



**Malé Declaration on Control and Prevention of Air Pollution and its Likely
Transboundary Effects for South Asia**

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**Compendium of
Best Practices on Prevention and Control of
Air Pollution**

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Table of Contents

Table of Contents.....	i
List of Tables.....	iii
List of Figures.....	iv
List of Abbreviations.....	v
Chapter I: Introduction.....	1
1.2 Objective.....	2
1.2 Scope.....	2
1.3 Organization of the report.....	2
Chapter II: Status and Major Issues of Transboundary Air Pollution in South Asia.....	4
2.1 Introduction.....	4
2.2 Status of Emission of Major Transboundary Air Pollutants in South Asia.....	4
2.3 Issues related to Air Pollution in South Asia.....	8
2.3.1 Growing thermal power generation and the role of coal.....	8
2.3.2 Low Efficiency in Power Generation.....	10
2.3.3 Inefficient Coal Preparation/Cleaning Mechanism.....	11
2.3.4 Lack of emission control mechanism in power plants.....	12
2.3.5 Lack of regulations on Industrial pollution and enforcement of existing regulations.....	12
2.3.6 Urbanization and growth of personal transport vehicles.....	14
2.3.7 High dependence on biomass fuel burning in rural areas.....	17
2.3.8 Lack of information on emission source apportionment.....	17
2.3.9 Lack of effective regulatory and economic policies to improve air quality.....	18
2.3.10 Lack of comprehensive and regular monitoring of air pollution.....	20
Chapter III: Approaches for controlling and preventing air pollution.....	21
3.1 Introduction.....	21
3.2 International Treaties and Agreements.....	21
3.2.1 Convention on Long-Range Transboundary Air Pollution (CLRTAP).....	22
3.2.1.1 Protocols on SO ₂ emission reduction.....	22
3.2.1.2 Protocols on NO _x emission reduction.....	23
3.2.1.3 Protocols on VOCs emission reduction.....	23
3.2.1.4 Protocols dealing with multi-pollutants.....	24
3.2.2 European Commission National Emission Ceilings Directive (2001/81/EC).....	25
3.2.3 The US Clean Air Act Amendment 1990.....	26
3.3 Approaches for controlling and preventing transboundary air pollution.....	27
3.3.1 Command and Control approaches.....	27
3.3.2 Market based instruments.....	28
3.3.2.1 Emission Taxes.....	28
3.3.2.2 Emission Taxes in Practice.....	29
3.3.2.3 Fuel Taxes, Excise Duty/Tax.....	31
3.3.2.4 Fuel Taxes, Excise Duty/Tax in Practice.....	31
3.3.2.5 Emission Reduction Credit and Emission Trading System.....	32
3.3.2.6 Emission Reduction Credit and Emission Trading in Practice.....	32
3.3.2.7 Innovative mechanisms in Emission Trading.....	34
3.3.3 Approach based on voluntary action.....	35

3.3.4 Fuel Switching and cleaner fuel use	35
3.3.4.1 Fuel Switching and cleaner fuel use in practice	35
3.3.5 Congestion Charge and Transport Management	36
3.3.5.1 Congestion Charge and Transport Management in Practice	36
3.3.6 Co-benefits of GHG emission reduction policies and technologies.....	38
3.3.6.1 Renewable Portfolio Standard Policy	38
3.3.6.2 GHG Emission Reduction Technologies	39
Chapter IV: Best practice cases on controlling and preventing air pollution.....	40
4.1 Introduction.....	40
4.2 NO _x charges as feebate in Sweden	41
4.3 Two Control Zone (TCZ) Plan and Program to control Sulfur pollution.....	43
4.4 The Acid Rain Program in US	45
4.5 Road Transportation Travel Demand Management in Singapore	51
4.6 Compressed Natural Gas Conversion of Public Passenger Vehicles in Delhi	58
4.7 Environmental Measures and NO _x Tax System in Norway.....	63
Chapter V: Summary and Conclusions	69
References	74
Annexes.....	822
Annex I.....	833

List of Tables

Table 2.1: Emissions of key transboundary air pollutants in South Asian countries in 2000	5
Table 2.3: Sources of VOCs in India	8
Table 2.4: Biomass burned in South Asian countries	17
Table 2.5: Ambient Air Quality Standards of the South Asian countries in comparison to EU, USEPA and WHO	19
Table 2.6: Sulfur content in diesel	20
Table 3.1: Fuel Taxes in Finland	32
Table 4.1: Percentage of cities in Two Control Zones meeting SO ₂ Grades	45
Table 4.2: NO _x Emission Limit by Boiler Type	49
Table 4.3: Preferential Additional Registration Fee (PARF) Structure	53
Table 4.4: Result of 2 nd Bidding Process conducted on 18 July 2007	54
Table 4.5: Average Speed During Peak hours.....	56
Table 4.6: 24-hr PSI at 4pm, 25 July 2007.....	58
Table 4.7: Ambient Air Quality of Delhi from 1998 - 2005.....	63
Table 4.8: Emission ceiling 2010 according to the Gothenburg Protocol and status 1990 and 2006.....	64
Table 4.9: Emission limit values and the deadlines to be met:	65
Table 4.10 Assessment threshold for health protection	66
Table 4.11: Assessment threshold for the protection of vegetation.....	66

List of Figures

Figure 2.1: Share of SO ₂ emission in South Asia (based on data 1990s data)	6
Figure 2.2: NO _x emission in South Asian countries in 1990 and 2020	6
Figure 2.3: Sectoral shares in NO _x emission in selected countries	7
Figure 2.4: Fuel mix in the power sector	9
Figure 2.5: Efficiency of coal fired power generation in selected countries in year 2002.....	11
Figure 2.7: Stock of Passenger cars in South Asian Countries	15
Figure 2.8: Trend of NO _x and PM in Delhi	15
Figure 4.1: Annual average levels of sulfur dioxide, nitrogen oxide and PM ₁₀ in Singapore.....	57
Figure 4.2: Annual average Pollutant Sub Index (PSI) in Singapore	57

List of Abbreviations

ABC	:	Atmospheric Brown Cloud
ADB	:	Asian Development Bank
ALS	:	Area Licensing Scheme
BAT	:	Best Available Technology
CAAA	:	Clean Air Act Amendment
CAC	:	Command and Control
CH ₄	:	Methane
CLRTAP	:	Convention on Long Range Transboundary Air Pollutants
CNG	:	Compressed Natural Gas
CO ₂	:	Carbon dioxide
COE	:	Certificate of Entitlement
CSE	:	Center for Science and Environment
ERC	:	Emission Reduction Credit
ERC	:	Emission Reduction Credit
ERP	:	Electronic road pricing
EU	:	European Union
EV	:	Electric Vehicle
FY	:	Fiscal Year
GBP	:	Great Britain Pound
GEO	:	Global Energy Outlook
GHG	:	Greenhouse Gas
IEA	:	International Energy Agency
IPCC	:	Intergovernmental Panel on Climate Change
IPPC	:	Integrated Pollution Prevention and Control
NAAQS	:	National Ambient Air Quality Standard
NEC	:	National Emission Ceiling
NEQS	:	National Environmental Quality Standard
NH ₃	:	Ammonia
NMVOC	:	Non-methane Volatile Organic Compound
NO _x	:	Nitrogen Oxides
NSPS	:	New Source Performance Standard
OECD	:	Organisation for Economic Co-operation
OMV	:	Open Market Value
PARF	:	Preferential Additional Registration Fee
PEPA	:	Pakistan Environmental Protection Agency
PSI	:	Pollutant Sub Index
RPS	:	Renewable Portfolio Standard
RZ	:	Restricted Zone

List of Abbreviation (Contd.)

SCR	:	Selective Catalytic Reduction
SEK	:	Swedish Kroner
SEPA	:	Singapore Environmental Protection Agency
SEPA	:	State of Environmental Protection Agency- China
SEPA	:	Swedish Environmental Protection Agency
SIP	:	State Implementation Plan
SO ₂	:	Sulfur dioxide
SPM	:	Suspended Particulate Matter
TAP	:	Transboundary Air Pollution
TCZ	:	Two Control Zone
TGC	:	Tradable Green Certificate
TOMA	:	Tropospheric Ozone Management Area
UNDP	:	United Nations Development Programme
UNECE	:	United Nation Economic Commission for Europe
UNEP	:	United Nations Environment Programme
UNESCAP	:	United Nations Economic and Social Commission for Asia and the Pacific
USEPA	:	United States Environmental Protection Agency
VOC	:	Volatile Organic Compound
VQS	:	Vehicle Quota Scheme
WHO	:	World Health Organization

Chapter I

Introduction

The South Asian region is the home of over a billion people, i.e., 22.83% of the global population (World Bank, 2007). With the high economic growth and industrialization, the region is experiencing a rapid growth in energy consumption, which is mainly based on fossil fuels. The average annual growth rate of total primary energy supply during 1990-2005 across the countries in the region varied from 1.84% in country Sri Lanka to 4.23% Pakistan in South Asia. Due to increasing dependence on fossil fuels, countries in the region are faced with the growing problems of local and transboundary air pollution in recent years. According to Carmichael et al. (2002), sulfur emissions in Southeast and South Asia (particularly India) continue to increase rapidly and regional air pollution problems may intensify. According to the Garg et al. (2001), sulfur and NO_x emissions in India had increased at the average annual rate of 5.5% during 1990-1995. With the high economic growth of the country and continued heavy reliance on coal as the energy source (particularly in the power sector), the emission of SO₂ is likely to grow at a higher rate in future. Similarly, NO_x emission in South Asia is also likely to grow more rapidly in future to a large extent due to rapid growth in oil and gas based road transport sector.

Emissions of pollutants resulting from burning of biomass (including agricultural waste) and use of fossil fuels in power generation, industry and transport sectors have also contributed to the haze in South Asia (also known more generally as the phenomenon of “atmospheric brown cloud (ABC)”) besides the emission of greenhouse gases. The ABC is believed to be disrupting weather systems (including rainfall and wind patterns), triggering droughts in western parts of Asian continent and affecting health and agricultural productivity (UNEP, 2002).

The South Asian region is also undergoing through rapid urbanization and includes four of the twelve mega cities of the Asian region (UNESCAP, 2000). Many urban areas in the region are facing increased levels of air pollution and poor air quality. Concentrations of PM₁₀ are still several times higher than the World Health Organization (WHO) Guideline

values in some South Asian cities (i.e, Kolkata, Mumbai and Delhi) despite their dramatic reductions in recent years. With increasing urbanization and motorization, it is likely that urban air quality in South Asia would worsen in future in the absence of appropriate strategies and mechanisms to manage the air quality.

In view of the emerging problem of transboundary air pollution in South Asia, the Environment Ministers of South Asia adopted the Declaration for Prevention of Transboundary Air Pollution (also known as the Malé Declaration) in 1998. Following the Male' Declaration, a number of activities have been carried out already in two phases for the implementation of the Malé Declaration. The ongoing phase (i.e., Phase III) of the implementation program of the Malé Declaration aims at providing inputs to stakeholders to facilitate coordinated interventions on transboundary air pollution at national and regional level.

1.2 Objective

One of the specific objectives of Phase III for the implementation of the Malé Declaration is to provide decision support information for policy formulation and air pollution prevention. Towards meeting the objective, an activity has been undertaken to prepare to a compendium of best practices in preventing and controlling air pollution that have been adopted in different countries in the world and to identify potential strategies to implement and upscale the best practices in South Asia. The objective of this report is to discuss key issues related to air pollution in South Asia and present some promising best practices that exist for the control of air pollution.

1.2 Scope

The report considers the issues and best practices on control and prevention of key transboundary air pollutant emissions to the extent information is available.

1.3 Organization of the report

This report is organized as follows: Major issues related to air pollution in South Asia are discussed in Chapter II. The chapter includes a discussion of energy consumption, energy-mix and their implications for pollutant emissions in different sectors. The chapter also

discusses the existing regulatory frameworks in South Asian countries for managing air quality. In Chapter III, approaches for controlling and preventing air pollution with several examples adopted in different countries are described. In Chapter IV, case examples of the best practices to reduce air pollution and thus to improve the air quality in different countries are presented. Summary and conclusions are presented in Chapter V.

Chapter II

Status and Major Issues of Transboundary Air Pollution in South Asia

2.1 Introduction

South Asian countries have economies that have wide variation in the energy mix. The key fuel types being used are coal, oil and biomass. Combustion of these fuels for different purpose is giving much of the pollution of the concern. Specially, the three sectors, i) power, ii) industries and iii) the transport sectors, are mostly responsible for the most of the air pollution related problems in the region. In this chapter major issues in air pollution in South Asia are explained.

2.2 Status of emission of major transboundary air pollutants in South Asia¹

According to Streets et al. (2003), total emissions of SO₂, NO_x, NMVOC and NH₃ from Asia as a whole in year 2000 were 34,316 Gg, 26,768 Gg, 52,150 Gg, and 27,519 Gg respectively as shown in Table 2.1. Six of the South Asian countries (Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka) together accounted for 21% of the total SO₂ emission in Asia. Similarly, the study shows that these countries accounted for 20% of total NO_x emission, 26% of total NMVOC emission and 35% of NH₃ emission in Asia. As can be seen from the table, among the six South Asian countries shown in the table, India is the largest emitter of SO₂, NO_x, NMVOC and NH₃ emissions accounting for 77% of total SO₂, 84% of total NO_x, 79% of total NMVOC and 78% of total NH₃ emissions from the six countries in South Asia. The second largest emitter among the six countries is Pakistan which accounts for 20%, 10%, 10% and 13% of total SO₂, NO_x, NMVOC and NH₃ emissions from the six countries respectively. The rest of the four countries together accounted for 3%, 6%, 11% and 11% of SO₂, NO_x, NMVOC and NH₃ respectively.

¹ Unless stated otherwise, the term “South Asia” in this chapter refers to the group of following countries: Bangladesh, Bhutan, India, Nepal, Sri Lanka and Pakistan.

Table 2.1: Emissions of key transboundary air pollutants in South Asian countries in 2000

Countries/ Region	Total SO ₂ emission (Gg)	Total NO _x emission (Gg)	Total NMVOC emission (Gg)	Total NH ₃ emission (Gg)
Bangladesh	140	220	819	763
Bhutan	6	8	36	10
India	5536	4591	10,844	7399
Nepal	38	55	346	168
Pakistan	1416	539	1344	1214
Sri Lanka	58	57	275	92
Total of Six countries	7194	5470	13664	9646
Asia	34,316	26,768	52,150	27,519

Source: Streets et al., 2003.

According to Garg et al. (2001), the all India SO₂ emission increased from 3.54 Tg in 1990 to 4.64 Tg in 1995, i.e., at an annual growth rate of about 5.5%. In terms of emission by fuel type, coal consumption contributed 64% of total SO₂ emissions in India in 1990, while consumption of oil products and, biomass accounted for 29% and 4.5% respectively and non-energy consumption contributed 2.5%. SO₂ emissions from natural gas use were negligible.

Recent information on sectoral contributions to total SO₂ emission are lacking for most countries. A study on India by Garg et al. (2001), shows that the power sector had a share of 46% in total SO₂ emissions of India in year 1995, while the industry sector is the second largest SO₂ emitter at 36% followed by the transport sector (7.8%), biomass consumption (6%) and other sectors (3.8%). A study on SO₂ emissions in Asia based on 1990 data (assuming no further control is carried out under existing laws and regulations) shows that in South Asia the largest source of sulfur emission is the power sector followed by the industrial and domestic sectors. The transport sector has the least emission of sulfur (Figure 2.1). In the case of Pakistan, the industry sector had the large contribution owing to the coal and oil use. Similarly, in Nepal and Bhutan the domestic sector had a higher share in sulfur emission largely due to the consumption of traditional fuelwood using conventional biomass stoves.

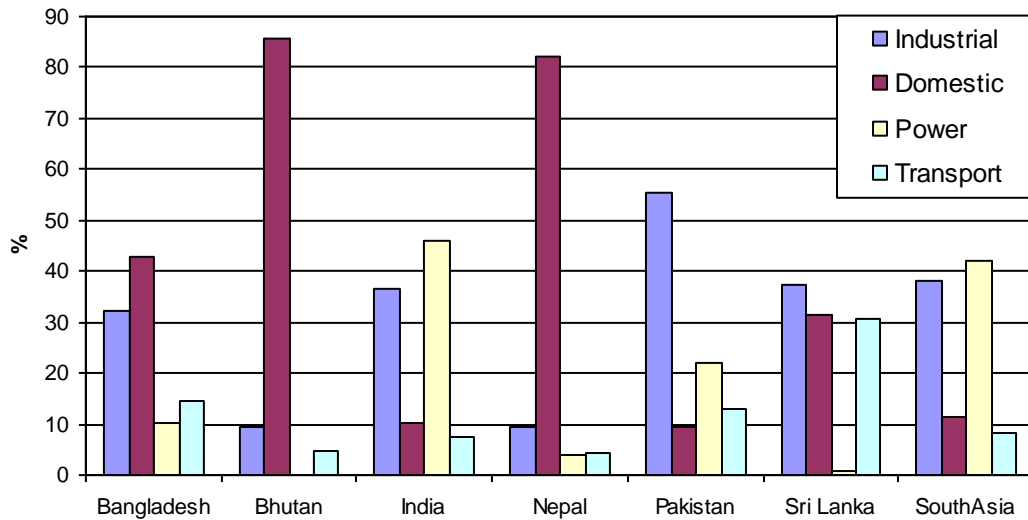


Figure 2.1: Share of SO₂ emission in South Asia (based on data 1990s data) (Shrestha et al, 1998)

Note: Domestic sector accounts combined emission from residential, commercial and agricultural sector. Data on Maldives is not available, however, in Maldives the major source of sulfur emission is the power sector which is fully based on petroleum products.

Aardenne et al. (1999) have studied the future projection of NO_x emission in the Asian region up to year 2020. It estimates that the NO_x emission would grow significantly by 2020 (Figure 2.2). The study also shows that the NO_x emission in India will grow by a factor of 5 in 2020 and the transport sector will be the largest contributor (more than 50%) to total NO_x emission in India by 2020 (Figure 2.10). The study also estimated NO_x emission in selected megacities of Asian countries and highlighted that the transport sector would be the largest contributor to NO_x emissions (Table 2.2).

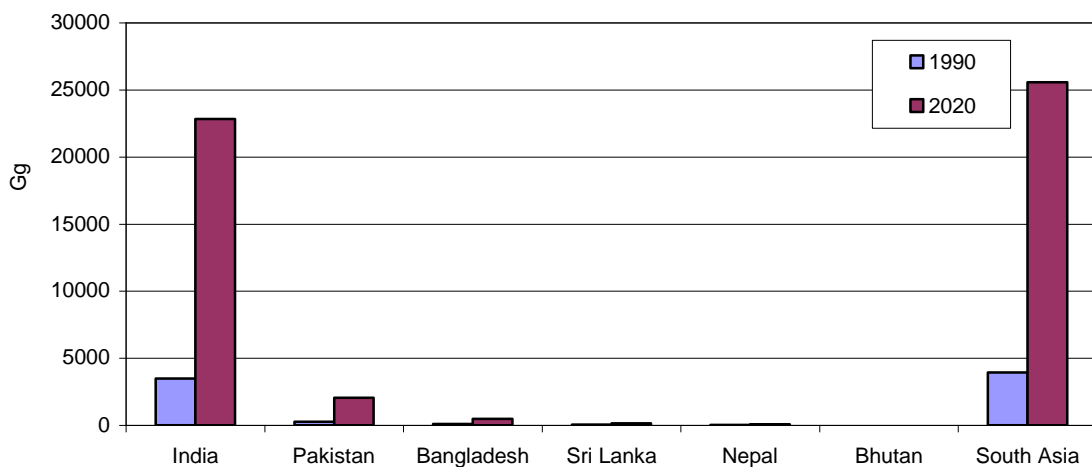


Figure 2.2: NO_x emission in South Asian countries in 1990 and 2020 (Aardenne et al., 1999)

Table 2.2: Sectoral shares (%) in NO_x emission in selected Asian Mega cities from 1990 to 2020

Sector	Bangkok		Delhi		Jakarta		Manila		Seoul		Beijing		Shanghai	
	1990	2020	1990	2020	1990	2020	1990	2020	1990	2020	1990	2020	1990	2020
Conversion	1	1	0	0	12	12	0	0	0	0	3	2	2	1
Industry	7	6	2	1	3	1	13	4	11	18	46	23	38	18
Domestic	2	1	2	0	9	3	1	0	11	3	8	5	3	1
Transport	80	89	61	80	77	84	65	66	67	45	12	46	7	29
Power	10	4	2	5	0	0	21	29	9	24	3	5	7	8
Large point source	0	0	33	14	0	0	0	0	0	11	27	19	42	44
Total NO ₂ (Gg)	192	1382	55	648	63	301	48	221	295	1749	184	772	280	1053

Source: [Aardenne et al., 1999](#)

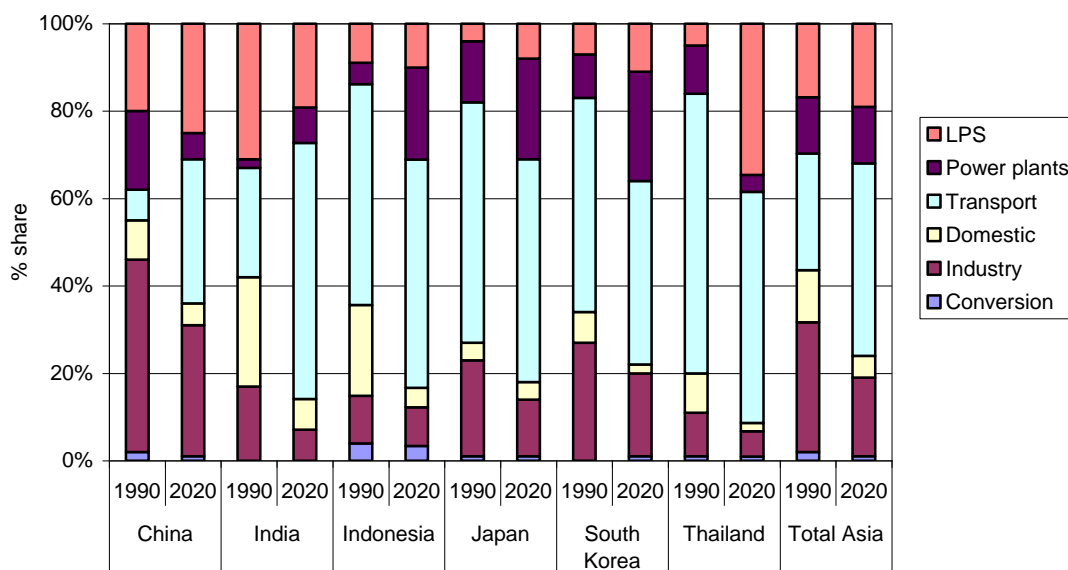


Figure 2.3: Sectoral shares in NO_x emission in selected countries in Asia in 1990 and 2020 ([Aardenne et al., 1999](#))

Country specific emissions of VOCs are mostly lacking in South Asia ([Streets et al., 2003](#)). Streets et al. has estimated total NMVOCs in Asia. A study by Varshney et al. (1999) has studied anthropogenic emissions of VOC by different sources in India. It estimates that the burning of biomass is the major contributor to NMVOC emissions ([Table 2.3](#)). Rice paddy fields and live stock together are estimated to emit more than half of the total VOCs emission in the region (Varshney et al, 1999).

Table 2.3: Sources of VOCs in India

Sources	Total VOCs (tons)	Share (%)
Fuelwood and agricultural straw burning	4,706,813	21.94%
Petroleum industry: production and refining	1,007,878	4.70%
Fuel consumption for power generation	161,354	0.75%
Natural gas: production and distribution	518,040	2.41%
Transportation	975,515	4.55%
Manufacturing	1,343,886	6.26%
Coal mining (CH ₄)	531,200	2.48%
Rice paddy fields (CH ₄)	4,223,417	19.69%
Others (livestock) (CH ₄)	7,984,622	37.22%
	21452725	100%

Source: Varshney et al., 1999

2.3 Issues related to Air Pollution in South Asia

In this section, issues related to air pollution in South Asia are discussed. The issues include: (1) Growing thermal power generation and the role of coal, (2) low efficiency in power generation, (3) inefficient coal preparation/cleaning mechanism, (4) lack of emission control mechanism in power plants, (5) lack of regulations on industrial pollution and enforcement of existing regulations, (6) urbanization and growth of personal transport vehicles, (7) high dependence on biomass fuel burning in rural areas, (8) lack of information on emission source apportionment, (9) lack of effective regulatory and economic policies to improve air quality and (10) lack of comprehensive and regular monitoring of air pollution. Each of them is discussed next.

2.3.1 Growing thermal power generation and the role of coal

In South Asia as a whole, coal accounts for 72% (147,368 ktoe) of energy use in power generation. Out of it, nearly 99% (147,287 ktoe) is used by India (rest of it, which is less than 1% (81 ktoe), is used in Pakistan in power generation) (IEA, 2004). Coal based electricity generation accounts for 80% of total electricity generation in India in 2004 (Figure 2.4).

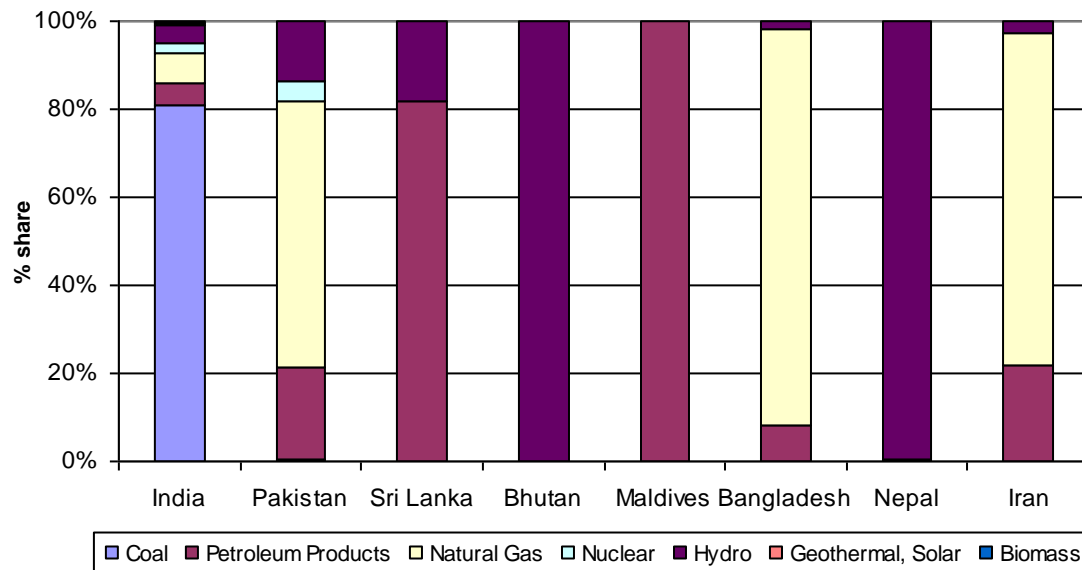


Figure 2.4: Fuel mix in the power sector (Source: IEA (2004) except for Bhutan and Maldives)
 (Note: Estimates on Bhutan and Maldives are based on information available on State of the Environment reports on these countries published by UNEP/RRC.AP)

Studies have estimated that historically the power sector accounted for the largest share in SO₂ emission in India (Garg et al., 2001; Shrestha et al., 1998).

Streets et al. (2003) estimated that the total SO₂ emission of India reached 5.54 Tg in year 2000. These studies show that the higher share of coal use in the power sector is responsible for higher share of SO₂ emission in India.

With the growing economy in India, World Energy Outlook shows coal demand in India increases to 1020 million tonnes by 2030 from 441 million tonnes in 2004 in reference scenario (IEA, 2006a). However, Government of India, under the various scenarios, has estimated its higher coal requirement from a low of 1580 Mt to high of 2555 Mt for year 2031/32 (GOI, 2006). The coal consumption in India had increased from 140 Mt in 1984 to over 400 Mt in 2004 with a growth rate of 5.4% (GOI, 2006). In this context, if coal import is to be avoided in future, India has to increase its domestic coal production in order to meet its growing coal demand (GOI, 2006).

In Pakistan, coal has historically played a rather minor role in power generation but the discovery of new large volumes of low ash, low sulfur lignite will probably increase its demand in future. Thermal power stations produce more than 80% electricity generation in

Year 2004 (Figure 2.1). Thermal power generation in Pakistan is mainly based on natural gas (60%) besides some generation using furnace oil and diesel (WAPDA, 2007).

Sri Lanka whose power supply is predominantly based on hydroelectricity is now gearing towards thermal electricity generation. Thermal power generation share has increased from below 1% in 1990s (Siyambalapitiya et al, 1993) to around 30% recently. There is already 405 MW installed capacity and it has plans to build its first coal-fired power plant which will be equipped with particulate, SO₂ and NO_x emissions control systems. By 2010, the installed capacity of thermal power plants in Sri Lanka would reach 2200 MW (UNEP RRCAP, 2007a).

With the increasing dependence on thermal power generation, SO₂ emission from the power sector is growing in South Asia.

Besides power generation, coal is used by the industrial sector as a source of energy in South Asia. In some countries like Iran and India, coal is also used in residential and commercial sectors. Similarly, petroleum products are also used in industries but their share is relatively lower than that of the transport sector.

2.3.2 Low Efficiency in Power Generation

There is a wide variation in efficiency of electricity generation in Asia. Considering the South Asian countries as a whole, coal plays a major role in power generation mainly because of the dominant share of coal in the power sector of India. The overall efficiency of coal fired power generation in India was 26.8% in year 2002 (IEA, 2004), which is significantly lower than the corresponding figure in the OECD countries as a whole (36.7%) (Figure 2.5). It is also lower than the average efficiency of coal fired power plants in Asia. The efficiency of electric power plants in an average in Asia as a whole in 2002 was 29.1% while the corresponding values for China and Japan were 33.1% and 41.9% respectively. If the efficiency of coal fired power generation in India was improved to the level of Japan in year 2002, coal requirements of and SO₂ emission from the power sector in India would be reduced by about 36%. Similarly, if the efficiency in India was improved to the OECD level, the coal requirement and SO₂ emission would be reduced by 26.9%.

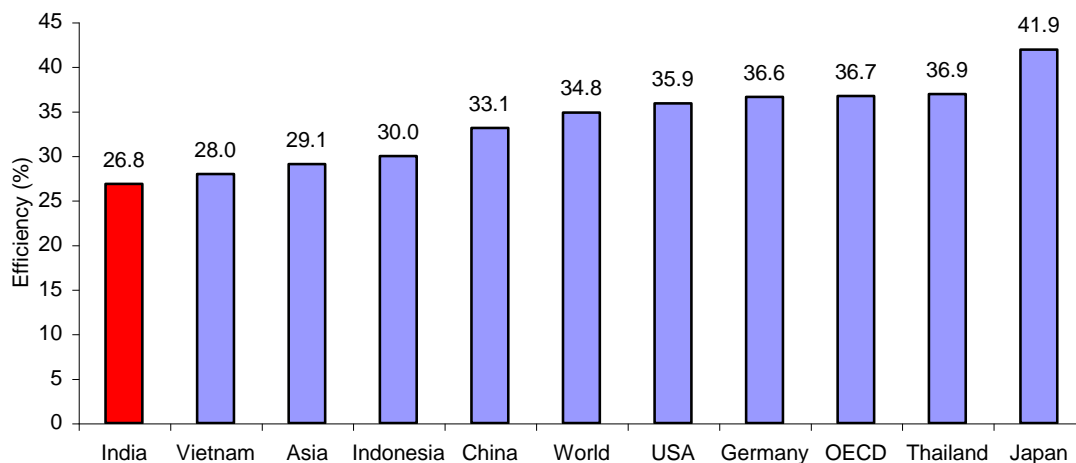


Figure 2.5: Efficiency of coal fired power generation in selected countries in year 2002
Sources: IEA (2004) based on public electricity plants. For Japan, Germany and USA data are from ECOFYS (2005)

2.3.3 Inefficient Coal Preparation/Cleaning Mechanism

Coal production in India has been largely based on opencast mining (ECOAL, 2006; GOI, 2006). Inefficient exploitation of the in-place coal reserves and lack of control on mining practices are some of issues that have deteriorated the quality of domestic thermal coal over the years (GOI, 2006). Although the sulfur content of Indian coal is low, it has high ash content, which can result in higher emissions of suspended particulate matters (SPM) (GOI, 2006). Further, the domestic coal in India has low calorific value – an average of 4000 kcal/kg as compared to 6000 kcal/kg in imported coal (GOI, 2006). The average calorific value of coal burnt in India’s power plants is only about 3500 kcal/kg. Presently untreated coal with ash content typically in the range 40-45% is used in the power sector in India (DTI, 2000). The Ministry of Environment and Forests (MOEF) of India has introduced a regulation prohibiting the use of unwashed coal containing more than 34% ash if this has to be transported to longer distances than 1000 km. While the power stations are often located longer distances from the major coalfields, this regulation might give a push for clean coal preparation technologies; however, the effectiveness of the regulation would depend upon the level of its enforcement. The increased dependence of the power sector on lower quality coal has been associated with increased emissions from power plants in the form of particulate matters, toxic elements, fly ash, oxides of nitrogen, sulfur and carbon (UNEP, 2001).

2.3.4 Lack of emission control mechanism in power plants

Existing coal-fired power generation in India is mainly based on conventional sub-critical pulverized combustion technologies with low efficiency of conversion. The country is moving towards greater use of clean coal technologies and has plans for addition of 20GWe of supercritical coal fired thermal units ([ECOAL, 2006](#)). However, the current priority in India is particulate matters through the use of electrostatic precipitators on existing and new generating units. There seems to be no emphasis on using other technologies for SO₂ and NO_x controls except considering advanced clean coal technologies ([Wu and Soud, 1998](#)).

Bangladesh started its first coal based power generation plant of 250-MW capacity in January 2006. Some coal mining projects are being planned in the country. However, there is no emphasis on emissions control at present.

There are no coal fired plants in Bhutan and Nepal at present nor is there any plan for having such plants in the future in these countries. Nepal is using some oil for captive power generation. With the increasing electricity demand during dry seasons in peak hours and shortage of generation capacity in the national grid, the usage of such power plants has been increasing ([NEA, 2007](#)).

2.3.5 Lack of regulations on Industrial pollution and enforcement of existing regulations

Industry sector is a major source of transboundary air pollutants. Disaggregated sectoral estimates are not available for most countries in South Asia. [Streets et al. \(2003\)](#) stated that the industrial sector is the second largest contributor to national SO₂ emissions after the power sector. According to [Garg et al. \(2001\)](#), iron and steel industry accounted for one fourth of the total industry sector SO₂ emission in India in 1995 ([Figure 2.6](#)). Together iron and steel, cement and fertilizer industries accounted for more than half of the industrial SO₂ emission in that country. In Bangladesh, the major SO₂ emitting industries are identified as Textiles, Non-ferrous metal, Sugar and refineries, Vegetable Oil, Iron and Steel and Tobacco ([BBS, 2005](#)). Similarly, Textiles, Sugar and refineries, Cement and Vegetable oil are reported as the major particulate emitting industries.

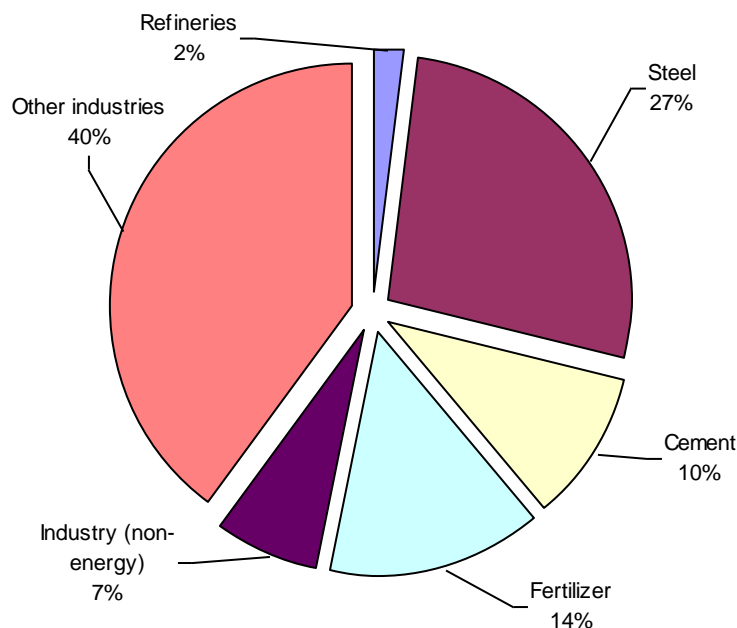


Figure 2.6: Shares in total industry sector SO₂ emission in India by type of industry
(Source: Garg et al., 2001)

While not much information on sectoral level NO_x emission are available for most South Asian countries, Garg et al. (2001) report that the industrial sector is the third largest contributor of NO_x emission in India after the Transport and Power sector (Industry sector accounted for 21% of total NO_x emission in India in year 1995). Given the importance of the industrial sector in emissions of pollutants, it is clear that significant regulatory mechanisms and/or economic policies are warranted to deal with the emissions from the sector.

In 2000, Pakistan imposed a pollution levy on industrial effluents (including discharge in water as well as in air). The pollution levy was set initially at Rs. 50 per unit of pollution load and was to be increased proportionately in the following years till it reaches Rs.100 per unit pollution load (PEPA, 2000). The country also has a provision to provide tax incentives to the industries for importing pollution abatement equipments. However, this policy is yet to be implemented effectively.

Bhutan has introduced the Environmental Discharge Standards for Industrial Pollution effective from year 2000. These standards are mandatory for new industries. Also an Environment Fund has been created in that country to support the existing industries to upgrade and meet the new standard.

Although some initiatives have been undertaken by some countries in the region to introduce standards to regulate emissions in the industrial sector, they are not comprehensive and seem to be highly inadequate for an effective management of air quality. Further, there are indications that the enforcement of existing standards is weak in most countries.

2.3.6 Urbanization and growth of personal transport vehicles

South Asian countries are undergoing through rapid urbanization. As a result, the countries have witnessed high growth in consumption of energy in transport, residential, industrial and commercial sectors in the cities and the resultant emissions of air pollutants. Air quality in most cities in South Asia has been deteriorating over the years. Presently, air pollutants originating from the urban areas are recognized as increasing sources of regional- and global-scale pollution. [Guttikunda et al, \(2003\)](#) estimates huge sulfur emission in urban centers in Asia if current sulfur emission is unabated. Due to urbanisation and motorisation; in particular, concentration levels of suspended particulate matter (SPM) are very high and exceeded WHO guidelines ([Hayashi et al., 2004](#) and [Siddiqi, 2007](#)). One of major causes of transport-related environmental problems in Asia is the severe traffic congestion resulting from increasing travel demands and a lack of appropriate public transport infrastructure ([Hayashi et al., 2004](#)). This could be seen from the tremendous growth of passenger cars in use in countries like in India ([Figure 2.7](#)).

Over the last 10 years, the total personal vehicle registration has increased by 105%; cars alone have increased by 157% and diesel cars have increased by 425% ([Greencarcongress, 2006](#)).

In a recent study, the Centre for Science and Environment (CSE) in India has warned that the level of pollution has started to increase. The rising pollution level in Delhi is due to the rapid growth in cars, especially diesel cars, in the city. It is reported that particulate levels are still very high and NO_x levels are steadily rising ([Figure 2.8](#)).

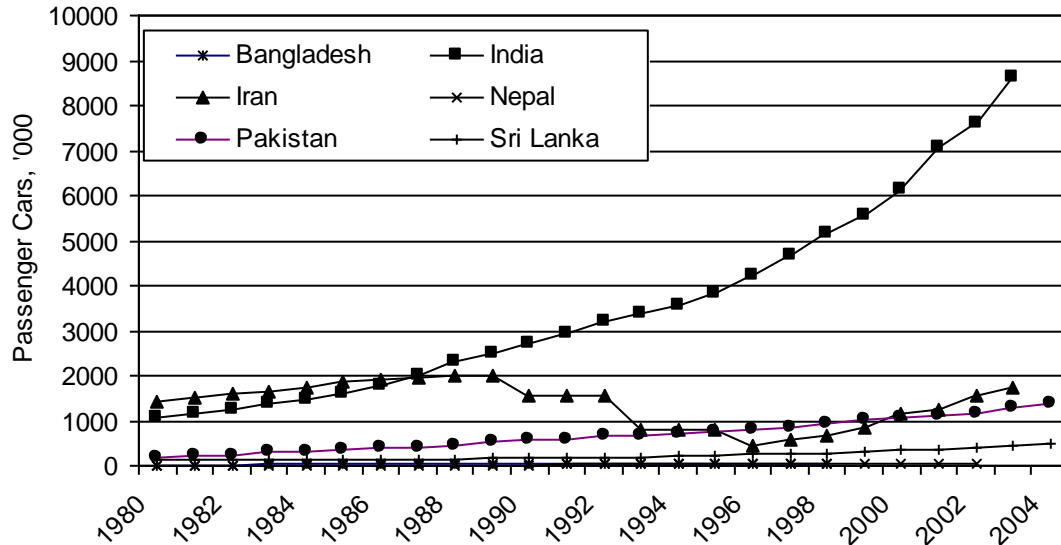


Figure 2.7: Stock of Passenger cars in South Asian Countries

Source: GEO, 2007 (UN Statistics Division Transport Statistics Database, UN Statistical Yearbook extracted from GEO Data Portal/UNEP)

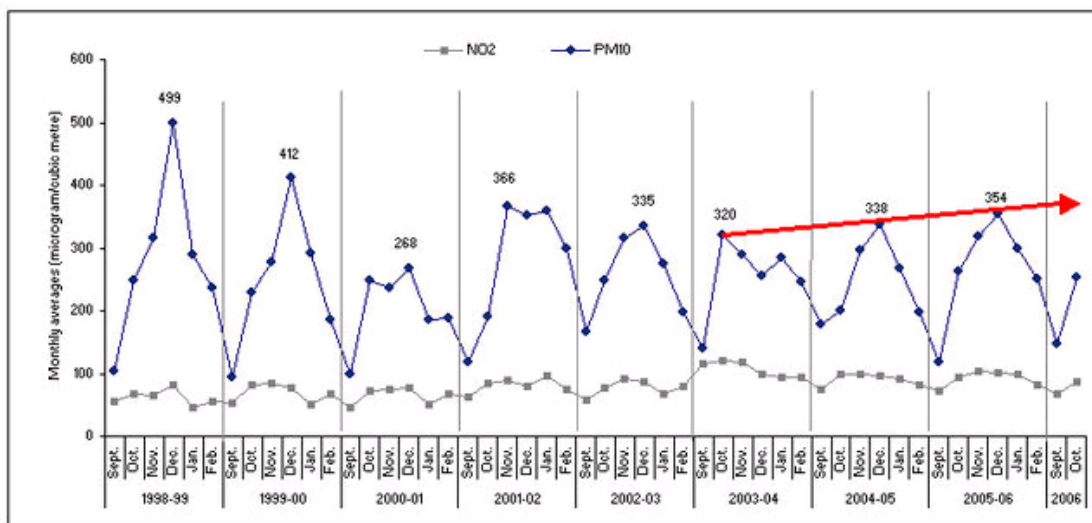


Figure 2.8: Trend of NOx and PM in Delhi

Source: Greencarcongress, 2006

In Delhi, diesel cars represent nearly 20% of new car registrations in 2006, up from 4% in 1999. While gasoline cars have increased at 8.5% annually, diesel cars have maintained a growth rate of 16.6%. According to the estimates of CSE, addition of 118,631 diesel cars on the city’s roads are equivalent to adding particulate emissions from nearly 30,000 diesel buses (Greencarcongress, 2007). It further warns that the diesel personal cars are threatening to nullify the impact of the compressed natural gas (CNG) program.

There is lack of well defined policies to promote private participation in public transport in the region (Siddiqi, 2007). There is also lack of transport policies that consider environmental concerns at the national level in most of the countries. With the increasing population, growing urbanization and economy, the travel demand has seen a rapid growth in the last decade in the region. Countries in the region also suffer from inefficient and inadequate public transport system, which result in larger switch to the use of personal motorized vehicles.

The stock of low occupancy personal vehicles like 2-wheelers and cars is steadily increasing in South Asian cities and is contributing to increasing traffic congestion and air pollution. Road transport vehicles also contribute to particulate matter emissions. The concentration levels of particulate matters greatly exceed the national and World Health Organization standards, and the vehicular transport is by far the largest source of air pollution in several cities in the region. This is indicated by the high growth of vehicles in the cities. For example, in the past 30 years, Delhi's population more than tripled and the number of vehicles increased almost fifteen-fold (Bose et al., 2001). In Kathmandu Valley, vehicular emissions are reported to be responsible for 38% of the total PM₁₀ emission (ICIMOD, 2007).

In Thimphu, Bhutan, two-wheelers are estimated at 45%, cars and jeeps account for 35%, and buses account for 2% of the total number of vehicles. Traffic movement in 2003 had increased by more than 100% as compared with that in 1997. It is projected that by 2020, the number of vehicles in Bhutan would rise to 100,000, with more than 45,000 in Thimphu alone (BEO, 2006).

The vehicle population in Nepal has grown over three times in the previous decade and reached 472,795 in FY2004 with an annual growth rate ranging from 10% to 16%. Further two wheelers have larger share (43% in 1989 and 63% in 2004). In Pakistan the number of vehicles has increased from 0.8 million to 4 million within 20 years showing an overall growth of more than 400% (PEPA, 2005). A World Bank study on the Kathmandu valley shows that particulate matters (PM₁₀) from vehicle exhaust has increased to 471% during 1993-2001 (ADB, 2006a).

The foregoing discussion shows that the vehicle stock in South Asia is growing rapidly and would thus further increase the pollution load in the cities.

2.3.7 High dependence on biomass fuel burning in rural areas

Biomass (including agricultural waste and dung) has been the major source of energy in most of the rural households in the South Asia. The share of biomass in total primary energy is high in most countries of the region. In some countries of the region, e.g., Nepal, biomass is the predominant source of energy accounting for about 80% of the total primary energy requirements. Mostly, biomass is used for domestic (residential) cooking. Traditional firewood cooking stoves are mostly being used for the purpose. Biomass is also used in the industrial sector in several countries including India, Pakistan and Iran (IEA, 2004).

Table 2.4 shows that the crop residues are burnt in relatively large amount in South Asia. Though not much information is available, these data imply that the use of biomass burning in rural region of South Asian countries could be one of the major sources of VOCs as biomass burning is considered a major source of VOC emissions.

Table 2.4: Biomass burned in South Asian countries

Countries in South Asia	Biomass Burned (Tg)		
	Savanna/ Grassland	Forest	Crop Residue
Bangladesh	0	9	11
Bhutan	0	1	0
India	9	37	84
Nepal	0	5	2
Pakistan	3	1	10
SriLanka	0	4	0
Asia Total	147	330	250

Source: Streets et al., 2003.

2.3.8 Lack of information on emission source apportionment

There is lack of information and scientific studies on source apportionment of different

pollutants in urban as well as rural areas in South Asian countries. Sound scientific studies and database on sources of emission and how the manner they contribute to air quality are required in order to formulate/design effective air pollution control regulations, policies and strategies.

2.3.9 Lack of effective regulatory and economic policies to improve air quality

Most countries in South Asia have developed some, if not comprehensive, ambient air quality standards (see [Table 2.5](#))². In order to attain the air quality standards, one would need effective instruments (e.g., emission standards, technology standards, fuel quality standard or economic instruments like emission charge or permits). While Euro-I standard is being implemented in all countries for cars and heavy diesel trucks, India has implemented Euro-II in its 4 metropolitan cities. Several countries have also adopted standards on fuel quality of diesel in that the limit on sulfur content of diesel is specified (which vary from 0.05 to 1% across the countries); see [Table 2.6](#).

While there are some regulatory frameworks (e.g., standards) in place in some countries, they are either inadequate or suffer from poor enforcement in most countries in the region. The approach of economic instruments (i.e., using emission charge or permits) is yet to be adopted by countries in the region except perhaps Pakistan, which has started levying emission charges to the industries after amending the National Environmental Quality Standards (NEQS) in 2000. The policy of emission charge in Pakistan requires the industries to monitor and report the emissions regularly as per the standard to the authority. Emissions exceeding the NEQS would be charged. Interestingly, the charge is collected by Chambers of Commerce and Industry. The outcome of the policy is yet to be evaluated.

² In the case of Bhutan, it appears to follow the USEPA and WHO guidelines in the absence of its own standards for ambient air quality ([CAI, 2006](#)). The country has also developed Industrial Emission Standards in 2004 ([BEO, 2006](#)).

Table 2.5: Ambient Air Quality Standards of the South Asian countries in comparison to EU, USEPA and WHO, $\mu\text{g}/\text{m}^3$

Type	Averaging Time	EU guidelines	USEPA guidelines	WHO guidelines	Iran*	Sri Lanka/ Colombo	Bangladesh/ Dhaka	Nepal/ Ktm	India/ Delhi/ Kolkata/ Mumbai
Carbon Monoxide	15 mins	-	-	100,000		-		100,000	-
	30 mins	-	-	60,000		-		-	-
	1 hour	-	40,000	30,000	40000	30,000		-	4,000
	8 hours	10,000	10,000	10,000	10000	10,000	2,000	10,000	2,000
	24 hours	-	-		-			-	-
Lead	1 hour	-	-	-				-	-
	24 hours	-	-	-		2		-	1.0
	1 month	-	-	-		-		-	-
	3 months	-	1.5	-		-		-	-
	1 year	0.5	-	0.5		0.5		0.5	0.75
Nitrogen dioxide	1 hour	200	-	200		250		-	-
	8 hours	-	-	-		-	80	-	-
	24 hours	-	-	-		100		80	80
	1 year	40	100	40	100			40	60
Ozone	1 hour	-	240	-	280	200		-	-
	8 hours	120	160	120		-		-	-
	1 year	-		-		-		-	-
Sulfur Dioxide	10 minutes	-	-	500		-		-	-
	1 hour	350	-	-	210	200		-	-
	8 hours	-	-	-		120	80	-	-
	24 hours	125	370	125	-	80		70	80
	1 year	20	78.5	50	-	-		50	60
TSP	1 hour	-	-	-		500		-	-
	3 hours	-	-	-		450		-	-
	8 hours	-	-	-		350	200	-	-
	24 hours	-	-	-	260	300		230	200
	1 year	-	-	-		100		-	140
PM ₁₀	1 hour	-	-	-	-	-		-	
	24 hours	50	150	-	-	-		120	100
	1 year	40	50	-	-	-		-	60
PM _{2.5}	24 hours	-	65	-	-	-		-	
	1 year	-	15	-	-	-		-	

Source: Clean Air Initiative – Asia, 2007,

* Data for Iran is extracted from Aziz, J.A., 2006, Towards establishing air quality guidelines for Pakistan”, Eastern Mediterranean Health Journal, Vol. 12, No. 6, 2006,

Table 2.6: Sulfur content in diesel

Type	Bhutan	Maldives	Pakistan	Iran	Sri Lanka	Bangladesh	Nepal	India
Sulfur content in diesel	0.25%	0.5%	1.0%*	0.05%#	0.8%	0.5%	0.25%	0.25%

Source: Extracted from state of environment of the countries

*PEPA, 2005, State of Environment-2005, Pakistan,

Hastaie P., 2000, Presentation on Air Quality Management in Tehran

2.3.10 Lack of comprehensive and regular monitoring of air pollution

Inadequate air quality monitoring and lack of data have been a major hindrance in South Asian countries for assessing air quality and for formulating efficient policies and regulations for air quality management. The problems associated with monitoring mainly include insufficient monitoring stations to represent adequate geographical coverage, lack of monitoring of all major pollutants and lack of regular monitoring. In India, particulate matters, SO₂ and NO_x are monitored regularly (MoEF, 2006). In most other countries, it is only particulate matters that are monitored regularly in few places. The lack of comprehensive and regular monitoring poses a barrier to proper understanding of air quality problem and also hinders in formulation of proper strategies and policies to control or prevent air pollution.

Chapter III

Approaches for controlling and preventing air pollution

3.1 Introduction

In the literature, the approaches for environmental management are mainly of the following types: i) command and control, ii) market based approaches iii) property rights based approach and iv) approaches based on voluntary action. In the case of transboundary air pollutants (TAPs), often collective actions by countries involved would be necessary in order to effectively deal with the transboundary air pollution problem. That means, countries involved in the transboundary pollution will have to commit themselves through an agreement to achieve necessary reductions in emission of pollutants by stipulated time frame. Thus, the first step towards the control of TAPs is to secure such an agreement among the countries involved in TAP emissions in a region. Once the target level of emission reduction by each country is agreed, the next step for a country concerned is to formulate appropriate measures/strategies/policies to attain the committed emission reduction targets.

This chapter first discusses various important international treaties and agreements to prevent/control emissions of TAPs. Some of the treaties and agreements are designed to deal with a single pollutant while others deal with multiple pollutants. The chapter then discusses different types of approaches and measures (including approaches based on command and control, market or economic instruments, and voluntary actions) as adopted by various countries to attain their emission reduction targets.

3.2 International Treaties and Agreements

International treaties are regional agreements among the member countries/states with consensus to combat transboundary air pollution. These treaties formulate specific protocols targeted stipulated to reduce specific pollutants over specific time period. These protocols are ratified by member countries/states. In the Europe and the US, such treaties are in practice. These treaties and protocols are discussed next.

3.2.1 Convention on Long-Range Transboundary Air Pollution (CLRTAP)

The Convention on Long Range Transboundary Air Pollution (CLRTAP) is the initiative taken to address major environmental problems in United Nation Economic Commission for Europe (UNECE) region (with special focus on Eastern Europe, the Caucasus and Central Asia and South-East Europe). Since 1979 the Convention has been active and up to now it has 51 parties (members). The Convention entered into force in 1983 and it has been extended by eight protocols that identify specific measures to be taken by Parties to cut their emissions of air pollutants ([UNECE Website](#)).

The Convention was the first international legally binding instrument to deal with problems of air pollution on a broad regional basis. Besides laying down the general principles of international cooperation for air pollution abatement, the Convention also set up an institutional framework bringing together research and policy to fight the transboundary air pollution in the region. The convention has adapted eight protocols. The approach of these protocols is either on the basis of stabilization of ambient level of emission, or on the effect based on critical load concept. The protocols on SO₂, NO_x, VOCs and NH₃ are discussed next.

3.2.1.1 Protocols on SO₂ emission reduction

Helsinki Protocol

This protocol required to reduce sulfur emissions by at least 30 per cent between 1980 and 1993. This was the first sulfur protocol under the Convention on Long-Range Transboundary Air Pollution (CLRTAP), which was signed in Helsinki in 1985. The protocol was able to have an average reduction of 46 per cent among the signatories. Many western European signatories had further reduction than that. The reduction of sulfur emissions resulted in the reduction of ambient level sulfur dioxide by 40-60 per cent in most places in the Western Europe.

Oslo Protocol

This protocol was the second protocol on the reduction of sulfur emission. It required further reduction on sulfur emission. It was signed in 1994 in Oslo and it came into force in 1998. The protocol stipulates most western European countries to reduce their sulfur

emissions by 70 to 80 per cent by the year 2000, while eastern European nations have reduction targets of typically between 40 to 50 per cent (from 1980 levels).

The protocol was based on the effects-based approach with the critical load concept, best available technology, energy savings and the application of economic instruments. An effects-based approach aims at gradually attaining critical loads, sets long-term targets for reductions in sulfur emissions, although it has been recognized that critical loads will not be reached in one single step ([UNECE Website](#)). Critical load is a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur, according to present knowledge ([UNECE Website](#)).

3.2.1.2 Protocols on NO_x emission reduction

Sofia Protocol

Sofia Protocol requires all signatories (which include European countries and United States) to ensure that their NO_x emissions as from 1994 do not exceed their 1987 levels. It was signed in 1988 in Sofia (Bulgaria). A reduction of 9% NO_x emission from their cumulative emission in 1987 is achieved. Nineteen of the 25 Parties to the NO_x Protocol have either reached the target by 1994 and stabilized emissions at 1987 levels or reduced emissions below that level.

3.2.1.3 Protocols on VOCs emission reduction

Geneva Protocol

It was the first protocol adapted by the CLRTAP to control emissions of volatile organic compounds (VOCs), the second major air pollutant responsible for the formation of ground level ozone. It was signed in Geneva in 1991. The Protocol entered into force in 1997. It stipulates three ways of emission reduction to meet the emission reduction targets. These ways are targeted for the emission reduction by 1999 with flexibility to choose base year in between 1984-1990 as per the data availability. These options are:

- i) 30% reduction in emissions of volatile organic compounds (VOCs) by 1999 using base year between 1984 and 1990 to be chosen by each country. The base year chosen varied across the countries. Austria, Belgium, Estonia, Finland, France,

Germany, Netherlands, Portugal, Spain, Sweden and the United Kingdom used 1988 as the base year, while it was 1985 in the case of Denmark, 1984 in the case of Liechtenstein, Switzerland and the United States, and 1990 in the case of Czech Republic, Italy, Luxembourg, Monaco and 1990 in the case of Slovakia.

ii) The same amount of reduction as in (i) within Tropospheric Ozone Management Area (TOMA)³. The party can choose any base year emission level from 1984-1990 but it has to ensure that by 1999 total national emissions do not exceed the 1988 emission levels. TOMAs in Norway (base year 1989) and Canada (base year 1988));

iii) If the total VOC emission in 1988 is lower than 500,000 tonnes, and 20 kg/inhabitant and 5 tonnes/km², the parties are to ensure for stabilization at that emission level by year 1999. (This has been chosen by Bulgaria, Greece, and Hungary). ([UNECE Website](#)).

3.2.1.4 Protocols dealing with multi-pollutants

Gothenburg Protocol (A multi-pollutant and multi-effects protocol)

The protocol is a natural continuation of the earlier protocols under the CLRTAP. The protocol is unique in that it focuses on abatement of three effects namely acidification, eutrophication, and ground-level ozone and targets reduction of four pollutants namely sulfur dioxide (SO₂), nitrogen oxides (NO_x), volatile organic compounds (VOCs), and ammonia (NH₃). The protocol was adapted by the Convention on Long-Range Transboundary Air Pollution in its Seventeenth session in 1999 in Gothenburg (Sweden). The protocol is also called as ‘Multi-pollutant and multi-effects protocol’ ([UNECE Website](#)). The protocol sets binding emission ceilings for the four air pollutants to be achieved by 2010. It also prescribed the application of emission and fuel standards ([UNECE Website](#)).

³ The Protocol designates TOMA 1 as the Lower Fraser Valley in the province of British Columbia and the Windsor-Quebec Corridor in the provinces of Ontario and Quebec in Canada; and TOMA 2 as the Norwegian mainland as well as the exclusive economic zone south of 62°N latitude in the region of the Economic Commission for Europe (ECE)

3.2.2 European Commission National Emission Ceilings Directive (2001/81/EC)

This is the directive issued by European Commission for limiting the emission of SO₂, NO_x, NH₃ and VOCs. The directive enforces the Gothenburg Protocol with further stringent national ceilings than that of the protocol. The directive came into force on 27 November 2001. With accession of new member states in European Union, the directive was amended in 2003 and issued to the member states Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom. The directive has issued national ceilings to these member states for the four pollutants and requires member states not to exceed the national ceilings of the four pollutants at the latest by 2010. The directive has issued interim environmental objectives which aims to reduce the acidification and ground level ozone formulation effect of these pollutants using three different ways. These ways utilize either the control of all pollutants or achieve a level of ground level ozone not exceed the ozone level of health based standard or vegetation standard. These are discussed next (the [EC-Directives issued on 2003](#)).

- Acidification: In the areas, where critical loads are exceeded, emission of all pollutants is to be reduced by at least 50 % compared to that of year 1990.
- Ground-level ozone (health): The ground-level ozone load above the critical level for human health⁴ to be reduced by two-thirds in all grid cells⁵ compared to that of year 1990. In addition, the ground-level ozone load is not to exceed an absolute limit of 2,9 ppm.h in any area;
- Ground-level ozone (vegetation): The ground-level ozone load above the critical level for crops and semi-natural vegetation⁶ to be reduced by one-third in all grid cells compared to that of 1990. In addition, the ground-level ozone

⁴ It means the sum of the difference between hourly concentrations of ground-level ozone greater than 120 µg/m³ (=60 ppb) and 120 µg/m³ accumulated throughout the year (termed as AOT60) is zero.

⁵ It is a 150 km x 150 km square, which is the resolution used when mapping critical loads on a European scale, and also when monitoring emissions and depositions of air pollutants under the Cooperative Programme for Monitoring and Evaluation of the long-range Transmission of Air Pollutants in Europe (EMEP)

⁶ It means the sum of the difference between hourly concentrations of ground-level ozone greater than 80 µg/m³ (= 40 ppb) and 80 µg/m³ during daylight hours accumulated from May to July each year (termed as AOT40) is 3 ppm.h;

load not to exceed an absolute limit of 10 ppm.h, expressed as an exceedance of the critical level of 3 ppm.h in any area.

For compliance of [the EC Directive \(2001/81/EC\)](#), the member states are allowed to decide which measures to take in for compliance. For example, in Denmark, the government has set an annual sectoral SO₂ emission limit for power plants with a capacity of 25MW or larger. There is a consortium of two power companies, which decides how to allocate the SO₂ emission limit (or cap) among their individual power plants ([OECD, 1998](#)). There is flexibility for utilities to exceed the limit by 10% in any one year, as long as the cumulative emission limit over four years is reached.

3.2.3 The US Clean Air Act Amendment 1990

In the United States, the approach to limit emission of transboundary air pollutants is primarily based on Title IV of the 1990 Clean Air Act Amendment (CAAA). Studies in the US during the late 1980s suggested that SO₂ was the largest contributor to acid rain and that the electricity sector accounted for two-thirds of the SO₂ emissions. Therefore, the US approach had a major focus on SO₂ emissions reduction from the electricity sector while the reduction of NO_x was also targeted but it was programd with different approach than SO₂ reduction. The US adopted a nationwide program to address the reduction of these pollutants and the program was called as ‘Acid Rain Program’. The program has used economic instrument like sulfur emission allowance and emission trading to control sulfur emission and stipulated rate based emission standards for NO_x emission.

In fact, the US effort on limiting SO₂ can be traced back to 1970 when for the first time the US, through amendments on the Clean Air Act as a federal legislation, established a national standard for maximum ambient concentration of SO₂. However, the primary concern then was not acid rain rather it was the damage to human health ([Ellerman et al., 2000](#)).

The US approach has addressed the impacts of acid rain formation by addressing emissions in a regional basis i.e. controlling emission reductions from bordering or “upwind” states. Each state was required to prepare state implementation plan (SIP) specifying actions to be taken for the compliance. It also imposed a standard for new plants called as New Source Performance Standard (NSPS), according to which new plants could not exceed 1.2 lb of

SO₂ emission per million Btu of fuel burned. However, many states would not be able to comply with the standards by the deadlines specified in the Act. In 1977, the US congress again amended the Act with extended deadline until 1982 but required Environmental Protection Agency (EPA) to designate the areas failing to meet the initial deadline as ‘non-attainment’ areas and these areas were subject to tight regulatory controls. Two alternative rate based emission standards were imposed for coal-fired plants built after 1978. Such standards link the maximum allowable emission rate with the percentage of sulfur removal attained. The power plants were required to operate either at SO₂ emission rate below 1.2 lb per million Btu with 90% removal of potential SO₂ emission or at SO₂ emission rate below 0.6 lb per million Btu with 70% removal of potential SO₂ emission.

3.3 Approaches for controlling and preventing transboundary air pollution

Different types of approaches and measures are practiced to control and prevent TAPs. These approach include command and control, market or economic instruments, and voluntary actions) which are adopted by various countries to attain their emission reduction targets.

3.3.1 Command and Control approaches

It is a traditional approach of control in which a standard is set on the polluting activity. The standard can be of different types: e.g., technology based standard, emission standard, fuel quality standard. A technology based standard stipulates the use of specific type of technology or equipment (e.g. catalytic converter, SO_x scrubber mechanism etc.). An emission standard sets the level of permissible emission per unit of output or input: e.g. kg of SO₂/kWh or NO_x/kWh). A fuel quality standard sets an allowable limit for the pollutant content in the fuel. Different type of emission standards in practice are discussed next.

SO₂ emission standard in the US and Europe

The United States imposed an emission standard for new plants as 1.2 lb of SO₂ per million Btu of fuel burned in 1970s. Later, two alternative emission standards were imposed for coal-fired plants. The plants could:

- a) either operate at SO₂ emission rate less than 1.2 lb per million Btu with 90% SO₂ removal of potential SO₂ emission;
- b) or operate at SO₂ emission rate less than 0.6 per million Btu with 70% SO₂ removal of potential SO₂ emission.

This kind of standard based on sulfur removal rate required all new as well as existing coal fired plants to use flue gas desulfurization system (scrubbers) whether they burn high or low sulfur coal (Ellerman et al., 2000).

The Integrated Pollution Prevention and Control (IPPC) Directive of EU requires each member state to adapt Best Available Technology (BAT); in that sense the directive sets technology based standards. This directive adapts Integrated Pollution Prevention and Control emission permits based on BAT instead of ambient standards and fines are imposed for noncompliance.

While the practice of technology based standards with fuel taxes is also available, study by Peszko et al. (2001) mentions that when all firms comply with the BAT requirement, the differences in marginal abatement costs among them may become negligible which leaves few rooms to apply economic instruments on top of BAT standards to achieve additional emissions reduction.

3.3.2 Market based instruments

Market based instruments (also called economic instruments) can include direct instruments, e.g., emission tax (or emission charge) and emission permits as well as indirect instruments such as fuel tax (i.e., tax per unit of fuel such as per liter of gasoline) and energy tax (i.e., tax per unit of heat input) and subsidy on cleaner fuel or efficient technologies.

3.3.2.1 Emission Taxes

Emission tax or charge is pollution charge, which is applied as a penalty for the amount of pollution that a source emits and it is based on the 'Polluters Pay Principle (PPP)'. It is mostly a debated issue while fixing the charge tax as this has direct implication with the abatement cost of pollution for a firm as the firm may reduce emission to the point where its marginal abatement cost is equal to the tax rate (Stavins et al, 2003). Studies (Stavins et al, 2003, Tietenberg, T, 2003) have emphasized that the tax rate should be equal to the marginal benefits of cleanup at the efficient level of cleanup.

3.3.2.2 Emission Taxes in Practice

Emission Taxes on Volatile Organic Compounds (VOCs) emissions from aircraft engines

In 1997 in Switzerland, for the first time, an aircraft engine emission charge was introduced in Zurich Airport to control aviation related pollution (Knaus et al, 1997). It is reported that during the Landing and Take-Off cycle (LTO), 20-30% of the NO_x emissions and up to 90% of the VOC emissions occurs in an entire flight. The aircraft engine emission charge is expressed as a percentage of the regular landing fee, which is added to the landing fee as such. Based on a number of considerations such as clean air incentives, available technologies, existing and forecast aircraft fleet mix, five classes were defined each for turbofan and turboshaft engines, giving a range of engine emission factors within each class. Class 5 (which currently includes 48% of all scheduled and chartered planes) is free of charge. Airline operators with planes in Class 4 (17% of all planes) pay 5% of the regular landing fee; while those with planes in Class 3 (30%), Class 2 and Class 1 pay 10%, 20% and 40% of the landing fee respectively (Knaus et al, 1997). It should be noted that the charge doubles from one class to the next, which indicates the intended economic incentive for promoting and accelerating the introduction and use of best available engine technology in order to stabilize airport emissions without having to set limits to operations. Apart from the size of aircraft engines, the aircraft emission charge is based on NO_x and VOC emissions in the LTO (Landing and Take-Off) cycle (Knaus et al, 1997).

The charge was intended primarily to provide an incentive to encourage operators to use lowest emissions aircraft and to accelerate the use of best available technology (BAT). These charges are revenue neutral and do not affect consumer demand (IPCC, 1998). They do, however, provide an incentive to airlines to purchase and operate aircraft with lower engine emissions. Revenues are used to finance emissions reduction measures at the airport (Carlsson, 1999). Similar emissions-related charging scheme was applied at 10 Swedish airports in 1998 and in France in 2003. UK has also applied emission charges at its 2 airports in 2004 and Germany is going to introduce it in 2008 (Fleuti E., 2007; ECAC, 2005).

Emission charges in France

France has imposed a charge on emissions of sulfur-containing compounds, nitrogen

oxide-containing compounds, non-methane hydrocarbons, solvents, and other volatile organic compounds. The fee of \$30 per metric ton has been imposed on combustion facilities with a maximum thermal power of at least 20 MW, waste incineration facilities with a capacity of three metric tons per hour, and facilities emitting more than 150 metric tons of these pollutants per year (NCEE, 2004).

Emission Taxes as a pollution damage levy in Japan

In Japan, emission tax in the form of pollution damage is levied on the polluting firms. The tax revenue is used to compensate the victims of designated diseases, upon certification by a council of medical, legal, and other experts (NCEE, 2004). Emission on SO₂ is charged at a rate, which is determined by the requirement of compensation in the fund needed. While the purpose of this emission tax is to raise the fund for compensation to the victims of pollution, the rate of tax has been increasing as the amount of emission has been decreasing. This results in high charge rates in order to have sufficient revenue generation.

SO₂ and NO_x charges in European countries

In Poland, Czech Republic, Estonia, Latvia, Lithuania, and Slovakia (SIEI, 2000), a base emission charge is applied to SO₂ and NO_x emission within the permitted level and a penalty charge is added for pollution above that level (called as non-compliance fee). Large point source polluters (combustion plants, heavy industry) are applicable for these instruments. The charges are intended to raise revenues and encourage cost-effective abatement below the permitted level. The fines or noncompliance fees are primarily intended to provide incentive to reduce pollution to permitted levels but these played an important role in making polluters comply with the system (SIEI, 2000). Norway also has adapted introduced tax on NO_x emission since January 2007.

Refund Based Tax System in Sweden for SO₂ and NO_x

An innovative approach has been in practice in Sweden which is called as Refund Based Tax System (SIEI, 2000; Roseveare D., 2001; NCEE, 2004). The approach is not intended to raise revenue but it provides incentive to the participants for emission reduction. The system imposes tax to the emitting sources as per the rate of their emission and then refunds the charges collected if the emission is reduced. Since 1991, Sweden has imposed the Sulfur tax of 30 SEK/kg S (\$ 3.3 /kg S) which is applicable to heavy fuel oils and coal. If sulfur is removed from the exhaust gases, the tax is refunded accordingly.

In the case of Nitrogen oxides, a charge of 40 SEK/kg NO_x (\$ 4.4/kg) has been imposed since 1992. The charge is applied to large heat and power plants, which produce more than 25 GWh/yr (Roseveare D., 2001). Before 1996/97 it was applied only to the large plants producing more than 50 GWh/yr (IISD, 1994). While the tax is collected on the basis of emissions, it is rebated (redistributed) to them in proportion of energy production. This means, the total tax thus collected is divided by total energy production (certain amount is deducted for administration charge) and redistributed in proportion to their rate of energy production. So, the redistributed amount among the participants based on their rate of energy production results that the plants which produce more energy with less emission will benefit more from this system. As a result, Swedish Environmental Protection Agency (SEPA) has mentioned that the target has been achieved with significantly reduced emission per unit of produced energy in Sweden (Roseveare D., 2001).

3.3.2.3 Fuel Taxes, Excise Duty/Tax

Historically, fuel taxes are the most used market mechanisms internationally. These taxes are applied as tax to the fuel or on polluting products and services so as to increase the price of these fuel, products or services. These affect environmental quality in two ways: first, they can affect polluting behavior and the choice of inputs by the firms. Second, they can influence the demand for polluting products (NCEE, 2004).

3.3.2.4 Fuel Taxes, Excise Duty/Tax in Practice

In countries like Finland, Mexico and Australia fuel taxes in the form of excise duty are levied. Similarly in Germany, the form of tax levied is Eco-tax along with Excise duties. The level of eco-tax varies as per their sulfur content (IEA, 2002). Differential fuel tax rates are applied according to the sulfur content of fuel in European countries like in Finland, Belgium, Denmark, France, Norway, Portugal, Sweden, Switzerland and in United Kingdom (SIEI, 2000) with higher tax applied for fuels having higher sulfur content. Finland has been levying excise tax, special tax (Environmental Damage Tax) system and Oil Pollution fee for the oil imports (IEA, 2007) (Table 3.1).

Table 3.1: Fuel Taxes in Finland

Fuel Type	Tax Type	Date	Tax Rate	Remark
Light Fuel Oil	Excise Tax	2003 onward	19.30 Euro/kl	
	Oil Pollution fee (imports)	1990 onward	032 Euro/kl	
Automotive Diesel Oil	Excise Tax	2003 onward	0.295 Euro/kl	(sulfur content > 0.005%)
	Excise Tax	2004 onward	0.295 Euro/kl	sulfur content 0.001 - 0.005%
	Excise Tax	2004 onward	0.268 Euro/kl	sulfur content 0.001 - 0.005%
	Oil pollution fee (imports)	1990 onward	0.00032 Euro/kl	
Gasoline	Excise Tax	2003 onward	0.618 Euro/kl	Premium leaded
			0.539 Euro/kl	Premium unleaded
	Oil Pollution Fee (imports)	1990 onward	0.00029 Euro/kl	

Source: [IEA, 2007](#)

3.3.2.5 Emission Reduction Credit and Emission Trading System

In Emission Reduction Credit (ERC) system, firms are issued a permit or allowance, which is based on the target set based either on ambient air standard in the region or on the necessity of the reduction from a reference emission level. These are also called ceiling. If a source reduces emission below the level required, the difference is a credit earned by the source. These credits can be used by the same or another firm to comply with the emission allowance. As the cost of pollutant abatement may be different for different firms, some firms may opt for buying the credits from other firms if the former's cost of abatement is higher than that of the latter. This mechanism is called as Emission Trading. It lowers the cost of abatement to the firms as compared to the measures under the Command and Control (CAC) approach.

3.3.2.6 Emission Reduction Credit and Emission Trading in Practice

SO₂ allowances trading in the United States

In the case of sulfur emission allowances trading mechanism practiced in the US under its Acid Rain Program, emission permits are issued to the polluting sources. The ceiling has

been based on the reduction requirement with reference to a baseline emission projection. In its sulfur emission allowance trading program, some proportion of the surplus allowances is also auctioned to the public ([USEPA Website](#)). Agencies lobbying for environment protection and other public ventures concerned on environmental conservation have been buying the credits (allowances) in the auction. These credits are retired physically⁷ so that the emission is permanently reduced on the following year. In this case, it is observed that the cost to the society of emission reduction has been lowered ([Tietenberg, T, 2003](#); [Stavins, R. N., 2003](#)).

SO₂ Emission Trading in Slovakia

In 2002, Slovakia started issuing the SO₂ emission permits (quotas) based on the combination of historical emissions, future plans and programs of power plants on annual basis ([EEA, 2005](#)). It is applied to power plants with capacity more than 50 MW, representing about 90% of emissions in 1998. Ministry of Environment of Slovakia decides an overall envelop of allowances on an annual basis. This overall allowance is then divided into districts allowances; the districts may transfer the unused quota to other districts under certain circumstances. However few such trades are noted ([EEA, 2005](#)).

NO_x Emission Trading in Netherlands

Some countries in Europe (Netherlands and Slovakia) have adopted emission trading. In Netherlands, emission trading is being used as a flexible policy tool with which the Dutch government is regulating the electricity generation sectors for NO_x emission as a part of national policy to comply with the EU directive on National Emission Ceilings (NEC Directive) ([VROM Website](#)). According to this directive, the Netherlands is obliged to reduce its overall NO_x emissions from 490 kilotons in 1995 to 260 kilotons in 2010. An annually decreasing cap with emission permits are issued as per the obligatory participant's commitment to monitor the emission adhering to the monitoring protocol⁸. The participant then needs to monitor, report and verify the emission every year, which is registered to compensate the allowance and credits are issued accordingly by the Dutch Emission Authority ([DEA Website](#)). The companies participating in NO_x trading are approximately the same as those that participate in CO₂ emissions trading. All participants are allocated

⁷ Buyer of the credit terminates the allowances so that that allowance is neither traded nor transferred in the following year.

⁸ Issued by Netherlands Emission Authority (NEa)

the uniform annually declining performance standard rate (which declines from 68 g/GJ in 2005 to 40 g/GJ in 2010) (IEA, 2004). The participants can borrow or bank a proportion of the credits (limited to 10% of the 2004 NO_x allocation of each source, 7% of the corresponding figure in 2005 and 5% of the corresponding annual allocation for subsequent years). As the emission is based on the energy input, the major disadvantage with this scheme is that it does not encourage firms to reduce their emissions by increasing their energy efficiency, as lowering their input would also lower their baseline emissions.

3.3.2.7 Innovative mechanisms in Emission Trading

There are four separate innovative mechanisms which are being practiced in emission trading (Stavins, R. N., 2003; Tietenberg, T, 2003):

a) Offset Mechanism

It was used as a mechanism where new or expanded sources can be installed in non-attainment areas provided they acquire sufficient emission reduction credits from either existing sources or new sources. Thus, the emission by new sources can be offset by using the emission reduction credits earned by the existing sources. It is in practice in Netherlands for ammonia (Roseveare D., 2001)

b) Bubble Mechanism

In this policy mechanism, the existing source in non-attainment areas can either adopt control technology or acquire the technology that emits at higher rates provided the sum of emission reduction credits plus actual reductions must equal the assigned reduction considering emission from the system as an emission from imaginary bubble. These are in practice in Netherlands and United Kingdom (Roseveare D., 2001)

c) Netting Mechanism

It is a policy that allows sources undergoing modification or expansion to escape the burden of new source review requirements so long as any net increase in plant wide emission is insignificant.

d) Banking Mechanism

It allows the firms to store emission reduction credits for use in the bubble, offset or

netting mechanism. In some countries (United States, Netherlands), certain proportion of total surplus allowances is allowed for banking (Tietenberg, T, 2003; Roseveare D., 2001).

3.3.3 Approach based on voluntary action

It is an approach in which individuals or individual firms engage in pollution-control activities in the absence of any formal, legal obligation to do so (Field et al, 2002). Generally two types of voluntary actions are in practice. One is moral suasion and other is informal community pressure. In addition to command and control approach, Poland practices publishing of the names of top 80 worst national polluters. This has informally influenced to comply with the standard in Poland (Peszko et al, 2001). Another example of voluntary action is the willingness on the part of some electricity users to buy green electricity (electricity from renewable energy technologies) at a premium price. This is also known as the concept of Green Pricing, which exists in Europe and the US.

3.3.4 Fuel Switching and cleaner fuel use

One of the most widely used practice for controlling air pollution is switching to the cleaner fuel. In the developed countries, cleaner fuels, like hydrogen fuel cell, biofuels etc. have been in use for improvement of air pollution. Use of low sulfur content fuel has been widely adapted in developed countries like USA and European countries. Switching to cleaner fuels like CNG and electric vehicles are some of the options in practice. These are discussed next.

3.3.4.1 Fuel Switching and cleaner fuel use in practice

Switching to Compressed Natural Gas Vehicles in Delhi

In developing countries like India and Pakistan, public passenger transport system is made to switch from diesel/petrol to compressed natural gas (CNG). Delhi, the capital city of India, has converted its fleet of public passenger vehicles to CNG with success following the intervention of the Supreme Court of India (DPCC, 2001).

Electric Vehicles in Nepal

In Nepal, electric vehicles (EVs) were introduced in 1975 with the support from Chinese government in the form of Electric Trolley Buses in Kathmandu. In early 1996, a group of

private investors started a company with 7 EVs. Currently, there are over 600 Safa Tempos (three wheelers) plying on the streets of the Kathmandu valley and five EV manufacturers in the country. Electric vehicles (EV) in Nepal virtually has no emission as electricity in Nepal is produced using hydro resources (CEI, 2007). However, if electricity is produced using fossil fuels, electric vehicles will not be a solution to reduce a transboundary air pollution.

3.3.5 Congestion Charge and Transport Management

It is a charge applied to the vehicles using a designated region based on the degree of congestion. While entering these designated zones, the vehicles have to pay taxes and the level of the taxes depends upon the time of day, vehicle type etc. It is practiced successfully in Singapore, Hongkong and London. Though the main purpose of these practices is to reduce traffic congestion in and around the charging zone rather than to obtain environmental benefit, it is widely believed that they have helped improve air quality in these cities. Similarly limiting the vehicles operation by issuing license permits and banning of vehicles from running in designated day of a week are some of the approach in practice. These are discussed next.

3.3.5.1 Congestion Charge and Transport Management in Practice

Congestion Charge in London

In London, congestion charge was introduced in 2003. It is applied to the vehicles using a designated region based on the degree of congestion. Though the major focus was not to obtain environmental benefit, rather it was to reduce traffic congestion in the charging zone. Vehicles entering, or parked on the streets, in central London on weekdays during the day (7.00 to 18.30 hrs) are subject to a daily charge of GBP 5, which can be paid electronically. The charging zone covers 22 km² in the heart of the capital. Certain passenger vehicles, for example taxis, buses and alternatively fuelled vehicles are exempted from the charge, while some users, for example, residents and the disabled, benefit from discounts.

Congestion Charge in Singapore

In Singapore, the government introduced differentiated congestion taxes to the vehicles. Initially it introduced Area Licensing Scheme (ALS) which was a road tax charged to users on pay-as-you-use principle and it required each vehicle to have a license to enter certain

restricted zones (RZ) during peak hours in the morning (7:30 AM – 9:30 AM). The system was later replaced by electronic road pricing (ERP), later converted into Area Road Electronic road pricing (ERP). The ERP charges vary each half-hour of a day and vary from S\$ 0.5 to S\$ 9 depending upon the time of the day (e.g. peak vs non-peak hours) and the type of vehicles.

License Permits in Singapore

The License Permit policy is aimed at reducing the congestion related pollution from vehicles in designated time. These permits are used by Regulatory body in countries like Singapore, Mexico and Chile for regulating the vehicular operation. A user requires acquiring these permits in order to run his/her vehicle.

In Singapore, popularly known as Vehicle quota scheme (VQS) was introduced in 1990. The government issues certain number of quota for new users as well as quota for renewing for the existing users limiting the vehicles on road. The quota was called as Certificate of Entitlement (COE) which was required to operate the vehicles on road. However, the government issues the quota on bidding process. All COEs were offered at the lowest offered price subject to it would exhaust the total available quota of COEs when arranged from highest to lowest priced bidders. The bidding process was conducted twice a month ([LTA, 2007](#)).

License Permits in Chile

In Santiago of Chile, the government imposed an auctioning system for access right licenses for buses and taxis to enter certain congested areas. While in this system, in order to participate in auction, the vehicles need to comply to uniform emissions standard. The system is claimed to have significant improvement in vehicular emissions due to traffic congestion ([Stavins, R. N., 2003](#)).

Banning of vehicles from running in designated days in Mexico

In Mexico, the city administration imposed a regulation that banned car running on specific day which was determined by the last digit of the license plate. However, this approach reported to be counter productive in long run as the large number of users started buying an additional car having a different banned day. This policy is taken as a failed attempt to anticipate behavior reactions in longer run ([Tietenberg T, 2003](#)).

Banning of vehicles from running in designated days in China

Mexican practice has been followed up in China recently (Philly, 2007). Cars with even-numbered license plates are ordered off roads on Fridays and Sundays, and vehicles with odd-numbered plates are banned Saturdays and Mondays. Emergency vehicles, taxis, buses and other public-service vehicles are exempted from this requirement. The government officials claim that air quality after imposing this requirement is in good condition (air index below 100 according to State Environmental Protection Agency of China). But other additional measures to supplement the program may be required as a lesson learnt from the bad experience from Mexico City. In Mexico City during the initial phase of such program, it was a success but after few years, it proved to be a mistake in that it led to over investment in vehicles (Tietenberg T, 2003).

3.3.6 Co-benefits of GHG emission reduction policies and technologies

Several measures to abate GHG emissions could reduce air pollutants and vice versa. Many of the driving forces underlying air pollution and climate change are identical: economic growth, consumption and production processes, and demography. Air pollutants and greenhouse gases are simultaneously emitted from the same sources. Any measure that modifies the activity level of a source also influences emissions of air pollutants and greenhouse gases simultaneously. And these benefits are attributed as co-benefit of the GHG emission reduction measures. Promotion of renewable energy by using Renewable Portfolio Standard (RPS) policy and implementing GHG reduction technologies are some of the practices which are discussed next.

3.3.6.1 Renewable Portfolio Standard Policy

Electricity from Renewable Energy Sources (RES-E) is being currently promoted in the European countries through a wide array of different instruments (feed-in tariffs, tradable green certificates (TGCs), bidding/tendering schemes, investment subsidies, fiscal/financial and green pricing schemes) (Rio, P., 2004). Similarly, in many countries, firms are required to have certain proportion of electricity generation mix from renewable energy resources popularly known as maintaining Renewable Portfolio Standard (RPS). Electricity generation from wind resources has been increasing. While the policy is aimed at reducing CO₂ emission from electricity generation from fuels like coal, it has co-benefit as the reduced coal consumption will also reduce the sulfur emission.

3.3.6.2 GHG Emission Reduction Technologies

GHG emissions reduction technologies could reduce air pollutants in addition to emission reduction of GHG pollutants. Energy conservation, fuel substitution, change in production level etc. with the implementation of technical emission control measures have effects on more than one pollutant. Thus, measures aimed at the reduction of one pollutant may lead to reductions of other pollutants, e.g. efficiency improvement measures not only reduce coal use but they also simultaneously reduce sulfur emissions too. But the increase of pollutants with the implementation of controlling measures also could be possible, e.g. implementation of SO₂ and NO_x scrubber mechanism may increase the fuel consumption and this may increase GHG emission.

There are a number of emission control technologies that reduce both air pollutants and greenhouse gases. For instance, some of the measures in the agricultural sector that reduce NH₃ emissions (e.g. dietary changes, improved storage of manure) also lead to lower Nitrogen Oxides emissions. Under certain conditions, new engine technologies that improve fuel efficiency and reduce CO₂ emissions also, at the same time, reduce NO_x emissions. Selective catalytic reduction (SCR) on gas boilers reduces not only NO_x, but also N₂O, CO and CH₄. The three-way catalysts on cars reduce NO_x, CO and CH₄. Regular inspection and maintenance programs on oil and gas production and distribution facilities will reduce losses of CH₄, but also of other VOCs (EEA, 2004).

Some technologies in controlling air pollutants might increase the emission of other pollutants. Desulfurization techniques involving CaCO₃ increase CO₂ emissions, and catalysts that are used to reduce NO_x, VOC and CO emissions from vehicles tend to cause higher N₂O and NH₃ emissions. In general all emission control measures which increase energy consumption (e.g. scrubber mechanism reducing SO₂ or NO_x from flue gases) will ultimately increase related emissions of greenhouse gases.

Chapter IV

Best practice cases on controlling and preventing air pollution

4.1 Introduction

The United Nations Development Programme (UNDP) defines the best practices as “Planning and/or operational practices that have proven successful in particular circumstances. These are used to demonstrate what works and what does not and to accumulate and apply knowledge about how and why they work in different situations and contexts” (ADB, 2006b). Thus the best practices are those practices that have succeeded in achieving the target and are replicable to other regions/countries (ADB, 2006b and ADB, 2006c). However, all best practices may not be transferable to other countries/regions as the success of a particular practice depends upon the country specific factors and conditions. Some best practices may not be transferable at all and often it is difficult to know impacts of some best practices over time (ADB, 2006c). However, important lessons can be learnt from the study of the best practices as to their applicability and potential for their up-scaling in a different country/regional context.

In Chapter III, several approaches for preventing and controlling transboundary air pollution have been discussed with giving brief references to practical examples of their applications. In this chapter, more detailed descriptions of the successful practices under different approaches are presented. The best practices presented in this chapter are: the NO_x charge applied in Sweden, the Two Control Zone plan and program implemented in China, the Acid Rain Program in the US, Road transportation and travel demand management in Singapore, the switch of public passenger transport system to compressed natural gas in New Delhi and environmental measures and NO_x tax system in Norway.

4.2 NOx charges as feebate in Sweden

Country/Region	:	Sweden/Europe
Area coverage	:	Sweden
Sectoral Category	:	Energy
Type of approach	:	Policy/Economic Instrument
Pollutant Type	:	NO _x
Year of Introduction	:	Since 1990
Participants	:	Electricity generation utilities
Implemented by	:	Swedish Environmental Protection Agency (SEPA)

Description

In 1990, Swedish parliament endorsed NO_x emission charge applicable to large combustion plants. It was implemented since 1992. The NO_x charge is a feebate economic instrument that applies to every real emission of NO_x from these plants as per the measurement. However, the charge is redistributed among the plants as per the proportion of energy production from these plants. So, the NO_x charge is not taken as tax (IISD, 1994). In this system, the plant that produces more energy in compare to per unit emission gets the benefit. The Swedish NO_x charge is an example of how an economic instrument can be used to reduce pollution without distorting an industry's competitiveness while meeting the objective of reducing the emission at the least cost.

The charge is SEK 40 (US \$4.80 at the August 1993 exchange rate) per kilogram of NO_x emitted, and the revenue from the charges paid by liable operations is redistributed among the plants in proportion to their energy production. While the tax is collected on the basis of emissions, it is rebated (redistributed) to them again on the proportion of energy production. This means that the total tax thus collected is divided by total energy production and redistributed in proportion to their energy production. So, the redistributed amount among the participants based on their rate of energy production results that the plants which produce more energy with less emission will benefit the incentive from this system. Since 1992, Large combustion plants were subjected to the charge scheme. 'Large' plants are defined as the installations having a capacity of 10 MW or more and an annual energy production exceeding 50 GWh. In 1996 and 1997, the coverage was expanded to include all installations producing more than 25 GWh of useful energy per year (Roseveare D., 2001). Currently some 400 units are covered by the charge. It is administered by the Swedish Environmental Protection Agency (SEPA). The administration cost of the system

(not more than 0.5% of the revenue generated from the tax) is deducted from the pay-out (IISD, 1994).

Smaller combustion plants were not liable because of the higher relative cost of continuously measuring the emissions (IISD, 1994). Most of the liable combustion plants are found in energy production, that is, heating and power plants. The pulp and paper industry, the chemical industry and the metal industry also have combustion plants for energy production. Waste incineration plants producing energy are similarly liable for the charge.

The unique feature of the system was the refund system which was necessary in order to achieve a fair system. The competition between small (non-labile) and large (liable) combustion plants would have been distorted if the charge was not refunded to the liable plants (IISD, 1994). The fact that the charge is refunded and thereby only has an environmental purpose has facilitated acceptance of the charge. A positive side effect is that less polluting plants are favoured economically and thus given a competitive advantage. The refund system has contributed to a considerable success of the charge scheme. Though the combustion plants are given an economic incentive to reduce their emissions, they are not forced to do so by regulation. It is up to the individual plants to decide ways to reduce the NO_x emission. Companies can choose whether to reduce their NO_x emissions or pay the charge. With this flexibility on choosing the technology type, it is noted that the number of NO_x emission reduction technologies after implementation of such system is significantly increased.

Major Activities

The utilities are not forced for any specific technology for the NO_x reduction. The liable companies are left on their own to choose the most cost effective NO_x reduction technology.

Impact on Air Pollution Scene

Significant improvement in the reduction NO_x emission was noted after implementation of NO_x charge scheme (IISD, 1994):

- Total NO_x emission was 35% lower in 1992 than in 1990. By 1993, NO_x emission was 44% below the 1990 level.

- The number of combustion plants with NO_x-reducing technologies increased by a factor of about 16 between 1982 and 1994. Sharp increase is noted post implementation of the charge scheme, and further installations are planned (IISD, 1994).
- SEPA noted that NO_x emissions have decreased much more rapidly than expected. The target for 1995 of a 35% reduction from 1990 levels was already achieved in 1993.
- The average cost to reduce NO_x is SEK 10/kg (\$1.2/kg). The charge of SEK/kg-NO_x has provided a substantial economic inducement to reduce emissions.

4.3 Two Control Zone (TCZ) Plan and Program to control Sulfur pollution

Country/Region	: China/South East Asia
Area coverage	: 64 major cities and 12 provinces
Sectoral Category	: Energy
Type of approach	: Policy/Planning/Technology/Fuel Substitution
Pollutant Type	: SO _x and PM _{2.5} (Sulfate) (Acid rain)
Year of Introduction	: 2000-2005
Participants	: SEPA-China, CRAES, EPB (Hebei and Hunan Province and Shijiazhuang and Greater Changsa region), CGRER, University of Iowa, boiler manufacturing industries.
Implemented by	: State Environmental Protection Agency - China

Description

In 1998 China adopted a national legislation “Tenth Five-Year Plan for Prevention and Control of Acid Rain and Sulfur Dioxide Pollution in the Two Control Zones” to limit ambient sulfur dioxide (SO₂) concentration and to curtail the increasing occurrences of acid rain in the country. The major backbone of this policy and plan was to reduce the sulfur concentration in the country by understanding its local as well as transboundary effect ([ESMAP, 2003](#)).

China is the world’s the largest coal producer (43%) and nearly half (45 %) of China’s coal in 2004 was used in the industrial sector ([IEA, 2007a](#)). The use of coal has been the major source of air pollution in the country and is the major cause of acidic precipitation as well as Particulate Matters (PM) ([ESMAP, 2003](#)). Though several cities have seen declined in air pollution, the major cities in China are heavily polluted by SO₂ and PM emissions ([Yi et al., 2007](#)). Acid rain affects about 30 percent of the land area in China ([SEPA 2004](#),

[SEPA, 2005](#)). The combustion sources include small domestic stoves as well as large industrial plants and power plants. The major sources of SO₂ emissions are fossil fuel, including coal-fired power plants and boilers, ore smelters, and oil refineries. Smaller stationary combustion sources, such as space heating, also contribute to the problem, especially in urban areas during the winter.

The “Two Control Zone (TCZ)” Plan, as the name suggests classified two control zones, of which Sulfur Pollution Control Zone (SPCZ) covered 64 major cities, where the ambient sulfur concentration was high and the other was Acid Rain Control Zone (ARCZ), which encompassed 12 provinces of southern and eastern China, which were affected by acid rain. These two zones covered 1.09 million km² and these were responsible for 2/3rd sulfur emission of the country ([ESMAP, 2003](#)). Closing of mines producing high-sulfur coal, limiting the sulfur content of coal and emission controls in power plants and large industries were the measures taken to control the sulfur pollution. Most of the major cities in China were required to comply with the SO₂ pollution requirement and SO₂ emission charges were applied. Sulfur emissions and acid rain reduction plans for large areas of the south and the east area of the country were the major thrust areas of the TCZ plan. The legislation covers wide-ranging sulfur control measures usually observed in Europe and North America. Probably such policy has been placed for the first time in developing countries ([ESMAP, 2003](#)).

Major Activities

- Gradual phasing out of mining of coal containing 3% or more sulfur
- Prohibition of Coal fired power stations (except heat producing for household use) inside large and medium-sized cities and surrounding suburbs.
- Mandatory use of 1% sulfur or less in coal to be used in new and in renovation of old power stations
- Flue gas desulfurization
- Implementation of Sulfur emission charges

Impact on Air Pollution Scene

The State of Environment in China Reports ([SEPA, 2002](#); [SEPA, 2004](#) and [SEPA, 2005](#)) showed significant reduction in SO₂ emission. The emission reduction is observed during 1998 to 2005.

In the Sulfur Dioxide Pollution Control Zone, the major achievement was 12.7% point increase in cities meeting Grade II and 16.5 % point decrease in the cities not meeting Grade III standard in terms of SO₂ annual average concentration. The cities meeting Grade III was increased by 4.2 % point (Table 4.1).

In the Acid Rain Control Zone, the major achievement was the 11.2% point decrease in the cities not meeting Grade III in terms of SO₂ annual average concentration and 3.3% point increase in the cities witnessing annual SO₂ average concentration meeting Grade II quality standard. The cities reaching Grade III was increased by 7.9 % point.

Table 4.1: Percentage of cities in Two Control Zones meeting SO₂ Grades

SO ₂ Grading	SO ₂ Control Zones (64 major cities)					Acid Rain Control Zones (12 provinces)				
	1998	2000	2002	2004	2005	1998	2000	2002	2004	2005
Cities reaching Grade II, % (SO ₂ ≤ 0.06 mg/m ³)	32.8	47.7	40.6	40.6	45.1	70.6	81.2	79.5	73	73.9
Cities reaching Grade III, % (0.06 mg/m ³ ≤ SO ₂ < 0.1 mg/m ³)	29.7	24.6	31.3	29.7	33.9	13.7	6.3	13.7	20	21.6
Cities worse than Grade III, % (SO ₂ > 0.1 mg/m ³)	37.5	27.7	28.1	29.7	21	15.7	12.5	6.8	7	4.5

Source: [SEPA, 2002](#); [SEPA, 2004](#) and [SEPA, 2005](#)

4.4 The Acid Rain Program in US

Country/Region	:	United States of America/North America
Area of coverage	:	United States of America
Sectoral Category	:	Energy
Type of Approach	:	Policy
Pollutant Type	:	SO _x and NO _x
Year of Introduction	:	Since 1995
Participants	:	Utilities, coal and gas companies, emissions control equipment vendors, labor, academia, public utility commissions, state pollution control agencies, and environmental groups.
Implemented by	:	United States Environmental Protection Agency (USEPA)

Description

Acid Rain Program is a market based approach to control SO₂ and NO_x emission created for the first time by the US Government in 1990 by Title IV of Clean Air Act Amendment.

The main purpose of the program was to reduce the adverse effects of acid deposition by reducing its key precursor pollutants SO₂ and NO_x.

SO₂ Reduction

The Title IV of the Clean Air Act set a goal of reducing annual SO₂ emissions by 10 million tons below 1980 levels by 2010. To achieve these reductions, the law required a two-phase tightening of the restrictions placed on fossil fuel-fired power plants.

Phase I began in 1995 and affected 263 units at 110 mostly coal-burning electric utility plants. An additional 182 units joined Phase I of the program as substitution or compensating units, bringing the total of Phase I affected units to 445. Phase II, which began in the year 2000, tightened the annual emissions limits imposed on these large, higher emitting plants and also set restrictions on smaller, cleaner plants fired by coal, oil, and gas, encompassing over 2,000 units in all. The program affects existing utility units serving generators with an output capacity of greater than 25 megawatts and all new utility units.

The program is an innovative cap and trade approach in which a permanent cap is allocated on the total amount of SO₂ emission that may be generated by a utility, based on its historic fuel consumption and its specific emission rates, prior to the start of the program ([USEPA Website](#)). Currently, one allowance provides a regulated unit limited authorization to emit one ton of SO₂. The total allowances allocated for each year equal the SO₂ emission cap.

SO₂ Allowance Trading Mechanism

Reductions in SO₂ emissions are facilitated through a market-based system for capping and trading—the centerpiece of EPA’s Acid Rain Program ([USEPA Website](#)). Through the market-based allowance trading system, utilities regulated under the Acid Rain Program decide the most cost-effective way to use available resources to comply with the requirements of the Clean Air Act. Utilities can reduce emissions by employing energy conservation measures, increasing reliance on renewable energy, reducing usage, employing pollution control technologies, switching to lower sulfur fuel, or developing other alternate strategies.

Units that reduce their emissions below the number of allowances they hold may trade allowances with other units in their system, sell them to other utilities on the open market

or through EPA auctions, or bank them to cover emissions in future years ([USEPA Website](#)).

The USEPA holds an annual auction of SO₂ allowances (Chicago Board of Trade used to administer it till 2005) in which anyone including the utilities can participate. The USEPA set aside 2.8% of annual sulfur emission from each utility for Auction Allowance Reserve ([USEPA, 2007a](#)). The allowances are awarded to the highest bidder. Typically environmental groups⁹ bids acquire the allowances for different purpose including ‘retiring’ them so that they cannot be used to legitimize emissions, thus lowering the emission limit permanently ([Tietenberg, 2003](#)).

Conservation and Renewable Energy Incentives

The Acid Rain Program has a provision to promote renewable energy and energy conservation initiatives. A reserve of 300,000 SO₂ allowances is provided as the Conservation and Renewable Energy Reserve (CRER). Utilities could apply for these allowances if they employed efficiency or renewable energy measures to produce early emissions reductions before their generating became subject to the Acid Rain Program ([USEPA Website](#)).

NO_x Reduction

The Clean Air Act Amendment 1990 had also set a target to reduce 2 million tons of NO_x emission below 1980 level by year 2000. The program focuses on one set of sources that emit NO_x, coal-fired electric utility boilers. As with the SO₂ emission reduction requirements, the NO_x program was implemented in two phases, beginning in 1996 and 2000. The NO_x program is similar in principle to SO₂ emission reduction program but it does not "cap" NO_x emissions as the SO₂ program does, nor does it utilize an allowance trading system.

Emission limitations for the NO_x boilers provide flexibility for utilities by focusing on the emission rate to be achieved (expressed in pounds of NO_x per million Btu of heat input, See [Table 3.5](#)). In general, two options for compliance with the emission limitations are provided:

⁹ In a bid in 2007, Washington College Student Environmental Alliance bid 1 allowance at \$1,120, AEM 250 Cornell University bid 1 allowance at \$490, and similarly Clean Air Conservancy Charitable Trust bid 3 allowances for \$1,800. (<http://www.epa.gov/airmarkets/trading/2007/07summary.html> downloaded on 5 July 2007)

- Compliance with an individual emission rate for a boiler.
- Averaging of emission rates over two or more units to meet an overall emission rate limitation.

If a utility properly installs and maintains the appropriate control equipment designed to meet the emission limitation established in the regulations, but is still unable to meet the limitation, the NO_x program allows the utility to apply for an alternative emission limitation (AEL) that corresponds to the level that the utility demonstrates is achievable.

Phase I of the NO_x program began on January 1, 1996 and applied to two types of boilers (which were already targeted for Phase I SO₂ reductions): a) dry-bottom wall-fired boilers and b) tangentially fired boilers (Table 4.2). Dry-bottom wall-fired boilers had to meet a limitation of 0.50 pounds of NO_x per million Btu averaged over the year, and tangentially fired boilers had to achieve a limitation of 0.45 pounds of NO_x per million Btu, again, averaged over the year. Approximately 170 boilers needed to comply with these NO_x performance standards during Phase I.

Phase II of the NO_x program began in 2000. These regulations:

- Set lower emission limits for Group 1 boilers first subject to an acid rain emissions limitation in Phase II, and
- Established initial NO_x emission limitations for Group 2 boilers, which include boilers applying cell-burner technology, cyclone boilers, wet bottom boilers, and other types of coal-fired boilers (Table 4.2).

The Acid Rain Program is flexible in allowing a utility to select its own methods of emission control for SO₂ and NO_x emission reduction compliance. The program encourages early reductions of the emissions so that the utilities can bank unused allowances in one year and can carry them forward to the next year. These allowances are transferable among the affected utilities such that utilities can trade the surplus allowances to other utilities. This is a *Win Win* situation as it not only reduces the cost to utilities but also reduces the cost of reducing pollution to the society ([Tietenberg, 2003](#)).

Table 4.2: NO_x Emission Limit by Boiler Type

Coal-Fired Boiler Type	Title IV Standard Emission Limits (lb/mmBtu)	Number of Units
Phase I Group 1 Tangentially Fired	0.45	132
Phase I Group 1 Dry Bottom, Wall-fired	0.50	113
Phase II Group 1 Tangentially Fired	0.40	301
Phase II Group 1 Dry Bottom, Wall-fired	0.46	295
Cell Burners	0.68	37
Cyclones >155 MW	0.86	54
Wet Bottom >65 MW	0.84	24
Vertically Fired	0.80	26
Total	n/a	982

Source: EPA, 2006, Acid Rain Program Progress Report, 2004 and 2005

Special features of this program are:

- a) It has a fixed upper limit on total annual sulfur emissions from the utilities;
- b) It allows anyone to lower the limit by acquiring the allowances; and
- c) It facilitates real time emission monitoring and real time online allowance trading mechanism.
- d) It has a mechanism of penalty for non-compliance and it is adjusted with inflation rate.

The program has an online real time emission monitoring mechanism, in which each utility must continuously measure and record its emissions of SO₂, NO_x, and CO₂, as well as volumetric flow and opacity. A continuous emission monitoring (CEM) system is used for this (USEPA, 2007b). This has been taken as an important feedback to boost the confidence among the stakeholders by the realization of emission reductions in real time.

The program has a real time online allowances trading mechanism which facilitates utilities to trade the sulfur allowances in real time so that the utilities' sulfur emission do

not exceed their allowances at the end of the year and the allowance transfer can be recorded to meet the compliance.

The program has set a penalty of \$2,000/ton sulfur in 1990, which is adjusted annually as per the inflation rate. The 2005 penalty level was set at \$3,042 per excess ton of SO₂.

Major Activities

With the implementation of the Acid Rain Program, the utilities have adapted one or more options that include blending low-sulfur coal, installing SO₂ and NO_x controls such as scrubbers and low-NO_x burners, or purchasing allowances from the market or using banked allowances in order to meet the emission reduction requirements.

Furthermore, there were also increased use of efficient advanced combined gas cycle units using natural gas as fuel source.

Impact on Air Pollution Scene

The program achieved the following progress by the end of Year 2005 ([USEPA Website](#)):

SO₂ emission has been reduced by more than 5.5 million tons from the 1990 levels, which is about 35% of total power sector emissions. When it is compared to 1980 levels, SO₂ emissions from power plants have reduced by more than 7 million tons (41%).

Similarly, the program was able to reduce NO_x emissions by 3 million tons from the 1990 levels, so that emissions in 2005 were less than half the level anticipated if such program was not in place.

The program was able to originate the following other emission reduction policy programs in 2005, which also contributed to the reduction:

- Clean Air Interstate Rule (CAIR),
- the Clean Air Visibility Rule (CAVR), and
- the Clean Air Mercury Rule (CAMR).

Similarly,

- NO_x Budget Program,
- NO_x State Implementation Plan (SIP) Call, and

- Regional NO_x emission control programs

4.5 Road Transportation Travel Demand Management in Singapore

Country/Region	: Singapore/South East Asia
Area of coverage	: Singapore City
Sectoral category	: Energy/Transportation
Type of approach	: Policy
Pollutant Type	: SO _x , NO _x and particulate matter
Year of introduction	: Since 1960s
Participants	: Government Agencies, vehicle operators and public
Implemented by	: Government of Singapore, Land Transport Authority

Description

The major source of air pollution in most of the countries is the vehicular emission and the reduction of vehicular emission has been a major issue. Control of exhaust emission from vehicles utilizing technological options has been exercised in many of the countries. But the control of air pollution using policy measures based on traditional command and control approach to curtail travel demand has been a difficult task, though it has been tried in several countries ([Dhakal, S., 2003](#)). However, the transport policies of Singapore are good examples of the government authority being able to limit the air pollution by limiting private vehicle growth with series of demand management measures ([Chin, A. T.H., 1996](#)) while sustaining rapid economic growth for last 40 years ([Willoughby C., 2001](#)). Though the initial purpose of the government policies was the reduction of the growing traffic congestion thereby reducing the travel time and not reduction of environmental pollution but their secondary effect has been higher vehicular average speed, controlled private vehicular ownership, promotion of public passenger vehicles resulting ultimately in reduced fuel consumption and lower vehicular emissions. Currently 24-hr average air quality of Singapore so far is found to be within the acceptable limit within of the USEPA Annual Mean Ambient Air Quality Standard for the pollutants SO₂, NO_x, Carbon Monoxide, Ozone and PM₁₀ measured ([NEA, 2007a](#)).

Since its independence in 1967, the approaches taken by Singapore for transportation management were a mix of command-and-control in earlier period and later market-based-instruments which were able to manage traffic demand and related environmental problems too. However, the command and control, and market based policies exercised by the government in Singapore ([See Annex 1](#)) is found being analyzed and evaluated in

several studies (Phang, et al., 1997). A series of the policies were exercised in order to curb the travel demand in the past. Also quick enforcement of the revised policies was exercised after sensing the undesired impact of policy, which has resulted better later. The Area Licensing System enforced in the beginning for peak hours was revised as it increased traffic volume before and after the peak hours. Then the policy was enforced for the whole day instead. Initially the demand for growth of vehicles in the country was found more elastic with respect to income than with respect to the vehicle price, which has led the government to the policy of allocation of vehicle quota system in 1990. Studies have argued that the policy was largely focused on limiting of vehicle ownership rather than maximum utilization of the transport infrastructure and pointed out disadvantages of the policy instrument making under utilization of the road infrastructure because of the high tax rate. However in 1998 and in subsequent years, the reform of the tax structure along with introduction of more flexible schemes (like off peak car scheme, park and ride schemes, increasing the number of bidding process to twice a month and short duration of bidding process) marked the shift from its vehicle ownership limiting policy to the increasing use of road usage policy.

Major Activities

The evolution of road transport management policy instruments and activities implemented in Singapore since its independence is shown in [Annex 1](#).

Major policies for road transport management implemented in Singapore are:

- a) Additional registration fee (ARF)
- b) Area license scheme (ALS)
- c) Vehicle quota scheme (VQS)
- d) Electronic road pricing (ERP)
- e) Flexible schemes (Off-Peak Car Scheme)

a) Additional registration fee (ARF)

ARF is a tax on new vehicle registrations charged in addition to Registration fees. This was originally introduced by the colonial government in the late 1950s as a revenue-raising measure. In 1975, its value was increased to 100% of the Open Market Value of a vehicle (OMV). With the fear that higher ARF might discourage the renewal of the existing

vehicles, a preferential additional registration fee (PARF) was introduced as an alternative, to counter the effect. It offered reduced rates when an old vehicle of the same size-class was taken off the road at the same time as the new vehicle was acquired. In 1990 the standard ARF rate reached up to 175% of OMV (Koh, W. T.H., 2003). ARF/PARF proceeds were the largest single source of government revenue from the road transport sector in the 1980s. Currently in addition to Registration fee of S\$ 140, two tier system ARF is in place:

- a) Vehicles registered before 2004 March has 130% of OMV
- b) Vehicles registered after 2004 March has 110% of OMV

Currently PARF has following structure:

Table 4.3: Preferential Additional Registration Fee (PARF) Structure

Age of Vehicle at De-registration	Graduated PARF Rebate (For cars registered with COEs ¹⁰ obtained before May 2002 tender exercise)	PARF Rebate (For cars registered with COE obtained from May 2002 tender exercise and onwards)
Not exceeding 5 years	130% of OMV	75% of ARF paid
Above 5 years but not exceeding 6 years	120% of OMV	70% of ARF paid
Above 6 years but not exceeding 7 years	110% of OMV	65% of ARF paid
Above 7 years but not exceeding 8 years	100% of OMV	60% of ARF paid
Above 8 years but not exceeding 9 years	90% of OMV	55% of ARF paid
Above 9 years but not exceeding 10 years	80% of OMV	50% of ARF paid

Source: [LTA, 2007](#)

b) Area license scheme (ALS)

It is a license required by a vehicle to enter a designated area. In 1975 ALS was introduced for the first time. It was a road tax charged to user on pay-as-you-use principle and it required a license by each vehicle to enter certain restricted zones (RZ) of the city during peak hours in the morning (7:30 AM – 9:30 AM). The license was mandatory to be displayed and polices in the entry posts (22 entry posts) were used to observe the license and record the vehicle number of the defaulters. As a result of the combined effect of ALS and simultaneous sharp increases in downtown parking charges which was around

¹⁰ Certificate of Entitlements

approximately double the cost of commuting to work by car (Willoughby C., 2001), the car traffic in the peak morning hours sharply fell and it was more than expected. Further, traffic volume was found increased during the period before and after the restricted hours. In 1989, the requirement for area licenses was extended to vehicles entering the RZ during afternoon peak hours. The exemptions for car pools and goods vehicles were also eliminated. In 1994, ALS was extended to vehicles entering the RZ any time from 7.30 am to 7.00 pm on all working week-days. Later in 1998, to overcome the difficulty in observing and recognizing the different license types issued according to vehicle type, and in order to make the system efficient, the system was later replaced by electronic road pricing (ERP).

c) Vehicle quota scheme (VQS)

Under the Vehicle quota scheme a quota is issued by the government which all prospective purchasers of new vehicles are required to own a Certificate of Entitlement (COE) to operate the vehicles on road. The VQS was implemented in 1 May 1990. The COEs are issued by the government equivalent to the vehicle quota issued quarterly. The COE was valid for 10 years and need to buy in closed bidding in an auction conducted quarterly (later twice a month). All COEs are offered at the lowest offered price subject to it would exhaust the total available quota of COEs when arranged from highest to lowest priced bidders (LTA, 2007). This price is called as the Quota Premium (QP) (Table 3.7). In early auction, the price of Quota Premium was modest but later in 1994 its price increased quite steadily and reached above S\$ 27,000 for medium sized cars and above US\$45,000 for larger cars. Prevailing quota premium (PQP) was also introduced so that vehicle owners could renew the COE for the next period. The price of PQP was based on the monthly average of the price of QP for 3-months. Later, bidding process was conducted twice a month. In 2002, open bidding process replaced the closed bidding process (LTA, 2007a).

Table 4.4: Result of 2nd Bidding Process conducted on 18 July 2007

	Category	Quota Issued	Quota Premium (S\$)	Prevailing Quota Premium (S\$)
A	Car (1600cc & below) & Taxi	2,208	16,000	15,957
B	Car (Above 1600 cc)	1,133	17,602	18,413
C	Goods Vehicle & Bus	492	3,889	6,582

D	Motorcycle	480	1,052	1,190
E	Open	1,105	17,410	

d) Electronic road pricing (ERP)

ERP is an electronic tax system which has replaced ALS in 1998. It was applied (from 7.30 am to 7.00 pm) to all areas which had been covered by ALS and also extended to few other expressways. ERP scheme is similar to ALS but its enforcement is automatic and electronic equipment like sensors, cameras with short-range radio communication system are utilized to sense the vehicle entry. Vehicles are equipped with an electronic In-vehicle Unit (IU), in which a general-purpose smartcard (cash card) with positive cash balance has been inserted before the vehicle entry; the toll applying at the particular time when the vehicle passes under a gantry is automatically deducted without the driver having to slow down. Also the system is well setup to recognize vehicle category. Charges are different for motorcycles, cars, good vehicles, taxis and buses; different IU units are installed in each category of vehicles. Half of the approximately US\$125 million total cost of the ERP scheme was for the fitting of IUs, provided free to the vehicles on first come first basis at the time requested, and carried out in less than one year. Total cost per vehicle for the scheme was less than US\$190 in the then existing fleet ([Willoughby C., 2001](#)). Prices presently applied under ERP do not fluctuate directly with actual traffic volumes, but they are subject to quarterly (and in June and December during School holidays) adjustment in light of evolving traffic conditions ([LTA, 2007](#)). Since February 2003, graduated ERP was implemented in order to avoid vehicles speeding or slowing down to avoid paying higher ERP charges during few minutes before and after the restricted hours. At the ERP charge vary every half-hour of a day and varies by type of vehicle and by time of day (e.g. peak and off-peak).

e) Flexible Schemes (Off-Peak Car Scheme)

The Off-Peak Car (OPC) Scheme was introduced (replaced Weekend Car Scheme) on 1 October 1994. Under Weekend Car Scheme, special permits were issued to cars allowing them to run during weekends only. While under OPC, permits are issued to cars allowing them to run during off peak hours only. The scheme is intended to increase off-peak car usage. OPC offers the new and existing car owners an option to save on car registration and road taxes so that car usage can be reduced. Currently an upfront rebate of S\$17,000 is

provided to be offset against COE Quota Premium and Additional Registration Fee (ARF). Whereas, the rebate is first offset against the COE premium payable and if there is any excess, then it is offset against the ARF payable. Also a flat discount of S\$ 800 on annual road tax is provided, subject to a minimum road tax payment of \$50 per year. Normal car is also allowed to be converted to Off-Peak Car after paying additional fees of S\$ 100 (LTA, 2007b).

In addition to above policy instruments for demand management, the following were other coordinated and integrated approach taken that focused on (Chin, A. T.H., 1996):

- i. construction and improvement in land communications;
- ii. reorganization, investments and improvements to public transport;
- iii. traffic management schemes;
- iv. integrated transport and landuse planning.

Impact on Air Pollution Scene

The average speed of the vehicles was found maintained at about 62-65 km/hour in expressways and about 24 – 27km/hour in Arterial roads (Table 4.5).

Table 4.5: Average Speed During Peak hours* (km/hour)¹¹

	Expressways	Arterial Roads
2002/03	65.2	25.1
2003/04	64.2	24.4
2004/05	62.7	26.1
2005/06	63.0	27.2

Source: LTA, 2007

Note: * Average of AM Peak (8am - 9am) and PM Peak (6pm - 7pm)

The air quality of Singapore has been meeting USEPA standards except for the levels of PM₁₀ in 1994 and 1997 (Fig 4.1 and Fig 4.2) when Singapore was affected by transboundary smoke haze, the rest of the air pollutants (sulfur dioxide, carbon monoxide, ozone and nitrogen oxides) are well within the standards prescribed by WHO and USEPA.

¹¹ Downloaded on 26 July 2007

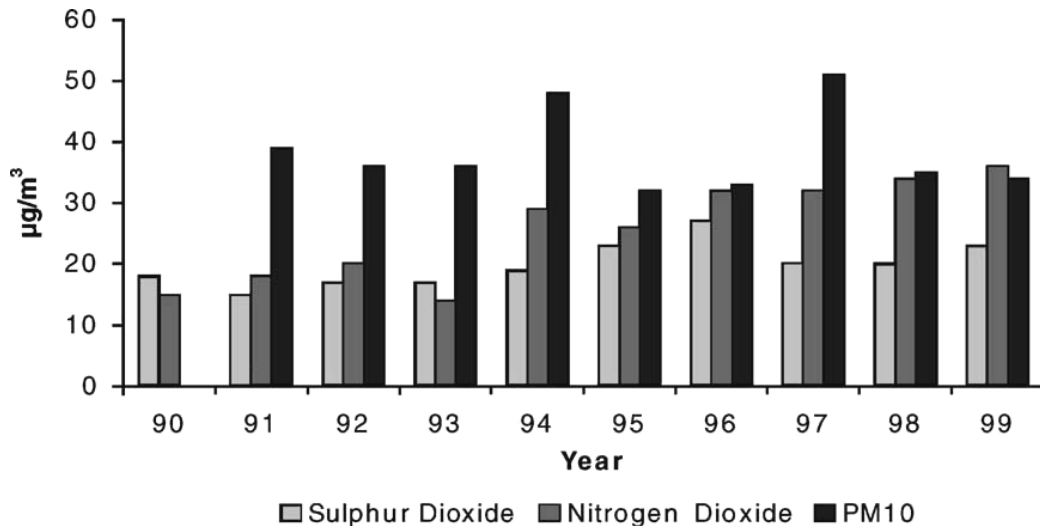


Fig 4.1: Annual average levels of sulfur dioxide, nitrogen oxide and PM₁₀ in Singapore (Quaha et al., 2003)

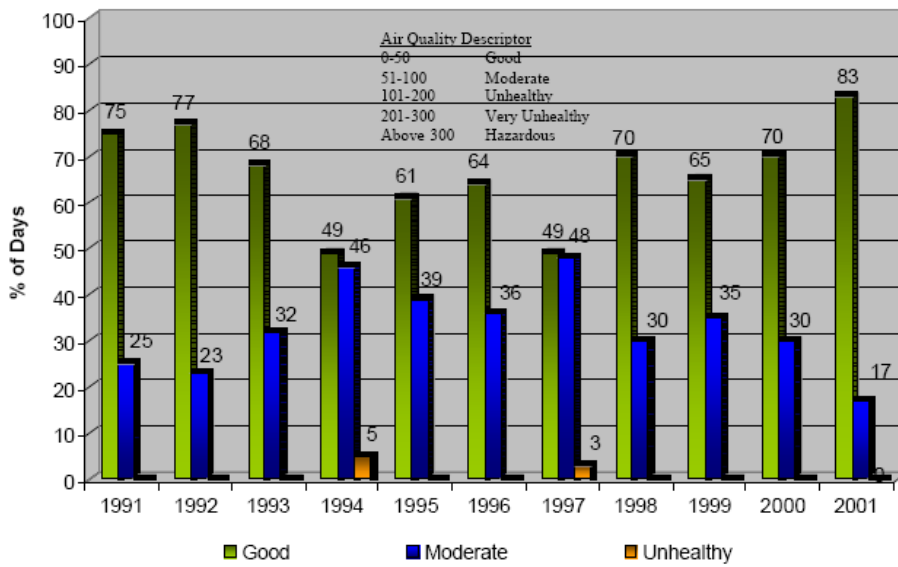


Fig 4.2: Annual average Pollutant Sub Index (PSI) in Singapore (Yong, K.C., 2002)

Air quality data shows good air quality in over all Singapore (Table 4.6).

Table 4.6: 24-hr PSI¹² at 4pm, 25 July 2007¹³

Region	24-hr Sub-Index at 4pm, 25 July 2007					PSI*	Air Quality Descriptor	Responsible Pollutant
	Sulfur Dioxide	PM10	Ozone	Carbon Monoxide	Nitrogen Dioxide ⁺			
North	8	31	7	7	-	31	Good	PM ₁₀
South	11	27	3	6	-	27	Good	PM ₁₀
East	7	25	3	7	-	25	Good	PM ₁₀
West	13	27	11	8	-	27	Good	PM ₁₀
Central	4	27	2	8	-	27	Good	PM ₁₀
Overall Singapore*	13	31	11	8	-	31	Good	PM ₁₀

Source: NEA, 2007a

Note:

A sub-index value of 1 to 50 of a pollutant indicates that the level of the air pollutant for the day is in the good range and within the USEPA annual mean ambient air quality standard. A sub-index of 51 to 100 indicates the level of the air pollutant is in the moderate range, but still within the USEPA 24-h ambient air quality standard.

+Sub-index for Nitrogen Dioxide is reported only when the one-hour Nitrogen Dioxide concentration exceeds 1130µg/m³).

*Based on the highest indices in accordance with the USEPA guidelines for PSI reporting.

4.6 Compressed Natural Gas Conversion of Public Passenger Vehicles in Delhi

Country/Region	:	India/South Asia
Area of coverage	:	Delhi
Sectoral category	:	Energy/Transport
Type of approach	:	Policy/Technology
Pollutant Type	:	SO ₂ and NO _x
Year of introduction	:	1998 onward
Participants	:	Supreme Court, Delhi Government, Environmental Pollution (Prevention and Control) Authority, Gas Utilities, Automobile Industries, Transport Operators and Civil Society
Implemented by	:	Delhi Government

¹² PSI is Pollutant Sub Index based on highest indices in accordance with USEPA guidance

¹³ Downloaded on 26 July 2007 (<http://app.nea.gov.sg/psi/psi2mthv1.asp>)

Description

In 1998, the Supreme of India issued directives to the Delhi Government to convert entire public transport system (comprising of auto rickshaws, taxies and buses) to compressed natural gas (CNG) by March 31, 2001 which was in response to a writ petition filed in 1985. This was a historic decision where a judiciary body had to intervene for the implementation of counter measures in transport sector to improve air quality in the city (Bell et al., 2003). The transport sector is the major polluter in Delhi (DPCC, 2003).

The Supreme Court had also issued an order in March 2001 that all operators of the Public Transport System (comprising buses, taxis and auto rickshaws) to show proof of commitment for switching over to CNG. The proof of commitment had to be in the form of conversion/booking to CNG kits or booking of new CNG vehicles. On the basis of the proof, all operators were issued Special Permits (by 15th April, 2001) with a limited period validity till 30th September 2001, which were further extended till 31st January 2002 in pursuance of directions of the Supreme Court. On the expiry of the stipulated period, the Supreme Court imposed a daily fine for not converting to CNG. Fines amounting to about Indian Rupees 0.24 billion were collected through such daily fines. Sales tax exemption, interest subsidy on loan was provided for conversion to CNG.

Basically, the measures to reduce vehicular pollution has been either to require use of improved fuel quality (like lowering the sulfur in the diesel), retrofitting the exhaust tail end pipe with catalytic converters, switching to cleaner fuel or traffic management. However, the complete conversion of the public transport to CNG in Delhi was a unique example through which a significant reduction in air pollution was achieved within few years in the city, which was otherwise taken as the one of the world's top 10 most polluted city (Mumbai Newline, 1998). Though the role played by other sectors could not be undermined but the major role played on this was by the ruling of the Supreme Court of India and the court was active in issuing series of directives to the implementing agencies and also in many occasions, it even criticized them for its slow responses with excuses of not available required infrastructures (UNEP, 2006). It was on July 28, 1998, that the Supreme Court had ruled that the total passenger bus fleet of Delhi be increased from the then figure of about 6,000 to 10,000 by April 1, 2001 and the entire city bus fleet be converted to CNG with an objective to expand the city's public transport system and also to control air pollution. This was based on the recommendations of Environment Protection Control Authority (EPCA), also known as Bhure Lal Committee (BLC), set up by the Ministry of Environment & Forests.

Now, Delhi had the largest fleet of CNG buses in the world. There were 2,394 buses, over 27,000 autos and 14,000 other vehicles running on CNG. More than 146 fueling stations

(till March 2006) have been established ([IGL, 2006a](#)).

Major Activities

The major activities conducted could be traced back to early 90s. An effort is taken to compile here the activities that made the historic decision to reality.

1991:

The Supreme Court (SC) makes its first order to the Gas Authority of India, Ltd. (GAIL), the gas distribution arm of the Delhi government, to switch over to a clean fuel. It orders that at least five stations providing CNG should be set up, and that a minimum of 5 DTC buses should be converted to CNG.

1995:

The SC ordered and agreed to a schedule to convert government cars to CNG or retrofitted to catalytic converters.

1996:

The SC ruled that 720 Delhi government vehicles must either be fitted with a catalytic converter or be converted to CNG and gave a deadline. The SC ordered the Ministry of Surface Transport (MoST) and Ministry of Environment and Finance (MoEF) to ensure that the conversions take place on time.

1998:

The SC passed directions for switching over the entire public transport system comprising of autos, taxis and buses to the compressed natural gas (CNG/clean fuel mode) as per schedule specified by the SC

The Court had also directed to establish 80 CNG dispensing stations in Delhi by March 2000. India's first CNG bus was launched in Delhi. The bus was run by Delhi Transport Corporation (DTC)¹⁴ on a trial basis.

1999:

A committee was formed to devise the implementation plan of SC directives. CNG was

¹⁴ state owned transport company

made available at 9 dispensing stations in the capital.

Motor Vehicles Act was amended to include CNG.

All 7,500 DTC buses plying in the capital would be converted to CNG by March 31, 2001 – was announced. Twenty five hundred new CNG buses were to be added.

Diesel with 0.25% sulfur content was introduced.

2000:

First emission standard for CNG-vehicles was introduced. 12 CNG stations were operating in Delhi. Bharat Stage II standard equivalent to Euro II standard was issued.

Significant reduction in pollution at traffic intersections and in industrial areas was reported.

Ministry of Science and Technology provided certification of standards for converted CNG vehicles.

Inadequacy of CNG filling stations and shortage of kits hampered meeting of the implementation plan deadlines. Out of total converted 10 CNG buses, 7 were only running on trial basis.

About 1,800 buses (almost all); 17,000 rickshaws; and 1,200 taxis, all more than 8 years old, go off the road. Commuters panic and some were left stranded.

The SC directed the central government to supply petrol and diesel with 0.05% sulfur content and 1% benzene content from June 2001. The SC directed the ministry to supply petrol with 0.05% sulfur content with 1% benzene content.

2001:

The SC refuses to extend the March 31, 2001 CNG conversion deadline. Private bus operators requests financial assistance from the government for the conversion.

SC sought more precise definition of “clean fuel”. The other fuels, particularly low (500 ppm) and ultra low (10 ppm) sulfur diesel, should be considered in addition to CNG as “clean fuel” for vehicles.

The Court granted a temporary extension for the CNG conversion of buses until the end of September 2001 for groups that showed conformity of commitment

2002:

The SC directed that no retro-fitted or converted CNG bus be allowed to ply without certificate of conformity that the buses met the safety standard after CNG conversion. New CNG buses would not come under this order.

2003: All 8,000 buses in Delhi were reported to operate on CNG. Nearly all autorickshaws in the city had converted to CNG.

Delhi won the US Department of Energy’s first ‘Clean Cities International Partner of the Year’ award for “bold efforts to curb air pollution and support alternative fuel initiatives”.

2006:

Delhi had 10,761 buses (owned by DTC and private), 63,962 three wheelers, 5,229 taxis & 5,258 Vans running on CNG (India Times, 2006). 19,351 private cars in Delhi had also converted to CNG (IGL, 2006).

Impact on Air Pollution Scene

The improved air quality of Delhi in recent years is widely acknowledged. Central Pollution Control Board of India is continuously monitoring the ambient air quality of the major cities of the country. The air quality measurements of Delhi from 1998 to 2005 show that average concentration of SO₂ is drastically reduced to the safe limit. Further, the concentration of NO_x also meets the criteria of the annual average national standard value, but relatively these values are increased ([Table 4.7](#)). However, the suspended particulate matter in the city is far above than the national ambient air standard. These can be seen from [Table 4.7](#).

Table 4.7: Ambient Air Quality of Delhi from 1998 - 2005

Area	SO ₂						
	1998	1999	2000	2001	2002	2003	2004
Sarojini Nagar ^a	15.7	19.6	15.9	13.8	11.8	9	7
Town hall	12.2	17.4	14.3	13.3	11.5	11.5	11
Mayapuri Industrial Area ^b	17.8	20.2	17.7	13	16.7	11.4	12

Area	NO _x						
	1998	1999	2000	2001	2002	2003	2004
Sarojini Nagar ^a	28	24.8	24.6	22.5	27.3	31.8	53
Town hall	44	54.5	64	70.1	53.3	58.9	60
Mayapuri Industrial Area ^b	28.7	25	26	22.5	36.3	32.6	56

Area	Suspended Particulate Matter (SPM)						
	1998	1999	2000	2001	2002	2003	2004
Sarojini Nagar ^a	384	337	225	324	378	281	356
Town hall	465	505	590	561	534	478	508
Mayapuri Industrial Area ^b	371	345	282	291	415	343	484

a - Data from 1998-2003 is from Siri Fort

b - Data from 1998-2003 is from Shahadra

All units are in yearly average $\mu\text{g}/\text{m}^3$.

Annual Average National Ambient Air Quality Standard:

SO₂/NO_x – 80 $\mu\text{g}/\text{m}^3$ for industrial and 60 $\mu\text{g}/\text{m}^3$ for residential.

SPM – 360 $\mu\text{g}/\text{m}^3$ for industrial and 140 $\mu\text{g}/\text{m}^3$ for residential.

Source: CPCB Website, Central Pollution Control Board/National Air Quality Monitoring Program (NAMP)

4.7 Environmental Measures and NO_x Tax System in Norway

Country/Region	:	Norway/Europe
Area of coverage	:	Norway
Sectoral category	:	Energy/Transport
Type of approach	:	Policy/Technology
Pollutant Type	:	NO _x
Year of introduction	:	January 2007 onward
Participants	:	Manufacturing Industries, Transport comprising of ships, fishing vessels, air traffic and railways
Implemented by	:	Norwegian Government, Norwegian Pollution Control Authority

Description

In 2006, the Norwegian Parliament had endorsed a tax policy on emissions of NO_x to be applicable from January 1, 2007. The tax amounts to NOK 15 per kg NO_x (US \$ 2.5/kg) emitted. It comprises ships, fishing vessels, air traffic and diesel railways, and also engines, boilers and turbines in energy plants in the manufacturing industries. The large units in these categories are applicable for the tax system. In addition, NO_x tax is also imposed on flaring offshore and on oil and gas installations on shore. The tax covers approximately 55 % of the total Norwegian NO_x emissions ([Statistics of Norway, 2007](#)).

Table 4.8: Emission ceiling 2010 according to the Gothenburg Protocol and status 1990 and 2006 (in Tonnes)

Component	Emissions 1990	Emissions 2006	Emission ceiling 2010	Necessary reduction 2006-2010
Nitrogen oxides (NO _x)	212 524	194 506	156 000	39 000 tonnes (20 per cent)
NMVOC	294 875	196 345	195 000	1 000 tonnes (1 per cent)
Ammonia (NH ₃)	20 375	22 610	23 000	Emission ceiling reached at the moment

Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority. ([Statistics Norway, 2007](#))

The tax is geographically delimited in accordance with the Gothenburg Protocol. This implies that emissions from foreign sea and air transport not are covered, for instance. As per the Gothenburg Protocol, Norway is required to meet its NO_x emission target of 156,000 tonnes in 2010 ([Table 4.8](#)). The tax system is expected to assist in meeting this target. However, it is not sufficient and requires further measures or strengthening of existing measures to fulfill the obligation ([Statistics Norway, 2007](#)).

Major Activities

Environmental Regulation

The regulation has been considering emission from locally-created contributions when determining whether a source contributes substantially to exceeding individual limit values. Emission from road traffic is seen as a whole, regardless of who owns the roads. Similarly it is applied to the emissions from contiguous port areas with different owners. Emissions from small heating plants are also taken as a whole.

The emission limit values with averaging periods and the deadlines to meet these targets are given in [Table 4.9](#).

Municipalities are authorized to draw necessary assessments of possible measures in consultation with parties involved. Municipalities are also authorized to ensure the smaller heating plant owners to comply with the regulation. Also they are given authority to order/issue directives to plant owners to comply with the regulation even such plant does not contribute significantly to the concentration of the pollutant. Municipal Council is given authority to regulate emissions from smaller heating plants.

Table 4.9: Emission limit values and the deadlines to be met:

	Averaging period	Limit value	Margin of tolerance	Date by which limit value is to be met
Sulfur dioxide				
1. Hourly limit value for the protection of human health	1 hour	350 µg/m ³	The limit value must not be exceeded more than 24 times a calendar year	1 January 2005
2. Daily limit value for the protection of human health	1 day (fixed)	125 µg/m ³	The limit value must not be exceeded more than 3 times a calendar year	1 January 2005
3. Limit value for the protection of ecosystems	Calendar year and winter (1/10–31/3)	20 µg/m ³		4 October 2002
Nitrogen dioxide and oxides of nitrogen				
1. Hourly limit value for the protection of human health	1 hour	200 µg/m ³ NO ₂	The limit value must not be exceeded more than 18 times a calendar year	1 January 2010
2. Annual limit value for the protection of human health	Calendar year	40 µg/m ³ NO ₂		1 January 2010
3. Annual limit value for the protection of vegetation	Calendar year	30 µg/m ³ NO _x		4 October 2002
Particulate matter PM₁₀				
1. Daily limit value for the protection of human health	1 day (fixed)	50 µg/m ³ PM ₁₀	The limit value must not be exceeded more than 35 times per year	1 January 2005
2. Annual limit value for the protection of human health	Calendar year	40 µg/m ³ PM ₁₀		1 January 2005

Source: [NPCA, 2007](#)

The air quality is being measured and/or calculated according to health-based (Table 4.10) and vegetation-based evaluation thresholds (Table 4.11):

Table 4.10 Assessment threshold for health protection

Pollution component	Upper assessment threshold	Lower assessment threshold
Sulfur dioxide	75 µg/ m ³ (day value) which must not be exceeded more than 3 times a calendar year	50 µg/ m ³ (day value) which must not be exceeded more than 3 times a calendar year
Nitrogen dioxide	140 µg/ m ³ (hourly mean) which must not be exceeded more than 18 times a calendar year 32 µg/ m ³ (annual mean)	100 µg/ m ³ (hourly mean) which must not be exceeded more than 18 times a calendar year 26 µg/ m ³ (annual mean)
Particulate matter (PM10)	30 µg/ m ³ (daily mean) which must not be exceeded more than 7 times a calendar year 14 µg/ m ³ (annual mean)	20 µg/ m ³ (daily mean) which must not be exceeded more than 7 times a calendar year 10 µg/ m ³ (annual mean)
Lead	0.35 µg/m ³ (annual mean)	0.25 µg/ m ³ (annual mean)
Benzene	3.5 µg/m ³ (annual mean)	2.0 µg/m ³ (annual mean)
Carbon monoxide	7 µg/m ³ (8-hourly mean)	5 µg/m ³ (8-hourly mean)

Table 4.11: Assessment threshold for the protection of vegetation

Pollution component	Upper assessment threshold	Lower assessment threshold
Sulfur dioxide	12 µg/m ³ (winter mean)	8 µg/m ³ (winter mean)
Oxides of nitrogen	24 µg/m ³ (annual mean)	19.5 µg/m ³ (annual mean)

Source: [NPCA, 2007](#)

NO_x Tax System

The tax base is applicable to propulsion machinery with a collective installed engine rating of more than 750 kW. The installed propulsion power if exceeds 750 kW, the NO_x emissions from other auxiliary machinery is also subject to tax in addition to the tax on the propulsion machinery. The tax is calculated based on 3 principles a) according to actual emission; or b) according to a fixed source specific emission factor; or c) If 'a' and 'b' are non-existent, based on the maximum rotations per minute (rpm) template. Documentation for (a) requires actual emission documented measurements carried out by competent party approved by the Norwegian Maritime Directorate (a pre-defined NO_x Tax Calculations Table or 'rate card'); for b) requires a source specific emission factor documentation, in accordance with guidelines given by the Norwegian Maritime Directorate, submitted and

approved by the Norwegian Maritime Directorate (a source-specific Manual Onboard Measurement) and for c) requires documentations based on rotation speed recorded or main engine manufacturer's certificates (continuous onboard monitoring).

Norwegian registered vessels in 'near waters' - defined as sea areas within 250 nautical miles from Norway's coast are applicable to the tax system. Emissions from all domestic and foreign vessels operating within Norwegian territorial waters, i.e. within 12 nautical miles of the coast are also applicable to the tax system. However, vessels sailing direct routes between Norwegian and foreign harbours, and vessels in transit through Norwegian territory (innocent passage) are exempted from the tax system.

The policy has provision to refund the cost of the installation of cleansing equipment, measuring equipment, or fixing source specific emissions factors.

Impact on Air Pollution

In 2006, Norwegian NO_x emissions have been reduced by 8.5 per cent since 1990 which amounts to 195 000 tonnes (1 % lower than in 2005) (NPCA, 2007). There are two main reasons for the decline. A significant part of the reduction is due to lower emissions from the manufacturing industries, most likely caused by lower production in some industries and closing down of a couple of important plants. The other main reason is reduced emissions from road traffic, due to specific environmental measures. The share of cars equipped with catalytic converters is rising and heavy vehicles have reduced their emissions because of new restrictions on exhaust gas.

The three emission sources a) domestic sea transport and fishing, b) oil and gas activities and c) road traffic together accounted for almost 80 per cent of NO_x emissions in 2005. The remainder came mainly from oil used for heating and other combustion, air traffic and use of motorised equipment. Domestic sea transport and fishing had the largest NO_x emissions in 2005, with 73,000 tonnes or 37 per cent of total emissions. The emissions from this source have increased considerably since 1990, and are now 13 per cent above the 1990 level. Fishing caused 23,000 tonnes, and the rest came from coastal traffic, ferries, supply ships, mobile oil rigs etc. Measures to reduce NO_x emissions from domestic sea

transport and fishing include cleansing of exhaust gases (SCR) and motor technical reconstruction of ships.

In 2005, NO_x emissions from road traffic have been less than half of 1990. The main cause for this decline is the mandatory introduction of catalytic converters in petrol vehicles in 1989 combined with stricter rules in subsequent years. The emissions have decreased steadily since catalytic converters became mandatory. The emissions from heavy diesel vehicles have also decreased, following the introduction of emission limits for heavy vehicles in 1993.

Chapter V

Summary and Conclusions

With the increasing dependence on fossil fuels and heavy use of biomass, in the countries in the South Asia are facing air pollution. Three sectors, i.e., Power, Industry and Transport are reported to be mainly responsible for air pollution in the region. Power sector is reported to be the largest emitter of SO₂, while transport sector, biomass burning and agriculture (rice paddy and live stocks) are considered to be the largest contributors to NO_x, NMVOC and CH₄ emissions respectively in the region.

The use of coal is increasing in the region (especially in India) to meet the growing demand for electricity. As a result, SO₂ emission is also expected to rise in the region in the future. In addition, the problem of SO₂ emission is getting aggravated by the deteriorating quality of coal, inefficient coal preparation and coal cleaning mechanism in the region. Low efficiency of the thermal power generation (especially coal fired power plants) is another factor resulting in higher SO₂ emission and offer potential for significant coal and SO₂ reduction from the region. Lack of regulations/mechanisms to control emissions other than particulate matters from the power plants, lack of regulations on Industrial pollution and enforcement of existing regulations are some of the key issues that need to be addressed in the region for prevention and control of transboundary air pollution.

The South Asia region is also facing the problem of worsening air quality in urban areas largely due to growing emission from the urban transport sector. On the other hand, the rural areas in the region are facing the pollution problems related to biomass burning due to their high dependence on such fuels.

Most countries in the region also lack regular monitoring of air pollution as well as information on emission source apportionment, which are prerequisites for formulation of effective air quality management strategies. Furthermore, most countries lack effective regulatory and economic policy instruments in order to improve the air quality in an effective manner.

The region is yet to have regional treaties/agreements/protocols that set quantitative targets for reduction of transboundary pollutant emissions at the national levels. International treaties and agreements provide the legal and political basis for formulating national level strategies and policies to control transboundary air pollution. This report has therefore reviewed various existing international treaties and agreements that address the problem of transboundary air pollution in other regions of the world, especially Europe and North America. Worth mentioning in this context are the Convention on Long Range Transboundary Air Pollution (CLRTAP), the European Commission National Emission Ceilings Directive (2001/81/EC) and the mechanism set by Title IV of Clean Air Act 1990 Amendment in the US. The Convention on Long Range Transboundary Air Pollution (CLRTAP) addresses the major TAP problems in the United Nations Economic Commission for Europe (UNECE) region (with special focus on Eastern Europe, the Caucasus and Central Asia and South-East Europe). The convention adapted 8 protocols targeting emission reduction of major transboundary air pollutants. Likewise, the United States of America has taken an initiative to control transboundary air pollution under Title IV of Clean Air Act 1990 Amendment. The Act requires the states to reduce exclusively SO₂ and NO_x emission within a time horizon.

As a prerequisite to setting national emission reduction targets in any regional level agreements/treaties for control of transboundary air pollution, it is important to have reliable information on emissions and their effects/impacts as well as the costs of abatement measures. This requires installation of comprehensive monitoring system.

Once the targets for reduction of national emissions are agreed upon, next important task is to formulate and introduce most appropriate approaches to control emissions of pollutants. Keeping this in view, the report also discusses the approaches used by different countries to control air pollution so that appropriate lessons could be learned for controlling transboundary air pollution in the region.

The major approaches used for environmental management in general and air quality management particular are categorized as (i) command and control approaches including emission standards, fuel quality standards and technology standards, (ii) market based or economic approaches which include emission tax (with or without refund), emission permits and emission trading and (iii) approaches based on voluntary actions (In addition,

property right based approaches are also mentioned in the environmental economics literature). Further, the report has presented in greater detail several examples of good practices (or “best practices”) existing in different countries in the world for the control of transboundary air pollution that the policy makers of the South Asian countries could benefit from.

Examples of the application of command and control approach include the requirement of the Integrated Pollution Prevention and Control (IPPC) Directive of EU for each member state to adapt Best Available Technology (BAT); in that sense the directive sets technology based standards. In the case of the United States imposed an emission standard for new power plants in terms of SO₂ emission per unit of heat content of fuel burned.

Economic or market based approaches for environmental management employ emission tax (or emission charge) or emission permits (which could be tradable) as the instruments. The economic instruments are designed to influence the polluters’ behavior (and thus the level of their pollutant emissions) through economic means. There are several examples of emission charges in practice. Countries like France, Italy, Norway, Sweden and Switzerland have introduced a tax on NO_x emissions, while Denmark France, Norway, Sweden and Switzerland have also a system to tax on SO₂ emission. In Switzerland, there is a tax on volatile organic compounds (VOCs) from the emission of aviation engines. Differential fuel tax rates based, on the amount of sulfur content of fuel, are also applied in European countries. Finland has been levying excise tax, special tax (Environmental Damage Tax) system and oil pollution fee for the imported oil.

Apart from the purpose of emission reduction, emission taxes are also in use in the form of fuel tax for the purpose of revenue generation and for specific fund (e.g. to compensate the damage claimed by victims of air pollution in Japan).

A refund based tax system is followed in Sweden, which is not intended to raise revenue but it provides an incentive to the participants for emission reduction by refunding the tax collected. The system imposes tax to the emitting source as per the rate of their SO₂/NO_x emission. It refunds the tax revenue as per the SO₂ emission reduction. In the case of NO_x, it divides the collected tax to the total energy produced and refunds based on the electricity

produced so that it will benefit the participants generating more energy output with less NO_x emission.

The system of allowing emission reduction credits (ERC) and emission trading are in practice in the United States and also in some European countries. In this system, firms are issued an emission permit to the emission sources and if the sources reduce emission below the permitted level, the firms are given a credit for such reductions. These credits could be used by the same firm or through trade by another firm to meet the latter's emission reduction target. This system usually lowers the cost of abatement to the firms as compared to the Command and Control (CAC) approach. In the US, in its sulfur emission allowance mechanism under the Acid Rain Program, some portion of the surplus allowances is auctioned to the public. Agencies lobbying for environment protection are allowed to buy the credits (allowances) in the auction. These credits are also allowed to retire physically so that the emission is permanently reduced on the following year. Innovative approaches in emission trading include the mechanisms of Offset, Bubble, Netting and Banking which are in practice in the US.

Approaches for voluntary action to reduce emissions included publication of top worst polluters (e.g., in Poland) and green electricity pricing that are in practice in some countries in Europe.

Apart from emission tax and emission permits, emission control measures adopted in different countries include switching to the cleaner energy sources/fuels like hydrogen fuel cell, compressed natural gas (CNG) and electricity. The switch of public passenger transport system in India and Pakistan from Diesel/Petrol to compressed natural gas (CNG) is already an example in the South Asia region of such approach. Use of low sulfur fuel has been widely adapted in the USA and European countries. In Nepal, electric vehicles are used in public passenger transport system which use electricity generated from hydropower.

Congestion charges have been applied successfully in Singapore, Hong Kong and London on the vehicles using a designated region based on the degree of congestion. Though the major focus of this practice is to reduce traffic congestion rather than environmental benefits, it is believed to have also contributed to the improvement of air quality in the cities. Similarly license quota system with permits to run the new or existing vehicles in

Singapore and Chile are some of the successfully adopted mechanisms to control vehicular emission. Banning of vehicles from running in designated days of a week was also followed in Mexico. However, the scheme does not seem to have the desired effect.

In many cases emissions of pollutants like CO₂, SO₂ and NO_x are closely linked with the level of fossil fuel combustion. Thus, any measure that modifies the level of fossil fuel combustion (e.g. energy conservation by increasing energy efficiency, fuel substitution, change in production level, etc.) would also influence emissions of air pollutants and greenhouse gases simultaneously. Several countries in Europe, Asia and North America are promoting electricity generation from renewable energy sources countries under the policy of renewable portfolio standards (RPS). They have utilized the mechanisms like feed-in tariffs, tradable green certificates (TGCs), bidding/tendering schemes, investment subsidies, fiscal/financial and green pricing schemes for the purpose. While the policy is aimed at reducing CO₂ emission from electricity generation from thermal power plants, it also can yield co-benefits in the form of reduced SO₂ and/or NO_x emissions.

It should be noted that the success of any emission control approach adopted would, to a large extent, depend on the effective monitoring of emissions and enforcement of the policies introduced to control/prevent the emissions.

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Annexes

Annex I

The Evolution of Road Transport Management Policies in Singapore

- 1967 : Singapore city separated from Malaysia and became independent city-state
- 1968 : *Ministry of Communications established; Imposed 30% import duty on Cars*
- 1970 : Bus service reform begins with an effort to consolidate ten small bus companies into three bus companies to serve different geographical sectors.
- 1972 : *Import duty and Additional Registration Fees (ARF) was increased*
- 1973 : The 3 bus services were merged to Singapore bus service (SBS)
- 1974 : Bus lanes were introduced (left-most lanes on major roads were designated for exclusive use by buses during peak hours); ARF was raised to 55%;
- 1975 : *Area Licensing Scheme (ALS) initiated in peak hours during week days only; Manual implementation of ALS was conducted, ARF raised to 100% of the cost of vehicle, Preferential ARF (called as PARF) was started*
- 1975 : *ARF raised to 125%; Park and Ride Scheme was introduced*
- 1977 : Double Decker buses were operated
- 1980 : *ARF raised to 150%*
- 1983 : Another bus service operator (now SMRT) came into operation
- 1987 : MRT was started; Public Transport Council was setup as regulatory body for bus route, tariff approvals and other bus services.
- 1989 : *ALS extended to other areas; Transit Link Setup integrating, all bus and train services forming single comprehensive road network*
- 1990 : *Implementation of Vehicle Quota System;*
Compulsion to have Certificate of Entitlements (COEs) to run vehicles on the road;
Closed bidding for limited Certificate of Entitlements (COEs) which was valid for 10 years
Weekend Car Scheme (WEC) was introduced
Single card system implemented for public transport network
- 1992 : *COEs was made valid for 5 years instead of 10 years in the past*
Graduated PARF was introduced ranging from 80% to 130% of Open Market Value of vehicles (OMV)
- 1994 : *ALS was implemented for whole day and also for part day*

- Off peak Car scheme was introduced and replaced WEC Scheme
 Vehicle Parking Certificate (VPC) Scheme for heavy vehicles was implemented
- 1995 : Institutional Reformation with the merger of 4 utilities to a single utility named as Land Transport Authority (LTA)
Road Pricing System (RPS) on expressway
Euro I emission standard was applied to vehicles
- 1996 : *LTA brought White Paper with the purpose to build World Class Transport System*
- 1998 : *Electronic road pricing (ERP) was started;*
Vehicle tax structure reformed
 Complete phase out of leaded petrol
- 1999 : *ERP was extended to highways*
Sulfur content of diesel was reduced to 0.05% by weight
- 2000 : Classic Car Scheme was introduced
Chassis Dynamometer Smoke Test (CDST) was enforced for defaulters
- 2001 : *Euro II – Emission Standard applied, all vehicles was equipped with catalytic converters*
 Green Vehicle Rebate Scheme was introduced; Low emission vehicles: CNG, Electric and Hybrid Vehicles were given rebate on registration fees and special tax incentives
- 2002 : Open Bidding System fully replaced the Closed Bidding System of the Certificate of Entitlement (COE).
- 2004 : *Two tier ARFs (110% for new vehicles and 130% for old vehicles)*
- 2005 : *Sulfur content of diesel was reduced to 0.005%*
- 2006 : *Euro IV – Emission Standard was applied to diesel vehicles*