below[3]:

- Reduce diesel sulfur content to 0.05% (or 500ppm) by October 2000, and reduce it further to 0.035% by 1 April 2003;
- With effect from 1 May 2000, all new buses purchased by BEST should be CNG-operated until Euro 2 compliant engines or higher version diesel engines become available;
- The engines of all the existing BEST buses should be Euro 2 compliant ones by 1 October 2002;
- All taxis fifteen years old and all 3-wheelers more than ten years old should be converted to CNG or any other clean fuel with effect from 1 January 2001;
- The maximum age of all vehicle types should be prescribed and strict action taken in this regard;
- MGL should draw up a program aiming to open around ten new CNG outlets every year for the next 5 years, which are spread across the city so that the vehicle re-fuelling time does not exceed five minutes;
- All oil companies should ensure that the diesel and gasoline sold at their retail outlets is unadulterated.

These recommendations are at various stages of consideration. A number of initiatives have been launched to reduce air pollution, especially from vehicles in Mumbai. For example, there have been some improvements in the quality of fuel being supplied in the city. From 1 January 2001, 500-ppm sulfur diesel and 1% (maximum) benzene gasoline has been supplied in Mumbai. CNG has been introduced in the city for use in transport sector and there are further plans for expanding the dispensing facilities. Other measures such as the Pollution Under Control (PUC) test for vehicles have been initiated—this test is mandatory every six months. The concept of "No PUC, no Fuel" has also been introduced, and vehicles without valid certificates are not given fuel.

[3] (Office of the Transport Commissioner, 2000)

With the High Court acting on the recommendations of the V. M. Lal Committee report, and a greater consciousness among the public, more initiatives aimed at reducing vehicular pollution are likely to improve the air quality in Mumbai.

Air Quality

The Municipal Corporation of Greater Mumbai (MCGM) regularly monitors air quality for the criteria air pollutants, SO_2, NO_2, PM and lead (Pb) (MCGM, 2001). MCGM's ambient air quality monitoring network comprises six receptor sites in different parts of Mumbai, with most of them located on the roofs of municipal schools. MCGM has a network of 22 fixed monitoring stations in commercial, industrial and residential areas. Air quality levels for major pollutants are also monitored at the main traffic junctions. Apart from this, the Maharashtra Pollution Control Board (MPCB) and MCGM also monitor air quality using mobile vans.

The Comprehensive Transport Plan for Bombay Metropolitan Region, a study carried out by WS Atkins International in 1994, reports that air pollution due to road traffic increased by almost 400% in the period 1973 to 1991. This rose from an estimated 399 tonnes of pollutants per day to 1538 tonnes per day (WS Atkins International, 1994). Of the different vehicle modes, motorcycles, scooters and autorickshaws were estimated to produce 34.5% of the total pollutants; trucks and buses produced 33.2% and cars produced 32.4%.

Another study by WS Atkins International in 1997 revealed that the concentration of total suspended particulate matter, particularly PM_{10}, was significantly higher than the standards prescribed for residential areas (WS Atkins International, 1997). The 24-hour average PM_{10} was reported to be 190.2 $\mu g/m^3$ on 17–18 May 1996, substantially more than the standard for residential areas, 100 $\mu g/m^3$. The main reason cited for the higher levels of PM and PM_{10} was re-suspension of dust particles due to vehicular traffic.

One of the most comprehensive studies carried out on the status of the Mumbai's environment is URBAIR by the World Bank in 1996–1997 (World Bank, 1996). The study reported an increase of almost 50% in the annual average concentration of total suspended particles between 1981 and 1990, from 180 $\mu g/m^3$ to approximately 270$\mu g/m^3$. According to the study, the World Health Organization (WHO) and national guidelines for PM_{10} are frequently and substantially exceeded in Mumbai. The study also reported that PM_{10} exposure in 1982 was much higher than WHO air quality guidelines, with the maximum values as high as six times those in the guidelines. The concentration of NO_x in this period rose by almost 25% while that of SO_2 declined. The suspended PM continues to be an area of concern.

TERI completed a study in 1997 titled the "Environmental Aspects of Energy Use in Large Indian Metropolises," which reported that the maximum PM concentrations increased gradually (TERI, 1997). Average PM concentrations between 1980 and 1993 increased from 500 $\mu g/m^3$ in the mid-1980s to around 700 $\mu g/m^3$ in the early 1990s. The average concentration of SO_2 gradually decreased between 1983-1993, with a slight variation in the dispersion. The average concentration of NO_x, increased between 1983 and 1987 with values ranging between 30 and 80 $\mu g/m^3$, and was stable in the period 1987-1993 ranging around 35 $\mu g/m^3$.

The air quality levels evaluated by the MCGM for the period of 2000-2001 for its compliance with national ambient air quality standards (NAAQS) revealed that pollution related to SO_2, NO_2 and lead is not as severe as that related to PM (MCGM, 2001). The annual average ambient air quality levels for various pollutants for the year 2000-2001 are given in Table 3.1.

Table 3.1

Ambient Air Quality Levels at Fixed Monitoring Stations in 2000-2001

Annual Average

(μg/m^3)

Stations	SO_2	NO_2	PM	Pb
Worli	23	31	172	0.17
Khar	16	69	290	0.28
Andheri	16	39	219	0.14
Borivili	7	14	148	0.12
Tilaknagar	25	38	253	0.28
Maravali	26	65	373	0.25
NAAQS for residential area	60	60	140	0.75

Note: A minimum of 104 measurements in one year were taken twice a week, 24-hourly at uniform intervals.
Source: MCGM, 2001.

However, levels of SO_2 and NO_2 exceeded the 24-hour standards 1% to 36% of the time in 2000-2001. PM levels, on the other hand, exceeded the standards (24-hourly and annual average) at all sites 24% to 87% of the time.

Air quality monitored at traffic junctions in the year 2000-2001 reveals that NO_2, and respirable suspended particle (RSP) levels exceeded the average 24-hour standards at all the sites (Figure 3.1). SO_2 levels were within the limits at all sites except one where the concentration exceeded the NAAQS. A comparison of the air quality levels in 2000-2001 and 1999-2000 at traffic junctions revealed that NO_x concentrations had come down by 34–40%, while RSP levels were down by 16–37%. The ambient air quality levels at traffic junctions recorded by mobile vans are given below in Table 3.2.

Table 3.2

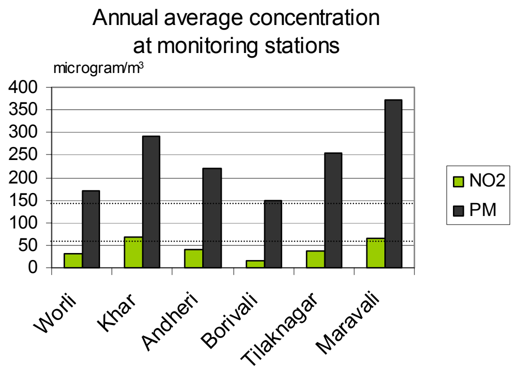
Ambient Air Quality Levels at Traffic Junctions, 24-Hourly Average

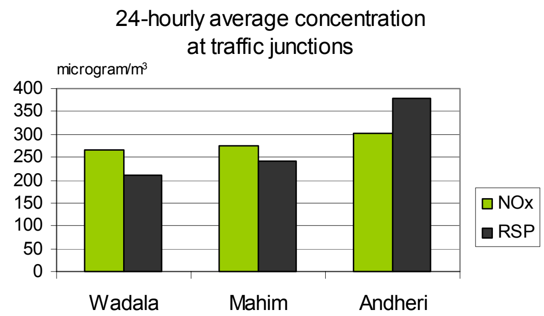
(μg/m^3)

Pollutants	NAAQS	Wadala		Mahim		Andheri	
		2000-2001	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000
SO_2	80	25	62	36	50	159	98
NO_x	80	266	446	276	419	302	520
RSP	100	212	338	242	291	378	520

Note: All these values should be met 98% of the time in a year, however, they may be exceeded for 2% of the time, but not on consecutive days.
Source: MCGM, 2001 and 2000.

Figure 3.1
Critical Pollutants and their Ambient Levels in 2000-2001





Air pollution levels are generally low during the monsoon season and high in the winter. The seasonal fluctuation is attributed to meteorological conditions, such as wind direction, turbulence and frequency of inversion, rains etc. This has multiple effects. Dispersion of pollutants is fast due to high turbulence and washing down of pollutants by rain. On the other hand, pollutants accumulate because of frequent inversion stable conditions in the winter.

Major Sources of Pollution

According to the Environmental Status Report of Greater Mumbai, the major sources of pollution in Mumbai can be categorized as industrial, transport and domestic. Table 3.3 gives the daily emission loading of pollutants in the city from these sectors with a total loading level of 768 tonnes per day in 2000-2001. Table 3.3 also provides the sector-wide distribution of the emission load for different pollutants.

Table 3.3
Emission Loading in Mumbai City and Sectoral Contributions: 2000-2001

Sources	Unit	SO_2	PM	NO_x	CO	HC	Others	Total
Domestic	%	10.27	0.43	4.20	-	-	-	1.78
Industrial	%	64.80	36.07	13.50	0.34	0.37	10.26	10.81
Refuse burning	%	0.15	3.97	0.17	1.30	-	7.82	1.18
Transportation	-							
A Diesel	%	23.68	50.93	66.29	12.66	27.25	81.23	29.28
B Gasoline	%	1.10	8.60	15.84	85.70	72.38	0.69	56.94
Total	Tonnes/day	72	35	147	416	73	25	768

Source: MCGM, 2000-2001.

Over the years, the emission load from the industrial sector has shown a decline because some industries have closed down, shifted to other states, or changed fuel. There is also a ban on the use of coal as a fuel in the city. This has considerably reduced the levels of particulate matter of anthropogenic origin. However, the contribution of the transport sector to the emission load has shown an upward trend as a result of the rapidly growing vehicle fleet. The emission load from the transport sector alone accounted for 86% of the total pollution load in 2001 (MCGM, 2000-2001). The contribution of the transport sector has increased by over 20%

from 551 metric tonnes per day (MTPD) compared to 1999-2000, and by over 30% (from 501 MTPD) as compared to its level in 1998-1999 (MCGM, 2000 & 1999).

Changes in Energy Consumption

Even though India has oil and gas reserves, it depends substantially on imports to satisfy the growing demand for petroleum products. The rapidly growing vehicle fleet has made the transport sector one of the major users of petroleum products. The transport sector in India consumed approximately 35% of all petroleum products in 1994 and is heavily biased towards road-based modes, which together accounted for over 32% (WS Atkins International, 1994). The fuel consumption from road-based transport is further increased by traffic congestion: at a vehicle speed of less than 10 kph, motor vehicles' fuel consumption can be 60–100% higher than that of free-flowing traffic at an average speed between 35–50 kph.

Generally, the passenger transportation sector in Mumbai depends heavily on public transport—rail and road—as compared to other modes of transport. Even with relatively low energy intensive transport activities, the vehicular pollution in Mumbai is reaching alarming proportions due to an increase in private motor vehicles, traffic congestion, type and age of engines, etc. In 2000, Mumbai's vehicle fleet was 967,000 with a growth rate of 7% over the previous year. Of this, around 76% are private vehicles, 16% intermediate public vehicles, 6% heavy vehicles and 1% buses. The traffic density at peak hours is so high that vehicles move at a speed of five to eight km/h, which increases fuel consumption.

Over the last two years in Mumbai, diesel consumption has decreased by over 10% from 551 to 486 thousand kiloliters (KL)/year (Table 3.4). Gasoline consumption during this period increased marginally by 2% from 375 to 388 thousand KL/year (Table 3.4). The increase in gasoline consumption can be explained by a 3% increase in gasoline vehicles over this period. However, the increase in the number of HSD vehicles by 8% is contradictory to the decrease in consumption. Possible explanations for the decline in diesel sales are the depressed economic condition, improved technology fuel efficiency of vehicles, etc. Around 24,000 taxis/cars, a small proportion of the autorickshaws (around 1,200), and 46 buses are operating on CNG. CNG consumption in Mumbai has more than doubled between 1988 and 2001 from about 18 to 41 million standard cubic meters (SCM) during this period. Apart from this, a certain proportion of the vehicle fleet has shifted to CNG, which might have influenced the consumption of liquid fuels.

Table 3.4

Sales of Gasoline, Diesel and CNG in Mumbai for 1998-2001

Year	MS* (KL)	Diesel** (KL)	CNG (in thousand SCM)
1998-1999	375197	551430	18062
1999-2000	363755	540532	23358
2000-2001	388633	486622	40957

* Motor Spirit (MS) sales include only sales through retail outlets.

** Diesel sales include sales through retail outlets as well as consumer pumps.

Source: Personal communication with BPCL.

Given Mumbai's rapidly growing population and higher per capita income, transportation demand and energy use is likely to show an upward trend. Hence, emissions from the transport sector will become more and more relevant to air pollution. If an efficient public transport system and efficient and low or non-polluting personal vehicles can meet this increasing demand, the emissions can be controlled.

CHAPTER 4

Review of Clean Fuel Policies Around the World

Both industrialized and developing nations have taken major steps in recent years to control vehicle emissions and improve fuel efficiency. Strictly enforced programs in several countries have produced impressive emissions reductions and improvements to fuel efficiency over the last decade, indicating the potential for improvement in countries with younger programs. Emerging technologies, in combination with suitable government policies, offer hope for dramatic emission reductions in the future. The role of clean and environmentally friendly fuels (both cleaner conventional fuels and alternative fuels) has become very important in this context. Automobile manufacturers are introducing new technologies such as catalyzed particulate traps, oxidation catalysts, continuously variable transmission, lightweight materials, advanced gaseous-fuel engines, turbo-charging and after cooling, electronic engine magnetic controls, battery operated and fuel cell vehicles in an effort to reduce vehicular emissions.

Clean Fuels

CNG and ULSD with maximum 0.005% sulfur content (when used with exhaust fitments such as CRT) are considered to be "environmentally acceptable" fuels. International experience reveals that these clean fuels result in substantial reductions in vehicular pollution.

There is general agreement in the literature that when used with CRT, ULSD produces comparable emission results for all regulated pollutants except NO_x when compared to CNG vehicles equipped with catalyst (Barton, 1997; Lanni, et al 2001; Chatterjee et al, 2001; Lev-On et al, 2001; Walsh, 1998). It is generally felt that CNG is particularly suited to small commercial vehicles such as taxis and autorickshaws, which are seldom used for long-haul travel or to carry heavy payloads. For heavy-duty vehicles such as buses, recent literature reveals that buses powered by CNG—long viewed as the cleanest alternative to diesel buses—are no better if scientific, technological, social and economic and financial factors are taken into account (Sierra Research Inc., 2000). Without any doubt, buses using high-sulfur diesel are a major source of particulate emissions. However, simply changing the fuel to CNG is not the only option; it may be necessary, but not sufficient. Moreover, it imposes an enormous burden in terms of infrastructure such as pipelines, gas-filling stations, and new engines.

It is increasingly clear as emissions regulations become more stringent that fuel properties and vehicle technologies must be closely intertwined and should be treated as an integrated system. A reduced lead or sulfur content is a prerequisite for introducing advanced vehicle technologies. Having eliminated lead from much of the world's supply of motor fuels, many regulators now see ULSD as crucial to meeting air quality goals, and are aggressively reducing fuel sulfur levels (The Energy Foundation, 2002). Sulfur in diesel fuel produces harmful sulphate particulate emissions. Sulfur also has a variety of negative effects on the most promising technologies for controlling NO_x, particulate and toxic emissions from diesel vehicles.

Many other fuel properties, such as aromatic content and Reid vapor pressure, must be controlled to enable maximum emissions reduction at the lowest cost. Refineries are beginning to produce reformulated, very low sulfur fuels that enable the use of advanced emissions technologies, such as all refineries in the UK. It is important to set specifications for any alternative fuel being introduced because variations in fuel composition can impair vehicle performance and result in higher emissions.

Vehicle emissions depend on a number of factors: engine rating, city driving cycle and traffic speed, fuel efficiency, and occupancy level. Tests have been conducted in different countries for evaluating the emission levels of buses operating on CNG and ULSD. Based on these field trials, city transit authorities have arrived at a policy on auto fuel and technology.

The literature review completed during the course of this study and the case studies referred to below indicate that along with advances in engine technology, post-combustion ECDs and cleaner fuels will be necessary to reduce emissions of fine particulates from diesel vehicles to acceptable levels. For example, a study sponsored by the Manufacturers of Emissions Controls Association at Southwest Research Institute found that particulate filters substantially lower the mass of PM, the number of ultrafines, and the overall toxicity of diesel fumes (MECA, 1999).

EVALUATION PROGRAMS FOR CLEANER FUELS AND VEHICLE TECHNOLOGIES FOR BUSES WITH HEAVY-DUTY ENGINES

In India, public transportation buses, which have heavy-duty diesel engines, form the backbone of urban public transport services and form a sizeable share. For instance, in many large Indian cities such as Mumbai, Delhi, etc., buses form about 1% of vehicles but meet over half the travel demand. Existing diesel buses may actually have higher emissions than a new CNG bus. However, vehicles manufactured to the same emissions standard would be very similar with respect to emissions. The widespread use of old diesel buses running on relatively poor quality fuel has raised concerns regarding the potential health effects of exhaust emissions from such engines. Of particular concern is diesel suspended particulate matter (PM) and nitrogen oxides (NO_x). Therefore, CNG is considered a cleaner fuel than the diesel currently available on the market. It may be true that a dedicated CNG bus fitted with an ECD, like a three-way catalyst, or a diesel bus operating on ULSD equipped with after treatment devices would meet the Euro 4 emissions standards. However, these emission results are based on tests carried out under laboratory conditions without subjecting the engine to the stresses and strains that it would normally be subjected to in any specific country driving cycle. Congestion, overloading, poor maintenance, adulterated fuel, poor roads—realities that cannot be wished away—all take their toll; solutions that appear simple and effective on paper turn out to be complicated and ineffective in practice.

An engine dynamometer test of heavy-duty engines gives the emissions of regulated pollutants in gram/kWh. The real test is the chassis dynamometer test because it simulates city driving conditions and records emissions in gram/km. Ideally, the tests need to mimic a typical bus journey on city roads—a mix of fast and slow stretches, low average speeds, frequent stops at traffic intersections to pick up and discharge passengers, extended idling times, and so on. These conditions are then accurately reproduced in a laboratory as a typical test cycle with a chassis dynamometer to evaluate the emissions from modern buses powered by CNG, low sulfur diesel (0.05% S) to ultra low sulfur diesel (0.005% S), each equipped with ECDs. International experience suggests that field trials of clean fuel buses equipped with ECDs, coupled with laboratory tests done on a chassis dynamometer test bed, are absolutely essential under local conditions to evaluate the technological and economic feasibility of a particular technology. Field trials performed under just these conditions were commissioned by the London Transport Board and New York City Transit Authority and provide concrete examples. The tests mimicked a typical bus journey on city roads. The emission results of these bus experiments are summarized below.

The London Experiment

Rigorous and comprehensive studies conducted in central London show that buses using a combination of ULSD, which contains only 0.003% sulfur, and CRTs (continuously-regenerating particulate traps) have substantially less PM_{10} emissions compared to those emitted by buses using CNG with an oxidizing catalyst (see Table 4.1). These buses also emit significantly lower quantities of hydrocarbons and carbon monoxide but slightly more nitrogen oxides than those using CNG do.

Table 4.1

Millbrook London Bus Test Cycle Engine Emission Comparison on a Chassis Dynamometer Test Bed

(grams/km)

Technology	HC	CO	NO_x	PM_{10}
Euro 2 bus + LSD + No ECD	0.61	1.29	14.27	0.18
CNG bus + oxidising catalyst	3.01	0.66	9.92	0.05
Euro 2 bus + ULSD + CRT	0.14	0.20	11.90	0.02

Source: Barton, 1997.

The London Transport Board has shown its commitment to improving their environmental performance. London Buses are responsible for the contracts of over 800 bus routes with some 5,500 buses in its fleet. In 2000, around half of the London bus fleet had Euro 2 engines and 30% of them were fitted with after-treatment devices. All buses in London have been operating on ULSD (with 50 ppm maximum sulfur diesel) since 2000.

The New York Experiment

The US Government sponsored emissions testing research on PM filter-equipped New York Metro Transit Authority (MTA) buses fuelled with ULSD (0.003% sulfur) beginning in February 2000. This is a fleet demonstration program in which 25 buses equipped with JM's "CRT" soot-catalyzed filter and using ULSD have been in service in Manhattan for one year without any problem. In addition, one entire depot with 140 buses was operated on LSD but without CRTs for one year. Environment Canada's laboratories have carried out emissions testing with a chassis dynamometer, using the Central Business District (CDB) and the much more aggressive New York City (NYC) bus test cycles. Trials conducted by New York City Transit following the NYC bus test cycle showed ULSD buses equipped with CRT emitted less of every pollutant except nitrogen oxides (see Table 4.2). The results are quite similar to the emission results of the London Bus experiment.

Table 4.2

Comparison of CNG and ULSD Buses in New York (grams/km)

Driving cycle	New York Bus Cycle	
	CNG	ULSD
PM	0.044	0.023
NO_x	32	45
Total HC	42	0.038

Source: http:/www.epa.gov/OMS/retrofit/documents/nyc_crt_presentation.pdf 2001. "Interim Report: Emissions Results from Clean Diesel Demonstration Program with CRT™ Particulate Filter at New York City Transit.
Note: Heavy-duty diesel buses (1999 model year) using diesel containing 30-ppm sulfur and Johnson Matthey's CRT filter system (but not lean deNO_x catalysts); CNG buses (1996, 1998 and 1999 model year) equipped with oxidation catalysts.

Experimental results show that clean diesel technology relies on dramatic reductions in the level of sulfur in diesel fuel (sulfur content of below 50 ppm and preferably even below 10 ppm) to enable the use of such emission control devices as CRT for reducing fine particles and lean NO_x catalysts for reducing oxides of nitrogen. Limited available data indicate that CNG may not have measurable advantages over the state-of-art clean diesel technology for particulate emissions, as can be seen from Table 4.2.

Based on the success of the pilot program, NYCT is committed to aggressive implementation of a clean diesel technology fleet-wide. NYCT has already converted its entire fleet to ULSD. Also, 250 buses are equipped with catalyzed filters and their plan is to equip an additional 3,500 buses with these filters by December 2003.

The California Experiment

Sierra Research, Inc. (2000) has carried out a comparative analysis of the emission benefits, costs, and cost effectiveness of meeting the proposed standards using both diesel and natural gas engine buses in California. To control emissions of PM and NO_x from heavy-duty diesel vehicles in California, the California Air Resources Board (CARB) has adopted a two-pronged strategy for only urban transit buses. In the short run, transit districts are required to choose between two pathways, one where districts will use diesel-fuelled buses and another where districts will employ natural gas-powered buses. Different emissions standards would apply to diesel and natural gas powered buses between now and 2003; however, from 2004, engines using either fuel would have to be certified to the same standards.

Further, Table 4.3 as reproduced from Sierra Research Inc. (2000), compares the emission reduction potential and cost-effectiveness of future diesel and natural gas powered heavy-duty vehicles based on CARB's on-road motor vehicle emissions inventory model.

Table 4.3

Cost-Effectiveness Ratio for Transit Buses in California

Action	Emission Reduction over lifetime (tons per vehicle)		Cost ('000$/vehicle)	Cost-Effectiveness ('000$/ton)	
	NO_x	PM		NO_x	PM
1. Substitute current natural gas engine for current diesel engine	3.5	0.03	35-75	10-20	1,167-2,333
2. Add exhaust gas recirculation and after-treatment to current diesel engine	6.1	0.05	11-15.2	1.8-2.5	220-304
3. Substitute natural gas engine with after-treatment for diesel engines with exhaust gas recirculation and after treatment	0.5	-	37.5-72.5	70-140	-
Maximum Acceptable Cost-Effectiveness Ratios for NO_x and PM Control Measures based on CARB guidance ('000$/ton)				24	10

Source: Sierra Research, Inc. 2000, page 3.

Table 4.3 reveals that the cost-effectiveness ratios for PM and NO_x reductions achieved through the substitution of natural gas engines for diesel engines are all higher than those computed for application of exhaust gas recirculation and diesel engine after-treatment devices. Sierra Research Inc. (2000) concludes that the substitution of natural gas engines as a means of reducing emissions from heavy-duty vehicles is not cost effective.

In the US, as a result of clean fuel initiatives in the Clean Air Act Amendments of 1990 and the Energy Policy Act of 1992, 36 states have developed programs mandating fleet conversions or adopting conversion incentives.

CURRENT BUS EVALUATION PROJECT IN INDIA

In India, TERI collaborated with a number of other agencies and the UK government to commence field trials on Mumbai's buses in May 2002. This involved advanced technology and fuel combinations under city driving conditions as is being done in developed countries. The overall scope of the project is to carry out a comparative evaluation of exhaust emissions of Indian buses with and without ECD, and powered by CNG and different grades of diesel (different grades of sulfur in diesel, from 500 ppm to 50 ppm) when operated under similar conditions. Each diesel bus is Euro 2 compliant and manufactured in India. Each CNG bus has a stochiometric engine and is equipped with a three-way catalytic converter. More specifically, the project objectives are to:

- Compare the emission characteristics of Euro 2 diesel buses equipped with ECD, operating on ULSD (i.e. 50 ppm sulfur) with buses equipped with a three-way-catalyst, operating on CNG.
- Compare the emission characteristics of Euro 2 buses with and without ECD, operating on 500 ppm and 350 ppm sulfur diesel.
-

International Experience on Cleaner Fuels

CNG

Many countries are known to use CNG as an automotive fuel. In most parts of the world, NGVs are introduced to replace cars and taxis as well as buses and other public vehicle fleets. This has become increasingly popular in European countries and some developing countries like Argentina, Mexico, Egypt, People's Republic of China, etc. Forty-seven countries now have natural gas vehicles (see Annex 4.1). CNG buses account for only an insignificant share of city fleets world wide except for a few cities in India (Delhi), People's Republic of China (Beijing) and the US (Los Angeles). The number of buses operating on CNG is given in Table 4.4. The CNG experience of some countries is also given below.

Table 4.4
Number of Buses Operating on CNG in Major Global Cities in 2000

Country / City	Total buses	CNG buses	% of CNG buses
US			
Dallas	810	22	2.71
Los Angeles	2638	795	30.10
New York	5675	358	6.30
New Jersey	3094	55	1.79
Canada			
Toronto	1500	125	8.33
Vancouver	1006	51	5.06
Germany			
Berlin	1700	10	0.58
France			
Paris	4000	53	1.32
Italy			
Rome	2383	40	1.67
Spain			
Barcelona	800	2	0.25
Madrid	1000	15	1.50
Greece			
Athens	1500	40	2.67
Australia			
Sydney	3900	254	6.51
Brisbane	1100	12	1.09
Perth	850	52	6.11
Melbourne	1400	24	1.71
PRC*			
Beijing	10000	1640	16.4
Shanghai	18500	330	1.78
Republic of Korea*			
Seoul	8200	450	5.5
India*			
Delhi	10065	4231	42
Mumbai	10599	46	0.5

* In PRC, Republic of Korea and India the number of total city buses presented are the 2002 data.
Source: Zero Draft Revision - II Final Report of the Expert committee on Auto Fuel Policy, 5 July 2002, Chapter 8; Indian data is taken from http://www.ndtv.com as of 27 June 2002 for Delhi.

Argentina

The greatest penetration of CNG is in Argentina, with a NGV population of 721,830 as of October 2001. In 1984 the Argentine government launched its "Compressed Natural Gas Project". The initial policies to encourage CNG included strict standards, a differential of over 65% between gas and liquid fuel prices (the government offered no subsidies, instead the incentive for fuel switching stemmed entirely from high gasoline taxes), a guaranteed gross margin for filling stations, and support for the local conversion kit industry. In December 1999, the fuel prices were $ 1.04 per litre of premium gasoline, US $ 0.50 per litre of diesel and US $ 0.33 per cubic meter of natural gas (US $ 0.41 per kg). The bulk of the Buenos Aires taxi fleet converted to CNG as a result of these initiatives. Most of the CNG vehicles are those which converted from gasoline vehicles. There has been little conversion from diesel to CNG because the price differential between CNG and diesel is insufficient to recover the incremental cost of NGVs within a reasonable period. As a result, there are no CNG buses in regular operation in the country. In fact, diesel is actively competing with CNG to capture the taxi market from CNG[4].

Europe

The penetration of NGVs is increasing rapidly in Europe—the largest natural gas country members are Italy, Germany, France and the UK. With 380,000 mostly commuter vehicles and 369 mainly public fuel stations (as of November 2001), Italy has lead the NGV initiative and has only recently been outpaced by Argentina. Italy introduced a low level of taxation on natural gas in 1999, to rise incrementally over the next five years but still remain lower than diesel or gasoline taxes. The country is embarking on a significant expansion program to increase both the number of vehicles running on NG and refuelling stations, with plans to double both by 2005. However, public transport buses operating on CNG comprise a very small proportion of the total NGVs in Italy (Watt, 2000).

In France, the number of NGVs is increasing steadily and as of October 2000, there were 4,550 NGVs operating in the country. It has developed a good network of CNG stations along the country's road network and has introduced CNG fuelled buses in half its cities with populations over 200,000. Gaz de France (GdF) is responsible for supplying natural gas in France and has 3,000 NGVs in its own fleet, making it the largest in Europe. In 2000, there were 350 natural gas buses in France. About thirty cities have chosen NGV buses (Watt, 2000). The French government maintains a long-term outlook for the development and use of alternative fuels, particularly in its municipal fleets. Cooperation agreements for NGVs have been signed between the government and industry. In addition, various non-financial policies are also offered to promote natural gas vehicles. For instance, Paris allows all natural gas vehicles to drive in the city on high-pollution days, when standard vehicles (gasoline and diesel powered) are restricted to even or odd license plate numbers.

The German NGV market has been most expansive, and from a handful of vehicles in 1994 grew to more than 10,000 in January 2001 supplied by over 146 refuelling stations. A very small proportion of these vehicles belongs to the public transport (heavy-duty vehicle) category. In 2000, there were around eighty buses operating on natural gas in the country. The NGVs are promoted through rebates and tax incentives. Germany offers a low tax on CNG (15% of the service station price), and their government is committed to maintaining the low tax rate until 2009. The tax benefit for using CNG will be even more attractive in 2003, when a new ecological tax will be levied on petroleum fuels.

In the UK, the penetration of natural gas vehicles is mostly focused on municipalities, with about 22 municipalities having NGVs. There were 18 refuelling stations and approximately 835 NGVs in the country in 2000. A government funded group called Powershift offers grants to help offset the incremental price of cleaner vehicles, giving subsidies of 45–70% for conversions of vehicles to CNG or LPG to promote clean fuels[5]. Since 1993, the fuel excise duty on gasoline and diesel has increased by 6% per year in real terms while the actual duty on CNG has been frozen or reduced each year. In the 2001 budget, duty rates on CNG and LPG were cut by 25% so as to maintain the differential between these cleaner fuels and gasoline and diesel. NGV buses in public transit use receive a 100% rebate of the fuel duty equivalent to 36 UK pence/litre. The economics remain insufficient, however, to encourage fleet operators to

[4] http://lnweb18.worldbank.org/SAR/sa.nsf/a22044d0c4877a3e852567de0052e0fa/2f391e72031478f685256b17006ff5bb/$FILE/urban2.pdf as on 25 February 2002.

[5] www.westport.com

switch to natural gas. Hence, the number of buses operating on natural gas is very few (Watt, 2000).

United States

The number of natural gas buses in operation has grown from 100 in 1992 to 3,204 in 1999 and 5,000 by 2000 (American Gas Magazine, November 2000). More than fifty companies in the US operate their fleet vehicles on CNG. As of January 2001, there were approximately 102,430 NGVs in the U.S. and over 1,250 refuelling stations. The Los Angeles County Metropolitan has a very large CNG powered bus fleet. By 2005, the transit operator intends to have more than 99% of its fleet fuelled by natural gas[6]. In order to promote clean fuels, Los Angeles allows natural gas vehicles to use highway bus lanes. Furthermore, a federal income tax deduction ranging from $2,000 to $50,000 is offered as an incentive for purchase or conversion of individual Alternative Fuel Vehicles.

Japan

The number of NGVs is around 10,659 with 152 quick refuelling facilities as of January 2002. There are about 460 buses that operate on CNG. The movement to promote popularization of clean energy automobiles gained momentum in December 1997. The Japanese government is committed to replace all public vehicles with Low Emission Vehicles (LEVs), which include NGVs, electric vehicles, hybrid vehicles, methanol vehicles, LPG and diesel vehicles. The Ministry of Economy, Trade, and Industry, the Ministry of Land, Infrastructure, and Transport and the Ministry of Environment have all announced action plans for the development and spread of LEVs with an aim to have more than 10 million LEVs in use by 2010. The Government has set plans to popularize one million NGVs by 2010, and gives various incentives to promote NGVs and install refuelling facilities.

Pakistan

The number of NGVs in Pakistan is around 200,000 and there are about 200 refuelling stations as of June 2001. These vehicles are essentially gasoline driven vehicles which have been converted to CNG, as the thrust has been on replacing gasoline with CNG (there is a price differential between CNG and gasoline). None of the diesel vehicles have been converted to CNG as diesel is also attractively priced[7].

People's Republic of China

The number of NGVs was around 36,000 and supported by 70 fuelling stations as of January 2001. Much of the focus is on public transport—buses and taxicabs. In People's Republic of China, the guidelines for issuing new vehicles licenses are very strict. Under pressure to clean up the air due to the approaching Olympic Games in 2008**,** Beijing has resorted to an alternative fuel strategy. Latest figures indicate that Beijing will have 18,000 buses fuelled by CNG, LPG and electricity.

[6] http://www.energy-futures.com
[7] As of 16 May 2002; http://lists.isb.sdnpk.org/pipermail/eco-list/2001-July/001717.html

Republic of Korea

The Ministry of Environment (MoE) of the Republic of Korea aims to replace its diesel powered transit bus fleet with CNG buses starting from 2000. They intend to replace up to 20,000 buses and construct 400 gas stations, in nine major cities over a seven-year period. To promote this program, financial aid would be given to buses with a subsidy funded by the MoE and local governments. Also, the MoE has allocated substantial assistance to gas station owners in the form of low interest loans. In addition, CNG will be priced lower than diesel and gasoline. As of December 2001 there were 746 NGVs and 28 refuelling stations.

New Zealand

A CNG conversion program was started in the 1970s and continued through the late nineties. The government of New Zealand was heavily involved in the NGV program, and gave substantial financial incentives for both conversion and establishment of refuelling stations. As a result of these incentives, the number of CNG vehicles doubled every year to reach a total of 110,000. The industry became so preoccupied with meeting the demand for conversion that quality often suffered, and this resulted in a perception of CNG as a secondary fuel used only because it was much cheaper than gasoline. However, the NGV market suffered heavily once the financial incentives were withdrawn, with the number of CNG vehicles declining to a low of about 10,000. In 2000, the number of NGVs in the country was 12,000[8].

Australia

In 2000, there were around 2,100 NGVs and 127 refuelling stations in the country. The government has provided a package of federal programs to help establish the NGV industry. These include the Alternative Fuels Conversion Program which gives up to 50% funding for conversion to CNG, the CNG Infrastructure Program for installing refuelling facilities, the Diesel and Alternative Fuel Grants scheme which ensures that the fuel price advantage of natural gas over diesel is maintained, and the Alternative Fuels Grants scheme for urban buses.

The experience of various countries reveals that financial incentives are essential for CNG programs to be successful. Various kinds of incentives have been given to promote the use of natural gas, such as price and tax differentials between gas and other conventional fuels, government funding, soft loans, etc. for setting up CNG refuelling stations and converting to or purchasing natural gas vehicles, etc. In some countries the withdrawal of incentives has led to reduced popularity of CNG vehicles.

International experience has also revealed that in most countries, the majority of the NGV fleet is comprised of gasoline vehicles that have been converted to CNG. The use of natural gas in public transport is not very widespread. There are no instances in the world where the entire bus fleet of a particular city has been converted fully to operate on natural gas. Also, no country has ever mandated a particular fuel.

ULSD

Across the world, a number of countries are moving towards reducing emissions from diesel vehicles. Diesel vehicles are a significant source of both NO_x and PM in many countries. There-

[8] http://lnweb18.worldbank.org as on 25 February 2002

fore, environment agencies have continued to dramatically tighten exhaust emissions standards. In an effort to enable manufacturers to achieve these low pollution levels, fuel quality improvements—especially with regard to diesel sulfur content—are being mandated. The ULSD experience of some countries is given below.

Sweden

Sweden was the first country to introduce ULSD and its ULSD specifications (city diesel) are among the toughest in the world. ULSD was introduced by the Swedish Government with Environmental Classification E1 (less than 10 ppm S) and E2 (below 50 ppm) from 1 January 1991. The E2 grade was discontinued in 1996. The E1 product was given a very high tax incentive, making it attractive enough for some oil companies to switch all diesel fuel to the E1 grade. The tax differential between E1 and E3 (350 ppm max) was 19 US cents per gallon in 2000. As a result of this high tax incentive, E1 has a market share of almost 100%.

Denmark

Tax incentives of 0.18 DKK/litre for 50 ppm sulfur diesel were introduced on 30 June 1999. The result was a nearly 100% penetration of 50 ppm sulfur diesel in the Danish market from July 1999.

Germany

The government will offer tax breaks for sulfur-free gasoline and diesel from 2003. The tax break of Euro 0.015 (0.014 cts) per litre for fuels with no more than 10 ppm sulfur will be offered from 1 January 2003 until 1 December 2005. The incentives are expected to accelerate the EU-wide shift towards sulfur-free motor fuels. Germany already gives differential tax incentives to encourage transition of its domestic market to fuels containing less than 50 ppm of sulfur.

US

In the US, the Environmental Protection Agency (EPA) issued final rules late in December 2000 to cut sulfur levels by 97% from 500 ppm to 15 ppm. The new standard will be effective for 75–80% of the total diesel fuel supply by June 2006. The remaining suppliers have until late 2009 to comply. Refiners will receive credits, which they will be able to buy and sell, for meeting the standards early.

Japan

The Japanese government has adopted a requirement that all diesel fuel must be under 50 ppm by 2005. The oil industry has announced that they will do even better and has committed that all fuel sold in the country by 2003 will be under 50 ppm. Some fuels with less than 50 ppm sulfur are already being sold to certain bus fleets in Tokyo. The government has announced financial support to public transportation such as city buses, which are introducing effective retrofit systems on a voluntary basis. The total subsidy in 2001 was 200 million yen (US$ 1.6 million).

Hong Kong, China

The Hong Kong, China government adopted a tax incentive scheme in 2000 of concessionary duty of Hong Kong dollars 1.11 per litre, which made diesel fuel with less than 50 ppm sulfur less expensive than diesel fuel with more than 50 ppm. The duty differential of Hong Kong dollars 0.89 was given to offset the higher price of ULSD. As a result, all diesel fuel now sold in Hong Kong, China is 50 ppm or less.

Thus, international experience in the use of ULSD reveals that financial incentives like tax differential and credits have encouraged refineries to start producing ULSD.

USE OF FISCAL INSTRUMENTS TO PROMOTE CLEAN FUELS

In order to encourage clean, alternative fuels for vehicles, countries have resorted to both command-and-control measures and economic incentives. Many developed and developing countries have adopted stringent emission norms. Table 4.5 gives a summary of environmentally motivated fiscal policies around the world.

Another strategy used to reduce vehicular pollution has been to encourage the use of new technology and phasing-out of old vehicles. For this, both market-based instruments and command-and-control measures have been used. These include differential vehicle taxation, tax allowances on new car purchase after scrapping the old one, environmental taxes on vehicles not meeting prescribed standards, penalties for violations of air pollution standards, and vehicle phase-out programs whereby vehicles have to scrapped after a certain age. In Singapore for example, the life of certain categories of vehicles is fixed, at the end of which they must be scrapped. While taxis must retire at the end of seven years, buses and goods vehicles are not allowed on the road beyond fifteen years. Also, fiscal incentives are given for replacing older vehicles. The registration fee is waived for replacing older vehicles with the waiver being higher for newer vehicles.

Table 4.5
International Experience

Instrument	Countries
Price differential between leaded and unleaded gasoline	Australia, Britain, Denmark, Finland, Germany, Luxembourg, The Netherlands, New Zealand, Norway, Sweden, Switzerland, Hungary, Mexico, Philippines, Portugal, Taipei,China, Thailand
Price differential between ULSD and ordinary diesel	United Kingdom, Sweden
Tax incentives to promote natural gas	Argentina, Italy, Germany, Australia, Ireland, Russia, Colombia, Canada, Pakistan
Taxes on non-catalytic converter cars	Finland, Sweden, Greece
Higher tax on diesel cars	Germany
Incentives for natural gas vehicles	Belgium, UK, US, Australia, Ireland, Egypt, Malaysia
Vehicle taxes based on emissions	Austria, Belgium, Britain, British Colombia, Germany, Japan, Netherlands, Sweden, Republic of Korea
Annual road tax differentiated by vintage	Germany
Emissions trading	Chile
Tax on lead acid batteries	British Colombia, US
Congestion pricing	Norway, Chile

Source. Pandey, 2000, www.engva.org.

India's Experience

In India, vehicular pollution has become the major source of air pollution. While CO and HC emissions are mainly on account of vehicles, for the PM & SO_2 emission loading, other sources contribute as well. PM load is contributed by many sources, including industry, power gensets, burning of fossil fuels, re-suspension of traffic dust, natural dust, building activities, etc.

SO_2 is emitted in significant quantities by various industrial processes during numerous reaction and manufacturing processes of different products and in power plants. The Motor Vehicles Act is the principal instrument for regulating motor vehicle traffic throughout the country and its implementation rests with the state governments. However, there is no comprehensive transport policy in any Indian state. India lacks any conscious auto-fuel policy based on field trials and also lacks any policy to manage demand in the transport sector such as in Singapore. It is only the judiciary's intervention that has resulted in some initiatives to curb vehicular pollution.

The first step towards controlling vehicular pollution was taken by the Supreme Court of India in response to a writ petition filed in 1985. The problem of air pollution is severe in the country's metropolitan areas with the capital being most affected. Due to the efforts of the Supreme Court, significant progress has been made on several issues. The status of the issues arising out of the Court's directions is given below.

- Phase out programs for gasoline lead and diesel sulfur: The details of the phase-out program are given in Tables 4.6 and 4.7.

Table 4.6
Phase-out Program for Lead in Gasoline

Phase I	June 1994	Low leaded (0.15 g/litre)	Cities of Delhi, Mumbai, Kolkata and Chennai
Phase II	April 1995	Unleaded (0.013 g/ litre) (+ low leaded)	Cities of Delhi, Mumbai, Kolkata and Chennai
Phase III	January 1997	Low leaded (0.15 g/ litre)	Entire country
Phase IV	September 1998	Ban on Leaded fuel (only unleaded fuel)	NCT Delhi
Phase V	September 1998	Unleaded (0.013 g/ litre) (+ low leaded)	All other capitals of State/Union territories and other major cities.
Phase VI	January 1999	Unleaded only (0.013 g/ litre)	NCR
Phase VII	April 2000	Unleaded only (0.013 g/ litre)	Entire country

Source: TERI, 2001.

Table 4.7
Phase-out Program for Sulfur in Diesel

Phase I	April 1996	Low sulfur (0.5%)	Four metros and Taj Trapezium
Phase II	August 1997	Low sulfur (0.25%)	Delhi and Taj Trapezium
Phase III	April 1998	Low sulfur (0.25%)	Metro cities
Phase IV	April 1999	Low sulfur (0.25%)	Entire country
Phase V	April 2000	Low sulfur (0.05%)	NCR; Mumbai, Chennai and Kolkata (in 2001)

Source: TERI, 2001

- Tightening of vehicular emission norms: In India, the general consensus is to use the European standards. India's emission norms lag behind Europe's by four to five years for all vehicle categories except for two and three wheelers. For these, India 2000 norms are far stricter than Euro 2 norms and are some of the world's most stringent. These norms have been implemented throughout the country since April 2000. The progression in the severity of norms in India and Europe for different vehicle categories is given in Annex 4.2.
- Emissions standards for different vehicle categories including transport vehicles were introduced in 1990 and subsequently modified with stringent standards effective from 1992, 1996 and 2000. Euro 1 norms were brought into force throughout the country with effect from 4 January 2000 for all vehicle categories. However, Bharat Stage II norms (equivalent to Euro 2) were brought into force only in the NCT, Delhi with effect from 4 January 2000 and further extended to the city of Mumbai with effect from 1 January 2001. The Bharat Stage II norms are applicable to vehicles up to 3500 kg GVW (gross vehicle weight). Draft Bharat Stage II norms for commercial vehicles have also been notified and are in the process of being finalized. Catalytic converters have been made mandatory for all four-wheeled gasoline driven vehicles registered in the four metro cities and 45 other cities in the country. From April 1995, along with supply of Unleaded Gasoline (ULG), mandatory fitment of catalytic converters in new gasoline passenger cars sold in the four metros of Delhi, Kolkata, Mumbai and Chennai was effected.
- Phasing out vehicles: In Delhi, commercial vehicles more than fifteen years old have been phased out with effect from December 1998. Buses that are eight years or more have also been phased out. The replacement of pre-1990 and conversion of post-1990 autorickshaws and taxis to clean fuels is in progress in the capital.
- The Court directed that the capital's entire city bus fleet be steadily converted to CNG by March 2001. The date was extended to 31 January 2002. Recently, on 5 April 2002, the Supreme Court imposed a Rs 500 fine effective from 1 February 2002 and Rs 1000 effective from 6 April 2002, on diesel buses which continued to ply the roads against the Court's orders. The apex court also directed that priority should be given for CNG supply to the transport sector all over the country.
- Measures to check fuel adulteration: the Court directed that two independent fuel testing laboratories be established. One such independent laboratory has been commissioned at NOIDA.

The Supreme Court's March 2001 order directed that a report be submitted on clean fuels indicating which fuels can be regarded as clean, non-polluting and not injurious to health.

The Environment Pollution Authority for the National Capital Region in its report to the Supreme Court on clean fuels reported that only non-hydrocarbon fuels such as electricity, solar energy and fuel cells do not emit noxious pollutants (EPCA, 2001). However, these fuels are not yet commercially available for automobiles. The hydrocarbon fuels which are available and which can be regarded as 'environmentally acceptable fuels' under the prevailing pollution levels and available emission control technologies include CNG, LPG and propane. It further stated that ULSD and gasoline (without lead and with reduced benzene level) could be considered environmentally acceptable, provided that they were unadulterated and used in combination engines with after-treatment devices such as particulate traps and catalytic converters. Diesel with 500 ppm sulfur, which is compatible with Bharat Stage II emission norms, cannot be regarded as environmentally acceptable and must be treated as a transition fuel permitted for a limited period only.

On 13 September 2001, the Government of India constituted a committee of experts of national repute, headed by Dr. R. A. Mashelkar, Director General, Council of Scientific and Industrial Research. The committee was to recommend an "Auto Fuel Policy" for the major cities of the country, devise a road map for its implementation, and recommend suitable automobile fuels and technologies, and fiscal and institutional measures. The January 2002 interim report recommended that the Bharat Stage II norms (equivalent to Euro 2 levels) which are in place in Delhi, Mumbai, Kolkata and Chennai should be introduced into the entire country from 1 April 2005 (Expert Committee on Auto Fuel Policy, 2001). Euro 3 equivalent emission norms for all vehicle categories (excluding two-and three-wheelers) should be introduced in the seven mega cities from 1 April 2005 and extended to other parts of the country from 2010. The necessity and feasibility of extending the Euro 3 norms would be reviewed in the light of experience gained after the introduction of Bharat Stage II norms in the entire country. The government has accepted the report.

In Mumbai, a Writ Petition was filed in 1999 in public interest by the Smoke Affected Residents Forum seeking appropriate directions from the High Court with a view to control and reduce vehicular emissions in the city. Some leading Mumbai doctors and cardiologists have averred that up to 40% of the city's inhabitants suffer from respiratory diseases and illnesses such as asthma, bronchitis, etc. According to some studies, children in Mumbai have marked stunted lung development when compared to children in Chennai.

The Mumbai High Court also constituted a committee headed by V. M. Lal, then Transport Commissioner, under an order dated 15 December 1999. The committee has given several recommendations which have been placed before the High Court (see Annex 4.3) and are under various stages of consideration and implementation (Office of the Transport Commissioner, 2000).

The above gives rise to the following points. Nowhere in the world has a particular fuel (except for buses in Delhi) or specific vehicle technology been mandated. Internationally, improved quality fuels and technologies and alternative fuels have been promoted through various kinds of fiscal and other incentives. In India, the Environment Pollution Authority for the National Capital Region has specified CNG, LPG, propane, ULSD and gasoline (without lead and with reduced benzene level) to be regarded as environmentally acceptable fuels. The Government of India should now as a matter of policy provide fiscal and other incentives to promote environmentally acceptable fuels. Separately and as stated earlier, the Mashelkar Committee has suggested a road map for progressive introduction of Bharat Stage II (Euro 2 equivalent) and Bharat Stage III (Euro 3 equivalent) in the entire country by 2010. It is recommended that in order to obtain maximum air quality benefits, the Government should consider moving as quickly as possible towards Euro 4 emission norms, leaving it to the industry and service providers to employ the appropriate automobile technology and fuel. Until this happens, the Government should promote environmentally acceptable fuels.

Annex 4.1

Natural Gas Vehicle Statistics

Country	Vehicles Converted	Refuelling Stations
Argentina	721,830	950
Italy	380,000	369
Pakistan	200,000	200
Brazil	120,000	131
US	102,430	1,250
India	84,150	116
Venezuela	40,962	170
People's Republic of China	36,000	70
Egypt	34,754	60
Russia	31,000	205
Canada	20,505	222
New Zealand	12,000	100
Colombia	12,000	28
Japan	10,659	152
Germany	10,000	146
Bolivia	6,000	17
France	4,550	105
Trinidad & Tobago	4,000	12
Malaysia	3,700	18
Indonesia	3,000	12
Chile	3,000	6
Australia	2,104	127
Mexico	1,600	4
Sweden	1,550	25
Bangladesh	1,000	5
Iran	1000	3
Great Britain	835	18
Republic of Korea	746	28
Holland	574	27
Switzerland	520	26
Netherlands	300	15
Spain	300	6
Belgium	300	5
Turkey	189	3
Thailand	300	4
Austria	182	6
Ireland	81	2
Cuba	45	1
Finland	34	5
Czech Republic	30	11
Nigeria	28	2
Luxembourg	25	5
Iceland	21	1
Poland	20	4
Norway	18	3
Taipei,China	6	1
Denmark	5	1
North Korea	4	1
TOTALS	1,852,479	4,676

Source: http://statistics.iangv.org/#1 as on 20 May 2002.

Annex 4.2
Mass Emission Norms for Indian Vehicles: Notified until 2000 and Auto Industry Plan Beyond 2000

Gasoline Driven Four-wheeled Passenger Vehicles

Pollutant/fuel	1.4.91	1.4.96		1.6.1999	1.4.2000	1.4.2004[a]	1.4.2007[a]
		Without catalytic converter	With catalytic converter	Euro 1	Euro 2	Euro 3	Euro 4
CO (g/km)	14.3-27.1	8.68-12.40	4.34-6.20	2.72	2.2	2.3	1.0
HC (g/km)	2.0-2.9	-	-	-	-	0.2	0.1
$HC+NO_x$ (g/km)	-	3.00-4.36	1.50-2.18	0.97	0.50	0.35	0.18
Maximum Sulfur in fuel (ppm)	-	-	-	-	500	150	50
Year of implementation in Europe				1992	1996/97	2001	2006

[a] Proposed in the Indian auto industry roadmap to the government

Gasoline Driven Two-wheelers

Pollutant/fuel	1.4.91	1.4.96	1.4.2000 Bharat Stage 1	1.4.2005[a] Bharat stage 2	1.4.2009[a] Bharat Stage 3
CO (g/km)	12-30	4.5	2.0	1.5	1.25
HC (g/km)	8-12	-	-	-	-
$HC+NO_x$ (g/km)	-	3.6	2.0	1.5	1.25
Maximum Sulfur in fuel (ppm)	-	-	-	150	50

[a] Proposed in the Indian auto industry roadmap to the government

Gasoline Driven Three-wheelers

Pollutant/fuel	1.4.91	1.4.96	1.4.2000 Bharat Stage 1	1.4.2005[a] Bharat Stage 2	1.4.2009[a] Bharat Stage 3
CO (g/km)	12-30	6.75	4.0	2.25	1.88
HC (g/km)	8-12	-	-	-	-
$HC+NO_x$ (g/km)	-	5.4	2.0	1.88	1.88
Maximum Sulfur in fuel (ppm)	-	-	-	150	50

[a] Proposed in the Indian auto industry roadmap to the government

Diesel Driven Vehicles with Gross Vehicle Weight more than 3.5 Ton

	1.4.92	1.4.96	1.4.2000 Euro 1	1.4.2003[a] Euro 2	Skip[a] Euro 3	1.4.2008[a] Euro 4
CO (g/kW-h)	14	11.2	4.5	4.0	2.1	1.50
HC (g/kW-h)	3.5	2.4	1.1	1.10	0.66	0.46
NO_x (g/kW-h)	18	14.4	8.0	7.00	5.0	3.5
PM for > 85 kW (g/kW-h)	-	-	0.36	0.15	0.10	0.02
PM for < 85 kW (g/kW-h)	-	-	0.61	0.23	0.13	0.02
Maximum Sulfur in fuel (ppm)	-	-	-	500	350	50
Year of implementation in Europe			1993	1996	2001	2006

[a] Proposed in the Indian auto industry roadmap to the government ('Skip' means the auto industry proposed to the Indian Government in mid 2000 to go straight from Euro 2 to Euro 4 equivalent norms for diesel vehicles over 3.5 ton gross vehicle weight and skip Euro 3 norms.)

Diesel Driven Vehicles with Gross Vehicle Weight less than 3.5 Ton

	1.4.92	1.4.96	1.6.1999 Euro 1	1.4.2000 Euro 2	1.4.2004[a] Euro 3	1.4.2007[a] Euro 4
CO (g/km)	14.3-27.1	5.0-9.0	2.72	1.00	0.64	0.5
HC (g/km)	-	-	-	-	-	-
NO_x (g/km)	-	-	-	0.56	0.5	0.25
HC+NO_x (g/km)	2.7-6.9	2.0-4.0	0.97	0.7	0.56	0.30
PM (g/km)	-	-	0.14	0.08	0.05	0.025
Maximum Sulfur in fuel (ppm)	-	-	-	500	350	50
Year of implementation in Europe			1993/94	1998	2001/02	2006/07

[a] Proposed in the Indian auto industry roadmap to the government.
Note: According to the Mashelkar Committee recommendations, Bharat stage II norms (equivalent to Euro 2) should be extended to the entire country by 2005, Bharat stage III norms (equivalent to Euro 3) for all categories of vehicles except for 2 and 3 wheelers should be introduced in the seven mega-cities by 2005 and extended to the rest of the country by 2010.
Source: IIP, 1994; Bose and Nesamani, 2001; Bose 1998; Bose, Sundar and Nesamani, 2000; SIAM, 2000; CONCAWE, 1999.

Annex 4.3
Recommendations of the V. M. Lal Committee

Improvement in fuel quality

- Sulfur content in diesel supplied in Mumbai city should be reduced to 0.05% by 1 October 2000 and this should be extended to the entire state by 1 January 2001.
- Benzene content in gasoline supplied in Mumbai should be reduced from 3% to less than 1% by 1 October 2000 and this be extended to the entire state by 1 January 2001.
- Only reformulated gasoline should be supplied at all gasoline pumps from 1 October 2000 and in MMR by 1 January 2001.
- The sulfur content in diesel to be supplied should be further reduced to 0.035% by 1 April 2003 and to 0.005% by 1 April 2005. For the entire state by 1 October 2003 and 1 October 2005.
- The sulfur content in diesel supplied all over the country should be reduced to 0.05% by 1 October 2001.

Use of alternative fuel such as CNG/reformulated gasoline

- The Development Control Regulations, 1991 of the MCGR should be amended to enable setting up of CNG outlets at some of the existing gasoline pumps which are located in residential areas.
- BMC should create a single window clearance mechanism to expedite clearing of MGL proposals to open new CNG outlets.
- 5 CNG outlets should be opened in South Mumbai latest 30 September 2000.
- At least one existing retail outlet of each public sector oil company should be converted to supply CNG exclusively by 31 March 2001.
- Retail price of CNG should be kept at a significantly lower level than price of HSD.
- MGL should open around 10 new CNG outlets every year for the next 5 years so that the maximum waiting time for any vehicle does not exceed 5 minutes.
- Use of LPG as an automobile fuel must be permitted by MoST by 30 June 2000. The safety standards and specifications for the equipment must be laid down by the same date.
- Oil companies must plan for supply of reformulated gasoline for all metropolitan cites by 1 October 2000.

Desirability and feasibility of converting existing buses/taxis to CNG.

- All new buses to be purchased by BEST should be operated on CNG until Euro 2 compliant engines become available in these new vehicles, with effect from 1 May 2000.
- BEST may exercise option in having either CNG operated buses (which are preferable) or Euro 2 or higher version diesel engine buses such that by 1 April 2005, at least 1000 buses are operated on CNG.
- Engines of all the existing BEST buses must be changed to Euro 2 compliant engines by 1 October 2002.
- All MSRTC buses operating in and out of Mumbai should have Euro 2 compliant engines by 1 October 2002.
- All private contract buses registered and operating in MMR should have CNG or Euro 2 compliant engines by 1 January 2002.
- All taxis above age 15 years must be converted to CNG or any other cleaner fuel (LPG/CNG) by 1 January 2001.
- All diesel taxis above 8 years of age should be converted to clean fuel by 1 January 2002.
- All 3 wheelers above 10 years of age should be converted to CNG or any other clean fuel with effect 1 January 2001.
- All 3 wheelers above 8 years of age should run on clean fuel.

- Phasing out vehicles over a certain age limit
- The maximum age of all types of vehicles plying the metropolitan cities as well in the rest of the country should be specified by MoST by 31 December 2000.
- All 2 wheelers registered in MMR above the age of 15 years must be scrapped and their registration deemed to have been cancelled with effect from 1 January 2001.
- All 3-wheelers registered in MMR above age of 10 years shall be scrapped unless converted to clean fuel.
- All transport vehicles except 3 wheelers and BEST buses over the age of 15 years shall be scrapped unless converted to clean fuel with effect from 1 January 2001.
- All private cars older than 20 years shall be scrapped unless converted to clean fuel with effect from 1 January 2001.
- With effect from 1 January 2002, all transport vehicles over 8 years plying Mumbai city (except BEST buses) would be scrapped unless converted to clean fuel. The stipulated age would be subject to modification, if any.
- All BEST buses older than 20 years shall be scrapped or converted to CNG with effect from 1January 2001. With effect from 1January 2002, all BEST buses above 15 years of age shall be scrapped unless converted to CNG.
- BEST should have at least 1000 buses operating on CNG by 1 April 2005.
- No vehicle registered outside the state will be registered in Mumbai if it does not meet the stipulated age requirements or does not operate on clean fuel.
- The vehicle manufacturers should implement a scheme to take back their old vehicles under a buy back scheme for scrapping with effect from 1January 2001.

Actions required in respect of two-stroke 2 and 3 wheelers

- With effect from 1October 2000, only 4 stroke engine 2 and 3 wheelers shall be registered in MMR.
- After 1 July 2001, all 3 wheelers would have to be fitted with catalytic converters.
- After 1 July 2001, all 2 wheelers having 2-stroke engines registered in MMR will fit a catalytic converter.
- The retail outlets of the oil companies would sell pre-mixed gasoline only to 2 and 3 wheeler with effect from 1 October 2000.

Measures to prevent fuel adulteration

- The responsibility of ensuring that diesel and gasoline sold at retail outlets is unadulterated is that of the oil company.
- All tankers carrying gasoline or diesel must be painted wholly in maroon. Tankers carrying kerosene, naptha, NGL, SKO, OCS-93, C-9, benzene and other solvents should be painted wholly in bright yellow. All tankers carrying any other petroleum product should be painted wholly in bright green. This scheme should come into force from 1 October 2000.
- Sales of naphtha and benzene, which are used for adulteration, should be strictly monitored. The Controller of Rationing, Mumbai, should strictly monitor the total quantity imported into Mumbai and its sale.
- The price of imported kerosene should be at par with the price of diesel.
- All refineries should implement the Marker system for detecting adulteration in fuels and lubricants by 31 December 2000 in Mumbai city and 31 March 2001 in the rest of Maharashtra.
- Sale of petroleum products such as Patrex, Rexon, Cixon etc., should be prohibited with immediate effect.
- The price structure of different petroleum products should be rationalized.

Desirability and feasibility of ensuring pre-mixed oil, gasoline and 2 T and banning the supply of loose 2 T oil

- There should be a ban on sale of loose 2 T oil in all gasoline pumps in MMR with effect from 1 October 2000.
- All retail outlets in MMR should sell only pre-mixed gasoline to 2 and 3 wheelers with effect from 1 October 2000.

Assessment of whether the existing emission norms require revision for Mumbai city

- The permissible limit of CO emission should be reduced 3% for 2 and 3 wheelers to bring them at par with emission levels for 4 wheelers. MoST should adopt this revised norm for the entire country by 1 April 2001.
- The permissible limit for diesel vehicles should be reduced from 65 Hartridge Smoke Units to 45 HSU from 1 July 2000. MoST should prescribe the above limits for the entire country by 1 July 2001.
- Norms for other vehicular exhaust pollutants such as NO_x, PM, smoke density of gasoline vehicles etc. should by prescribed by MoST by 31 October 2000 for the metropolitan cities.

Applicability of Euro 1 and 2 norms to vehicles.

- MoST should lay down Bharat Stage II mass emission norms for all categories of vehicles by 30 September 2000.
- Subsequent mass emission norms equivalent to Euro 3 and 4 should be prescribed by MoST by 1 April 2002 so that Euro 4 norms become applicable from 1 April 2005.
- All heavy commercial vehicles and light goods vehicles to be registered in MMR from 1 April 2001 must be Bharat Stage II.

Measures for improvement of emission levels of in use vehicle

- MoST should be directed to prescribe norms and standards of roadworthiness for all transport vehicles by 31 December 2000.
- The system of annual fitness certificates for all transport vehicles should be brought in force by the Motor Vehicles Department with effect from 1 April 2002. Private vehicles must be brought under this system by 1 April 2005.
- For all new vehicles manufactured after 1 April 2001, the vehicle manufacturer will have to give an emissions warranty over the life of the vehicle through an Annual Maintenance Contract.
- All government, semi-government and local authority owned vehicles in-use in Mumbai should fit catalytic converters or convert their vehicles to a clean fuel by 1 July 2001.
- All 2-stroke 2 and 3 wheelers in-use vehicles in Mumbai should be fitted with catalytic converters by 1July 2001.
- All gasoline-driven vehicles registered in Mumbai prior to 1 April 1995 should fit catalytic converters by 1July 2001.
- All catalytic converters supplied by 2 wheeler manufacturers will carry a warranty covering effective working of the catalytic converter over a distance of 30000 km.

CHAPTER 5

Transport Fuel Demand in the Future and Emissions

GROWTH IN VEHICLE NUMBERS

Mumbai is India's industrial and commercial capital and also one of the world's largest and most crowded cities. While the growing population has accommodated itself in the city's suburbs, employment continues to be concentrated in the central business district South; traffic flows from the north to the south between 8 and 11 a.m. and in the reverse direction after 5 p.m. There is considerable pressure on the city's north-south transport links. The total number of motor vehicles in Mumbai in 2000-2001 had reached almost a million, an increase of around 13% from 1998-1999. The vehicle fleet in 2000-2001 was composed of approximately 42% two wheelers, 34% cars, 10% autorickshaws, 6% taxis and 1.1% buses (Table 5.1).

Table 5.1

Mumbai's Motor Vehicle Fleet Growth and Composition (1998-2000)

Vehicle Type	2000	1999	1998
Two wheelers	407,306	379,441	354,799
Cars/jeeps/stationwagons	329,546	310,943	298,905
Taxis	58,696	58,696	58,696
Three wheelers (autorickshaws)	97,565	97,565	97,565
Stage Carriage Buses	3,458	3,458	3,469
Contract Carriage Buses	6,436	6,091	5,888
School Buses	705	703	702
Light Commercial Vehicles (LCV)	52,935	49,937	47,815
Heavy Commercial Vehicles (HCV)	9,193	9,396	9,044
Total	**967,848**	**909,069**	**858,290**

Source. Transport Commissioner's Office, Mumbai, 2001.

Passenger Travel

There are a wide variety of modes and vehicles in use for passenger travel in Mumbai. A substantial portion of the demand is met by public transport, including the suburban railways and the buses operated by BEST. Mumbai is the headquarters of two zonal railways, the Western and Central, which run special suburban services to meet commuter travel demand. Mumbai's bus transport service is run by BEST and is well organized and efficient. The intermediate public transport (IPT), i.e. autorickshaws and taxis, supplements the public transport system. Apart from these, private cars and two wheelers form an increasing portion of the vehicular fleet. The public transport system serves 88% of the trips during the peak travel period. Private vehicles account for 7% of the travel demand while intermediate public transport (taxis) caters to 5% (WS Atkins International, 1994). This study concentrates on road-based transportation only. The travel demand distribution is given in Table 5.2.

Table 5.2:
Trip Distribution of the Total Peak Period Travel Demand in 1993

Category	Number of Trips in Peak Period
Public Transport	1893751 (88%)
Private Vehicles	148167 (7%)
Taxis	112942 (5%)
Total Trips	2154860

Source: WS Atkins International, 1994.

The suburban railways have contributed substantially to handling the growing number of commuters. Three railway systems operate in Mumbai, the Central Railway, the Western Railway and the Mumbai Port Trust Railway. The first two cater mainly to passenger travel while the last operates as a goods transporter. The Central Railway is also responsible for the services of the Harbour Line. Over 5 million one-way passenger trips originate daily from the suburban railway system in Mumbai, thus the suburban railway system forms the heart of Mumbai's transport system.

Nonmotorized traffic is in the form of cyclists and pedestrians. However, the restricted road space, inadequate facilities for nonmotorized traffic and increasing risk of accidents discourage this form of environment-friendly traffic, even over short distances.

The city faces major constraints in expanding to meet the growing traffic needs. The road network has developed primarily in a north-south direction due to the linear expansion of the city. The traffic movement is concentrated mostly in three corridors: western, eastern and central. The total length of roads in Mumbai is 1808.28 km, which is divided as city (572.05), suburbs (708.08) and extended suburbs (528.15). These roads, however, are not only for traffic movement but also function as parking areas for vehicles, sites for hawkers and other commercial activities. To ensure the smooth flow of traffic, the Maharashtra State Road Development Corporation (MSRTC) Ltd. has undertaken a project to construct 41 flyovers of which 24 are already complete, and work on eight more has started.

Public Transport

Apart from the suburban railways, which cater to a very large portion of travel demand, the public stage carriage bus service provided by BEST also caters to commuters. The advantage of buses over railways lies in their flexibility of movement. BEST is the only operator of stage carriage buses within the Brihanmumbai municipal limits, but it also operates services to three areas beyond Brihanmumbai into the limits of bordering corporations: Navi Mumbai, Mira-Bhayander, and Thane. Contract buses are allowed to ply the city, providing point-to-point service to individual subscribers, schools, and companies, and generally maintain fixed schedules. The MSRTC also operates buses from Brihanmumbai to other parts of the state.

BEST's fleet has 3,458 buses comprised of ordinary diesel, air-conditioned, CNG, and mini buses. The effective fleet utilization was 88.31% in 2001, 1% point below the 2000 level. BEST operates a total of 359 routes that can be classified as:

- Feeder routes: these feed the railway stations either from residential complexes or business districts.
- East-West connectors: these run east to west, connecting the western suburbs with the eastern.
- Trunk routes: these run south to north through the city, parallel to the railway lines.

The feeder routes are given priority. These buses carried on average 3.73 million passengers daily in May 2001. One of the worrying features of BEST's performance is the continuous decline in number of passengers carried, which was 2% during 2000-2001. This may reflect a growing preference for private vehicles over public transport. Over the years there has been a substantial increase in the number of personal vehicles, especially two wheelers (7% growth during 2000-2001). Another possible reason could be BEST's high fares which encourage people to share taxis or autorickshaws, both more convenient for the traveller. Yet another reason cited for the decline in the number of passengers carried by BEST is the introduction of long-distance routes by BEST as this implies that passengers need to make fewer bus changes. However, these factors do not entirely explain the decline. BEST buses are constrained by traffic in the same way as other road users.

Intermediate Public Transport

Taxis and autorickshaws supplement the public transport system. While taxis ply the entire region of Brihanmumbai, autorickshaw movement is restricted to the suburban areas north of Mahim-Sion. The taxi and autorickshaw fleet increased substantially between 1994 and 1997, when the registration of these vehicles was permitted. There will not be any further growth in their numbers unless registration is allowed again. The taxi population increased by 70% over the period 1991-2000. All ordinary taxis are Premier Padminis except for around sixty Maruti Omni taxis and sixty Ambassadors. Apart from the ordinary taxis, there are luxury (air-conditioned) taxis that also ply the city; these are 'cool cabs' and a charge a higher rate. These taxis include newer brands of cars such as Matiz, Fiat's Uno, Maruti 800, etc. After CNG was introduced to the transport sector, a large number of taxis converted to CNG to save costs. Taxi associations, which are a powerful force, also urged owners to convert to CNG. At present, more than 35% of the total fleet operates on CNG, while around 40% are gasoline taxis and 25% diesel. There is no age limit for the taxis and 60% are older than fifteen years. As per the High Court directive, taxis fitted with old three-cylinder diesel engines of 800-1000 cc have been banned from operating within Mumbai City.

The number of autorickshaws increased by almost 300% between 1991-2000. In contrast to taxis, very few of the autos have converted to CNG, approximately only 1000. Most autos run on gasoline. Diesel versions were introduced some time ago, but were unsuccessful due of technical problems. Since mid-2000, Bajaj Automobiles, a top autorickshaw manufacturer, started supplying 4-stroke autorickshaws. Table 5.3 gives the number of taxis and autorickshaws on road in 1991 and 2000.

Table 5.3:
Taxi and Autorickshaw Population in 1991 and 2000

Category	1991	2000-2001			
		Gasoline	Diesel	CNG	Total
Taxis	34,338	25,199	14,291	19,206	58,696
Autorickshaws	24,577	93,595	2,718	1,252	97,565

Source. Transport Commissioner's Office, Mumbai and MGL.

Personal Transportation

There was a substantial increase in the number of personal vehicles between 1991-2000. The increase in number of two wheelers was more than for cars. In the former case, there was a 68% increase in this period to around 400,000, while the number of cars grew by 24% to 310,000.

Personal vehicles can play a very large role in the urban transport policy. Personal vehicles form around 75% of the total vehicle fleet at present. About 55% of these vehicles are low-powered and highly inefficient mopeds, scooters and motorcycles. Motorized two wheelers provide an inexpensive and convenient mode of travel. The rapid growth of personal modes of transportation despite an efficient public transport system is a matter of concern, because their adverse impact on the environment is much greater than that of the comparable public transport system.

The LEAP Model to Analyze Energy Demand and Emissions

A simple model has been developed to analyze transport energy demand and emissions under alternative scenarios for intra-city movement of people and goods. This uses software called LEAP (long-range energy alternatives planning) and an associated environmental database (EDB). LEAP is an accounting and simulation tool designed to assist policymakers in evaluating policies related to energy and the environment, and was developed by the Stockholm Environment Institute, Boston. It must be noted that the LEAP model does not incorporate: 1) vehicle speed or 2) greater emissions with age, both of which could affect total emissions significantly. In the absence of speed related data on fuel efficiency and emission factors in India, this study has considered the average values for fuel efficiency as well as emission factors for different categories of vehicles in the LEAP model.

The central concept of LEAP is an end-use-driven scenario analysis. First, the current energy situation and estimated future changes based on expected or likely plans and growth trajectories are developed in LEAP. This scenario is referred to as the BL (baseline) scenario. Then, one or more policy scenarios with alternative assumptions about future developments are developed. Under scenario features, the consequences of any number of "what if" questions can be analyzed. For instance, what if more efficient technologies are introduced? What if cleaner alternative fuels are introduced? What if mass transport facilities are strengthened?

The LEAP framework uses a disaggregate hierarchical format based on four levels, namely sector, subsector, end-use and device. It contains two programme modules, the energy scenarios and the Environmental Data Base (EDB). Within the energy programme module, energy intensity values along with the type of fuel used for each device are required for estimating the energy requirements at the sectoral/subsectoral/end-use level. In the EDB, emission factors of different pollutants are required for each device to analyze the environmental impact of energy-use over a time horizon. Five reference years, including a base year, are chosen under each of the four levels. LEAP requires data for at least the base year and any of the future reference years. Then, using the interpolation/extrapolation or growth-rate method, energy demand scenarios and their resultant emissions are estimated for the other reference years.

A linkage is then built into the model at the device level in both energy scenarios and the EDB modules. LEAP was run to analyze the current energy scene and simulate alternative energy futures along with emissions under a range of user-defined assumptions to arrive at strategies that best address environmental and energy problems.

Level 1: Sector
Total travel demand, estimated using Equations (5.1) and (5.2)

$$D_t = \sum_k V_{kt} \times U_{kt} \times O_{kt} \qquad \text{...... (5.1)}$$

$$V_{kt} = a + bt \qquad \text{...... (5.2)}$$

where, D is the total travel demand expressed in bpkm (billion passenger-kilometers) for passenger transport and btkm (billion tonne–kilometers) for freight transport, V is the number of motor vehicles plying the road. U and O denote, respectively, the average vehicle utilization and occupancy of passenger vehicles or load carried by goods vehicles, expressed in km/vehicle and passenger/vehicle or tonne/vehicle. Index t denotes the year and k denotes the major modes. The coefficients in Equation (5.2) were obtained by the ordinary least square method.

Level 2: Subsector
Modal classification or modal split, i.e. the share of total passenger travel demand catered to by personal, intermediate, and public modes, was estimated using Equation (1). The same equation was also used to classify the share of total freight travel demand between heavy and light commercial vehicles.

Level 3: End-use
Share of technologies and alternative fuels under each mode. The classified modes were further disaggregated into different vehicle categories s along with their model year/technologies and alternative fuels.

Level 4: Device
Vehicle space per passenger, which is the inverse of the average occupancy level for passenger modes. Similarly, vehicle space per tonne, which is the inverse of the average load carried by different goods vehicles.

Energy Demand

The average energy intensity for each technology considered under device is compiled within the LEAP framework. The complete mathematical structure of the Energy Scenarios module is given in Equation (5.3).

$$F_{kit} = D_t \times S_{kt} \times S^*_{kit} \times O^{-1}_{kt} \times E_{ki} \qquad \text{..... (5.3)}$$

where, F is the annual fuel demand expressed in gigajoules (GJ) and S and S^* denote the percentage share of total passenger and freight travel demand by different modes and their respective technologies. E denotes the average energy intensity expressed in GJ/km. Index i denotes the type of technology under a given mode k. Total energy demand was obtained by aggregating fuel demand across different modes and technologies.

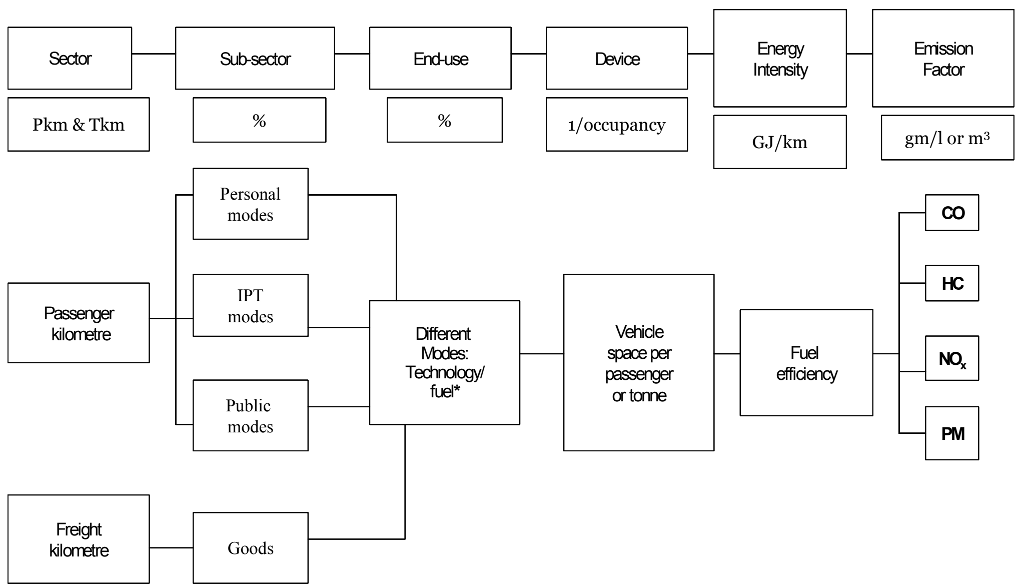
Emissions

Emission factors of criteria pollutants for different technologies under a typical Indian urban driving cycle are required in EDB. Annual emissions of each pollutant (CO, HC, NO_x, PM) denoted by j, are estimated in LEAP using Equation (5.4).

$$P_{jkit} = F_{kit} \times Y_{jkit} \qquad \text{..... (5.4)}$$

where, P denotes emissions expressed in tonnes and Y the emission factors expressed in mass of pollutants emitted per unit of fuel burnt (g/kg). Total annual emissions of a pollutant were obtained by aggregating the emission values across different modes and their technologies.
Figure 5.1 gives the components of the LEAP framework used for analyzing the fuel mix demand and resultant emissions of CO, HC, NO_x and PM in the baseline (BL) and two alternative cases—CNG and ULSD.

Figure 5.1
LEAP Structure for Urban Transport Energy Environment Analysis



*Reference years: pre-1990, 1990-95, 1995-2000, 2000-05, 2005-10

The LEAP structure presented in Figure 5.1 is simple and flexible, and can simulate the fuel demand and related emissions for an exogenously estimated travel demand in alternative strategies. Thus, the variables that drive the model include the following:

- Passenger and freight travel demand (a function of growth in the number of in-use motor vehicles of different modes, average vehicle utilization, and occupancy/load levels).
- Modal split (the share of total passenger or freight kilometer of travel demand catered to by different modes).
- Penetration of technologies (determined from the time-series sales data of different technologies within a given mode, e.g., sales figures of two-stroke and four-stroke vehicles under the two wheeler category).
- Average fuel efficiency of each technology (vehicle-kilometer run per unit of fuel consumed).
- Average emission factor of each vehicle (quantity of pollutant emitted per unit of fuel consumption). The pollutants considered are CO, HC, NO_x, and PM.

The reference years chosen for analyzing the transport energy demand and emissions are: pre-1993, 1995, 2000 (base year), 2005 and 2010, respectively.

Scenario Construction and Assumptions

The model was first run with the BL scenario, in which the on-going changes are extrapolated with an acceptable (and somewhat conservative) rate of growth. Since the implementation of reduction options requires considerable time, both for policymaking and technology diffusion, current emissions are an insufficient reference point for quantifying the reduction potential or constraints. The baseline scenario should therefore consist of a reference scenario of future, until say 2010, energy demand due to the growing travel demand and resultant emissions.

The notion of baseline here requires a precise definition that provides the basis for comparisons in future using alternative cases. According to one view, the future is simply an extrapolation of 'more of the same' of the present, and technology and economic structures are treated as mostly static and based on the currently perceived incentive structures, which typically exclude global considerations. Consequently, emissions rise unabated, typically at constant or even accelerating growth rates. According to another view, the changes in both technological and economic structures have been and will continue to be an inherent part of the evolution of social and economic systems. Adopting this view, we contrasted such conventional 'business-as-usual' scenarios with a different scenario of our own, which does not pursue any particular emission reduction strategy but which assumes that past trends in technological and economic structural change will continue to prevail. This scenario characterizes the 'dynamics-as-usual' or the 'baseline'.

The BL scenario considered in the present study is mostly built around the lines of dynamic-as-usual rather than the conventional business-as-usual. In the BL scenario, the following factors in future (2000-2010) will change as per current trends, during the period 1993 to 2000:

- Number of motor vehicles of different types;
- Penetration of improved technologies conforming to progressively stringent emissions standards equivalent to Euro norms, based on existing legislation;
- Penetration of CNG autorickshaws, taxis and buses based on existing legislation; and
- Improvement in vehicle fuel efficiency based on certain assumptions specified later in this chapter.

The following factors would remain the same during the period 1993 to 2000 but will vary across different modes.

- Occupancy/load factor of each vehicle; and
- Effective distance moved by each vehicle.

The BL scenario therefore is the best estimate of future energy use given (i) current trends in the travel demand of people and goods (expressed in passenger-kilometers and freight-kilometers) with changes in the modal split pattern, (ii) penetration of improved technologies and cleaner and alternative fuels, and (iii) all new vehicles to meet Euro emission norms as per the current set of policy measures. The assumptions made in constructing the BL scenario are discussed later in this chapter.

After outlining our 'reference' view of the future until 2010, as a baseline case the emission reduction potentials in Mumbai's transport sector were examined under two potential future cases, wherein promotion of CNG and alternatively ULSD are considered for certain categories of vehicles equipped with appropriate emission control devices (ECD) (see Table 5.4). The two cases are referred to as the CNG case and the ULSD case. Some of the critical emissions assumptions made in the study are highlighted below.

- Neither CNG nor ULSD is suitable for 2 wheelers;
- Technical and commercial viability of CNG for pre-Euro 2 buses or for light or heavy trucks is not established;
- ULSD and PM filters are feasible for all Euro 2 diesel light trucks and buses;

- ULSD and the DOC is feasible for all pre-Euro 2 diesel vehicles and for Euro 2 heavy trucks. In the case of Euro 2 heavy trucks, CRT is not being considered as PM filters are very sensitive to fuel sulfur content and these vehicles can operate outside Mumbai city limits where ULSD may not be available; and
- Vehicle life.

In both cases it is assumed that:
- All pre-2000 diesel vehicles will operate on ULSD and each vehicle will be equipped with a diesel oxidation catalyst (DOC);
- All pre-2000 CNG/gasoline vehicles will continue to run on CNG/gasoline; and
- All new cars are to run on gasoline/CNG with a 3-way catalyst and (if diesel) ULSD with PM filters.

In, addition to these assumptions, the two cases also make a number of assumptions (as given in table 5.4) in terms of the type of fuel and emission control technology that pre- and post-2000 vehicles of different categories would use. These two cases are different from the baseline only with respect to the level of penetration of advanced technology and fuel. The fuel demand and emission results would vary from 2005 onwards.

Table 5.4

Assumptions Made in the Two Cases

Vehicle type and year	CNG Case	ULSD Case
2 Wheelers: Pre and Post 2000	Gasoline	Gasoline
Diesel Vehicles: Pre 2000 (diesel cars, taxis, LCVs, Buses, HCVs)	ULSD + DOC	ULSD + DOC
CNG/Gasoline Cars: Pre 2000	CNG/Gasoline + 3 way catalyst	CNG/Gasoline + 3 way catalyst
New Cars: Post 2000	CNG/Gasoline + 3way catalyst	Gasoline/ULSD + PM filter
New Buses: Post 2000	CNG + 3 way catalyst	ULSD + PM filter
New Taxis: Post 2000	CNG + 3 way catalyst	ULSD + PM filter
LCVs: Post 2000 (Confined to Mumbai)	ULSD + PM filter	ULSD + PM filter
HCVs: Post 2000 (may go out of Mumbai	ULSD + DOC	ULSD + DOC

Method and Data Assumptions for Baseline Forecasts

VEHICLE PROJECTION

The data on motor vehicles for Mumbai is available until 2000. The motor vehicles were broadly classified into nine categories: two wheelers, private cars, taxis, autorickshaws, stage carriages, contract carriages, school buses, light commercial vehicles and heavy commercial vehicles. In order to forecast the number of motor vehicles on road from 2001 to 2010, the time trend method was used. In this method, the predicted future values are based on a linear regression of time series data of motor vehicles on road in the city. For intermediate transport, i.e. taxis and autorickshaws, the numbers were frozen (58,696 and 97,565 respectively) at 2000 levels, and a new autorickshaw/taxi can be registered only if an in-use taxi/autorickshaw retires. The extrapolation of vehicles is based on the vehicle population in the years 1993 to 2000 because the Mumbai vehicle registration office was split into two in 1992, with one in Brihanmumbai and the other outside its limits. As a result, some of the vehicles registered in Mumbai were shifted to the outer cordon, reducing the total number of vehicles registered in the city.

The time trend Equation (5.2) was used to extrapolate the growth of in-use motor vehicles in Mumbai up to the year 2010. Seven-years' data (from 1993 to 2000) on the number and type of motor vehicles in use was collected from the Transport Commissioner's Office in Mumbai. This time series data was used for estimating the regression coefficients, a and b in Equation (5.2). The estimated regression coefficients for the different categories of vehicles are given below.

- Two-wheeler: $V_{1t} = 210963 + 24038\ t \quad R^2 = 0.99$
- Private car: $V_{2t} = 184189 + 18319\ t \quad R^2 = 0.99$
- Stage carriage (BEST) bus: $V_{3t} = 3101.8 + 52.417\ t \quad R^2 = 0.84$
- Contract carriage bus: $V_{4t} = 3407.1 + 420.61\ t \quad R^2 = 0.72$
- School bus: $V_{5t} = 38.571 + 468.93\ t \quad R^2 = 0.88$
- Light commercial vehicle: $V_{6t} = 38914 + 1652.5\ t \quad R^2 = 0.98$
- Heavy commercial vehicle: $V_{7t} = 6646 + 371.33\ t \quad R^2 = 0.73$

According to these regression coefficients, the total number of vehicles in 2010 is projected to be 1.41 million, an increase of nearly 50% from 2000. The projections according to categories mentioned above are given in Table 5.5.

Table 5.5
Estimated Number of Vehicles from 2001 to 2010

Category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
2 wheelers	427305	451343	475381	499419	523457	547495	571533	595571	619609	643647
Private Cars	349060	367379	385698	404017	422336	440655	458974	477293	495612	513931
Autorickshaws	97,565	97,565	97,565	97,565	97,565	97,565	97,565	97,565	97,565	97,565
Taxis	58,696	58,696	58,696	58,696	58,696	58,696	58,696	58,696	58,696	58,696
Stage Carriage	3574	3626	3678	3731	3783	3836	3888	3940	3993	4045
Contract Carriage	7193	7613	8034	8454	8875	9296	9716	10137	10557	10978
School Buses	816	855	893	932	970	1009	1047	1086	1125	1163
LCV	53787	55439	57092	58744	60397	62049	63702	65354	67007	68659
HCV	9988	10359	10731	11102	11473	11845	12216	12587	12959	13330
Total	**1007983**	**1052875**	**1097768**	**1142660**	**1187552**	**1232445**	**1277337**	**1322230**	**1367122**	**1412015**

Database Development for the Model

TRAVEL DEMAND

Equations (5.1) and (5.2) were used to estimate the passenger and freight travel demand for the years 1993, 1995, 2000, 2005 and 2010. The average occupancy/load levels and the effective distance moved daily for each vehicle category were assumed to remain constant for the reference years considered in the model. This data is given in Table 5.6.

Table 5.6

Average Occupancy and Effective Vehicle Utilization

Category	Average Occupancy		Effective Utilisation (km/day)
	Passenger/Vehicle	Tonne/Vehicle	
2 wheeler (scooter/motor cycle)	1.50	-	13.5
Car/Jeep/Station-wagon	2.68	-	27.0
Taxi	1.57	-	85.0
3 wheeler (Autorickshaw)	1.76	-	100.0
Bus	39.00	-	208.0
Light Commercial Vehicle	-	1.50	28.0
Heavy Commercial Vehicle	-	5.00	28.0

Source: Bus data is compiled from BEST, 2001; for others, from ENCON, 1987.

Total travel demand estimates presented in Table 5.7 reveal that the total passenger demand (based on road transportation) in Mumbai city is expected to grow 2.7 times, from 28.09 to 75.38 billion passenger kilometer (BPKM) from 1993 to 2010. The same table also provides the estimated total freight travel demand catered to by road in the city. The freight travel demand within the city limits will nearly double from the 1990 level of 0.93 billion tonne kilometers (BTKM) to 1.73 BTKM in 2010.

Table 5.7

Passenger and Freight Travel Demand from 1993-2010

Description	Unit	1993	1995	2000	2005	2010
Total Passenger Travel Demand	10^9 PKM (BPKM)	28.09	40.45	52.22	64.50	75.38
Total Freight Travel Demand	10^9 TKM (BTKM)	0.93	1.07	1.28	1.51	1.73

MODAL SPLIT

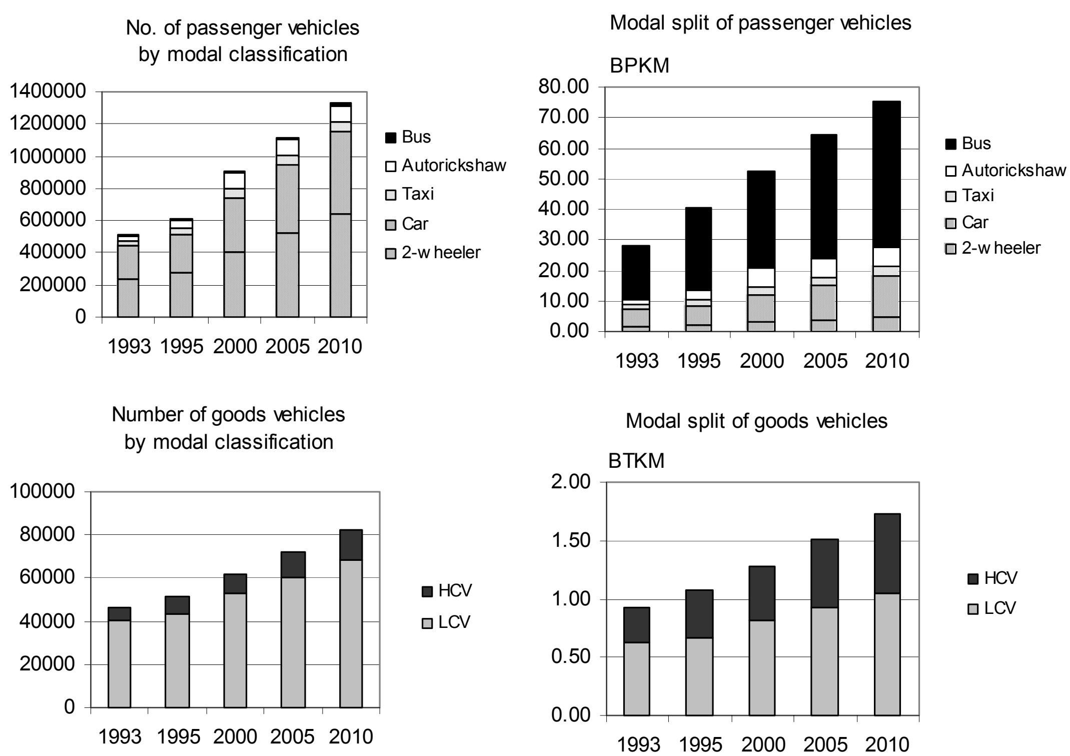
Table 5.8 gives the share of travel demand provided for different modes of transport for the five reference years considered in the LEAP model. The passenger travel demand catered to by buses, which was around 60% in 2000, is likely to go up to 64% by 2010. During the same ten-year period, while the share of private vehicles in the travel demand is also expected to increase from nearly 23% to around 24%, the share of intermediate public transport (taxis and autorickshaws taken together) is likely to come down from 17% to 12%. This is because taxis and autorickshaws are assumed to have reached their saturation points. In the case of goods vehicles, around 60% of the freight would be moved by LCVs, and the balance by HCVs.

Table 5.8
Modal Split

Mode	1993	1995	2000	2005	2010	1993	1995	2000	2005	2010
Billion Passenger Kilometer (BPKM)						**% Breakup**				
2 wheeler	1.78	2.07	3.01	3.87	4.76	6.33	5.13	5.76	6.00	6.31
Car	5.39	6.23	8.70	11.15	13.57	19.20	15.41	16.67	17.29	18.01
Taxi	1.58	1.96	2.86	2.86	2.86	5.61	4.84	5.47	4.43	3.79
3 wheeler	1.76	3.13	6.27	6.27	6.27	6.28	7.74	12.00	9.72	8.31
Bus	17.58	27.06	31.38	40.35	47.93	62.58	66.88	60.09	62.56	63.58
Total	28.09	40.45	52.22	64.50	75.38	100	100	100	100	100
Billion Tonne Kilometer (BTKM)						**% Breakup**				
LCV	0.62	0.67	0.81	0.93	1.05	66.77	62.76	63.34	61.23	60.71
HCV	0.31	0.40	0.47	0.59	0.68	33.23	37.24	36.66	38.77	39.29
Total	0.93	1.07	1.28	1.51	1.73	100	100	100	100	100

Figure 5.2 shows the growth of motor vehicles as per present trends and the shares of different modes of transport in the total fleet strength and in meeting the total travel demand until 2010.

Figure 5.2
Growth of In-use Passenger and Goods Vehicles and Modal Split



In the year 2000, buses made up slightly over 1% of the total number of motorized vehicles in Mumbai (Table 5.1) but met over 60% of the total travel needs (Table 5.8).

TECHNOLOGY CHARACTERIZATION AND ITS PENETRATION

The number of vehicles running on different fuels (gasoline, diesel or CNG) for each mode was collected from the Transport Department. As far as the penetration of 2-stroke vis-à-vis 4-stroke technology in 2 and 3 wheelers is concerned, assumptions are based on the sales trend data of these vehicles. Past trends were analyzed to project the share of technologies and alternative fuels under each mode for the future. For the construction of the BL scenario several assumptions were made which are given in Table 5.9.

Table 5.9
Baseline Assumptions

Mode	Baseline Case		
Year of Start	**2000**	**2005**	**2010**
Two wheeler	It is assumed that 75% of new vehicles are two-stroke and 25% are four stroke vehicles.	It is assumed that 60% of new vehicles are two-stroke and 40% are four stroke vehicles.	No vehicle powered with a two-stroke engine will be registered
Car/Jeep	At present, Gasoline driven cars: 81% Diesel driven cars: 18.5% CNG driven cars: <1%	5 % of the total number of new cars will run on CNG. The remainder will be in the ratio of 1:2 (diesel: gasoline).	10% of the new cars will run on CNG. Remaining vehicles will be split into 1:1 on gasoline and diesel.
Three Wheeler	At present, Gasoline driven 3 wheelers: 99% CNG driven 3 wheelers: 1%	No 2 stroke 3 wheelers will be registered. 5% of new vehicles will be on CNG, the remainder will be 4 stroke.	10% will be on CNG, the remainder will be on four-stroke.
Taxi	At present, Gasoline driven taxi: 43% Diesel driven taxi: 24% CNG driven taxi: 33%	60% will be on CNG. The remainder will be in the ratio of 1:2 (diesel: gasoline)	75% of vehicles will be on CNG. The remaining will be in the ratio of 1:2 (diesel: gasoline)
Bus	At present, Diesel driven buses: 99% CNG driven buses: <1%	5% will be on CNG, the remainder will be on diesel.	10% will be on CNG, the remainder will be on diesel.

Annex 5.1 gives the percentage of vehicles in use as per vintage in the baseline and the two alternative cases during 2010. These penetration levels also considered the penetration of improved technologies, keeping in mind the progressively stringent emission norms notified by the Ministry of Surface Transport, Government of India. Emission norms were notified in 1991, 1996, and 2000. It is assumed that norms will be made more stringent in 2005 and again in 2010. The Indian auto industry has been following European emissions standards for vehicles other than 2 and 3 wheelers. However, India has more stringent emissions standards for 2 and 3 wheelers than Europe.

FUEL EFFICIENCY AND EMISSION FACTORS

While developing this database, it is assumed that with advancement in engine technologies, vehicle fuel efficiencies and the corresponding emission factors of regulated pollutants (CO, HC, NO_x and PM) will improve as they have in the past. Also, ECD's fitted to vehicle tailpipes (3-way catalysts for CNG or gasoline vehicles and DOC and PM filters for diesel vehicles) would play a major role in controlling emissions and adhering to Euro 3/Euro 4 emission norms in the near future.

One of the major limitations of the study is the absence of a credible database on fuel efficiency and emission factors of in-use vehicles under city driving conditions. As a result of air quality concerns, all types of vehicles in India have been subjected to increasingly stringent emissions standards. For this, it is imperative that both fuel specifications and engine technology go hand in hand. With the improvement in the engine technologies through continuous R&D efforts by the auto industries, the fuel efficiencies of different vehicle categories are continuously improving. One factor motivating these fuel economy advancements is the rising fuel prices. By analyzing the fuel efficiency gains of different vehicles under Indian conditions, it is assumed that over the twenty-year period (1990 to 2010) the potential scope of fuel efficiency improvements would vary for different types of vehicles.

The mass emissions standards for new vehicles in the country were first notified on 5 February 1990 and became effective from 1 April 1991. These were revised and made more stringent in April 1996 and standards for 2000 and 2005 were also announced. Considering the progressive tightening of emissions standards in almost five yearly intervals, the Central Pollution Control Board (CPCB) published in-use vehicle emission factor data for the following five reference periods, for different category of vehicles and fuels (CPCB, 2000).

- 1986–1990 & 1991–1995 (Pre-controlled emission factors)
- 1996–2000 (1996 norms)
- 2001–2005 (2000 norms)
- 2006–2010 (2005 norms).

The emission factors in any given period are made more stringent compared to the previous period as the vehicle manufacturers have followed—and are expected to follow—progressively stringent emissions standards/norms for conformity of vehicle production s during these five reference periods. For the purposes of this study, the data source on emission factors for different category of existing diesel and gasoline is the same CPCB data. As far as the emission factors of vehicles in future years are concerned, particularly with CNG and ULSD and equipped with ECDs, the data is based largely on international field trial results as modulated by our judgement and exercised in consultation with the ADB technical consultant.

The assumptions made to compile the emission factor database for the study are detailed below. Annex 5.2 gives the fuel efficiencies and emission factors considered in the study.

- Emission factors of the following vehicle categories are taken from the CPCB published data —two- and four-stroke gasoline 2 wheelers; two-stroke gasoline 3 wheelers; car/taxi gasoline and diesel; diesel LCV, diesel HCV and diesel trucks.
- CPCB data provides different emission factors for gasoline 2 wheelers with two- and four-stroke technology, whereas for gasoline 3 wheelers only emission factor for two-stroke technology is provided. The same differential factor between 2- and 4-stroke technologies for two-wheelers is used to determine the emission factor of a four-stroke 3 wheeler on gasoline.
- The emission factor of CNG 3 wheelers are taken from a published study (Reddy, 2001) along with expert judgement in consultation with the ADB technical consultant.
- The emission factor of a CNG car/taxi is taken to be the same as that of gasoline car/taxi.

- With regards to the use of ULSD vehicles (excluding HCVs and buses), it is assumed that all pre-2000 registered diesel vehicles would be equipped with diesel oxidation catalysts (DOC) and run on ULSD, whereas all post-2000 registered vehicles would be equipped with a CRT and use ULSD. Further, it is assumed that:
  - o there would be 25% drop in emissions due to ULSD use and a further drop of 27% for using DOC in pre-2000 registered vehicles compared to the corresponding diesel vehicles.
  - o for all new diesel vehicles registered after 2000, the emission factors would be frozen at Euro 4 level.
- In the case of CNG or ULSD buses equipped with emission control devices, the published data of the London Bus experiment is used (Barton, 1997) along with expert judgement in consultation with the ADB technical consultant along the lines mentioned in 5.
- In the case of HCVs, it is assumed that all old and new vehicles would be equipped with DOC and use ULSD. There would be a 25% drop in emissions due to use of ULSD and further 25% for using DOC compared to the corresponding diesel vehicles.

Scenario Results

The LEAP model is run in three alternative cases using the database and assumptions presented in the previous section. The output of the model provided the estimates of energy demand for passenger and freight transportation in Mumbai and associated emissions of the critical pollutants, CO, HC, NO_x and PM. The annual energy demand estimates and the resultant emissions loading values are presented in Tables 5.10 and 5.11 respectively.

Table 5.10

Annual Energy Demand: Past, Present and Future

Fuel	Year	Base Case	CNG Case	ULSD Case	Base Case	CNG Case	ULSD Case
		'000 toe	'000 toe	'000 toe	'000 kl	MSCM	'000 kl
LSD	1993	243.1	243.1	243.1	271.81	271.81	271.81
	1995	336.15	336.15	336.15	375.86	375.86	375.86
	2000	402.96	402.96	402.96	450.56	450.56	450.56
	2005	478.82	0	0	535.38	0	0
	2010	560.35	0	0	626.54	0	0
Gasoline	1993	301.93	301.93	301.93	357.16	357.16	357.16
	1995	362.86	362.86	362.86	429.23	429.23	429.23
	2000	480.63	480.63	480.63	568.54	568.54	568.54
	2005	488.11	477.57	482.9	577.39	564.92	571.23
	2010	492.43	476.33	486.36	582.50	563.46	575.32
CNG	1993	0	0	0	0	0	0
	1995	0	0	0	0	0	0
	2000	36.82	36.82	36.82	42.58	42.58	42.58
	2005	76.46	182.87	41.63	88.41	211.46	48.14
	2010	107.18	300.45	46.03	123.94	347.42	53.23
ULSD	1993	0	0	0	0	0	0
	1995	0	0	0	0	0	0
	2000	0	0	0	0	0	0
	2005	0	362.55	464.63	0	405.37	519.51
	2010	0	368.26	553.02	0	411.76	618.34
Total	1993	545.03	545.03	545.03			
	1995	699.00	699.00	699.00			
	2000	920.41	920.41	920.41			
	2005	1043.39	1022.98	989.16			
	2010	1159.96	1145.04	1085.41			

Table 5.11
Annual Emissions Loading: Past, Present and Future

(thousand tonnes)

Pollutant	Year	BL	CNG Case	ULSD Case
CO	1993	56.82	56.82	56.82
	1995	75.61	75.61	75.61
	2000	95.39	95.39	95.39
	2005	91.16	82.80	81.63
	2010	87.52	78.98	77.12
HC	1993	18.60	18.60	18.60
	1995	26.95	26.95	26.95
	2000	40.13	40.13	40.13
	2005	38.11	37.29	36.59
	2010	35.73	35.26	33.96
NO_x	1993	16.33	16.33	16.33
	1995	22.46	22.46	22.46
	2000	25.51	25.51	25.51
	2005	27.72	27.14	27.95
	2010	30.03	29.06	30.42
PM	1993	2.87	2.87	2.87
	1995	4.15	4.15	4.15
	2000	4.85	4.85	4.85
	2005	4.75	3.17	3.18
	2010	4.68	3.07	3.09

BASELINE RESULTS

Energy Demand

The total energy demand in the base year, 2000, is 0.92 MTOE (million tonnes of oil equivalent), which is about 13% higher compared to the total sales of diesel (0.44 MTOE), gasoline (0.33 MTOE) and CNG (0.035 MTOE) in the city. Such a deviation in the sales data and model estimates of the base year raises two concerns. First, the fuel sales data may not truly reflect its actual consumption level in the city. A sizeable share of Mumbai's population commutes long distances and probably buys gasoline and diesel from retail outlets located outside the city limits. Second, the estimated fuel consumption could be an over or under estimate due to the use of normative values of fuel efficiency for a given technology, occupancy and vehicle utilization level each of which would vary under different driving conditions.

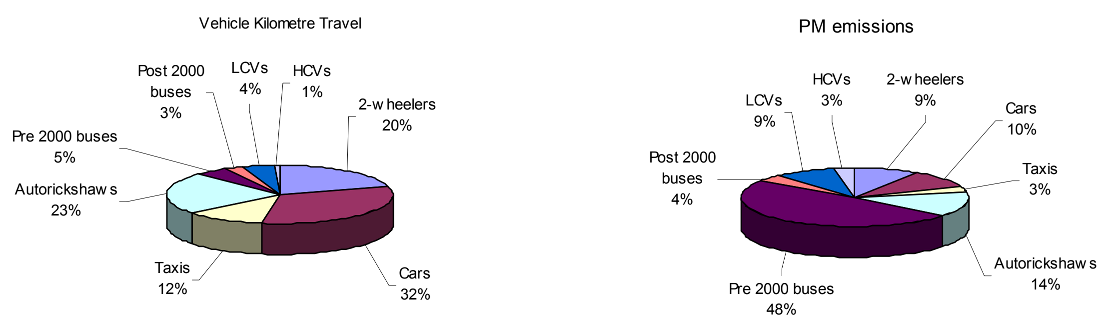
The total energy demand in the BL case will double from 0.55 MTOE in 1993 to 1.16 MTOE in 2010. During this period, gasoline and diesel consumption are expected to increase by 1.6 and 2.3 times respectively. By 2010, given the current government policy to promote use of CNG in the transport sector, the penetration of CNG would be around 9% of the total energy demand compared to the present 3%.

Emissions

The model indicates that emissions of CO, HC, and PM will increase until 2000. However, in 2005 and 2010, emissions will be lower than 2000 levels. The emission loading of CO, HC and PM in 2010 are 8%, 11% and 4% lower than those in 2000. This could be the result of introducing progressively more stringent emissions standards (in 1991, 1996, and 2000) and penetration of improved vehicle technology and cleaner fuels. However, in the case of NO_x, the emission loading shows a continuous increase of 84% between 1993 and 2010. This is primarily due to the increasing share of diesel vehicles in the total fleet, which account for around 80% NO_x emission loading in 2010.

The distribution of vehicle kilometers travelled by various modes and the contribution of PM emissions from vehicles in 2010 and in the BL case is shown in Figure 5.3. The figure shows that in 2010 nearly 52% of the total vehicular PM emissions are expected to be contributed by buses, whose share in total vehicle kilometers travelled (VKT) would be around 8%.

Figure 5.3
Distribution of VKT and PM Vehicle Emissions in 2010 under the Baseline Case



The Results of the Two Alternative Cases

ENERGY DEMAND

The CNG scenario shows a marginal decrease (about 1.2%) in the total energy demand in 2010 compared to the baseline case. With ULSD, the drop is about 6.4%. This is because in the two cases there is an improvement in engine technology to enable use of these cleaner fuels.

EMISSIONS

The emissions loading in the two cases are lower than the baseline case in 2005 and 2010 for all pollutants, excepting a marginal increase of NO_x in the ULSD case. The reduction in the emission loading of each pollutant in each of the scenarios as compared to the baseline case is given below in Table 5.12. It should be noted that since the CNG and ULSD cases are not built on the same assumptions, the results are not comparable as the penetration of CNG and ULSD vehicles is different.

Table 5.12

Emissions Loading Reduction in the Two Cases with Respect to BL Case

(%)

Pollutant	Year	CNG Case	ULSD Case
CO	2005	9.17	10.45
	2010	9.76	11.88
HC	2005	2.15	3.99
	2010	1.32	4.95
NO_x	2005	2.09	-0.83
	2010	3.23	-1.30
PM	2005	33.24	33.07
	2010	34.37	33.99

The following conclusions can be drawn from the model results:

- Total energy demand in 2010 is expected to be 1.3% less in the CNG case compared to the BL case. The corresponding figure for the ULSD case is 6.4%;
- Both CNG and ULSD have the potential to substantially reduce vehicle PM emissions;
- CNG can also reduce NO_x whereas ULSD brings a marginal increase;
- While less important in Mumbai's environment, small improvements in CO and reactive HC levels result from both fuels.

Annex 5.1

Percentage of Vehicles in Use as per Vintage in Different Scenarios in 2010.

Mode: Technology: Fuel: Period	BL	CNG Case	ULSD Case
2Wh:2Stroke:Gasoline:up to 2000	57.4	57.4	57.4
2Wh:4Stroke:Gasoline:1995-2000	5.9	5.9	5.9
2Wh:2Stroke:Gasoline:2000-05	10.8	10.8	10.8
2Wh:4Stroke: Gasoline:2000-05	7.2	7.2	7.2
2Wh:2Stroke:Gasoline:2005-10	-	-	-
2Wh:4Stroke:Gasoline:2005-10	18.7	18.7	18.7
Total	100.0	100.0	100.0
Car: Gasoline: up to 2000	56.8	56.8	56.8
Car:Diesel:up to 2000	7.2	-	-
Car:CNG:up to 2000	0.1	0.1	0.1
Car:ULSD:up to 2000	-	7.2	7.2
Car:Gasoline:2000-05	11.4	11.4	11.4
Car:Diesel:2000-05	5.7	-	-
Car:CNG:2000-05	0.9	6.6 [a]	-
Car:ULSD:2000-05	-	-	6.6 [a]
Car:Gasoline:2005-10	8.0	8.0	8.0
Car:Diesel:2005-10	8.0	-	-
Car:CNG:2005-10	1.8	9.8[a]	-
Car:ULSD:2005-10	-	-	9.8 [a]
Total	100.0	100.0	100.0
3 Wh:2stroke:Gasoline:up to 2000	73.5	73.5	73.5
3 Wh:4stroke:Gasoline: up to 2000	6.1	6.1	6.1
3 Wh:4stroke:Gasoline:up to 2000	0.5	0.5	0.5
3 Wh:2stroke:Gasoline:2000-05	1.0	-	1.0
3 Wh:4stroke:Gasoline:2000-05	4.0	-	4.0
3 Wh:4stroke:CNG:2000-05	5.0	10.0 [b]	5.0
3 Wh:2stroke:Gasoline:2005-10	-	-	-
3 Wh:4stroke:Gasoline:2005-10	5.0	-	5.0
3 Wh:4stroke:CNG:2005-10	5.0	10.0[b]	5.0
Total	100.0	100.0	100.0
Taxi:Gasoline:up to 2000	10.8	10.8	10.8
Taxi:Diesel: up to 2000	5.4	-	-
Taxi:CNG: up to 2000	33.0	33.0	33.0
Taxi:ULSD: up to 2000	-	5.4	5.4
Taxi:Gasoline:2000-05	3.3	-	-
Taxi:Diesel:2000-05	1.7	-	-
Taxi:CNG:2000-05	27.0	32.0 [b]	-
Taxi:ULSD:2000-05	-	-	32.0 [b]
Taxi:Gasoline:2005-10	2.5	-	-
Taxi:Diesel:2005-10	1.3	-	-
Taxi:CNG:2005-10	15.0	18.8 [b]	-
Taxi:ULSD:2005-10	-	-	18.8 [b]
Total	100.0	100.0	100.0

Mode: Technology: Fuel: Period	BL	CNG Case	ULSD Case
Bus:Diesel: up to 2000	65.5	-	-
Bus:CNG: up to 2000	-	-	-
Bus:ULSD: up to 2000	-	65.5	65.5
Bus:Diesel:2000-05	17.8	-	-
Bus:CNG:2000-05	0.9	18.7 [b]	0.0
Bus:ULSD:2000-05	-	-	18.7 [b]
Bus:Diesel:2005-10	14.2	-	-
Bus:CNG:2005-10	1.6	15.8 [b]	-
Bus:ULSD:2005-10	-	-	15.8 [b]
Total	100.0	100.0	100.0
LCV:Diesel: up to 2000	77.1	-	-
LCV:ULSD: up to 2000	-	77.1	77.1
LCV:Diesel:2000-05	10.9	-	-
LCV:ULSD:2000-05	-	10.9	10.9
LCV:Diesel:2005-10	12.0	-	-
LCV:ULSD:2005-10	-	12.0	12.0
Total	100.0	100.0	100.0
HCV:Diesel: up to 2000	69.0	-	-
HCV:ULSD: up to 2000	-	69.0	69.0
HCV:Diesel:2000-05	17.1	-	-
HCV:ULSD:2000-05	-	17.1	17.1
HCV:Diesel:2005-10	13.9	-	-
HCV:ULSD:2005-10	-	13.9	13.9
Total	100.0	100.0	100.0

[a] the percentage of vehicles using CNG/ULSD in the two alternative cases is the sum of the diesel and CNG vehicles registered in the given period as given in the BL case.
[b] The percentage of vehicles using CNG/ULSD in the two alternative cases is the sum of all the vehicles registered (i.e. gasoline, CNG, diesel) in the given period as given in the BL case. In the case of LCV, HCV and all pre-2000 diesel vehicles, the percentages of vehicles operating on ULSD given in CNG/ULSD case for a given period is the percentage of vehicles operating on diesel for that period as given in the BL case.

Annex 5.2
Fuel Efficiency and Emission Factors

Mode Description (Source/Note)	Year	Fuel Efficiency[a]	Fuel Efficiency in km/MMBTU	Emission Factors (g/km)			
				CO	HC	NO_x	PM
2 Wh: 2 stroke:Gasoline(1)	<1990	44.44	1299.99	6.500	3.900	0.030	0.230
	1990-1995	45.11	1319.58	6.500	3.900	0.030	0.230
	1995-2000	45.77	1338.89	4.000	3.300	0.060	0.100
	2000-2005	46.44	1358.49	2.200	2.130	0.070	0.050
	2005-2010	47.11	1378.09	1.400	1.320	0.080	0.050
2 Wh:4 stroke: Gasoline (1)	<1990	55.00	1608.89	3.000	0.800	0.310	0.070
	1990-1995	55.83	1633.17	3.000	0.800	0.310	0.070
	1995-2000	56.65	1657.16	2.600	0.700	0.300	0.060
	2000-2005	57.20	1673.25	2.200	0.700	0.300	0.050
	2005-2010	57.75	1689.34	1.400	0.700	0.300	0.050
3 Wh:2 stroke: Gasoline (1)	<1990	20.41		14.00	8.300	0.050	0.350
			597.05	0			
	1990-1995	21.23		14.00	8.300	0.050	0.350
			621.03	0			
	1995-2000	22.04	644.73	8.600	7.000	0.090	0.150
	2000-2005	22.76	665.79	4.300	2.050	0.110	0.080
	2005-2010	23.47	686.56	2.450	0.750	0.120	0.080
3 Wh:4 stroke: Gasoline (2)	1995-2000	28.00	819.07	5.590	1.485	0.450	0.090
	2000-2005	30.00	877.58	4.300	0.674	0.471	0.080
	2005-2010	32.00	936.08	2.450	0.398	0.450	0.080
3 Wh:4 stroke:CNG (3)	1995-2000	30.00		2.464	0.086	0.072	0.030
			920.96				
	2000-2005	32.00	982.36	1.232	0.025	0.088	0.016
	2005-2010	35.00	1074.46	0.702	0.009	0.096	0.016
Car: Gasoline (1)	<1990	9.43	275.85	9.800	1.700	1.800	0.060
	1990-1995	10.72	313.59	9.800	1.700	1.800	0.060
	1995-2000	12.00	351.03	2.720	0.410	0.560	0.050
	2000-2005	14.00	409.54	1.980	0.250	0.200	0.030
	2005-2010	16.00	468.04	1.390	0.150	0.120	0.020
Car: Diesel (1)	<1990	8.86	220.40	7.300	0.370	2.770	0.840
	1990-1995	9.68	240.80	7.300	0.370	2.770	0.840
	1995-2000	10.50	261.19	1.200	0.370	0.690	0.420
	2000-2005	11.25	279.85	0.900	0.130	0.500	0.070

Mode Description (Source/Note)	Year	Fuel Efficiency[a]	Fuel Efficiency in km/MMBTU	Emission Factors (g/km)			
				CO	HC	NO_x	PM
	2005-2010	12.00	298.51	0.580	0.050	0.450	0.050
Car: CNG (4)	1995-2000	14.40	442.06	2.720	0.410	0.560	0.050
	2000-2005	15.12	464.17	1.980	0.250	0.200	0.030
	2005-2010	15.84	486.27	1.390	0.150	0.120	0.020
Car: ULSD (5)	<1990	11.08	275.62	2.920	0.148	2.770	0.460
	1990-1995	12.10	301.00	2.920	0.148	2.770	0.460
	1995-2000	13.13	326.62	0.480	0.148	0.690	0.230
	2000-2005	16.88	419.90	0.180	0.026	0.500	0.025
	2005-2010	18.00	447.76	0.116	0.010	0.450	0.025
LCV: Diesel (1)	<1990	5.50	136.82	8.700	0.340	3.150	0.800
	1990-1995	5.64	140.30	8.700	0.340	3.150	0.800
	1995-2000	5.78	143.78	6.900	0.280	2.490	0.500
	2000-2005	5.92	147.26	5.100	0.140	1.280	0.200
	2005-2010	6.06	150.75	0.720	0.063	0.590	0.070
LCV: ULSD (5)	<1990	6.05	150.50	3.480	0.136	3.150	0.438
	1990-1995	6.20	154.23	3.480	0.136	3.150	0.438
	1995-2000	6.35	157.96	2.760	0.112	2.490	0.274
	2000-2005	7.70	191.54	1.020	0.028	1.280	0.025
	2005-2010	7.88	196.02	0.144	0.013	0.590	0.025
HCV: Diesel (1)	<1990	3.30	82.09	5.500	1.780	9.500	1.500
	1990-1995	3.38	84.08	5.500	1.780	9.500	1.500
	1995-2000	3.47	86.32	4.500	1.210	8.400	0.800
	2000-2005	3.55	88.31	3.600	0.870	6.300	0.280
	2005-2010	3.63	90.30	3.200	0.870	5.500	0.120
HCV: ULSD (6)	<1990	3.50	87.06	2.200	0.712	9.500	0.821
	1990-1995	3.59	89.30	2.200	0.712	9.500	0.821
	1995-2000	3.67	91.29	1.800	0.484	8.400	0.438
	2000-2005	3.97	98.76	1.440	0.348	6.300	0.153
	2005-2010	4.07	101.24	1.280	0.348	5.500	0.066
Bus: Diesel (1)	<1990	3.30	82.09	5.500	1.780	19.000	3.000
	1990-1995	3.38	84.08	5.500	1.780	19.000	3.000
	1995-2000	3.47	86.32	4.500	1.210	16.800	1.600
	2000-2005	3.55	88.31	3.600	0.870	12.000	0.560
	2005-2010	3.63	90.30	3.200	0.870	11.000	0.240

Mode Description (Source/Note)	Year	Fuel Efficiency[a]	Fuel Efficiency in km/MMBTU	Emission Factors (g/km)			
				CO	HC	NO_x	PM
Bus: CNG (7,8)	1995-2000	2.25	69.07	1.800	3.010	9.900	0.050
	2000-2005	2.42	74.29	0.720	3.010	9.900	0.050
	2005-2010	2.59	79.51	0.640	3.010	9.900	0.050
Bus: ULSD (7,8)	<1990	3.50	87.06	2.200	0.712	19.000	1.643
	1990-1995	3.59	89.30	2.200	0.712	19.000	1.643
	1995-2000	3.67	91.29	1.800	0.484	16.800	0.876
	2000-2005	3.97	98.76	0.720	0.174	12.000	0.056
	2005-2010	4.07	101.24	0.640	0.174	11.000	0.020
Taxi: Gasoline (1)	<1990	9.43	275.85	9.800	1.700	1.800	0.060
	1990-1995	10.72	313.59	9.800	1.700	1.800	0.060
	1995-2000	12.00	351.03	2.720	0.410	0.560	0.050
	2000-2005	14.00	409.54	1.980	0.250	0.200	0.030
	2005-2010	16.00	468.04	1.390	0.150	0.120	0.020
Taxi: Diesel (1)	<1990	8.86	220.40	7.300	0.370	2.770	0.840
	1990-1995	9.68	240.80	7.300	0.370	2.770	0.840
	1995-2000	10.50	261.19	1.200	0.370	0.690	0.420
	2000-2005	11.25	279.85	0.900	0.130	0.500	0.070
	2005-2010	12.00	298.51	0.580	0.050	0.450	0.050
Taxi: CNG (4)	1995-2000	14.40	442.06	2.720	0.410	0.560	0.050
	2000-2005	15.12	464.17	1.980	0.250	0.200	0.030
	2005-2010	15.84	486.27	1.390	0.150	0.120	0.020
Taxi: ULSD (5)	<1990	11.08	275.62	2.920	0.148	2.770	0.460
	1990-1995	12.10	301.00	2.920	0.148	2.770	0.460
	1995-2000	13.13	326.62	0.480	0.148	0.690	0.230
	2000-2005	16.88	419.90	0.180	0.026	0.500	0.025
	2005-2010	18	447.76	0.116	0.010	0.450	0.025

[a]For diesel and gasoline vehicles units are in km/liter, whereas for CNG vehicles it is in km/m^3

Note: The fuel efficiency values are compiled using the following references: TERI, 2000, Faiz et al. 1996 and Lanni et al. 2001.

Source/Note: As mentioned earlier, the following sources and assumptions are used to compile the emission factor data for different vehicle categories: (1) CPCB, 2000; (2) The same differential between 2- and 4-stroke has been used as in the case of 2 wheelers; (3) Reddy, 2001 along with expert judgment in consultation with ADB technical consultant ; (4) The same emission factor as gasoline car/taxi; (5) For CNG and ULSD bus; Walsh, 1998 (5) All vehicles registered prior to 2000 would be equipped with DOC and use ULSD, whereas all new vehicles registered after 2000 would be equipped with CRT and use ULSD. In consultation with ADB technical consultant, it is assumed there would be a 25% drop in emissions due to ULSD use and a further 27% for using DOC in pre-2000 vehicles compared to corresponding diesel vehicles. However, for all new vehicles registered after 2000 the emission factors are frozen at Euro 4 level; (6) All old and new vehicles would be equipped with DOC and use ULSD. There would be a 25% drop in emissions due to use of ULSD and further 27% for using DOC compared to corresponding diesel vehicles. (7) Barton, 1997 along with expert judgment in consultation with ADB technical consultant along the lines mentioned in (5). (8) Walsh, 1998.

CHAPTER 6

Supply of Ultra Low Sulfur Diesel (ULSD)

Domestic Production

LIKELY REFINERY SOURCES

There are two domestic refineries considered as probable suppliers of ULSD to Mumbai based on their proximity, their perceived ability to manufacture ULSD by 2004/2005, and logistical ability to deliver ULSD under strict quality control procedures to the Sewri oil terminals, which feed the city's retail outlets. These two refineries are (i) Bharat Petroleum Corporation Ltd. (BPCL), Mumbai, and (ii) Reliance Petroleum Ltd. (RPL), Jamnagar.

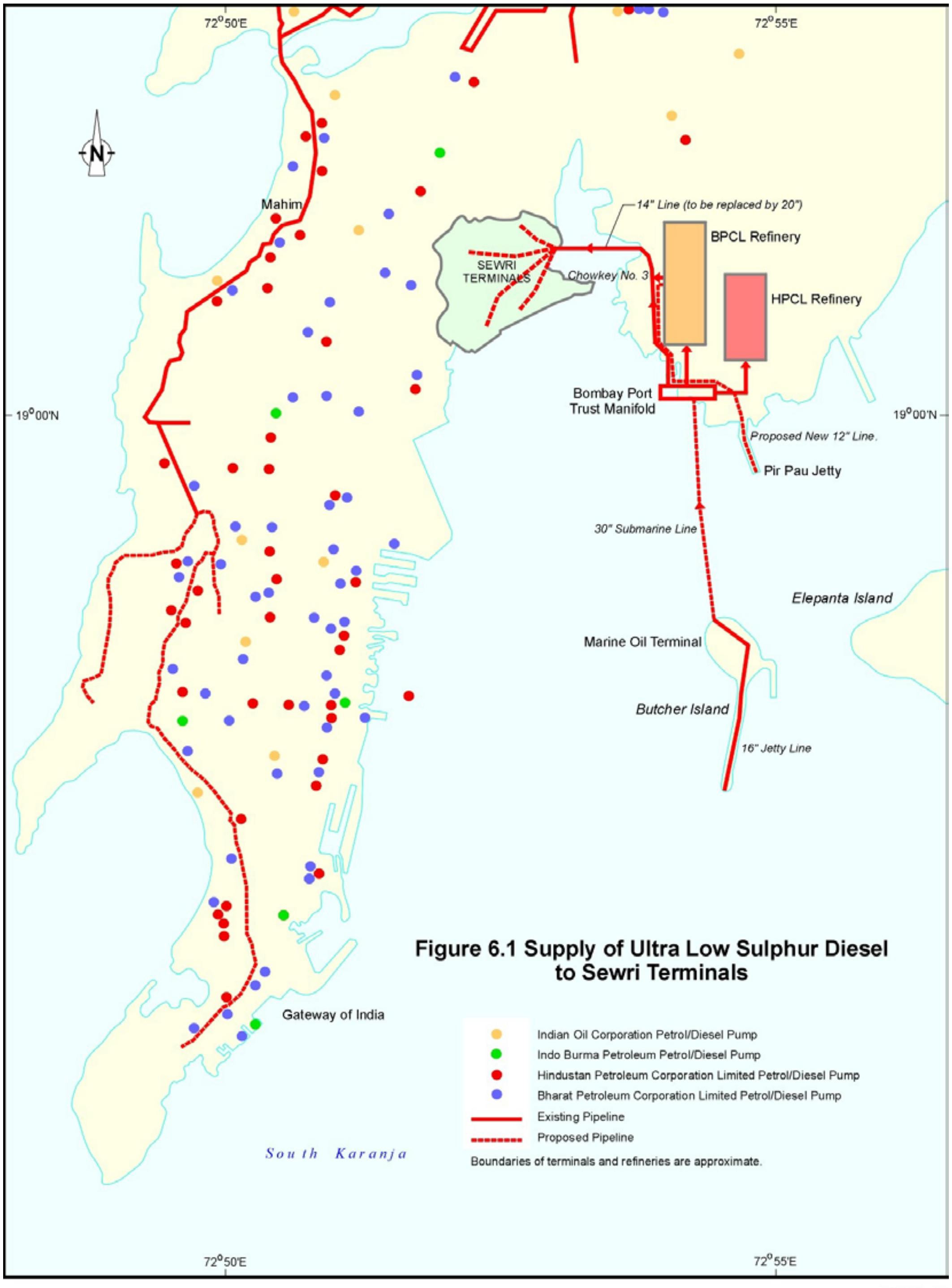
The Hindustan Petroleum Corporation Ltd. (HPCL) refinery, although located in Mumbai, has not been considered for reasons discussed later in this chapter. The map in Figure 6.1 shows the location of the BPCL and HPCL refineries, tanker loading and discharge terminals, Sewri terminals and interconnecting pipelines. For greater clarity, only pipelines used for diesel oil are shown.

Bharat Petroleum Corporation

BPCL is one of the oldest integrated refining and marketing companies in India. During 2000-01 BPCL marketed 19.35 MMT (million metric tonne) of petroleum products with a gross turnover of Rs 468,529 million. Its market share amongst the oil PSUs moved from 20.66% up to 21.43%. BPCL has an all-India network of 4,562 retail outlets and for historical reasons is particularly strong in Mumbai. In addition to its Mumbai refinery, in 2001 BPCL also acquired the Cochin and Numaligarh refineries as subsidiaries.

The refinery is located in the suburb of Mahul on the eastern side of Mumbai Island. The refinery was commissioned in 1955 with a capacity of 2.0 MMPTA (million metric tonne per annum).

Figure 6.1
Supply of Ultra Low Sulphur Diesel to Sewri Terminals



Crude Oil Supply

The refinery is considerably expanded, and in 2000/2001 processed 8.66 million tonnes of crude oil of which 70% was Bombay High offshore crude oil and the balance mainly middle-east crudes; the share of Dubai and Kuwait being 7% and 18% respectively. Bombay High is a sweet crude oil with a low sulfur content and is supplied by the ONGC from the offshore field via an undersea pipeline. Ships carrying imported crude dock at the Marine Oil Terminal on Butcher Island oil terminal from where the crude is pumped through undersea lines to the refinery. There are four jetties at the terminal that can accommodate vessels up to 70,000 DWt (dead weight).

High Speed Diesel Production

The high-speed diesel (HSD) production in 2000-01 was 2.92 million tonnes or approximately 240,000 MT per month.

Refinery Units

The main facilities at the refinery are crude distillation units, a high vacuum unit, two catalytic cracking units, a reformer, aromatics extraction facilities and various treatment facilities, including a diesel hydro-desulfurization unit (DHDS).

Diesel Hydro-desulfurization

The DHDS unit was commissioned in July 1999 in response to a Ministry of Petroleum and Natural Gas directive requiring all Indian refineries to reduce the sulfur in HSD production to 0.25% (2500 ppm). Hydrogen, generated in a hydrogen plant by steam reforming of naphtha, reacts in the DHDS unit with the feed diesel thereby reducing the sulfur content. Hydrogen sulphide gas is formed, which is further processed in an amine treating unit and sulfur recovery unit to produce elemental sulfur as a by-product.

The capacity of the DHDS unit is 1.4 MMTPA or 120,000 MTPM (metric tonnes per month) and cost Rs 6,220 million. Though the Ministry required 0.25% sulfur HSD, BPCL designed the plant to produce HSD with 0.05% sulfur (500 ppm) in anticipation of more stringent future specifications. The entire oil industry's demand in Greater Bombay of low sulfur HSD, amounting to approximately 50,000 MTPM in 2000/2001, was supplied by the BPCL refinery out of a total production of 70,000 MTPM. The balance HSD production of about 190,000 MTPM (with sulfur content varying between 0.20% and 2.0%) was supplied to certain direct consumers, other Maharashtra markets, and adjoining states.

Product Dispatch

Products are dispatched directly from the refinery by road, rail, pipeline and coastal tanker. Product tankers of 38000 MT capacity dock at the Marine Oil Terminal both for imports and export/coastal movements of surplus products. Products to be marketed in Mumbai are transferred by pipeline to its Sewri terminal. One of the main onshore dispatch facilities consists of a white products pipeline of 3.3 MMTPA capacity, which travels 250 to Manmad northeast of Mumbai for onward distribution. Products are pumped in batches and the interface suitably downgraded.

Pricing

When the Indian refineries started producing HSD with 0.25% (2500 ppm) sulfur content, the government adjusted the ex-refinery price to the import parity price of that grade. For the 0.05% (500 ppm) sulfur grade supplied by BPCL to the Greater Bombay market (and by other refineries to Delhi, Kolkata and Chennai) customers are charged a price higher by about Rs 0.50 per litre. Marketing companies reimburse the refineries the import parity price for 0.05% sulfur HSD advised by the Government (Empowered Standing Committee (ESC) to OCC (Oil Co-ordination Committee)) from time to time. Prior to the dismantling of the Administered Pricing Mechanism in April 2002, the difference between the import parity price and the metro price was absorbed by the oil companies. Now the oil companies are allowed to charge market-determined prices.

Expansion Project

The refinery is currently executing a project to expand its capacity to 12 MMTPA at a cost of Rs 16,000 million. Facilities include a new crude oil distillation unit, a hydro cracker, and a hydrogen unit, a sulfur recovery unit and augmentation of utilities and offsites. The project is scheduled for completion in 2004. The HSD production will be around 4.3 MMTPA or 360,000 MTPM.

Production of Euro 3 quality HSD with a sulfur content of 0.035% (350 ppm) and Euro 3 gasoline (maximum 1% volume benzene and will require a further investment of about Rs 17,000 million for which configuration studies are being undertaken. Half the HSD is planned to meet Euro 3 specifications whereas the rest will have a sulfur content of 0.05% (500 ppm).

ULSD

The refinery would need to make considerable further investments to supply Euro 4 quality ULSD with sulfur content of 0.005% (50 ppm). While some very preliminary work to examine its feasibility has been initiated, the size of investment required to produce ULSD has not been established. The refinery will obviously manufacture and market ULSD only if the price is attractive or incentives provided enable it to earn economic return on its investment.

Hindustan Petroleum Corporation Ltd.

HPCL is also one of the oldest integrated refining and marketing companies in India, with refineries in Mumbai and Vishakapatnam and a joint venture refinery in Mangalore. During 2000-2001 it sold 18.39 MMT of petroleum products and registered a gross turnover of Rs 471,800 million. HPCL has a network of 4,600 retail outlets and, similar to BPCL, is very well represented in Mumbai for historical reasons. The Mumbai refinery, commissioned in 1954, is located to the east of the BPCL refinery and separated by the Corridor Road.

Crude Oil Supply

The refinery currently has a rated capacity of 5.5 MMTPA and in 2000-2001 processed 5.57 MMT, consisting of mainly 2.2 MMT Bombay High crude oil and 3.0 MMT Arab mix (Arab light and Arab heavy in the proportion of 80:20). The Arab crude is required for the production of lube base oil stocks (LBOS). The logistics for receiving crude oils are the same as for BPCL.

HSD Production

The HSD production in 2000/2001 was 1.3 million tonnes or approximately 110,000 MTPM.

Refinery Units

The fuel refinery units consist of crude distillation units, a high vacuum unit, a catalytic cracking unit and various treatment facilities including a diesel hydro-desulfurization (DHDS) unit. There is a separate lubes refinery unit which consists of a high vacuum unit, a hydrogen unit and treatment facilities.

Diesel Hydro-desulfurization

As in the case of BPCL, in response to a directive by the Ministry of Petroleum and Natural Gas, the HPCL refinery also installed a DHDS unit. However, unlike the BPC refinery, it can only make HSD with sulfur content of 0.25% (2500 ppm) as mandated by the Ministry. Consequently, HPCL's requirements of 0.05% (500 ppm) sulfur HSD for Mumbai is met by BPCL and its own production is supplied to other markets in Maharashtra and adjoining states.

Product Dispatch

Products are dispatched directly from the refinery by road, rail, pipeline and coastal tanker. The main evacuation from the refinery is through a 161 km long white products pipeline of 3.67 MMTPA capacity which feeds the Pune terminal and hinterland. Products other than HSD are transferred by pipeline to its Sewri installation for further distribution in Greater Bombay.

Pricing

As in the case of BPCL, the refinery receives an adjusted import parity price for its HSD corresponding to a sulfur content of 0.25% (2500 ppm).

Expansion Project

Currently there is no approved project for refinery expansion. However, the refinery will be installing an additional reactor in its DHDS, and other facilities to meet HSD Euro 3 specifications in about two years time. Presumably, therefore, HPCL will continue post-deregulation to rely on BPCL to meet its requirement of HSD with a sulfur content of 0.05% (500 ppm) in Greater Bombay.

ULSD

Currently HPCL has no plans nor are they examining reduction of the sulfur content of HSD below 0.035% (350 ppm).

Reliance Petroleum Ltd.

Reliance Petroleum commissioned its 27 MMTPA capacity refinery at Jamnagar (located on the west coast of India, 830 nautical miles north of Mumbai) in April 2000, which achieved 95% capacity utilization in its first year. RPL presently does not have its own domestic marketing infrastructure and thus markets its products to the general public through the oil PSUs, apart from supplying feedstocks and fuels to other Reliance companies. In 2000-2001 it registered sales of Rs 309630 million and exports of Rs 64100 million, making it the country's largest exporter.

Crude Oil Supply

RPL is currently sourcing crude oil from a number of producers, some as far as Venezuela. It has the ability to process most kinds of crude oil including the heavy and sour varieties.

HSD Production

The HSD production in 2000/2001 was 9.58 MMTPA or approximately 800,000 MTPM.

Refinery Units

The main facilities at the refinery consist of a crude and vacuum distillation unit, a catalytic cracking unit, a delayed coking unit, a reformer and LPG, naphtha, kerosene and gas oil hydrotreaters and merox units.

Diesel Hydro-desulfurization

Being a modern state-of-the-art refinery, RPL is geared to supply diesel oil with a sulfur content of 500 ppm and manufactured a small quantity (34,000 MT) in 2000-2001. Depending on the demand for Euro 3 or Euro 4 quality diesel and the economics of manufacture, the refinery should be in a position to make the necessary investments to manufacture these grades by 2004-2005.

Product Dispatch

Products are despatched by road, rail, sea and pipeline. The refinery is linked to the Kandla-Bhatinda pipeline providing access to markets in northern India. Its world-class captive port enables it to achieve optimal tanker capacity both for crude and products. However, product tanker capacity will also be determined by constraints of the receiving port, i.e. in the case of Mumbai it will be 32,000 MT at the Pir Pau jetty.

Pricing

As refineries are already deregulated, RPL prices its products on import parity basis.

SUPPLY LOGISTICS OF DOMESTICALLY REFINED ULSD TO OIL COMPANY TERMINALS AT SEWRI

As RPL will need to move ULSD offshore from Jamnagar to Mumbai, its receipt will be through the import facility at Mumbai and is therefore dealt with separately in the next section. As the BPCL refinery currently supplies 0.05% sulfur (500 ppm) diesel oil to the Sewri terminals of various oil companies, no problem is anticipated in switching over to ULSD when manufactured by the BPCL refinery. More details are provided in Annex 6.1

Imports

LIKELY SOURCES

Based on discussions with Fesharaki Associates Consulting and Technical Services (FACTS), Hawaii (a consulting firm devoted to providing high quality strategic analysis in oil and gas), the likely scenario for ULSD manufacture in the Middle East and Asia Pacific region is broadly as follows:

- At present there are no Middle Eastern refineries planning to meet ULSD specifications of 50 ppm or less by 2004.
- In Asia, Japan will adopt 50 ppm diesel in 2004. The refiners in Japan are prepared to meet the specifications by the end of 2003, but initially all of ULSD is intended for the domestic market. Other countries that are planning to adopt 50 ppm include Australia, Republic of Korea, Taipei,China and Thailand (all by 2006).
- Certain Korean refiners—most notably SK and LG—will be capable of producing 50 ppm diesel, in limited amounts, starting in 2002. They plan to supply this diesel in the Seoul area in time for the FIFA (soccer) World Cup and the Asian Games in 2002. However, it is clear that they will still need to invest more to mass produce the 50 ppm diesel. SK and LG may be able to produce 30-40 kilo bbl/d and 15-25 kilo bbl/d, respectively, of ULSD by 2002. Whether they cater to the export market for this product depends on the price premium of the 50 ppm. Furthermore, if metropolitan areas such as Seoul continue to mandate use of this product after the sports events, Korean refiners may not have the capacity to export the ULSD.
- Shell has decided to upgrade its refineries in Singapore, Malaysia and Australia for 50 ppm, but are likely to fructify only by 2006-2007. Exxon Mobil is likely to follow suit.
- In short, 50 ppm ULSD is likely to be the norm all over Asia by 2007. When the new specification requirements are in place, domestic refineries will have no choice other than to produce it if they want to stay in business.

In conclusion, it appears that, except the Singapore refineries, all refineries will primarily be meeting their domestic ULSD demand. As the Singapore refineries are primarily export-oriented, it is presumed in this study that apart from two domestic refineries, India will have the additional option of sourcing its ULSD requirements for Mumbai city from the Singapore refineries by 2006-2007. However, ULSD can be imported from the European refineries in the short term.

IMPORT AND SUPPLY LOGISTICS OF ULSD TO OIL COMPANY TERMINALS AT SEWRI

For quality control reasons it will not be possible to receive ULSD imports at Butcher Island and at the same time permit imports and coastal movements out of the two refineries for other diesel grades. ULSD will therefore have to be imported at Pir Pau jetty for direct discharge to the Sewri terminals. More details are provided in Annex 6.1.

Currently the combined tankage of BPCL, HPCL, IOC and IBP at Sewri for HSD of 0.05% (500 ppm) is 52,500 MT, and this will need to be reallocated to ULSD in due course. Some additional tankage (possibly by adjustment with other HSD grades) may be required to facilitate receipt of a full tanker load of 32,000 MT to avoid incurring additional waiting times and demurrage.

Conclusions

The following three possible sources for ULSD have been identified:
- BPCL refinery, Mumbai
- RPL refinery, Jamnagar
- The Singapore refineries

For proximity to the Mumbai market and to ensure strict quality control in transferring ULSD to the Sewri terminals, BPCL is best placed of the three. However, RPL will be looking aggressively to market its products domestically and the Mumbai market should be attractive for RPL. While the Singapore refineries will be looking at the global market and the prices it can expect, BPCL and RPL would mainly target the domestic market and economic returns on their investment. Sales of ULSD in Greater Bombay (and other designated markets) will need to be promoted. At present ULSD is not produced in the country, but in the short run it can be imported to meet the Mumbai's specific requirements. It can also be made available on a wide scale once domestic production starts and importation from Singapore becomes possible. Domestic oil companies will need a 2 to 2½ year lead time to provide the requisite refining facilities to produce ULSD, if the right conditions are put in place straightaway.

ULSD Supply

RETAIL OUTLET NETWORK

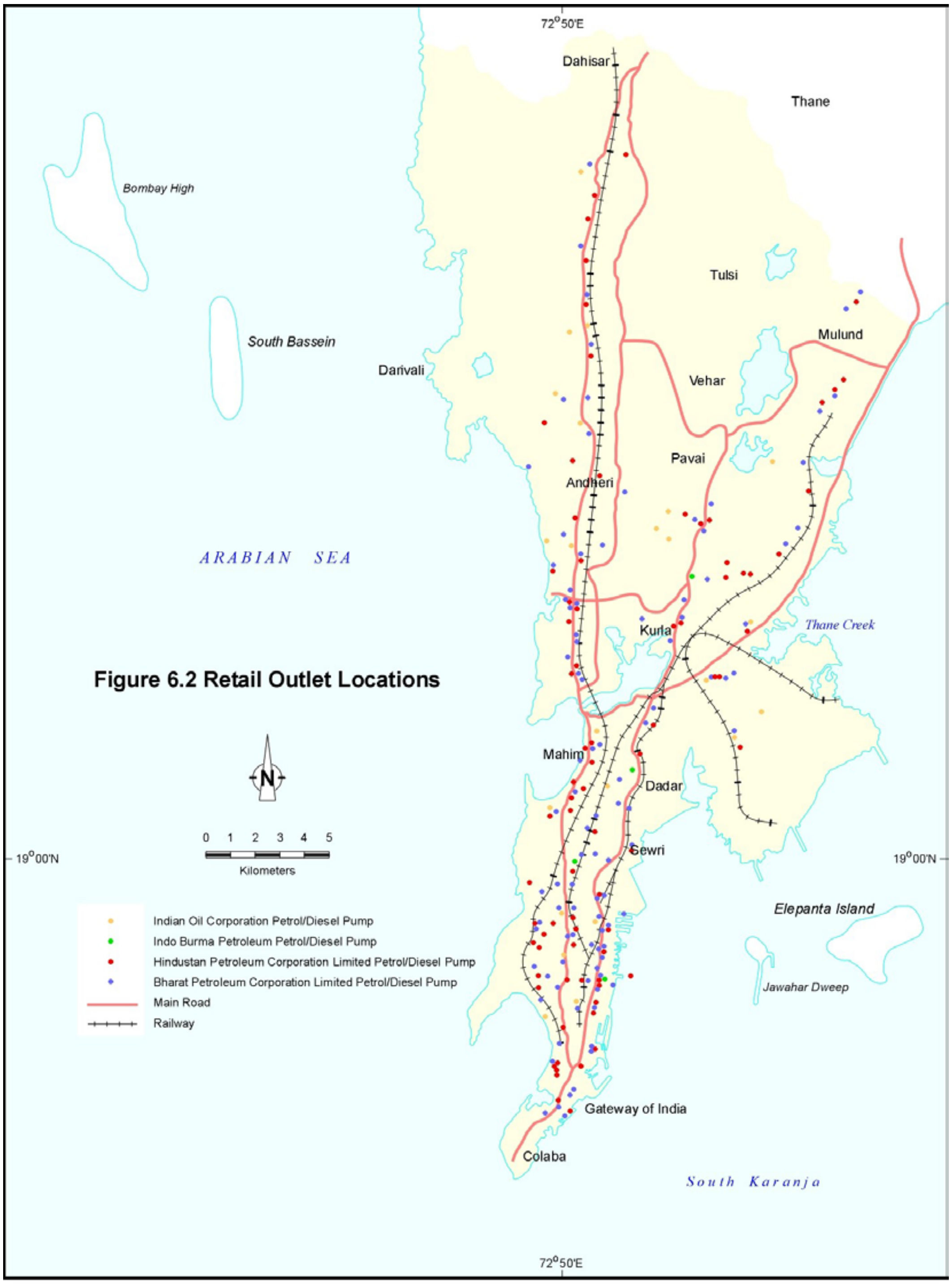
There are currently 257 retail outlets in Mumbai owned by the four oil majors, IOC (41), BPCL (101), HPCL (103) and IBP (12). Most of these outlets also sell gasoline or motor spirit (MS) and their location is shown in Figure 6.2. The density of retail outlets in south Mumbai is high. In central and north Mumbai these outlets are located mainly on the two highways that lead out of the city. On an average the outlets collectively dispense over 1000 KL per day.

The retail outlets have one or more underground storage tanks with capacity between 20 KL and 40 KL. Each outlet has between two to twelve filling nozzles. The outlets cater to all passenger modes of transport i.e. 2 wheelers, 3 wheelers, 4 wheelers, light commercial vehicles, and trucks. Most of the outlets have provision for services such as compressed air, lube oil sales, vehicle-servicing and pollution testing of gasoline vehicles. Some of the outlets have sufficient space for expansion.

The dispensing pumps can deliver 80 to 110 litres per minute at a pressure of 1.3 bar. However, it takes eight to ten minutes to fill a truck or bus tank as filling has to be stopped intermittently to avoid foam formation. Power bills in a typical outlet dispensing 20 KL/day are Rs 60,000 per month.

The leases of some retail outlet sites have come up for renewal and oil companies are under pressure from the lessors to increase the rents substantially. Also, to prevent the possibility of some of their dealer-owned sites from switching to other oil companies (especially when private players enter the retail business), the oil companies are taking vulnerable sites on company lease. They are also spending heavily on retail outlet modernization and adding convenience stores and other diversified activities to improve dealer profitability in order to retain their customer loyalty and promote brand equity.

Figure 6.2
Retail Outlet Locations



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CONSUMER PUMP NETWORK

Major HSD consumers such as BEST, MSRTC, BMC, the railways, fishing boat cooperatives, and private and government factories have their own storage facilities and diesel dispensing units called 'consumer pumps'. Of the diesel sold directly to the major consumers, the share of BEST is 65% and MSRTC, 10%. Some consumer pumps are set up temporarily to cater to specific construction project needs and dismantled as soon as a project is over. These units have one or more underground storage tanks with a capacity range of10 KL to 40 KL. Each unit has between two to six filling nozzles. Consumer pumps deliver 80 to 110 litres per minute. The sales vary widely, e.g., BEST consumes 235 KL/day and BMC, 5 KL/day.

DIESEL VOLUME SALES OF MARKETING COMPANIES

Tables 6.1 and 6.2 provide data on the quantity of HSD sold in the road transport sector through the network of retail and consumer pumps of Mumbai four oil companies. Consumer pumps account for 24% of the total diesel sold in Mumbai in the road transport sector. The total volume of diesel sales went down by 11% in 2000-01 compared to 1999-2000, due to depressed economic conditions that resulted in a decrease in transport vehicle movement.

Table 6.1
HSD Sales in Mumbai through Retail Outlets

(in kiloliters)

Year	BPCL		IOC		HPCL		IBP		Total	
	No. of Outlets	Sales (KL)	No. of Outlets	Sales (KL)	No. of Outlets	Sales (KL)	No. of Outlets	Sales (KL)	No. of Outlets	Sales (KL)
2000-2001	101	166837	41	64742	103	122143	12	14567	257	368289
1999-2000	101	182763	41	74621	103	137751	12	14390	257	409525
1998-1999	101	190939	41	77788	103	128921	12	18714	257	416362

Table 6.2
HSD Sales in Mumbai through Consumer Pumps

(in kiloliters)

Year	BPCL		IOC		HPCL		IBP		Total	
	No. of pumps	Sales (KL)	No. of pumps	Sales (KL)	No. of pumps	Sales (KL)	No. of pumps	Sales (KL)	No. of pumps	Sales (KL)
2000-2001	22	13318	46	81687	13	20186	1	3142	82	118333*
1999-2000	21	29304	44	80741	13	18178	1	2784	79	131007*
1998-1999	19	25546	44	85984	12	16818	1	6720	76	135068*

* In addition, consumption of diesel by railways and fishing boats aggregated 39,444 KL in 2000-2001. Figures for earlier years not available.

LOGISTICS OF DIESEL SUPPLY TO RETAIL OUTLETS AND CONSUMER PUMPS

Diesel (and gasoline) is transported from the four major oil company terminals at Sewri to the retail outlets by company-owned and contracted road tankers. The capacity of the road tankers varies from 12 KL to 20 KL, the majority being 12 KL capacity. Detailed data on oil tankers is provided in Table 6.3.

Table 6.3

Number of Tank Trucks Operating from Sewri Terminals for HSD and MS Delivery to Greater Mumbai Retail Outlets

Size of TT	BPCL		HPCL		IOC		IBP		Total
	Co-owned	Contract	Co-owned	Contract	Co-owned	Contract	Co-owned	Contract	
12 KL	15	58	13	50	5	70	4	16	231
14 KL	-	6	-	10	-	4	-	-	20
16 KL	10	-	-	-	-	2	-	-	12
18 KL	-	-	-	-	1	5	-	-	06
20 KL	6	1	-	-	-	5	-	-	12
Total	**31**	**65**	**13**	**60**	**6**	**86**	**4**	**16**	**281**

When the Mumbai oil companies switched from normal diesel (2500 ppm) to LSD (500 ppm), due to the multiplicity of tankage at Sewri it was possible to empty out and convert some storage tanks from normal diesel to LSD. However, this was not always possible in retail outlets. When supplies of LSD commenced to retail outlets in lieu of normal diesel, some mixing of the two grades resulted. However, over a fifteen-day period no mixed quantities were left and only LSD was available. It was after this period that the oil companies set new higher prices for LSD than normal diesel. A similar procedure will be required when switching over from LSD to ULSD.

ADULTERATION ISSUES

The adulteration of diesel with other petroleum products, mainly kerosene, has been a long-standing problem. Currently, diesel is sold in Mumbai at over Rs 23.75 per litre[9] while kerosene sells through the public distribution system (PDS) for Rs 9.01 per litre[10]. This price disparity has been responsible for unscrupulous truck drivers and dealer staff admixing small quantities of kerosene with diesel.

Adulteration is a criminal offense under the Essential Commodities Act (ECA) 1955, and is punishable with imprisonment and fine. In exercise of the powers conferred on it by the ECA, the Central Government has promulgated the Motor Spirit and High Speed Diesel (Regulation of Supply and Distribution and Prevention of Malpractices) Order 1998. The said order defines adulteration as a malpractice and prohibits dealers, transporters, consumers and any person from indulging in any manner in any of the malpractices including adulteration. It also authorizes officers of the Central or State Government or of an oil company to draw samples and for analysis at the laboratories listed in Schedule III of the Order. Schedule III lists 72 laboratories of which 59 belong to oil companies. The remaining thirteen are government, defence, and independent laboratories. In addition, forensic laboratories in the states are also authorized to receive and analyse samples.

9 http://www.bharatpetroleum.com/general/gen_petroprices.asp as on 26 November 2002
10 http://www.bharatpetroleum.com/general/gen_petroprices.asp as on 26 November 2002

Adulteration is thus a criminal offense. The law also enables government officials (apart from oil company officials) to draw samples and have them analyzed, if necessary, in independent laboratories and penalise those who indulge in adulteration whether they are transporters, dealers or consumers. In addition to the legal provisions discussed above, the oil companies have on their own taken initiatives to prevent and stop adulteration. These are:

Doping Kerosene with Furfural

In this method a chemical 'furfural' is added in small quantities to kerosene at the time it is dispatched from the storage point. If the kerosene is then used to adulterate diesel, its presence can be checked by adding aniline and citric acid to the sample, which turns pink. However, this pink colour is not easily detected, especially in dark diesel samples. This test has been largely nullified because people adulterating fuel found an antidote to neutralize furfural that rendered the test ineffective. Furfural continues to be used as a detection agent but not on a regular basis.

Addition of Blue Dye to Kerosene Sold under the PDS

To prevent diversion of kerosene to parallel marketers with higher selling prices, as no element of subsidy is involved, it was decided to add a blue dye to kerosene sold under the PDS. It was also expected that dye would help detect adulteration of diesel with PDS kerosene. However, as in the case of furfural, a chemical antidote was discovered to remove the color.

Marketing Discipline Guidelines

Oil companies have laid down marketing discipline guidelines that stipulate the duties and responsibilities of dealers and inspection guidelines for oil company officials. These guidelines specify the procedure to check HSD (and MS) adulteration, the types of tests to be carried out, sampling procedure and inspection frequency. These guidelines also stipulate the fines and penalties for adulteration, short delivery of product, stock variation and tampering with the seals on the dispensing pump totalizers. Broadly, penalties are imposed in two stages: the penalty for adulteration by first time offender is Rs 20,000 and 30 days suspension, and for second time offenders the dealership is terminated. Visiting company staff use totalizer readings on dispensing pumps to carry out quantity checks by tallying dealers' stock using. Dealers and visiting company staff check density and furfural, and more detailed checks are carried out by mobile company laboratories for the following:

- Visual test of appearance and color,
- Density,
- Kinematic viscosity, and
- Flash point and boiling point.

Mobile testing laboratories of oil companies check the dealers' stock about once every three months. Joint inspections are carried out by a team of officials from different oil companies on dealers' stock once every six months. While these checks do have some deterrent value, they are not foolproof.

Fuel Marker System

More recently, two companies have been promoting the use of biotechnology and electronic testing with claims that these systems are far superior to the two earlier ones that proved unsuccessful. In the case of furfural and blue dye the adulterant is marked but in these, it is the fuel (HSD or MS) that is marked. With the biotechnology method antigen and anti-bodies are used to detect adulteration, while with electronic testing a marker chemical is added and adulteration can be detected by a portable electronic device using spectrophotometry. Extensive test trials using the biotechnology method were conducted by two of the oil companies for over a year. However, it was found that layering of diesel in storage tanks (oil companies and dealers) can lead to incorrect test results, and the testing equipment also had an error margin.

The electronic marker system has been extensively evaluated at two oil company terminals in Mumbai and the results have been most encouraging. Computerised detector devices are used to give digital readings of fuel sample purity and there have been excellent responses to detect a variety of possible adulterants. The oil companies at six oil company terminals in Delhi will now conduct extended field trials. Once the system is fully proven, it is intended to introduce the same at retail outlets. The detector device can be used to check the fuel purity by the dealer at the time it is delivered by tanker. It can also be used to check the dealer's stocks by oil company representatives. Hence the fuel quality can be checked at two points of the supply chain. The cost of introducing the marker system is expected to be as low as Rs.0.01/litre.

'Pure for Sure' Retail Outlets

In 2001 BPCL introduced the 'Pure for Sure' concept. An extract from their Chairman's speech at the Annual General Meeting held on 26 September 2001, is given below:

> "BPCL has just launched an 'Enhanced Fuel Proposition (EFP) programme—a nationwide effort at dispensing pure quality of fuel in the correct quantity, and at the same time, delivering courteous, fast and efficient service. The retail outlets certified under this programme display the 'Pure for Sure' sign and BPCL guarantees that the correct quality and quantity is dispensed there. In order to be able to do so, strict quality control and tracking measures are in place. 100% adherence to quality control is being ensured at every point from the depot to the customers' fuel tanks. Special locks have been provided in tank lorries and comprehensive sealing has been undertaken of the dispensing units. Before certification, the retail outlets are subjected to stringent certification process tests to ensure that all parameters of the programme are complied with. Mystery audits and extensive inspections are carried out at these retail outlets to ensure that they continue to comply with the requirements of the EFP programme. The proposition has been rolled out at 98 retail outlets across Mumbai, Delhi, Kolkata, Bangalore and Chennai."

The special locks referred to are used by the storage point to seal the manifolds of the delivery valves and the manhole of each tank lorry. The locks are tamper proof and the keys cannot be duplicated. Individual locks are used for supplies to each retail outlet and the second key is kept by the dealer to use when decanting the tank lorry on arrival. Third party inspection by an outside agency has also been introduced.

So far, no adulteration of diesel stocks by transporters has been detected. Here the penalties for dealers are much stiffer than those prescribed in the Marketing Discipline Guidelines; they face instant termination of their dealership if found holding adulterated stocks. BPCL plans to expand the system to more dealers not only in Mumbai but also other cities. The other three marketing companies have instituted somewhat similar schemes.

Introduction of ULSD in BEST Buses

As BEST has their own dedicated consumer pumps it would perhaps be best to introduce ULSD initially only for BEST buses which acts as a captive fleet so that the quality of the product can be monitored (refuelling and maintenance is centralized) not only by the supplying oil company but also by BEST officials. It can then be extended to all types of diesel vehicles plying in Mumbai.

Conclusions

In conclusion, it can be said that the menace of adulteration has, to some extent, been checked but not completely eliminated. However, it should be possible in niche markets such as Mumbai or with certain customers e.g., BEST, BMC, to prevent adulteration in the short term through a combination of electronic technology, the 'Pure for Sure' or equivalent concept and close supervision of retail outlets/consumer pumps with stiff penalties. The long-term answer is the withdrawal of the subsidy on kerosene so that adulteration ceases to be a profitable activity.

Annex 6.1
Logistics of ULSD Supply

Logistics of Supply of Domestically Refined ULSD to Oil Company Terminals at Sewri

With HPCL refinery unlikely to supply ULSD, the logistics of BPCL refinery supplying the Sewri terminals is discussed here and reference made to Figure 6.1. BPCL refinery currently supplies 0.05% sulfur (500 ppm) diesel oil via Chowkey No. 3 to the Sewri terminals of BPCL, HPCL, IOC and IBP via a 14" line. As the line is also used to transfer high flash diesel oil with sulfur content of 0.20% and 0.25% for two important customers, as well as 0.25% sulfur diesel for retail outlets situated in the MMRDA and beyond up to Nasik, batch transfers are made and the interface between 0.05% sulfur diesel and other grades downgraded at the Sewri terminals. Due to the relatively short distance, the line quantity is only 500 KL and presents no problems. It is proposed to replace the 14" line by a 20" line when the line fill quantity will increase to 1000 KL requiring higher pumping rate by BPCL to ensure proper segregation of the different grades of diesel oil with ULSD substituting for the current diesel of 0.05% (500 ppm) sulfur.

Logistics of Import and Supply of ULSD to Oil Company Terminals at Sewri

Diesel oil imports at Butcher Island are discharged through a 16" jetty line and a 8 km long 30" submarine line up to the BPT manifold from where lines diverge to the HPCL refinery, the BPCL refinery and the Sewri terminals (using the 14" line referred to earlier). A reverse flow takes place for tanker loading to evacuate diesel out of Mumbai when required. As these lines will also be used for other diesel grades, when ULSD imports (or coastal movements of ULSD from RPL, Jamnagar) take place, batch pumping and interface downgrading would be required. However because of the very large line quantity and different line sizes i.e. 16", 30" and 14" (later to be replaced by a 20" line), ensuring laminar flow will not be possible because of the change in flow rates through different sections of the pipeline. This will affect the quality of ULSD received at the Sewri terminals. Therefore, imports of ULSD at Butcher Island do not appear to be a feasible proposition.

The new Pir Pau jetty has a draft of 10 m and can receive tankers of 32,000 MT capacity. Currently only low sulfur heavy stock, LPG and lubricants can be handled at this jetty. However, BPCL is considering a proposal to lay a 12" piggable line from Chowkey No 3 to the Pir Pau jetty for coastal movement and exports. By providing a cross-over connection at Chowkey No 3 to the 14" (later to be changed to 20") line to Sewri, the possibility of receiving ULSD imports at Pir Pau jetty for direct discharge to the Sewri terminals appears feasible, but a more detailed analysis will be required, which is beyond the scope of the present study.

CHAPTER 7

Supply of Compressed Natural Gas (CNG)

India is an emerging and an important player in the gas sector, both in terms of the size of its market and its incremental growth in the Asian region. India's balance of recoverable reserves of natural gas stands at 628 BCM (billion cubic meters). There has been a slow net depletion from the natural gas reserve figures since 1992 when the natural gas reserve figure was at 730 BCM. At the same time, gas sales have been growing over the last decade at an average annual rate of 7.1%. The Sub-Group on Development and Utilisation of Natural Gas (constituted under the Group on India Hydrocarbon Vision 2025) has projected that domestic gas availability is likely to decline from the current 78 million metric standard cubic meters per day (MMSCMD) to 36 MMSCMD by 2020, in the baseline scenario. According to the Natural Gas Development Master Plan, in 2004-2005 the gap between demand and supply is likely to be 120 MMSCMD, with supply projected to be 68 MMSCMD and demand (as per the Expert Group constituted by the Ministry of Petroleum and Natural Gas) at 188 MMSCMD. This gap will grow to 215 MMSCMD by 2009-2010.

Gas production and marketing has historically been held by the government as it controls the Oil and Natural Gas Corporation Limited (ONGC) and Gas Authority of India (GAIL). Recent initiatives, however, taken as a result of the restructuring of the oil and gas sector, have enabled both foreign and Indian private companies to explore new oil and natural gas reserves. Promoters are free to market gas at market price from gas fields being developed in the private sector. Currently, private players account for around 6-10% of the production and marketing. Given the declining production profile and the projections of rising demand, it is important to understand the prospects and logistics of CNG supply in Mumbai both via domestic production and import routes.

Domestic Natural Gas

In Mumbai, the main agency responsible for handling all activities related to natural gas is Mahanagar Gas Limited (MGL), which was incorporated on 8 May 1995. This is a joint venture company of the Gas Authority of India Limited (GAIL), a public sector undertaking, British Gas (BG), a leading international gas distribution company, and the Government of Maharashtra. At present, BG and GAIL's equity stake in the company's capital is 50% each. After public floatation however, GAIL and BG will ultimately each hold 35% while the public and the Government of Maharashtra will hold the remainder.

MGL provides CNG to domestic, industrial and commercial users and the transport sector. GAIL started the CNG movement for the transport sector in 1993 as a pilot project, and in April 1996 handed over all these activities to MGL. In order to promote natural gas, the Government of Maharashtra has granted interest-free deferral of sales tax for a period of thirteen years commencing 1 April 1996 to March 2009. This applies to the sale of natural gas/CNG effected to the domestic, commercial, industrial and transport sector.

Out of the total allocation of 1.5 MMSCMD of gas, MGL will supply about 32% to domestic consumers, 8% to commercial, 12% to CNG vehicles and 48%to industrial consumers. The company has drawn up a 'Vision 2004' document which envisages gas supply to 9,00,000 potential domestic households and 40,000 vehicles[11]. For this purpose it will lay a basic grid of steel pipelines of approximately 115 km and a polyethylene (PE) line distribution network of about 3,000 km.

At present, the MGL distribution network covers around 4,00,000 potential customers. Of this, over 80,000 domestic households and 300 commercial customers are already connected with piped natural gas, and around 20,000 domestic customers are in the process of being connected. Infrastructure for supplying natural gas has been laid in major residential areas of Greater Mumbai, and the company plans to cover the entire region of Greater Mumbai in two or three years. MGL has been quite successful with CNG in the transport sector, and there were 36,081 vehicles running on CNG in the city as of April 2002[12].

It is estimated by MGL that natural gas will replace 0.107 million tonnes of LPG and 0.04 million tonnes of kerosene per month in the domestic sector, 0.22 million tonnes of LSHS/FO/LPG per month in the commercial/industrial sector, and 18.39 thousand tonnes of gasoline per month in the transport sector.

SUPPLY SOURCE

MGL receives gas from Bombay High, which is India's largest oil and gas field. The gas comes via Uran and is brought to the city through steel pipelines by GAIL. The offshore oil and gas reaches landfall at Uran and is transported through pipelines to Trombay, from where it is transported to the city Gate station, near Chembur.

The demand for gas in India has been exceeding its supply since the 1990's. Due to this, the Government of India has been allocating gas through the Gas Linkage Committee. The Ministry of Petroleum and Natural Gas has allocated 1.5 MMSCMD of natural gas to the Government of Maharashtra for city gas distribution in Greater Mumbai. The natural gas allocation in the city according to MGL is:

- Transport sector: 0.18 MMSCMD (12%)
- Domestic sector: 0.48 MMSCMD (32%)
- Industry: 0.72 MMSCMD (48%)
- Commercial sector: 0.12 MMSCMD (8%)

At present MGL draws an average of 0.4 MMSCMD from GAIL. Of this, 0.15 MMSCMD (37.5%) is allocated to transport and the rest to the domestic, commercial and industrial sectors. Since MGL is drawing less than its sanctioned allocation, the sale of gas can be increased by that much. In the transport sector for example, the sales can be increased to 0.18 MMSCMD from the present 0.15 MMSCMD. If there is a need to increase the sales in this sector any further it can be done only at the cost of other sectors, such as power and fertilizer. However, the overall supplies are limited.

Table 7.1 provides the quantity of gas sold by MGL to various sectors. The sales volumes in 2000-2001, 94.5 MMSCM (0.259 MMSCMD), have been more than the sales of the past five years taken together. In the transport sector, utilization grew more than 7.5 times in the pe-

[11] As given on the MGL web site: www.mahanagargas.com
[12] As given on the MGL web site: www.mahanagargas.com

riod 1996-1997 to 2000-2001. In 2000-2001, the maximum gas utilization was by the industrial sector (around 44%). But, according to the long-term gas profile of the Bombay Offshore region as given in the Natural Gas Development Master Plan, the gas production of ONGC and the gas available for sales at Uran is likely to decrease by around 84% from 12.0 MMSCMD in 2000-2001 to 1.909 MMSCMD in 2009-2010.

Table 7.1
Sectoral Gas Utilization

(in MMSCMD)

Sector	2000-2001	1999-2000	1998-1999	1997-1998	1996-1997
Transport	0.11219	0.06397	0.04948	0.02896	0.01471
Domestic	0.01477	0.00978	0.00395	0.00134	0.00005
Commercial	0.01734	0.00718	0.01803	0.00071	-
Industrial	0.11438	0.02118	0.00425	0.00044	-
Total sales	**0.25871**	**0.10208**	**0.05951**	**0.03151**	**0.01477**

STORAGE AND DISTRIBUTION WITHIN THE CITY

Natural gas is transported from the source (Bombay High) to the end use through pipelines. CNG can be distributed to vehicles through various kinds of stations; the basic ones are online, mother and daughter stations. There are also mother-cum-online stations and daughter booster stations. The entire process is explained in Figure 7.1.

- Online stations are compression stations which tap the gas directly from the gas pipeline, compress it to the required pressure and dispense it to vehicles directly.
- In the mother-daughter type, the mother station is a compressor station, which dispenses compressed gas. The CNG thus produced is transported to refuelling stations using an LCV/trailer-mounted cascade of cylinders. The refuelling stations, where retail dispensing of CNG essentially takes place, is called the daughter station, and is a retail outlet of CNG. The daughter station dispenses gas using mobile cascade pressure. These are replaced when pressure falls and pressure depleted mobile cascade is refilled at the mother station. In the case of daughter stations, one mobile cascade can fill 25-30 vehicles total. As the pressure of gas goes down, the time taken to fill a vehicle increases.
- Some of the daughter stations also have a compressor that ensures that gas pressure is maintained at 250 bar. These stations are daughter booster stations.
- Some of the mother stations also have CNG dispensing facilities, these are mother-cum-online stations.
-

EXISTING INFRASTRUCTURE

Figure 7.2 presents the CNG distribution network map in Mumbai. At present, 90 km of steel pipeline and 720 km of PE pipeline network has been laid down. For the transport sector, MGL operates 24 CNG outlets in Mumbai. There are two mother-cum-online stations, eight online stations, thirteen daughter booster stations and one daughter station. The details of the retail outlets are given in Annex 7.1. Most CNG stations are located in the oil marketing company (OMC) outlets of IOC, BPCL and HPCL. Currently IBP, the fourth OMC in Mumbai, does not have any outlet with CNG dispensing facilities. MGL has only two retail outlets for CNG supply and private parties own two outlets. There is only one consumer pump, which is dedicated to the BEST buses. At present, there are no CNG outlets in the southern-most part of the city area, and MGL proposes to open a few retail outlets in this area.

Figure 7.1
CNG Distribution System in Mumbai

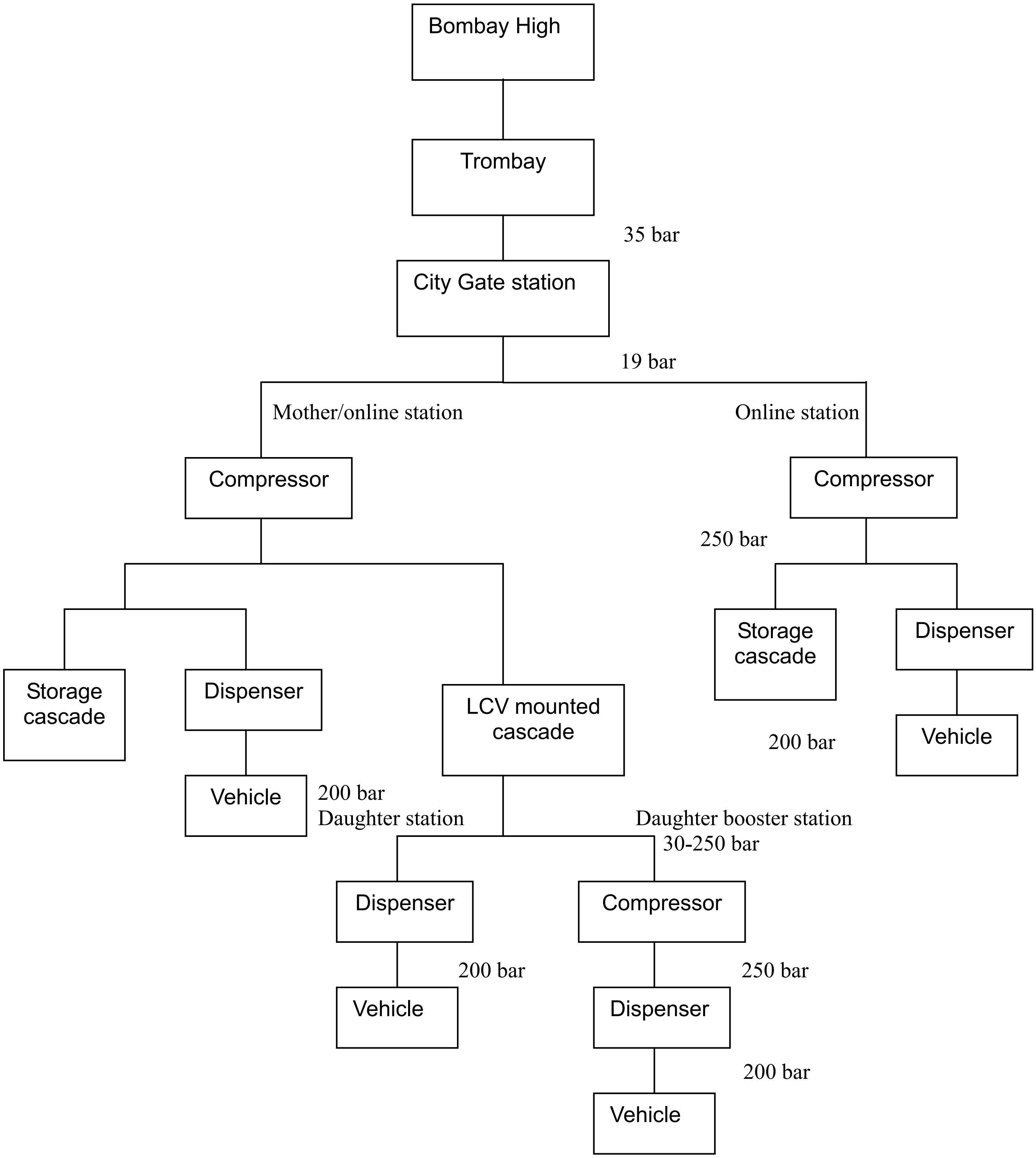
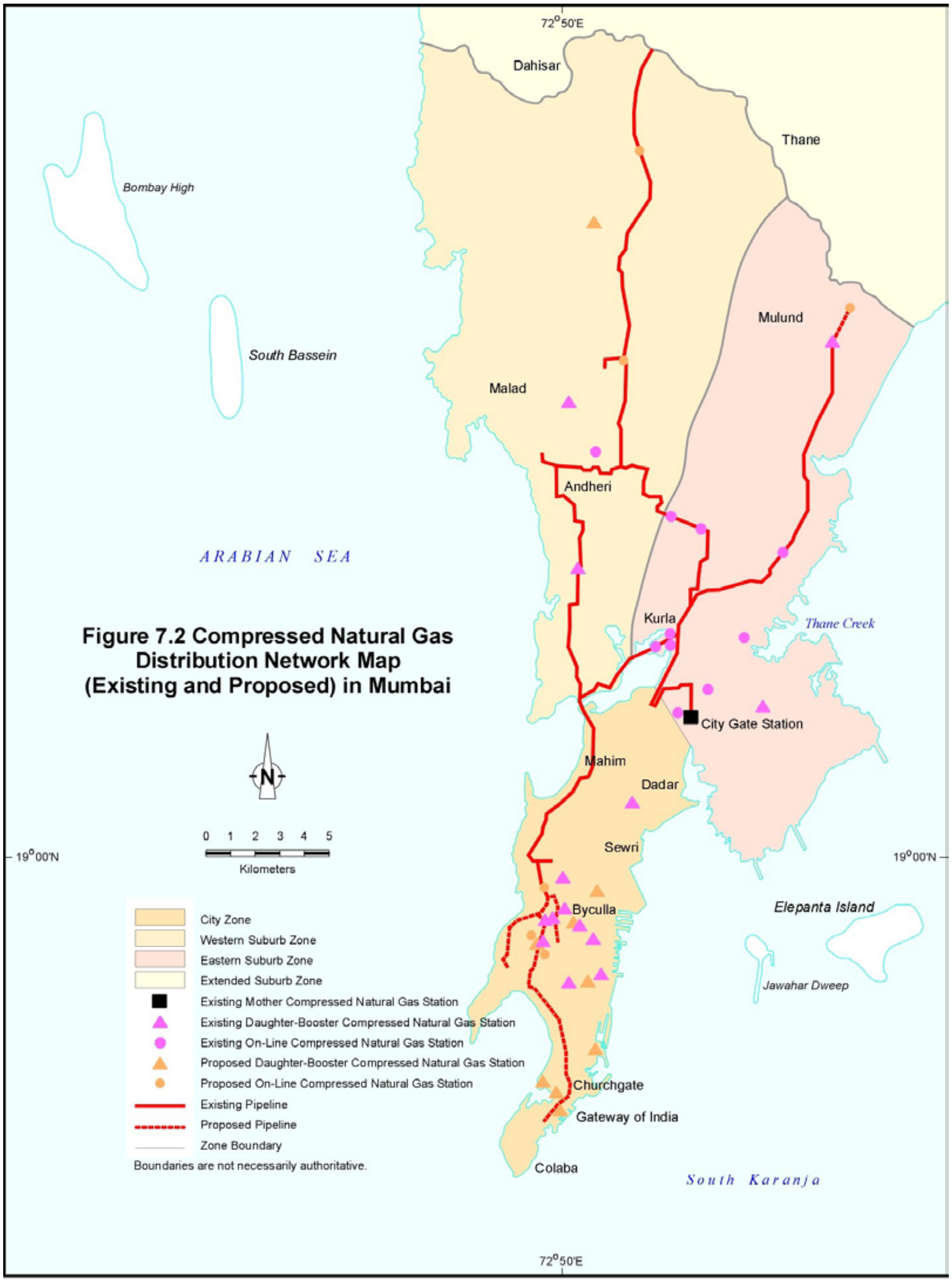


Figure 7.2
Compressed Natural Gas Distribution Network Map (Existing and Proposed) in Mumbai



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CNG is a competing fuel to gasoline and diesel oil. The oil companies initially allowed MGL to put up CNG dispensing facilities. However, as BPCL and HPCL (both heavily represented in the Mumbai retail market) are due to be privatised, this association may not continue for very long. The two oil companies are required to release some of their retail outlet sites where leases have expired and this has put additional pressure on the remaining outlets. Also, to protect their markets and improve their brand image, the oil companies are setting up convenience stores, ATMs, computer centers etc. at their retail outlets, which puts a further premium on space. Moreover, now that LPG has been allowed as an automotive fuel and is currently produced by these companies, promoting the use of LPG may be more attractive than CNG as all these oil companies are themselves marketing LPG. In view of these developments and also space and safety considerations, it appears unlikely that many more of the existing gasoline and diesel stations will be converted to CNG stations beyond the ones listed in Annex 7.2.

CNG VEHICLES

The total number of CNG vehicles in Mumbai in January 2002 was around 26,000. A large percentage of these vehicles (around 80%) are taxis. More than 35% of the total number of taxis (58,696) has converted to CNG on account of the initiative taken by the taxi associations, which are very powerful. Taxis fitted with three cylinder diesel engines have been banned from operating within Mumbai city. Given the choice between CNG and gasoline taxis, the former is economically more attractive as the operating costs for a CNG taxi are much lower. This issue does not arise in the case of autorickshaws, as there are no diesel-operated autorickshaws. Barely 1% of autorickshaws (1,252) have converted to CNG however, due to most owners being discouraged by the long refuelling wait times. Also in contrast to the taxis, the autorickshaws associations have not taken up this campaign. Around 1% (46) of the total number of BEST buses (3,458) is operating on CNG, and all of these are new CNG buses. To date, none of the diesel buses have been converted.

CNG FILLING STATIONS FOR BEST BUSES

The CNG filling station for BEST buses is located in one of its depots, but BEST is not satisfied with this arrangement. The situation is unsatisfactory because the buses can be refuelled only at night and the station has a compressor with a very low capacity of 250 SCM/h (200 kg/h) which cannot cater to this demand. However, MGL is not willing to provide a higher capacity compressor unless BEST allows the station to be used by other vehicles. As a result, BEST has put on hold its order for 170 new CNG buses. If more of the BEST buses are to operate on CNG in future, then MGL will have to provide more dedicated CNG-dispensing stations to BEST. At present, no private buses operate on CNG. If they do in future, MGL will have to make arrangements for providing more mother-cum-online or online stations for catering to their requirements.

FILLING TIME

The average vehicle filling time is given in Table 7.2. Currently in Mumbai, the waiting time for CNG filling is 1 to 1.5 hours, which is very high and discourages CNG use. The peak hours are in the mornings and evenings. For each of the daughter/daughter booster stations, LCVs carrying cascades (with a total capacity of 400kg) make three to four trips daily. Out of the fourteen daughter/ daughter-booster stations, only one station is a daughter station. The problem of lack of pressure is not as significant in daughter-booster stations as in daughter stations. The filling up time for online and daughter booster stations is more or less the same.

Table 7.2
CNG Filling Times, and Average Fuel Consumption of CNG Vehicles

Category	Time taken (in minutes)	Tank capacity (kg)	Average consumption (kg/day)
Cars	5-6	10/14	4.5 – 5
Autorickshaws	3-4	3	2.5 – 3
Bus	10-15	84	60

PROPOSED INFRASTRUCTURE

MGL plans to have a total of fifty retail outlets by 2004, thirty-five of these being online and fifteen daughter booster stations. The details of the proposed outlets are given in Annex 7.2 and are shown in Figure 7.2. Further, MGL plans to upgrade around seven daughter-booster stations to online stations. Four of these are located in areas of South Mumbai.

DEALERSHIP COMMISSION

The dealership commission that MGL paid to the Oil Marketing Companies (OMC) in February 2002 was Rs 1.2 per kg. The OMC was passing Rs 0.73 per kg to the dealer and kept the balance of Rs 0.47 per kg.

CURRENT PRICE BUILD-UP OF CNG

The retail-selling price of CNG to consumers in Mumbai as of February 2002 was Rs 18.35 per kg compared to Rs 21.12 per litre of current diesel (maximum 500 ppm S) supplied to Mumbai. The detailed price build-up is given below:

- Basic sale price — Rs 13.537
- OMC margin — Rs 1.200
- Sales tax @ 13% of basic price — Rs 2.069
- Surcharge of tax + Turnover tax* — Rs 0.365
- Excise duty — Rs 1.179
- Total (current sale price) — Rs 18.350

* The surcharge is 10% of sales tax and the turnover tax is 1% of basic price. The sales tax component has to be paid by the OMC, but the OMC's need not pay the excise duty as it is paid by MGL.

PROBLEMS FACED BY MGL

MGL is facing many problems in setting up the CNG stations. A shortage of available sites is one of the company's major concerns and as Mumbai is one of India's most densely populated cities, finding a suitable plot is quite difficult. Many of the available sites do not meet the technical requirements, viz. the minimum area required for setting up a CNG station. This is approximately 300 square meters for light duty vehicles, while catering to heavy-duty vehicles requires a larger plot area. Apart from this, once the site has been decided, permission from a number of statutory authorities is required. These include the Chief Controller of Explosives, Nagpur; Factories Department, BMC; Buildings Department, BMC; Chief Fire Officer, Mumbai;

Police Commissioner, Mumbai (in the case of private landowners, a No Objection Certificate). For laying pipelines, permission is required from statutory authorities such as the BMC (all the utility companies), Public Works Department, MMRDA, Railways etc. In addition, the OMCs are reluctant to give their prime sites for CNG dispensing facilities because of their preference for LPG. Some of the retail outlet sites are disputed, facing problems such as land lease expiration, issues of hiking rents, etc. Also, the land cost for retail outlets is very high, posing additional problems in expanding the number of retail outlets.

Import of Liquefied Natural Gas

Faced with a widening gap between the demand and supply of natural gas, the government has considered a number of options for importing gas. Initially the stress was on import of natural gas through pipelines, and so a number of pipeline projects have been proposed. Examples are the Oman-India pipeline conceived by the Oman Oil Company at a cost of $5 billion, the Iran-India offshore pipeline, the Iran-Pakistan-India onshore pipeline, the Bangladesh-India pipeline, etc. However, the pipeline projects have failed to take off due to geo-political problems with some under sea pipelines posing technical challenges, and some land pipelines traversing national boundaries facing political deadlocks. Thus, the government has encouraged LNG imports to meet the immediate requirements of imported gas. A number of LNG terminals in India have been proposed, including the Jamnagar LNG terminal, Pipavav LNG terminal, Dahej LNG terminal, Hazira terminal, Dabhol terminal, etc.

TROMBAY LNG TERMINAL

The most appropriate LNG terminal would have been the terminal proposed at Trombay, situated near Mumbai (Figure 7.3). The India Natural Gas Company Pvt. Ltd (Indigas), a company owned equally by Tata Power Company, Total Gas and Power India (a wholly owned subsidiary of the French oil major, Total Fina Elf) and GAIL was to build the LNG terminal facility. However, Total Fina Elf has put the project on hold. The first phase of the project with 3 MT capacity (expandable to 6 MT in phase II) was expected to begin by 2004 at an estimated cost of $350 million.

Figure 7.3
Liquefied Natural Gas Terminals in Maharashtra and Gujarat

It has recently been reported that the project may be scrapped due to non-availability of any captive customers for the gas, and also the ENRON crisis, which has dampened this project. As a result this project is not considered as a potential gas source through the LNG import route.

The next two LNG terminals that will be relevant for meeting the Mumbai's CNG demand, are the LNG terminals at Dahej and Dabhol. Pipelines will be laid to transport gas from both the Dabhol and Dahej terminals.

DAHEJ LNG TERMINAL

Dahej is situated in the Gulf of Cambay on the West Coast of Gujarat State (Figure 7.3), and was selected as an LNG terminal due to the substantial gas demand in its vicinity. The LNG terminal will be set up by Petronet LNG Ltd (PLL) which was incorporated in April 1998 with an authorized capital of Rs 12 billion. The promoters of PLL are public sector companies in the Indian oil and gas sector, GAIL, ONGC, IOC and BPCL. The combined equity share of these four companies is not to exceed 50%, with each having an equal share of 12.5% so as to ensure that PLL operates as a private sector company. The other half of the equity will be shared with the strategic partners, namely Gas de France (10%), LNG suppliers Rasgas (10%), the Gujarat state government (5%) and financial institutions (25%).

PLL entered into a long-term sales/purchase agreement with Rasgas of Qatar in July 1999 for the supply of 5 MMTPA of LNG on an FOB basis. This is a 25-year contract effective from July 2003. The LNG price payable by PLL will be linked to the weighted average price of a basket of crude oils imported by Japan. The total project cost estimate is Rs 25 billion. The initial terminal capacity is 5 MMTPA expandable to 10 MMTPA. LNG storage will consist of two 160,000 cubic meter tanks, with a provision to add a third tank.

The project has already received environmental and other clearances by the Gujarat State government. It has also received approval from the Ministry of Environment and Forests, Government of India, and clearance in principle from the Chief Controller of Explosives. The expected date of project implementation is June 2004.

GAIL (60%), IOC (30%) and BPCL (10%) will market the gas. GAIL will be exclusively responsible for gas transportation for all the marketers on payment of a transportation charge. It will also be responsible for laying additional pipelines that may be required. Feasibility studies are being carried out for a 400-km pipeline from Dahej to Uran (near Mumbai) via Hazira, where another LNG terminal is being set up by SHELL.

DABHOL LNG TERMINAL

The multinational company Enron initiated this project (location as shown in Figure 7.3). The company first negotiated a fast-track power project with the state government of Maharashtra in 1993-1994, and the project was renegotiated thereafter. The construction of the power plant was started in 1996 through the formation of the Dabhol Power Company (DPC), in which Enron held the majority stake (85%). The power plant was designed to use naphtha as the primary fuel. DPC also started construction of an LNG terminal at Dabhol to meet gas requirements of their power units, to phase out naphtha as a fuel and use gas to generate power.

As part of the first phase, 750 MW of power was to be generated and after the completion of both phases the generation capacity was supposed to be 2100 MW. The second phase also included a 5 MMTPA LNG terminal that would supply gas to the power plant and also sell it to consumers. Three storage tanks of 160,000 cubic meter capacity each are being installed, with provision for an additional fourth tank. A full-fledged port is ready at Dabhol with required arrangements to receive LNG ships of 135,000 cubic meter capacity. Enron had planned to market around 3 MMTPA of surplus re-gasified LNG, after meeting the Dabhol Power Corporation's requirement of 2 MMTPA for power generation. Metropolitan Gas, (Metgas) an Enron subsidiary in India, had planned to lay a 163-km pipeline from the Dabhol terminal towards Mumbai, parallel to the west coast and further to the industrial centres in west Gujarat.

Metgas had entered into an agreement with Oman-LNG in 1998 for the import of 1.26 MMTPA of LNG at Dabhol starting in 2001. Metgas signed a second agreement with Ad Gas of Abu Dhabi for a further 0.54 MMTPA of LNG. Metgas is also reported to have signed a confirmation of intent with Malaysia LNG Tiga for the supply of 2.6 MMTPA of LNG, starting in mid-2002 for supplying gas to Maharashtra consumers.

Soon after the operations began in the first phase, MSEB was unable to pay for the prohibitive cost of power from DPC. To review the Power Purchase Agreement and to solve the crisis, the Madhav Godbole Committee was instituted to study and further advise on the 'right' tariff that the MSEB (Maharashtra State Electricity Board) should pay to DPC for power. The recommendations of the committee could also form the basis for renegotiations for the troubled Power Purchase Agreement between MSEB and DPC. The main issue was the disparity in the price of power that MSEB buys from other suppliers and what it had to pay DPC. The price was Rs 2.11/unit for power purchased from other suppliers, while the price of power purchased from DPC varied between Rs 3.97 to about Rs 6.3/unit. The price of power purchased from DPC would depend upon the capacity utilization of the plant. There was a fixed cost component that DPC had to be paid as per the Power Purchase Agreement, which would have to be paid irrespective of whether the MSEB purchased any power from DPC or not.

The LNG terminal was slated to be complete by the end of 2001; the terminal is at present 85% complete however its commissioning is uncertain due to serious differences that have arisen between Enron and the MSEB. Attempts to resolve the issues by the intervention of the Indian financial institutions (IDBI, SBI etc) that have financed the project are also underway.

It is hoped that some compromise will eventually be worked out and talks are still underway to resolve the situation between the parties involved. At present, BSES and Tata Power Company have shown an interest in taking over the DPC project, and GAIL has also joined the fray as a potential bidder.

To conclude, the Dabhol and Dahej LNG terminals connected with Mumbai via gas pipelines are considered as potential sources of gas supply.

Annex 7.1

Existing CNG Retail Outlets in Mumbai

Outlet Name	Owner Company	Outlet Type
Mahanagar Gas Limited, City Gate Station, Sion	MGL	Mother station
National Highway Trucking, Chembur	HPCL	On-line station
Kausar Auto Services, Agripada	BPCL	Daughter Booster station
Gujarat Service Center, Arthur Road	IOCL	Daughter Booster station
Modern Auto, Mumbai Central	HPCL	Daughter Booster station
Parekh Petroleum Services, Vile Parle (W)	IOCL	Daughter Booster station
Shri CNG Filling Station, Chembur	Private	Daughter station
Mumbai Taxi Association, LBS Kurla	HPCL	On-line station
Universal Motors, Mazgaon	BPCL	Daughter Booster station
Royal Service Station, Andheri (E)	IOCL	On-line station
Chembur Service Station, Chembur	BPCL	On-Line station
Amar Automobiles, Wadi Bunder	BPCL	Daughter Booster station
American Auto Supply Co, Byculla	HPCL	Daughter Booster station
Anik Bus Depot, Sion	BEST	On-line station
Highway Automobiles, Ghatkopar (W)	BPCL	On-line station
Vijay Automobiles, LBS Marg, Kurla (W)	BPCL	On-line station
Jogeshwari Petrol Supply, Jogeshwari (W)	BPCL	On-line station
Global Automobiles, Mulund (W)	Private	Daughter Booster station
Mahanagar Gas Limited, Bandra (E)	MGL	On-line station
Mastakar Auto Service, Oshiwara (W)	BPCL	Daughter Booster station
Uganda Service Station, Wadala	BPCL	Daughter Booster station
New Bharat Automobiles, Jacob Circle	BPCL	Daughter Booster station
Sonal Super, Delisel Road	HPCL	Daughter Booster station
Royal Auto, Bhendi Bazar	HPCL	Daughter Booster station

Annex 7.2
Proposed CNG Outlets (by March 2002)

Outlet Name	Owner Company	Outlet Type
Tilak Automobiles, Frere Road	HPCL	Daughter Booster station
Jaya Auto, Borivali (E)	HPCL	On-line station
Sakinaka Petrol, Sakinaka	HPCL	On-line station
Premier Industrial Corporation	Private	On-line station
Express Petroleum, Colaba	BPCL	Daughter Booster station
Coco, Byculla	IBP	Daughter Booster station
R.T.O Plot, Tardeo, Mumbai Central	GOM	On-line station
Malhotra Automobiles, Mahalakshmi	BPCL	On-line station
Chheda Service Station, Mulund (W)	BPCL	On-line station
Modern Service Station, Mumbai Central	BPCL	On-line station
Plot No. 158A, Opp. Raheja Centre, Nariman Point	GOM	Daughter Booster station
Gill Auto Service, Cotton Green	BPCL	Daughter Booster station
Maharashtra Auto, Mumbai Central	HPCL	Daughter Booster station
Plot. No. 243A, Vidhan Bhavan Rd, Nariman Point	MMRDA/GOM	Daughter Booster station
Karfule Pvt. Ltd, Ballard (Estate)	HPCL	Daughter Booster station
Kapadia Bros, Malad (W)	HPCL	Daughter Booster station

CHAPTER 8

Costing of CNG and ULSD Supply and Distribution to Mumbai's Transport Sector

The cost of supplying CNG has been estimated via both the domestic route and the import route. For ULSD, the feasibility of its indigenous production and the cost involved has not been considered in the current study because refineries have not yet assessed this. However, since diesel prices are already import-parity based, ULSD imported to Mumbai from Singapore (which is a potential source of ULSD in future) is used for costing purposes, though indigenous refineries could well supply it in future.

Costing the two fuels essentially comprises a sum of the following three estimated costs, described in detail in the following sections.

- For ULSD, its CIF (cost insurance and freight) price imported from Singapore. For CNG, via the import route the LNG landed cost at the Dabhol/Dahej terminal and via the domestic source the derived cost of indigenous natural gas by drawing a thermal parity with fuel oil.
- Cost of transportation by road or pipeline of fuel to the entry point in Mumbai
- Cost of distribution in Mumbai

No import duty, excise duty and sales tax has been included in the estimations so that the actual cost of supply only is reflected.

Cost of Supplying CNG

LNG LANDED COST AT DABHOL/DAHEJ

Two methods were used to arrive at the landed cost of LNG in Dabhol/Dahej. In both cases a relationship was established between the LNG landed price (CIF price) and the JCC (Japanese Crude Cocktail) prices, because Japan was the first and continues to be the biggest LNG importer in the Asia-Pacific region. LNG prices in Japan have traditionally been based on the prices of imported crude oils.

Method 1

The standard formula given in equation (8.1)[13] is commonly used for arriving at the LNG CIF price based on JCC CIF price and the distance of the buyer from LNG sources.

[13] Equation (8.1) was taken from the website <www.gujfuel.com/ lnghistory.html.>

P = 0.1485 (JCC CIF) + a --- (8.1)

Where, P is the derived LNG CIF price in US dollars per million British thermal units ($/MMBTU); and the JCC price is the weighted-average CIF price of twenty crude oils imported by Japan in a given year. Based on the factor a, which represents the freight element in equation (8.1), the freight for LNG imported to the west coast of India from Oman/Qatar was estimated to be US$0.52/MMBTU (BECHTEL Consulting et al, 1998).

Three Dubai crude oil prices (namely US$ 22, 25 and 28 per barrel) were considered for estimating the landed CIF price of the fuels. The OPEC crude prices are expected to vary between $ 22 to 28 per barrel.

The JCC CIF monthly average price was related to the Dubai crude free on board (FOB) price for the period January 1998 to June 2001 and equation (8.2) was obtained. This equation was used to determine the JCC CIF price for the three levels of Dubai crude oil prices considered in the study.

JCC CIF= 1.0446 (Dubai Crude FOB) + 0.551, R^2 = 0.93 --- (8.2)

The projections of JCC CIF and LNG landed prices were estimated using equations (8.2) and (8.1) respectively for the three crude oil prices and are given in Table 8.1.

Table 8.1

LNG Landed Price

Dubai price ($/BBL)	JCC CIF ($/MMBTU)	LNG CIF ($/MMBTU)
22	23.53	4.01
25	26.67	4.48
28	29.80	4.95

Method 2

The LNG CIF price in $/MMBTU was calculated by relating the historical LNG CIF prices in Japan (imported from Qatar) with the JCC prices in $/bbl (barrel). Monthly data compiled from IEA statistics for the period January 1997 to June 2001 (54 data points) was considered for arriving at the regression equation (8.3)[14]. The LNG CIF price at Japan for Qatar imports was considered, as imports to Dabhol/Dahej will also be from Qatar.

P = 0.1079 (JCC) +1.6336, R^2 = 0.78 --- (8.3)

In order to arrive at the cost of LNG import in India the following changes were made in equation (8.3).

- Cost of freight from Qatar to Japan (7000 nautical miles) was deducted from the estimated value. This cost is $ 1.1/MMBTU as estimated in the BECHTEL-TERI study in 1998 (BECHTEL Consulting et al. 1998). This gave the FOB cost of LNG in the Middle East.
- To the modified equation the freight from Qatar to Dabhol (1352 nautical miles) was added. This value is $ 0.52/MMBTU (BECHTEL Consulting et al. 1998).

[14] Time series data has been compiled from various issues of IEA starting from 1st Quarter 1997 to 3rd Quarter 2001.

The modified equation 8.4 is given below.

$$P = 0.1079\,(JCC) + 1.0536 \qquad \text{--- (8.4)}$$

Equation (8.4) gives P, which is the LNG CIF price for Dabhol/Dahej. Using equation (8.4) the following prices for LNG CIF Dabhol/Dahej were arrived at for three levels of Dubai FOB prices and are presented in Table 8.2.

Table 8.2
LNG Landed Price at Dabhol/Dahej

(in $/MMBTU)

Dubai ($/BBL)	LNG CIF, Japan ($/MMBTU)	LNG CIF, Dabhol/Dahej ($/MMBTU)
22	4.17	3.59
25	4.51	3.93
28	4.85	4.27

The prices determined by Method 2 only were used as a basis for arriving at the landed cost of LNG at Dabhol/Dahej, because they are determined from real-time past price data for the period 1997 to 2001.

Receipt, storage and re-gasification of LNG, subsequent pipeline transfer to Mumbai from Dabhol/Dahej, and further supply costs in Mumbai are addressed in detail below.

LNG STORAGE AND RE-GASIFICATION COST

To the LNG (CIF) price estimated using equation (8.3) were added the storage and re-gasification costs at an LNG terminal nearest to the city. The storage and re-gasification costs were estimated to be $ 0.40 per MMBTU in the BECHTEL-TERI study (BECHTEL Consulting et al, 1998). The two terminals that were considered for supplying gas to Mumbai are Dabhol and Dahej.

TRANSPORTATION COST FROM DABHOL/DAHEJ TO MUMBAI

To the LNG (CIF) price and the storage and re-gasification cost was added the transportation cost of delivering natural gas at the City Gate Natural Gas station in Mumbai, from where natural gas is distributed throughout the city. It was assumed that the CIF price of LNG was the same for both Dabhol and Dahej terminals.

For both cases the pipeline size considered was thirty inches and the distances were 163 km for Dabhol and 400 km for Dahej. The flow rate of gas was assumed to be 18.5 MSCM/day. The power consumption and investment required were taken from the BECHTEL-TERI Study in India in 1998 (BECHTEL Consulting et al. 1998). The investment required for the Dahej-Mumbai pipeline was arrived at based on the investment requirement presented by GAIL keeping all other conditions similar to the Dabhol-Mumbai pipeline. The power tariff is assumed at Rs 2.40 per kWh, which is paid to Maharashtra State Electricity Board for purchase of power.

The tariffs calculated based on the above cases for both pipelines are given below:

- Dabhol-Mumbai $ 0.26/MMBTU
- Dahej-Mumbai $ 0.38/MMBTU

The cost of natural gas at the City Gate station in Mumbai from the LNG route is given in Table 8.3.

Table 8.3
Estimated Price of Natural Gas from LNG Route
up to the City Gate Station in Mumbai

Dubai crude price $/bbl	Natural gas from Dahej $/MMBTU	Natural gas from Dabhol $/MMBTU
22	4.37	4.25
25	4.71	4.59
28	5.05	4.93

INDIGENOUS NATURAL GAS COSTING

Natural gas has been historically priced based on its heating value with respect to fuel oil prices in India. Natural gas has traditionally replaced fuel oil as a heating medium. Even in refineries, fuel gas that is produced and used in power generation is valued at thermal parity with fuel oil.

Currently, domestic natural gas in India is priced at 75 % fuel oil parity. The price of a basket consisting of low sulfur and high sulfur fuel oil (HSFO) is used to arrive at the natural gas prices. However, there is a ceiling price, which is Rs 2,850 per thousand SCM. With the dismantling of the administered prices for natural gas, which is currently underway, it is expected that the natural gas price will be increased to 100 % fuel oil thermal parity. This still does not imply complete thermal parity with fuel oil prices. The calorific value of the fuel oil is assumed to be 10,000 Kcal/kg. The actual calorific value of the domestic natural gas depends on its hydrocarbon composition, and typically the calorific value of natural gas varies between 11,500-13,500 Kcal/kg (TERI, 2001).

The Gas Price Order of the Ministry of Petroleum and Natural Gas, Government of India, gives the methodology for relating fuel oil prices to calculate natural gas price. It has considered a basket of fuel oils consisting of two low sulfur and two high sulfur fuel oils. This study, however, considers only one fuel oil with 180 Centistokes (CST). This is because in principle a single fuel oil is sufficient for relating the thermal parity of fuel oil and natural gas. The principle would remain the same for any basket of fuel oils.

The following steps were taken for arriving at the indigenous natural gas price. First, a relation between Dubai crude FOB and fuel oil (HSFO) (180 CST) is established and is presented in equation (8.5).

$$F = 5.6896\ C - 5.866, \quad R^2 = 0.93 \qquad \text{----(8.5)}$$

Where, F is the FOB price of HSFO (180 CST) in $/MT; and C is the price of Dubai FOB in $/bbl). From the regression equation (8.5) the fuel oil price at the various crude price levels was estimated.

Currently at the refinery gate the price of petroleum products is the import parity price. This import parity price includes all components of the product price if the product is actually imported from the Arabian Gulf. The same principle is followed here. The cost elements indicated below are based on the judgement of experts working in the oil and gas sector.

- The freight for fuel oil was added based on dirty tanker Worldscale rates large range II (LR II) tankers. The average is $6.5/MT based on rates observed in 2001.
- Insurance and ocean loss were added at a rate of 0.3 % of the FOB price and freight cost of fuel oil.
- Terminal charges were added at Rs 200/ton, which is $ 4.21/tonne.
- Also note that no import duty was added to the CIF price of fuel oil similar to the LNG and ULSD case.
- The natural gas price was arrived at by thermal parity with FO @ 115 % of fuel oil, which is a standard factor used in valuation of gas.

Table 8.4 gives the estimated cost of natural gas at the City Gate station of Mumbai in $/MMBTU and in Rs/thousand SCM for the three levels of price of Dubai crude based on 115 % of fuel oil price.

Table 8.4
Cost of Natural Gas through Domestic Route at the City Gate Station in Mumbai

Dubai crude FOB	Natural gas	Natural gas
$/bbl	$/MMBTU	Rs/000 SCM
22	3.35	5725
25	3.79	6477
28	4.23	7228

Note. The conversion factor used is 1 kg of natural gas = 1.244 SCM.

The current natural gas price which GAIL receives is capped at Rs 2,850 / thousand SCM. This is only about 45 % parity with fuel oil price.

DISTRIBUTION COST WITHIN CITY

The distribution cost of CNG was estimated by calculating the total fixed and variable cost of supplying gas within the city. The capital cost for setting up the distribution infrastructure for the transport sector was estimated by apportioning the capital costs incurred by MGL according to gas sales in different sectors. The capital cost considered here was the total investment incurred by MGL until 2001 less the investment that was incurred in setting up CNG stations for the transport sector. Based on the gas demand in 2010 as estimated by the LEAP model, the additional fixed investment required was estimated. However, the cost of items such as land and buildings, wages, etc. was not included. Here it was assumed that there would be thirteen daughter booster stations while the rest would be online stations. Thus the total fixed cost for the transport sector was the sum of the apportioned fixed cost, the cost incurred on existing CNG stations, and the additional cost that would have to be incurred to meet the gas demand in 2010. To annualize the costs, the life of the infrastructure was assumed to be ten years and the cost of capital was assumed to be 12%. The variable cost was estimated by calculating the cost of gas compression, CNG transportation, and operation and maintenance.

The components in the cost were as follows:

- Fixed annualized cost
- Compression cost which was taken as Rs 1.20 per kg for online stations and Rs 1.90 per kg for daughter booster stations, provided by the MGL.
- Operation and maintenance cost, provided by MGL.
- Transportation cost of CNG within the city, provided by MGL.

The cost of supply of CNG within Mumbai is calculated to be Rs 5.15/ kg. The detailed breakup of calculations for arriving at this price is given in Table 8.5.

Table 8.5

Distribution Cost of CNG in Mumbai

Item	Unit	Cost
Fixed Cost		
Fixed Cost Incurred for the Transport Sector until 2001	Million Rs	989.44
Additional Investment Required	Million Rs	550.56
Annualized Fixed Cost	Million Rs	272.55
Variable Cost		
Compression Cost	Million Rs	126.49
Transportation Cost	Million Rs	15.49
Operation and Maintenance	Million Rs	49.81
Total Annual Cost	Million Rs	464.35
Total Gas Requirement in 2010	MSCM	123.94
Cost of CNG	Rs/SCM	3.75
Cost of CNG	Rs/kg	5.15

Note. The conversion factor used is 1 kg of CNG = 1.375 SCM.

The dealer's commission was also added, which is currently fixed by MGL at Rs 1.20/kg.

The cost of CNG at the dispensing station through LNG route for the three levels of crude prices is given Tables 8.6 and 8.7.

Table 8.6

CNG Cost at the Retail Outlet via LNG Route ex-Dahej

Dubai Crude Price, $/bbl	22	25	28
JCC CIF, $/bbl	23.53	26.67	29.80
LNG CIF Japan , $/MMBTU	4.17	4.51	4.85
LNG CIF Dahej, $/MMBTU	3.59	3.93	4.27
Storage and Re-gasification Cost, $/MMBTU	0.40	0.40	0.40
CIF Pipeline Tariff, $/MMBTU	0.38	0.38	0.38
Natural Gas at City Gate station, $/MMBTU	4.37	4.71	5.05
Natural Gas at City Gate station, Rs/kg (1)	9.31	10.03	10.75
Annualized Capital Cost, Rs/kg (2)	3.02	3.02	3.02
Cost of Distribution Plus Transportation Cost, Rs/kg (3)	2.13	2.13	2.13
Dealers Commission, Rs/kg (4)	1.20	1.20	1.20
Cost of Supplying CNG, Rs/kg (1+2+3+4)	15.66	16.38	17.10
Cost of Supplying CNG, $/MMBTU	7.36	7.70	8.04

Note. 1 tonne of natural gas = 44.79 MMBTU.

Table 8.7

CNG Cost at the Retail Outlet via LNG Route ex-Dabhol

Dubai Crude Price, $/bbl	22	25	28
JCC CIF, $/bbl	23.53	26.67	29.80
LNG CIF Japan , $/MMBTU	4.17	4.51	4.85
LNG CIF Dabhol, $/MMBTU	3.59	3.93	4.27
Storage and Re-gasification Cost, $/MMBTU	0.40	0.40	0.40
CIF Pipeline Tariff, $/MMBTU	0.26	0.26	0.26
Natural Gas at City Gate Station, $ / MMBTU	4.25	4.59	4.93
Natural Gas at City Gate Station, Rs/kg (1)	9.05	9.77	10.49
Annualized Capital Cost, Rs/kg (2)	3.02	3.02	3.02
Cost of Distribution Plus Transportation Cost, Rs/kg (3)	2.13	2.13	2.13
Dealers Commission, Rs/kg (4)	1.20	1.20	1.20
Cost of Supplying CNG, Rs/kg (1+2+3+4)	15.40	16.12	16.84
Cost of Supplying CNG, $/MMBTU	7.24	7.58	7.92

In the case of indigenous natural gas, the only component in addition to the fuel oil parity price of the gas is the cost of the distribution network and the dealer's commission, which is fixed at Rs 1.20/kg as mentioned above. The detailed calculations are given in the Table 8.8.

Table 8.8
CNG Cost at the Retail Outlet via the Domestic Route

Dubai Crude Price FOB , $/bbl	22	25	28
Fuel Oil Price FOB Arabian Gulf, $/tonne	119.31	136.37	153.44
Fuel Oil Freight Cost (AG to Mumbai), $/tonne	6.50	6.50	6.50
Insurance, Ocean Loss, Wharfage, $/tonne	0.37	0.43	0.48
Fuel Oil CIF Price, $/tonne	126.18	143.30	160.42
Terminal Charges (storage and port handling), $/tonne	4.21	4.21	4.21
Natural Gas, $/tonne	149.95	169.64	189.33
Natural Gas at City Gate Station, $/MMBTU	3.35	3.79	4.23
Natural Gas at City Gate Station, Rs/Kg (1)	7.12	8.06	8.99
Annualized Capital Investment, Rs/kg (2)	3.02	3.02	3.02
Cost of Distribution Plus Transportation Cost, Rs/kg (3)	2.13	2.13	2.13
Dealers Commission, Rs/kg (4)	1.20	1.20	1.20
Cost of Supplying CNG, Rs/kg (1+2+3+4)	13.47	14.41	15.34
Cost of Supplying CNG, $/MMBTU	6.33	6.77	7.21

Cost of Supplying ULSD

Currently, no Indian refinery produces diesel with less than 50 ppm sulfur. The maximum sulfur content in the diesel currently produced for supply in the National Capital Region (NCR) and Mumbai is 500 ppm. This is referred to in this study as low sulfur diesel (LSD).

Diesel prices have been linked to crude prices. There is also a seasonal dependence on diesel prices with prices being higher in winter and lower in summer, but broadly they can be linked to crude prices.

The cost of supplying ULSD (50 ppm sulfur diesel) in Mumbai is calculated through the imported route from Singapore to Mumbai. To arrive at the ULSD cost the following steps are followed:

- Relating the Dubai FOB price with the Singapore HSD (2500 ppm S).
- The premium of LSD (500-ppm Sulfur diesel) over HSD is added to get the price of the LSD.
- The premium of the ULSD (50 ppm S diesel) over LSD is added to get the ULSD price.
- The other cost elements of freight from Singapore to Mumbai and insurance are added to the ULSD price to get the CIF price of diesel at Mumbai port.
- The cost elements for distribution of diesel within the city are added to get the cost of ULSD at the retail outlet.

RELATING SINGAPORE FOB HIGH SULFUR DIESEL PRICES TO DUBAI FOB PRICES

The 2500 ppm high sulfur diesel is considered to arrive at a relation because this grade of diesel is widely traded in Singapore, while the 500 ppm sulfur diesel is traded more in the spot market. The data from January 1998 to June 2001 was adopted from Platts OilGram Monthly Reports and the regression equation (8.6) was obtained.

$$D = 1.1814(C) + 0.2468, R^2 = 0.92 \quad \text{--- (8.6)}$$

Where, D is the price of 0.25% S or 2500 ppm S diesel in $/bbl; and C is the Dubai crude oil FOB price in $/bbl.

Further, a two-step approach was used to determine the cost of supplying ULSD starting from the 2500 ppm S diesel price. In the first step, the premiums for 500 ppm S diesel over 2500 ppm S diesel were added and in the second step the premiums for 50 ppm S diesel (ULSD) over 500 ppm S diesel (LSD) were added.

PRICE DIFFERENTIAL BETWEEN 2500 PPM AND 500 PPM SULFUR DIESEL

To the derived price above, the differential between the Singapore FOB price for 2500 ppm S diesel and 500 ppm S diesel was added. As per Platts report this differential was $ 0.4/bbl ($3.01 per MT or Rs 171 per KL). As some refineries in India are producing this grade of LSD, the Oil Co-ordination Committee (OCC) provided the refineries a differential of Rs 411 per MT, or Rs 341 per KL until 31 March 2002. This is considerably higher than the Singapore differential of Rs 171 per KL and presumably takes into account actual investment and operating costs by the Indian refineries. In the deregulated scenario, there will be no central agency like the OCC to determine the price differential between different grades of diesel. Refineries and marketing companies will fix their prices based on import parity levels. Hence, the premium considered for 500 ppm sulfur diesel over 2500 ppm sulfur diesel is $ 0.4/bbl, which is the average premium for this grade.

PRICE DIFFERENTIAL BETWEEN LSD AND ULSD

Currently, neither the Middle East nor south Asia produces 50 ppm S diesel (ULSD). Therefore, differentials in various parts of the world (specifically Hong Kong, China and the UK) were examined and the differential considered most relevant to India selected. Some of the differentials that have been used in certain countries are discussed below.

Hong Kong, China

Hong Kong, China has switched over to ULSD, and the price differential between the weighted average monthly import price of ULSD and LSD between July and October 2000 is approximately Hong Kong dollars 0.46 per litre. This works out to Rs 2.84 per litre. The sources from which marketing companies in Hong Kong, China such as Shell, Exxon Mobil and Caltex are obtaining ULSD are not known. Since this grade is not being manufactured anywhere in South Asia it is presumed to be imported from Europe. The differential for Hong Kong, China therefore, includes not only the ex. refinery differential but also the differential in freight between ULSD from Europe and LSD from possibly Singapore or other refineries in close proximity to Hong Kong, China.

United Kingdom

The UK market has totally switched over to ULSD. According to Mr Mark Gaynor from the Department of Transport, Local Government and Regions (DTLR), UK,

> "The product first started to roll out into the UK market following a 1 pence per litre (p/litre) duty incentive announced in the July 1997 budget and implemented on 15 August 1997. The differential was widened to 2 p/litre in the March 1998 budget and 3 p/litre in the March 1999 budget. Once the differential reached 3 p/litre, ULSD roll out accelerated and it was available at virtually every UK retail outlet by August 1999. Therefore, the conversion from LSD to ULSD in the UK took just over two years."[15]

Refinery costs are not available since it is considered confidential information. This study has estimated the manufacturing premium of producing ULSD at around 1.5 p/litre. Some companies invested in new processing equipment, such as Total Fina Elf in Milford Haven and Conoco at Humber, while others managed by using existing equipment and importing low sulfur components. Every UK refinery produces ULSD.

From the three cases cited it is noted that the differential from different sources varies widely. This is understandable, as the differential will depend on the individual refinery, the quality of crude intake, extent of installation of new facilities, quantity to be manufactured and operating costs. The study proposed using the UK differential of 1.5 pence per liter (equivalent to 2.21 US cents per liter) which works out to Rs 1.05 per liter, as this estimated figure is for all UK refineries and not for an individual refinery (it is conceivable that it will cost Indian refineries more to make ULSD). The UK estimate was considered realistic as it represents very broadly the average reduction in duty that was required to make all UK refineries switch to ULSD manufacture.

FREIGHT COST

At the refinery gate the current price of petroleum products is the import parity price. The import parity price includes all components of the product price if it is actually imported from Singapore. The cost elements indicated below are indicative and are based on the judgement of experts working in the oil and gas sector.

The freight for diesel from Singapore to Mumbai is added based on the Worldscale data available for the previous year. The freight from Singapore to Mumbai is $ 1.14/bbl based on 2001's freight assessments. This is the freight for the medium range II (MR II) range of vessels (25000 to 45000 MT). Mumbai Pirpau port can receive vessels up to 32000 MT.

INSURANCE AND WHARFAGE COST

Insurance and wharfage were added at 0.3 % of the cost plus freight. Table 8.9 gives the estimated CIF price of ULSD based on the above methodology at three levels of prices of Dubai FOB.

[15] More details are available in Govt. published document from HM Customs and Excise, 2000).

Table 8.9

Estimated CIF Price of ULSD from Singapore

(in $/ton)

Crude ($/bbl)	2500 ppm S ($/bbl)	500 ppm S ($/bbl)	50 ppm S ($/bbl)	CIF price ($/bbl)	CIF price ($/ton)
22	26.24[a]	26.64	30.15	31.29	235.61
25	29.78[a]	30.18	33.69	34.84	262.27
28	33.33[a]	33.73	37.24	38.38	289.00

[a]These values are obtained by using equation (8.6) .

TRANSPORTATION AND OTHER COSTS

In order to arrive at the ULSD retail outlet price, various other costs elements were added. These are given below.

- Retail Pump Outlet (RPO) charges @ Rs 83.98/KL (this includes the cost of fuel transportation within the fixed delivery zone)
- Terminal charges @ Rs 175/KL
- Dealers commission @ Rs 277/KL

Thus, the final retail outlet cost of ULSD in Mumbai is the sum of CIF prices and the cost elements mentioned above. This detailed cost build up is given in Table 8.10.

Table 8.10

Retail Outlet Cost of ULSD in Mumbai

Crude Price, $/bbl	22	25	28
FOB Price 2500 ppm S Diesel $/bbl (1)	26.24	29.78	33.33
Premium 500 ppm S Diesel over 2500 ppm S Diesel $/bbl (2)	0.40	0.40	0.40
Premium ULSD over LSD, $/bbl (3)	3.51	3.51	3.51
Freight Cost from Singapore to Mumbai Port, $/bbl (4)	1.14	1.14	1.14
CIF Price ULSD, $/bbl (1+2+3+4)	31.29	34.84	38.38
CIF Price Rs/KL (5)	9345.73	10404.23	11462.74
Terminal Charges, Rs/KL (6)	175.00	175.00	175.00
RPO Charge, Rs/KL (7)	83.98	83.98	83.98
Dealers Commission, Rs/KL (8)	277.00	277.00	277.00
Cost of Supplying ULSD at Retail Outlet, Rs/litre (5+6+7+8)/1000	9.88	10.94	12.00
Cost of Supplying ULSD at Retail Outlet, $/MMBTU	5.18	5.73	6.29

As already stated in the introduction of this chapter, no duties or taxes are added at any point in the price determination.

Comparative Cost of Supplying CNG and ULSD

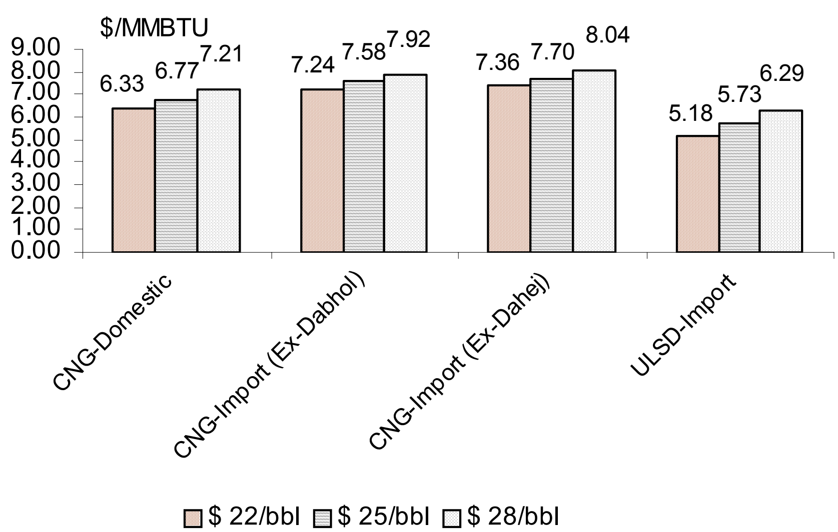
The research and analysis provide estimates of the cost of supplying the two fuels at the dispensing stations (less duties and taxes) and their retail price build-up (with duties and taxes) in Mumbai. With the dismantling of the Administered Pricing Mechanism (APM) in India and in the prevailing deregulated scenario, the cost of supplying ULSD and CNG (through LNG import) in Mumbai is estimated based on an import parity level. In addition, the cost of supplying indigenous natural gas is estimated by drawing a thermal parity with fuel oil. The distribution cost of CNG and ULSD in the city has been worked out by summing the landed cost, transportation cost and distribution cost. The unit costs of supplying the two fuels up to the retail outlets is related to three Dubai crude oil prices, US$ 22, 25 and 28 per barrel and are presented in Table 8.11.

Table 8.11
Cost of Fuel Supply per Unit up to the Retail Outlets

Dubai FOB ($ / bbl)	CNG, Rs/kg			Imported ULSD Price Ex Singapore, Rs/l
	Indigenous Production	LNG Ex-Dabhol	LNG Ex-Dahej	
22	13.47	15.40	15.66	9.88
25	14.41	16.12	16.38	10.94
28	15.34	16.84	17.10	12.00

Figure 8.1 shows the estimated unit cost of supplying CNG and ULSD up to the retail outlets (without taxes and duties) in Mumbai under three different crude oil prices which are expressed in common units, $/MMBTU. At US$ 25/bbl crude oil price, the cost of supplying ULSD up to a retail outlet in Mumbai is estimated as $5.73 /MMBTU. The corresponding cost for CNG is $6.77/MMBTU for domestic gas; $7.58/MMBTU via LNG ex-Dabhol and $7.70/MMBTU via LNG ex-Dahej.

Figure 8.1
Cost of Fuel Supply per Unit up to the Retail Outlets



Cost of Fuel from Well to Wheel

The cost of supplying CNG and ULSD to a bus was estimated and expressed in Rs per kilometer. This cost includes the cost of vehicle, fuel, and the vehicle's maintenance. This was done by first estimating the annualized capital cost for the vehicle. Since the true cost of fuel from well to wheels was calculated, the taxes and duties were not been taken into account in the capital cost for buses. The life of the bus was assumed to be twelve years and the cost of capital was taken to be 12%. The fuel efficiency and effective utilization were taken from Annex 5.3 in Chapter 5. The cost of fuel was taken to be corresponding to the crude price of $25/bbl. The cost of operating a bus on a rupee per kilometer basis is given in Table 8.12.

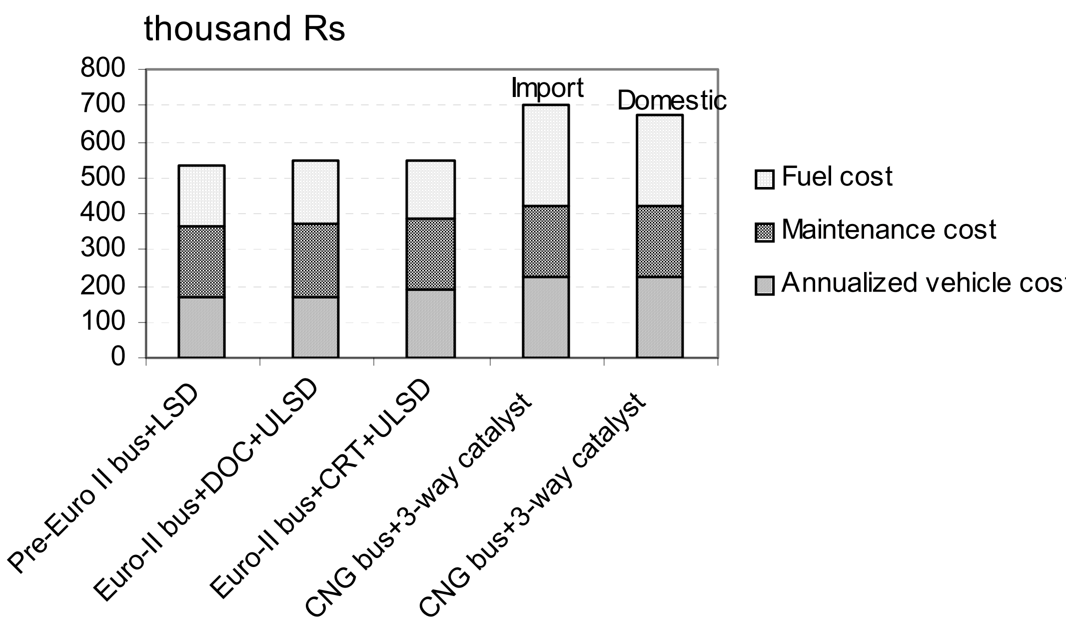
Table 8.12
Cost of a Bus on a per Kilometer Basis

Item	Unit	Pre-Euro 2 Bus + 500 ppm S Diesel	Pre-Euro 2 bus + DOC + 50 ppm S Diesel	Euro 2 bus + CRT + 50 ppm S Diesel	CNG Bus + 3 way Catalyst	
					Import	Domestic
Capital Cost (less taxes and duties)	Thousand Rs	1024	1060	1169	1387	1387
Annualized Capital Cost (1)	Thousand Rs	165.29	171.15	188.73	223.90	223.90
Annual Maintenance Cost (2)	Thousand Rs	200	200	200	200	200
Fuel Efficiency	km/liter for diesel and km/kg for CNG	3.47	3.67	4.07	3.6	3.6
Annual km run per Bus (4)	Thousand km	62.4	62.4	62.4	62.4	62.4
Fuel Cost (without taxes and duties)	Rs/liter for diesel and Rs/kg for CNG	9.40	10.94	10.94	16.12[a]	14.41[b]
Fuel Cost (without taxes and duties)	Rs/MMBTU	233.86	272.18	272.18	359.74	321.58
Annual Fuel Cost (3)	Thousand Rs	169.04	186.01	167.73	279.22	249.60
Annual Total Cost (1+2+3)= (5)	Thousand Rs	534.32	557.16	556.46	723.12	693.50
Cost per km in (5/4)	Rs/km	8.56	8.93	8.92	11.59	11.11

[a] Cost through import, [b] Cost through domestic production.

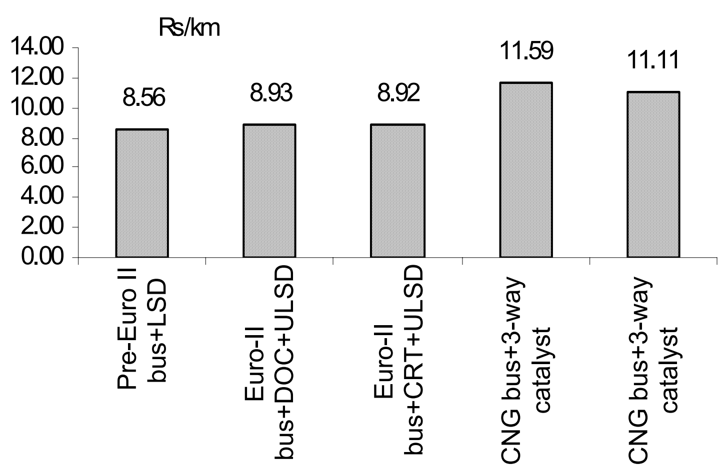
Figure 8.2 shows the annual cost of running a bus (less taxes and duties) with different technology-fuel alternatives. The cost is broken down according to the annualized capital and annual maintenance and fuel costs. The annual cost of operating a CNG bus is higher compared to that of an ULSD bus because of the higher capital cost and lower fuel efficiency of a CNG bus.

Figure 8.2
Annual Cost per Bus under Different Technology-fuel Alternatives



At $25/bbl crude oil price with no taxes and duties levied on the bus or its fuel, the cost of operating a CNG bus equipped with an ECD is 25-30% higher than a bus running on ULSD equipped with an ECD (Figure 8.3).

Figure 8.3
Estimated Overall Cost per Kilometer for Buses



As shown in Figure 8.3, the cost of operating a Euro 2 bus on ULSD equipped with an advanced post-combustion ECD, (like a continuously regenerating technology, CRT) is Rs 8.92 per km; the corresponding figure for a CNG bus equipped with a 3-way catalyst is Rs 11.11 if the gas is domestically supplied, but if it is imported the cost goes up to Rs 11.59 per km.

Cost of PM Abatement

Costs of abatement were calculated to estimate the cost of introducing vehicles that use cleaner technology and fuels vis-à-vis the reduction in emissions brought about. The emissions considered here are PM as it is the critical pollutant in Mumbai. The estimates of cost of abatement were calculated taking the additional cost of the new vehicle and dividing it by the total reduction in emissions achieved.

PM abatement is critical in the case of buses, as though buses constitute only 1% of the total vehicle fleet and just 8% of the total vehicle kilometers traveled, they contribute more than half of the PM emissions loading. Therefore, in this study the PM abatement cost of a bus was estimated for different technology and fuel combinations and is given in Table 8.13.

Table 8.13
Abatement Cost for Buses

Item	Unit	Pre-Euro 2 bus + 500 ppm S Diesel (BL Case)	Pre-Euro 2 bus + DOC + 50 ppm S Diesel	Euro 2 bus + CRT + 50 ppm S Diesel	CNG Bus + 3-way Catalyst	
Annual Emissions	Kg	99.84	54.66	1.25	3.12	3.12
Emissions Reduction w.r.t. BL	Kg	-	45.18	98.59	96.72	96.72
Annual Total Cost	'000 Rs	534.33	557.17	556.46	723.12	693.50
Additional Cost w.r.t. BL	'000 Rs	-	22.83	22.14	188.79	159.17
Abatement Cost	'000 Rs/tonne	-	505.42	224.52	1951.92	1645.68
	US$/tonne	-	10640	4727	41093	34646

From Table 8.13 it can be deduced that the abatement cost is lowest for a Euro 2 bus equipped with CRT and running on ULSD.

CNG and ULSD Price Build-up

The price build-up for the two fuels has been calculated based on the current structure of duties and taxes. Since ULSD is not available in the country at present, the tax structure assumed for it is same as that for low sulfur diesel with 500 ppm sulfur. Taxes at the central and state level vary with the fuel being considered. For instance, the customs duty for diesel is 20% while that for LNG is 5%. Similarly, the sales tax for CNG is 13% while that for diesel is 34%.

In addition to the taxes, certain components such as the marketing margin are added in the price build-up as per standard industry practices. The marketing margin is an important component of the price build-up for ULSD. After the total deregulation of downstream petroleum products with effect from 1 April 2002, oil-marketing companies have become free to fix the marketing margins. Also, a number of components such as Product Price Adjustment (PPA), C & F (cost and freight) surcharges and FSP (freight surcharge pool) surcharges of the current price build-up are no longer relevant. These surcharges together amount to about Rs 1,300/tonne. Under APM (administered pricing mechanism), the government fixed marketing margins at a fixed rate of 12 % post tax return on the net worth of the marketing companies for the controlled products.

The decontrol of products such as naphtha and fuel oil carried out in the past has shown an increase in the marketing margin as compared to the margins under the APM. Without increasing the final retail price of diesel, the marketing margin can be increased to about Rs 1,300 per tonne in lieu of these surcharges. This used to go to the oil pool account, which will not exist in the post-APM period. Taking these points into consideration, a good estimate of the marketing margin would be Rs 750 per tonne. For gas, since MGL is a monopoly, it does not specify the marketing margin separately in the price build up. Moreover, a return of 12% is assumed while estimating the cost of gas distribution infrastructure. Hence no additional marketing margin has been considered for gas.

The indicative price of the two fuels post tax as per the above assumptions is given in Tables 8.14 and 8.15. However, the actual market price will be determined by the oil companies.

Table 8.14
Indicative ULSD Price Build-up in Mumbai

Components of Price Build up	Rs/litre
Landed Price at Mumbai (CIF price + terminal charges)*	10.57
Basic Customs Duty @ 20 %	2.12
Marketing Margin	0.63
State Surcharge Maharashtra	0.32
Excise Duty @ 16 %	2.18
Additional Excise Duty, flat rate	1.00
Subtotal Including Excise	16.82
Retail Pump Operating Charges	0.08
Sales Tax @ 34 %	5.75
Price Including Sales Tax	22.65
Dealers Commission	0.30
Retail Selling Price. Rs/litre	22.95

*at $25/bbl of Dubai crude price.
**If the product is imported then a countervailing duty equivalent to the excise duty will be imposed on the product. (http://www.cbec.gov.in/cae/customs/cs-tariff/cst-note.htm as on 21 March 2002).
Source: http://www.cbec.gov.in/cae/excise.htm and http://www.cbec.gov.in/cae/customs/cs-tarriff.htm accessed on 21 March 2002, Ministry of Petroleum and Natural Gas, Statistics 1999-2000.

Table 8.15

CNG Price Build-up in Mumbai

Components of Price Build-up	CNG Import –ex Dahej Rs/kg	CNG Indigenous Rs/kg
CIF Price @ Mumbai*	10.03	8.06
Basic Customs Duty @ 5 %	0.50	0.00
Cost of Distribution	5.15	5.15
Excise Duty @ 16 %	2.51	2.11
Subtotal Including Excise	**18.19**	**15.32**
Sales Tax @ 13 %	2.36	1.99
Surcharge @ 10 % of Sales Tax	0.24	0.20
Turnover Tax @ 1 % of Basic Price	0.16	0.13
Price Inclusive of State Taxes	20.95	17.65
Dealers Margin	1.20	1.20
Retail Selling Price	22.15	18.85

*at $25/bbl of Dubai crude price.
Note: Price of CNG ex-Dabhol works out to be Rs 21.78/kg.
Source: MGL, www.cbec.gov.in/cae/customs/cs-tariff.htm and http://www.cbec.gov.in/cae/excise.htm as on 21 March 2002.

The price of ULSD inclusive of present level taxes and duties is Rs 22.95/litre, while that of CNG is Rs 22.15/kg through the import route and Rs 18.85/kg from the domestic route. The cost of supplying ULSD (i.e. less taxes and duties) is Rs 10.94/litre, and CNG is Rs 16.38/kg through the import route and Rs 14.41/kg through the domestic route. Thus, in the case of ULSD, the tax component comprises over 50% of the retail selling price, while for CNG the tax component is nearly one-fourth.

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