Compendium of Good Practices on Prevention and Control of Air Pollution July 2008

MALÉ DECLARATION ON CONTROL AND PREVENTION OF AIR POLLUTION AND ITS LIKELY TRANSBOUNDARY EFFECTS FOR SOUTH ASIA

Compendium of Good Practices on Prevention and Control of Air Pollution

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Malé Declaration Secretariat
UNEP Regional Resource Centre for Asia and the Pacific
July 2008

This report has been compiled by Prof. Ram M. Shrestha, School Environment, Resources and Development, Asian Institute of Technology, Thailand in collaboration with Malé Secretariat as part of the phase III implementation of the Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia. The report has been reviewed by the ninth Session of the Intergovernmental meeting from Malé Declaration. The contents of the report do not necessarily reflect the views, policies or opinions of any participating country and organisation.National Focal Points (NFP) and National Implementation Agencies (NIA) of Malé.

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TABLE OF CONTENTS

Table of Contents IV
List of Tables VI
List of Figures V
List of Abbreviations VIII

Chapter I: Introduction 1
1.2 Objective 2
1.3 Scope 2
1.4 Organization of the report 2

Chapter II: Status and major issues of transboundary air pollution in South Asia 3
2.1 Introduction 3
2.2 Status of major transboundary air pollutants emission 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 9
2.3.3 Inefficient coal preparation/cleaning mechanism 10
2.3.4 Lack of emission control mechanism in power plants 11
2.3.5 Lack of regulations on industrial pollution and enforcement of existing regulations 11
2.3.6 Urbanization and growth of personal transport vehicles 13
2.3.7 High dependence on biomass fuel burning in rural areas 15
2.3.8 Lack of information on emission source apportionment 16
2.3.9 Lack of effective regulatory and economic policies to improve air quality 16
2.3.10 Lack of comprehensive and regular monitoring of air pollution 18

Chapter III: International agreements and approaches for prevention and control of transboundary air pollution 19
3.1 Introduction 19
3.2 Major treaties, protocols and acts 20
3.2.1 Convention on Long-Range Transboundary Air Pollution (CLRTAP) 20
3.2.1.1 Protocols on SO_2 emission reduction 21
3.2.1.2 Protocols on NO_x emission reduction 21
3.2.1.3 Protocols on VOCs emission reduction 22
3.2.1.4 Protocols dealing with multi-pollutants 22
3.2.2 European Commission National Emission Ceilings Directive (2001/81/EC) 23
3.2.3 The US Clean Air Act Amendment 1990 24

3.3 Approaches for control and prevention of transboundary air pollution 25
3.3.1 Command and control approaches 26
3.3.2 Market based instruments 26
3.3.2.1 Emission charge 26
3.3.2.2 Emission charges in practice 26
3.3.2.3 Fuel and environmental taxes 28
3.3.2.4 Fuel and environmental taxes in practice 29
3.3.2.5 Emission reduction credit and emission trading system 29
3.3.2.6 Emission reduction credit and emission trading in practice 30
3.3.2.7 Innovative mechanisms in emission trading 31
3.3.3 Approaches based on voluntary action 32
3.3.4 Fuel Switching and cleaner fuel use 32
3.3.4.1 Fuel Switching and cleaner fuel use in practice 33
3.3.5 Congestion charge and transport management 33
3.3.5.1 Congestion charge and transport management in practice 33
3.3.6 Co-benefits of greenhouse gas emission reduction policies and technologies 35
3.3.6.1 Renewable Portfolio Standard policy 35
3.3.6.2 GHG emission reduction technologies 36

Chapter IV: Good practices on prevention and control of transboundary air pollution 37
4.1 Introduction 37
4.2 NO_x charges as feebate in Sweden 38
4.3 Two Control Zone (TCZ) Plan and Program to control Sulfur pollution 40
4.4 The Acid Rain Program in US 43
4.5 Urban Transportation Planning and Travel Demand Management in Singapore 48
4.6 Compressed Natural Gas Conversion of Public Passenger Vehicles in Delhi 56
4.7 Environmental Measures and NO_x Tax System in Norway 60
4.8 Solar Water Heater System (SHWS) Development and Promotion Policies 65
4.9 Vertical Shaft Brick Kiln Technology Promotion in Asia 67
4.10 Alternative Fuel Vehicle Promotion in Kathmandu Valley 70
4.11 The OTC NO_x Budget Program, the NO_x SIP Call and NO_x Trading Program in the Eastern States of the U.S. 73

Chapter V: Summary and concluding remarks 75

References 81

LIST OF TABLES

Table 2.1: Emissions of key transboundary air pollutants in South Asian countries in 2000 4
Table 2.2: Sectoral shares (%) in NO_x emission in selected Asian Mega cities in 1990 and 2020 6
Table 2.3: Sources of VOCs in India 7
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, $\mu g/m^3$ 17
Table 2.6: Sulfur content in diesel 18
Table 3.1: Fuel taxes in Finland 30
Table 4.1: Percentage of cities in Two Control Zones meeting SO_2 Grades 42
Table 4.2: NO_x Emission Limit by Boiler Type 46
Table 4.3: Preferential Additional Registration Fee (PARF) Structure 51
Table 4.4: Result of 2nd Bidding Process conducted on 18 July 2007 52
Table 4.5: Average speed during peak hours 54
Table 4.6: 24-hr PSI at 4pm, 25 July 2007 55
Table 4.7: Ambient Air Quality of Delhi from 1998 - 2005 59
Table 4.8: Emission ceiling 2010 according to the Gothenburg Protocol and status 1990 and 2006 60
Table 4.9: Maximum Allowable Limit on Concentration of pollutants in outdoor air and the date by which the limit value is to be met 62
Table 4.10 Assessment threshold for health protection 63
Table 4.11: Assessment threshold for the protection of vegetation 63

LIST OF FIGURES

Figure 2.1: Share of SO_2 emission in South Asia (based on data 1990s data) 5
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 in Asia in 1990 and 2020 7
Figure 2.4: Fuel mix in the power sector 8
Figure 2.5: Efficiency of coal fired power generation in selected countries in year 2004 10
Figure 2.6: Shares in total industry sector SO_2 emission in India by type of industry in 2005 12
Figure 2.7: Stock of Passenger cars in South Asian Countries 13
Figure 2.8: Trend of NO_x and PM in Delhi 14
Figure 4.1: Annual average levels of sulfur dioxide, nitrogen oxide and PM_{10} in Singapore 54
Figure 4.2: Annual average Pollutant Sub Index (PSI) in Singapore 55

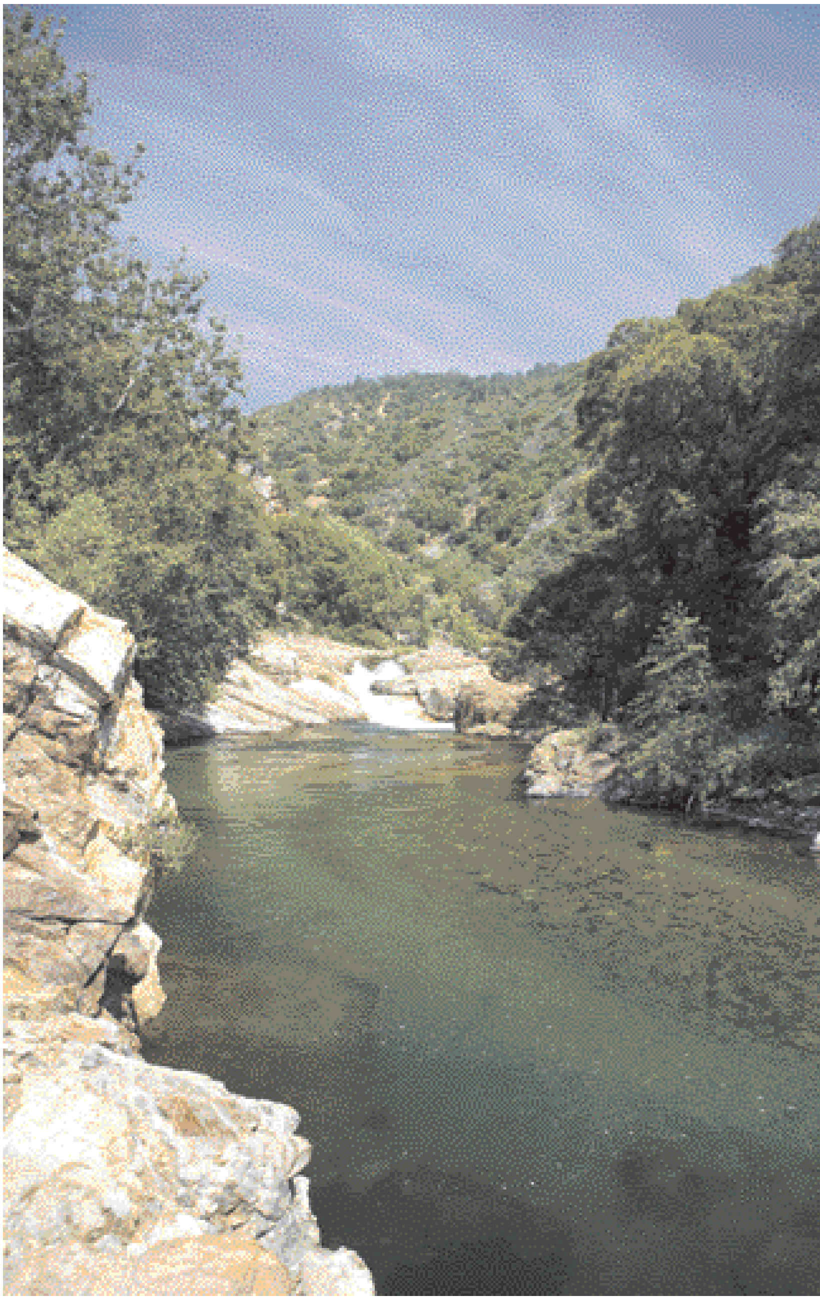
LIST OF ABBREVIATIONS

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
CO2	:	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
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, which accounts for over 22% of the global population. With 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) would continue to increase rapidly and regional air pollution problems would intensify. 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. Many urban areas in the region are also facing increased levels of air pollution and poor air quality. With growing 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 1998, the Environment Ministers of South Asia adopted the Declaration for Prevention of Transboundary Air Pollution (also known as the Malé Declaration). 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 levels.

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 formulation of policies for air pollution control and prevention. Towards meeting the objective, an activity has been undertaken to prepare to a compendium of good 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 good 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 good practices on the control of air pollution, which could help the policy makers in the formulation of effective policies and measures to control and prevent the emissions of transboundary air pollutants.

1.3 Scope

The report discusses the key issues related to emissions of air pollutants in South Asia and compiles good practices on control and prevention of emission of key transboundary air pollutants.

1.4 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. Chapter III first discusses major international agreements/protocols and national acts, which are followed by a discussion of different approaches for control and prevention of air pollution including practical examples of their adoption in different countries. In Chapter IV, selected cases of the good practices to reduce air pollution and thus to improve the air quality in different countries are presented. The final chapter presents a summary and concluding remarks.

Chapter II | Status and major issues of transboundary air pollution in South Asia

2.1 Introduction

Emissions of key transboundary air pollutants have been growing in Asia. According to Foell et al. (1995), sulfur emission in Asia would grow by a factor of 2.2 during 1990-2020. However, a more recent study (Streets et al., 2000) shows that the emission would increase by about 30% during the same period for a number of reasons (e.g., two-control zone policy in China, de-emphasis of coal use, fuel switching and spread of environmental awareness from East Asia to Southeast Asia and ultimately to Indian subcontinent). A study by Charmichael et al. (2002) reveals that sulfur deposition increased in most of Asia during 1975-2000 and that the largest increases have occurred in Southeast Asia and South Asia. The study also states that the area of high sulfur deposition (i.e., above 0.5g of sulfur per m^2 per annum) has expanded in South Asia during 1975-2000.

According to Aardenne et al. (1999), NO_x emission is estimated to grow by a factor of 3.5 in Asia during 1990-2020. During the period, NO_x emission from South Asia is estimated to increase by 5.5 fold.

South Asian economies have wide variations in terms of energy mix. The major types of fuel being used are coal, oil and biomass. Increasing use of the fossil fuels is the source of rising emissions of the transboundary pollutants in the region. The power, industry and transport sectors are mostly responsible for air pollution in the region. In this chapter, major issues of air pollution in South Asia are discussed.

2.2 Status of major transboundary air pollutants emission in South Asia[1]

According to Streets et al. (2003), total emissions of SO_2, NO_x, NMVOC and NH_3 from Asia as a whole in year 2000 were 34,316 Gg, 26,768 Gg, 52,150 Gg, and 27,519 Gg respectively[2] (Table 2.1). Six of the South Asian countries (Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka) together accounted for 21% of the total SO_2 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 NH_3 emission in Asia. As can be seen from Table 2.1, India is the largest emitter of SO_2, NO_x, NMVOC and NH_3 among the six South Asian countries shown in the table and accounts for 77%, 84%, 79% and 78% of total emissions of SO_2, NO_x, NMVOC and NH_3 respectively from the six countries as a group. The second largest emitter among the six countries is Pakistan, which accounts for 20%, 10%, 10% and 13% of the total SO_2, NO_x, NMVOC and NH_3 emissions from the six countries respectively. The remaining four countries together accounted for 3%, 6%, 11% and 11% of SO_2, NO_x, NMVOC and NH_3 respectively.

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	5,536	4,591	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.

[1] *Unless stated otherwise, the term "South Asia" in this chapter refers to the group of following countries: Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka.*
[2] *1 Gg = 10^9 g.*

According to Garg et al. (2001 and 2006), SO_2 emission at the all India level increased from 2.4 Tg in 1985 to 4.8 Tg in 2005[3], i.e., at a compound annual growth rate (CAGR) of about 3.5% during 1985-2005. In terms of emission by fuel type, coal contributed to 64% of total SO_2 emissions in India in 1990, while petroleum products and biomass accounted for 29% and 4.5% of the emission respectively and non-energy consumption contributed to 2.5% of the emission. The share of natural gas use in SO_2 emissions was negligible.

Recent information on sectoral contributions to total SO_2 emission are lacking for most countries. Studies on India by Garg et al. (2001, 2006) show that the power sector has the largest share in total SO_2 emissions of India. The share increased from 46% to 56% during 1995-2005. The industry sector is the second largest SO_2 emitter and its share has decreased from 36% to 32% during the same period. The share of the transport sector has decreased from 7.8% to 2.5%. Furthermore, the share of biomass consumption had decreased from 6% to 4.3% during the period. A study by Shrestha et al. (1998) on SO_2 emissions in Asia based on 1990 data (assuming no further control is carried out under existing laws and regulations) shows that the largest source of sulfur emission in South Asia was the power sector followed by the industrial and residential sectors. The transport sector had had the smallest contribution in the 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. In Nepal and Bhutan, the residential sector had the highest share in sulfur emission largely due to the consumption of traditional fuelwood using conventional biomass stoves.

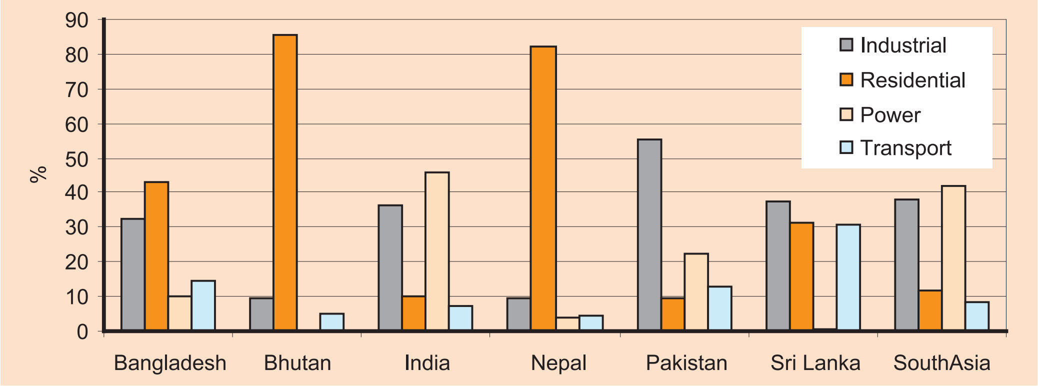


Figure 2.1: Share of SO_2 emission in South Asia (based on data 1990s data) (Shrestha et al., 1998)

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

[3] *U 1 Tg = 10^{12} g.*

According to Garg et al. (2006), NO_x emission in India was 5.02 Tg in 2005 and was growing at the CAGR of 4.4% during 1985-2005. The transport sector is the largest source of NO_x emission in India followed by the power sector. The share of the transport sector had increased from 31% to 38% during 1985-2005, while the share of the power sector had increased from 17% to 30% during the period. On the contrary, the share of industrial sector had decreased from 21% to 17% during the same period. Aardenne et al. (1999) estimates that the NO_x emission in the South Asian region would grow significantly by 2020 (Figure 2.2). The study estimates that the NO_x emission in India would grow by a factor of 5 in 2020 as compared to the 1990 level and that the transport sector would be the largest contributor (more than 50%) to total NO_x emission in India by 2020 (Figure 2.3). 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).

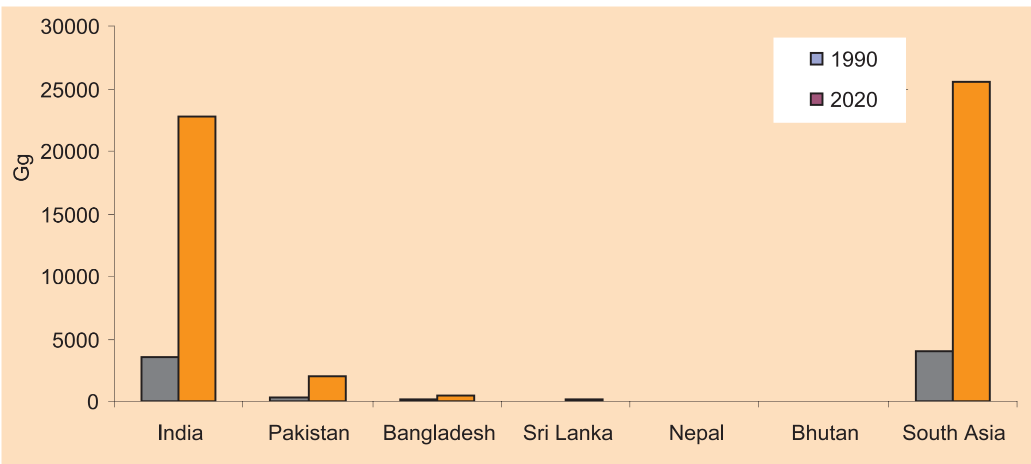


Figure 2.2: NO_x emission in South Asian countries in 1990 and 2020 (Aardenne et al., 1999)

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

	Bangkok		Delhi		Jakarta		Manila		Seoul		Beijing		Shanghai	
Sector	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

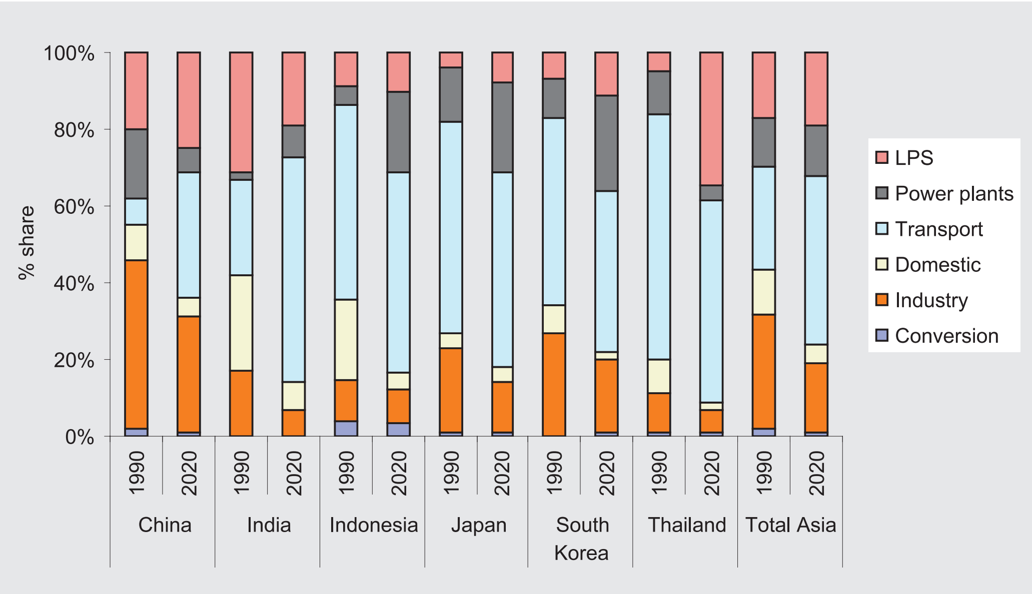


Figure 2.3: Sectoral shares in NO_x emission in selected countries in Asia in 1990 and 2020 (Aardenne et al., 1999)

Country specific emissions of VOCs are mostly lacking in South Asia. Streets et al. (2003) has estimated total emission of NMVOCs in the South Asian countries (excluding Maldives) to be 13,664 Gg in 2000, of which India accounted for nearly 80%. A study by Varshney et al. (1999) has studied anthropogenic emissions of VOC by different sources in India. The study estimates that the burning of biomass is the major contributor to NMVOC emissions (Table 2.3). Rice (paddy) fields and livestocks 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%
Total	21,452,725	100.00%

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 total energy used in power generation. Nearly 99% of the coal use for power generation in the region (i.e., 147,287 ktoe) took place in India in 2004, while the rest was used for power generation in Pakistan (IEA, 2006c). Coal based electricity generation accounted for 80% of total electricity generation in India in 2004 (Figure 2.4).

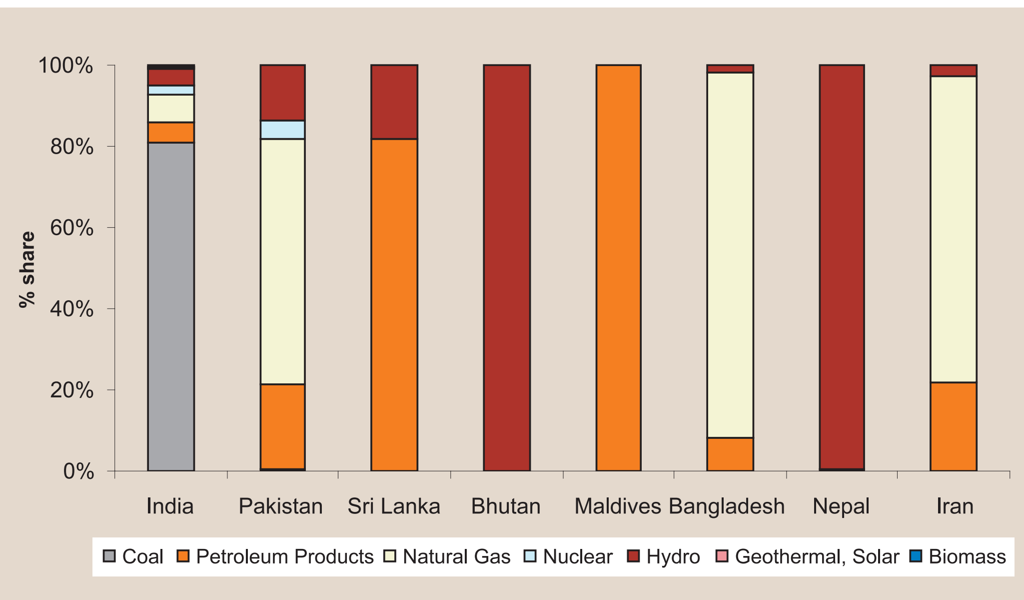


Figure 2.4: Fuel mix in the power sector

Sources: IEA (2004a) except for Bhutan and Maldives, DOEMTI/TERI (2005) for Bhutan; estimates for Maldives are based on information provided in UNEP/RRC.AP (2002).

According to Garg et al. (2006), the total SO_2 emission of India reached to 4.8 Tg in 2005, while Streets et al. (2003) estimated the emission to be 5.54 Tg in year 2000. Though there are variations in the estimated values, these studies show that the coal use in the power sector is mainly responsible for the high share of SO_2 emission in India.

With the high growth of economy in India, IEA (2006b) makes a projection that coal demand in the country would increase from 441 million tonnes in 2004 to 1,020 million tonnes by 2030 in the IEA's Reference Scenario. However, GOI (2006) has estimated the coal requirement of the country in 2031/32 to range from a low value of 1,580 Mt to a high value of 2,555 Mt under various scenarios. The consumption of coal 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. However, the recent discovery of large stock of low ash, low sulfur lignite will probably increase its use in future. Thermal power stations are mainly based on natural gas (besides some generation using furnace oil and diesel) (WAPDA, 2007) and accounted for over 80% of total electricity generation in Year 2004 (Figure 2.1). In Sri Lanka power supply is predominantly hydro-based, however, it 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 are several diesel-fired power plants with installed capacity of 405 MW in Sri Lanka. The country has a plan to build its first coal-fired power plant which will be equipped with particulate, SO_2 and NO_x emissions control systems. By 2010, the installed capacity of thermal power plants in Sri Lanka would reach 2,200 MW (UNEP RRCAP, 2007). Overall, with the increasing power generation based on fossil fuels (like coal and diesel), SO_2 emission from the power sector is likely to grow in South Asia in future.

Besides power generation, coal is also used as a source of energy in the industrial sector in South Asia (IEA, 2006c). In some countries like Iran and India, coal is also used in residential and commercial sectors but their shares are relatively lower than in the industrial sector. On the other hand, the transport sector has the largest share in the consumption of petroleum products followed by industrial and residential sectors (IEA, 2006c)

2.3.2 LOW EFFICIENCY IN POWER GENERATION

There is a wide variation in efficiency of electricity generation in Asia. In South Asia 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 29.6% in year 2004 (IEA, 2007), which is significantly lower than the corresponding figure in the OECD countries as a whole (41.9%) (Figure 2.5). It is also lower than the average efficiency of coal fired power plants in Asia. The efficiency of coal-fired electric power plants on an average in Asia as a whole (excluding China) was 32.5% in 2004, while the corresponding values for China and Thailand were 30% and 40.3% respectively. If the efficiency of coal fired power generation in India was improved to the level of the OECD, the coal requirement and SO_2 emission would be reduced by 29.4%. Similarly, if the efficiency of coal fired power generation in India was improved to the level of Thailand, the coal requirement and SO_2 emission would be reduced by 26.5%.

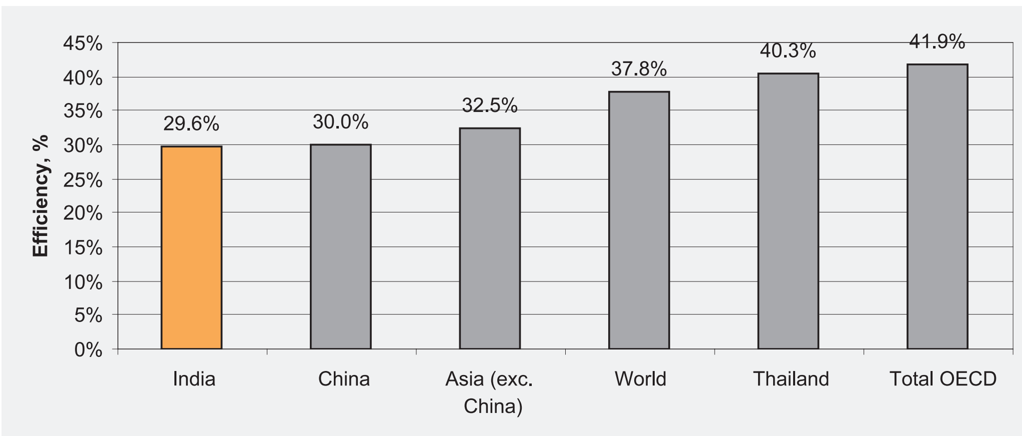


Figure 2.5: Efficiency of coal fired power generation in selected countries in year 2004

Sources: IEA, 2006c

2.3.3 INEFFICIENT COAL PREPARATION/ CLEANING MECHANISM

Coal production in India has been largely based on open-cast mining (WCI, 2006; GOI, 2006). Inefficient exploitation of in-place coal reserves and lack of control on mining practices are some of the factors that have led to deterioration in 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 – i.e., 4000 kcal/kg (on an average) as compared to 6000 kcal/kg of the imported coal. Furthermore, the average calorific value of coal used in India's power plants is reported to be about 3,500 kcal/kg (GOI, 2006). 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 a distance longer than 1000 km. As the power stations are often located at longer distances from the major coal fields, 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 of particulate matters, toxic elements, fly ash, oxides of nitrogen, sulfur and carbon from power plants (UNEP, 2001).

2.3.4 LACK OF EMISSION CONTROL MECHANISM IN POWER PLANTS

At present, most of the coal use for power generation in the South Asia region takes place in India. 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 20 GWe of supercritical coal fired thermal units (WCI, 2006). However, the Indian coal has high ash content and results in high emission of suspended particulate matter (SPM). Since the Sulfur content of the Indian coal is reported to be low (GOI, 2006), controlling particulate matters through the use of electrostatic precipitators on existing and new generating units has been given a priority. Thus there are standards on maximum emission limit for particulate matters and for minimum stack height for thermal power stations in India (CPCB, 2007a).

Bangladesh started its first coal based power generation plant with an installed capacity of 250 MW in January 2006. Some coal mining projects are being planned in the country (EIA, 2007a). However, there is no emphasis on emissions control technology except that there is a standard for stack height of the power plant (DOE/BMEP, 2003).

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 (Nepal Electricity Authority, 2007).

2.3.5 LACK OF REGULATIONS ON INDUSTRIAL POLLUTION AND ENFORCEMENT OF EXISTING REGULATIONS

Industry sector is one of the major sources of transboundary air pollutants. Streets et al. (2003) states that the industrial sector is the second largest contributor to national SO_2 emissions after the power sector in South Asia. Emission estimates by disaggregated industry types are not available for most countries in South Asia. According to Garg et al. (2006), iron and steel industry accounted for nearly one fifth of the total industry sector SO_2 emission in India in 2005 (Figure 2.6). Together iron and steel, cement and fertilizer industries accounted for nearly half of the industrial SO_2 emission in that country. In Bangladesh, the major SO_2 emitting industries are identified as textiles, non-ferrous metal, sugar and refineries, vegetable oil, iron and steel and tobacco (BBS, 2005). Similarly, textiles, sugar, refineries, cement and vegetable oil are reported as the major particulate emitting industries.

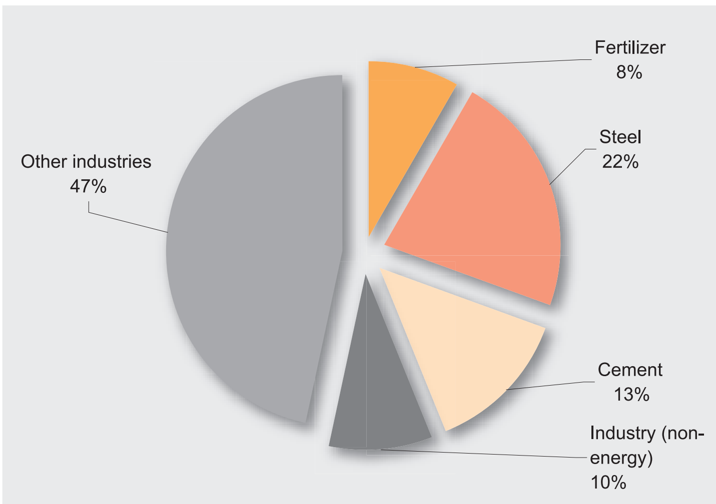


Figure 2.6: Shares in total industry sector SO_2 emission in India by type of industry in 2005 (Source: Garg et al., 2006)

While not much information on NO_x emissions at the sectoral level are available for most South Asian countries, Garg et al. (2006) report that the industrial sector is the third largest contributor of NO_x emission in India after the transport and power sectors (Industry sector accounted for 17% of total NO_x emission in India in year 2005). Given the importance of the industry 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 discharges to the water and air). The pollution levy was set initially at Pakistani 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 of energy consumption in transport, residential, industrial and commercial sectors in the cities and the resultant emissions of air pollutants (Guttikunda et al., 2003). Air quality in the cities (Dhaka, New Delhi, Calcutta, Mumbai, Chennai, Lahore and Karachi) under the study in South Asia has been deteriorating over the years (Guttikunda et al., 2003). Presently, air pollutants originating from the urban areas are recognized as the increasing sources of regional level pollution as well as greenhouse gases. Guttikunda et al., (2003) estimated that sulfur emission from urban centers in Asia would triple during 2000-2020 if current sulfur emission is unabated. Due to urbanization and motorization; concentration levels of suspended particulate matter (SPM) in particular are very high and exceeded WHO guidelines (Hayashi et al., 2004 and Siddiqi, 2007). One of the major causes of transport-related environmental problems in Asia is the severe traffic congestion resulting from growing vehicle stocks and lack of appropriate public transport infrastructure (Hayashi et al., 2004). This could be seen from the tremendous growth of passenger car ownerships in countries like India (Figure 2.7). For example, the total personal vehicle registration in Delhi,

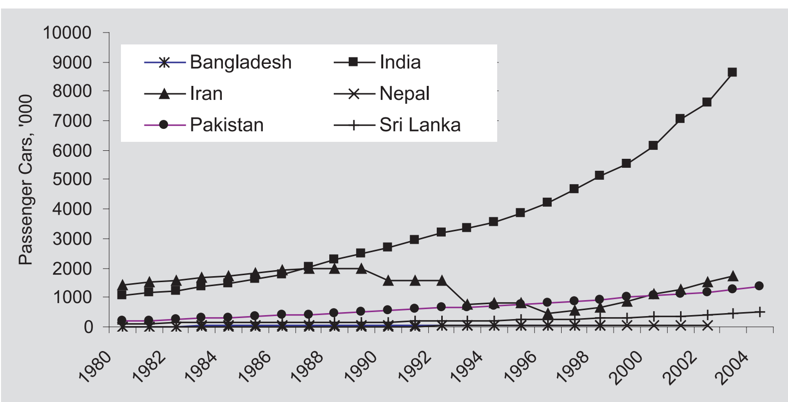


Figure 2.7: Stock of Passenger cars in South Asian Countries

Source: UNEP, 2007.

India has increased by 105% during 1996-2006; cars alone have increased by 157% and diesel cars have increased by 425% during the same period (CSE, 2006).

In a study by the Centre for Science and Environment (CSE) in India, it has warned that the level of pollution has started to increase (CSE, 2006). 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).

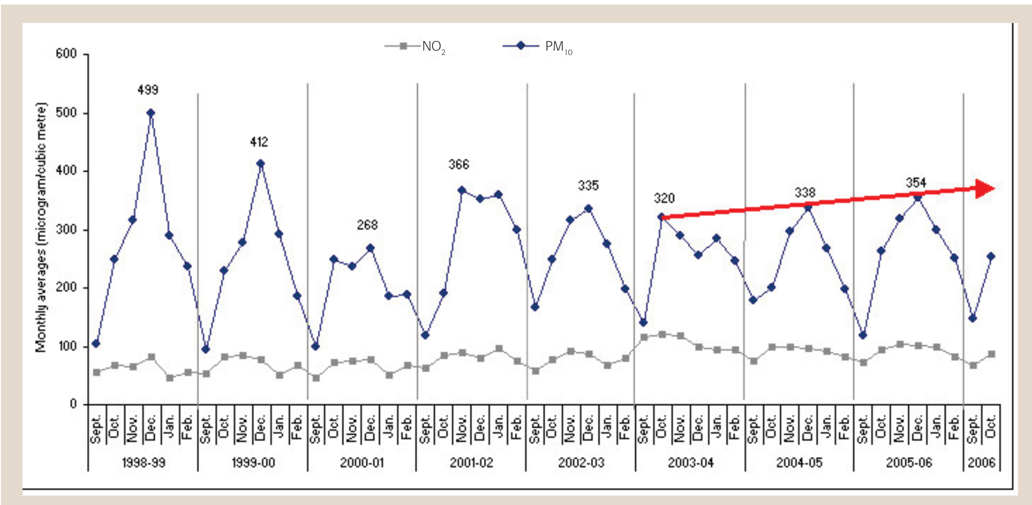


Figure 2.8: Trend of NO_x and PM in Delhi
Source: CSE, 2006

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

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

The stocks of low occupancy personal vehicles like 2-wheelers and cars are steadily increasing in South Asian cities and are contributing to increasing traffic congestions and air pollution. For example, in the past 30 years, total population of Delhi more than tripled, whereas the number of vehicles increased almost fifteen-fold (Bose et al., 2001).

In Thimphu, Bhutan, two-wheelers are estimated to have a share of 45% in total vehicle population, while cars and jeeps accounted for 35% and buses account for 2%. Traffic volume had increased by more than 100% during 1997-2003. 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 (NECS, 2006). In Nepal, there has been a three fold increase in vehicle population during 1989-2004 with the total vehicle stock being 472,795 in FY2004. Two wheelers account for the largest share in total vehicle population (i.e., 43% in 1989 and 63% in 2004). In Pakistan the number of vehicles has increased from 0.8 million to 4 million during 1984-2004 showing an overall increase of more than 400% (PEPA, 2005).

Road transport vehicles are the major contributors of 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; e.g., in the Kathmandu Valley, vehicular emissions are reported to be responsible for 38% of the total PM_{10} emission in the Valley (ICIMOD, 2007). A World Bank study on the Kathmandu Valley shows that particulate matters (PM_{10}) from vehicle exhaust 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 increase the pollution load further 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 for 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 supply. Mostly, biomass is used for 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, 2006c).

Table 2.4 shows that the burning of crop residues is relatively high in South Asia (when compared to the total residues burning in Asia as a whole. The data in the table indicate that the use of biomass burning, especially crop residues, could be one of the major sources of VOCs in rural region of South Asian countries.

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
Sri Lanka	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 air pollutants in both urban and rural areas in South Asian countries. Sound scientific studies and database on the sources of emission and 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 ambient air quality standards (see Table 2.5)[4]. 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-III in its 11 metropolitan cities and Euro II in the rest of the country[5]. Several countries have also adopted standards on quality of diesel in terms of allowable limit on sulfur content (which vary from 0.05 to 1% across countries of the region) (see Table 2.6).

While some regulatory frameworks (e.g., standards) are 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 Pakistan, which has started levying emission charges to the industries after amending the National Environmental Quality Standards (NEQS) in 2000 (PEPA, 2001). 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.

[4] Bhutan follows the USEPA and WHO guidelines in the absence of its own standards for ambient air quality. The country has developed its own Industrial Emission Standards in 2004 (CAI, 2006 and NECS, 2006).

[5] The rest of the country would implement Euro III by 2010 (See Society of Indian Automobile Manufacturers Website: http://www.siamindia.com/scripts/technicalregulations.aspx).

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

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
	year	40	100	40	100			40	60
Ozone	1 hour	-	240	-	280	200	-		
	8 hours	120	160	120		-	-		
	1 year	-	-	-		-	-		
Sulfur Dioxide	10 mins	-	-	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: CAI–Asia, 2007,
** Data for Iran is extracted from Aziz (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, # Hastaie, 2000*

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 the monitoring mainly include insufficient monitoring stations to have an adequate geographical coverage, lack of monitoring of all major pollutants and lack of regular monitoring. In India, particulate matters, SO_2 and NO_x are monitored regularly (MoEF, 2006). In most other countries, it is only the particulate matters that are monitored regularly in few places.

Chapter III | International agreements and approaches for control and prevention of transboundary air pollution

3.1 Introduction

In the environmental economics and management literature, the approaches for environmental management are categorized as follows: I) command and control approaches, 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 those based on command and control, market or economic instruments, and voluntary actions) adopted by various countries to attain their emission reduction targets.

3.2 Major treaties, protocols and acts

International/regional treaties on trans-boundary air pollution lead to formulation of protocols to reduce specific transboundary pollutants over specific time period. These protocols are ratified by member countries/states. Some major 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). The Convention was adopted in 1979 in Geneva and entered into force in 1983. Up to now it has 51 parties (members) and it has been extended by eight protocols that identify specific measures to be taken by parties to the Convention to cut their emissions of air pollutants (UNECE, 2007a). The following are the protocols:

I) The 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Entered into force in 2005)

II) The 1998 Protocol on Persistent Organic Pollutants (POPs) (Entered into force in 2003)

III) The 1998 Protocol on Heavy Metals (Entered into force in 2003)

IV) The 1994 Protocol on Further Reduction of Sulfur Emissions (Entered into force in 1998)

V) The 1991 Protocol concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes (Entered into force in 1997).

VI) The 1988 Protocol concerning the Control of Nitrogen Oxides or their Transboundary Fluxes (Entered into force in 1991)

VII) The 1985 Protocol on the Reduction of Sulfur Emissions or their Transboundary Fluxes by at least 30% (Entered into force in 1987)

VIII) The 1984 Protocol on Long-term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) (Entered into force in 1988)

The Convention was the first international legally binding instrument to deal with problems of air pollution on a broad regional basis in Europe. 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 combat transboundary air pollutions in the region. The approach of the protocols adopted by the convention is either on the basis of stabilization of ambient level of emission in critical level[6], or on the effect based on critical load concept[7]. The protocols on SO_2, NO_x, VOCs and NH_3 are discussed next.

3.2.1.1 PROTOCOLS ON SO_2 EMISSION REDUCTION

Helsinki Protocol

Signed in Helsinki in 1985, this protocol required to reduce sulfur emissions by at least 30% between 1980 and 1993 (UNECE, 2007b). This was the first sulfur protocol under the Convention on Long-Range Transboundary Air Pollution (CLRTAP). The protocol was able to have an average reduction of 46 % among the signatories[8]. Many western European signatories had achieved higher reduction than that. The reduction of sulfur emissions resulted in the reduction of ambient sulfur dioxide concentration by 40-60 % in most places in the Western Europe.

The Oslo Protocol

This protocol was the second protocol on the reduction of sulfur emission, which was signed in 1994 in Oslo and came into force in 1998. It required further reductions on sulfur emission and stipulated most western European countries to reduce their sulfur emissions by 70 to 80% by the year 2000, while eastern European nations have reduction targets of typically between 40 to 50 % (from the 1980 levels) (UNECE, 2007c).

The protocol was based on the effects-based approach using the critical load concept, best available technologies, energy savings and application of economic instruments. An effects-based approach aims at gradually attaining critical loads, sets long-term targets for reductions in sulfur emissions as it has been recognized that critical loads will not be reached in one single step (UNECE, 2007c). Further, the protocol had explicitly mentioned about the possible use of best available technologies and economic instruments for meeting the sulfur emission obligation by the signatories.

3.2.1.2 PROTOCOLS ON NO_x EMISSION REDUCTION

The Sofia Protocol

It was signed in 1988 in Sofia (Bulgaria) (UNECE, 2007d). The Sofia Protocol requires all signatories (which include European countries and United States) to ensure

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[6] *"Critical levels" means the concentration of pollutants in the atmosphere above which direct adverse effects on receptors, such as human beings, plants, ecosystems or materials, may occur, according to available knowledge.*

[7] *"Critical load" means a quantitative estimate of the exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to available knowledge.*

[8] *members who had ratified the protocol.*

that their NO_x emissions as from 1994 do not exceed their 1987 levels[9]. The protocol had also stipulated several NO_x reduction technological options (UNECE, 2007d). A reduction in NO_x emission of 9% from the cumulative emission in year 1987 of all the signatories was achieved. Nineteen of the 25 signatories to the NO_x Protocol had 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

The Geneva Protocol

It was the first protocol adopted by the CLRTAP to control emissions of volatile organic compounds (VOCs), the second major air pollutant responsible for the formation of the ground level ozone. It was signed in Geneva in 1991 and came into force in 1997. It stipulates three ways of choosing emission reduction targets (UNECE, 2007e). They were targeted to achieve 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 a base year lying 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 Slovakia.

II) The same amount of reduction as in (I) as aforementioned within the Tropospheric Ozone Management Area (TOMA)[10]. The party can choose any base year emission level corresponding to a year during 1984-1990. However, it has to ensure that by 1999 total national emissions do not exceed the 1988 emission levels. (TOMAs in Norway chose base year as 1989 and Canada chose base year as 1988).

III) If the total VOC emission in 1988 is lower than 500,000 tonnes, and 20 kg/inhabitant and 5 tonnes/km^2, the parties are to ensure stabilization at that emission level by year 1999. (This has been chosen by Bulgaria, Greece, and Hungary) (UNECE, 2007e).

3.2.1.4 PROTOCOLS DEALING WITH MULTI-POLLUTANTS

The 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

[9] *Except United States which chose 1978 as the reference year.*

[10] *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*

acidification, eutrophication, and ground-level ozone and targets emission reductions of four pollutants, namely sulfur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOCs), and ammonia (NH_3). The protocol was adopted 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, 2007f). The protocol sets binding emission ceilings on emissions of the four air pollutants to be achieved by 2010. It also prescribed the application of emission and fuel standards (UNECE, 2007f).

3.2.2 EUROPEAN COMMISSION NATIONAL EMISSION CEILINGS DIRECTIVE (2001/81/EC)

This is a directive issued by the European Commission for limiting the emission of SO_2, NO_x, NH_3 and VOCs. The directive enforces the Gothenburg Protocol with more stringent national ceilings than that of the protocol (European Parliament and the Council of the European Union, 2001). The directive came into force on 27 November 2001. With accession of new member states in the European Union, the directive was amended in 2003 and issued to the member states. 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 latest by 2010 (European Parliament and the Council of the European Union, 2003). The directive has issued interim environmental objectives, which aims to reduce the acidification and ground level ozone formulation effect of these pollutants by three different ways, which utilize either the control of all pollutants or achieve a level of ground level ozone not exceeding the ozone level of health based standard or vegetation standard. The EC-Directives issued in 2003 are discussed next.

• 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 health[11] is to be reduced by two-thirds in all grid cells[12] 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 vegetation[13] is to be reduced by one-third in all grid cells compared to that of 1990. In addition, the ground-level ozone load is not to exceed an absolute limit of 10 ppm.h, expressed as an exeedence of the critical level of 3 ppm.h in any area.

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)

[11] *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.*

[12] *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)*

[13] *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;*

For compliance of the EC Directive (2001/81/EC), the member states are allowed to decide on the measures to adopt for compliance. For example, in Denmark, the government has set an annual sectoral SO_2 emission limit for power plants with a capacity of 25 MW or larger. There is a consortium of two power companies, which decides how to allocate the SO_2 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 SO_2 was the largest contributor to acid rain and that the electricity sector accounted for two-thirds of the SO_2 emissions. Therefore, the US approach had a major focus on SO_2 emissions reduction from the electricity sector, while the reduction of NO_x was also targeted but it was programmed with different approach than SO_2 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 instruments like sulfur emission allowance and emission trading to control sulfur emission and has stipulated rate based emission standards for NO_x emission.

In fact, the US effort on limiting SO_2 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 SO_2. 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 on 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 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 SO_2 emission per million Btu of fuel burned. However, many states would not be able to comply with the standard by the deadlines specified in the Act. In 1977, the US congress again amended the Act with extended deadline until 1982, and required the 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 SO_2 emission rate below 1.2 lb per million

Btu with 90% removal of potential SO_2 emission or at SO_2 emission rate below 0.6 lb per million Btu with 70% removal of potential SO_2 emission (Ellerman et al., 2000).

3.3 Approaches for controlling and preventing transboundary air pollution

There are different types of approaches and measures to control and prevent TAPs. The approaches may be based on command and control, market or economic instruments, or voluntary actions.

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 SO_2/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.

SO_2 emission standard in the US and Europe

The United States imposed an emission standard for new plants as 1.2 lb of SO_2 per million Btu of fuel burned in 1970s. Later, two alternative emission standards were imposed for new coal-fired plants built after 1978. The plants could:

a) either operate at SO_2 emission rate less than 1.2 lb per million Btu with 90% SO_2 removal of potential SO_2 emission;
b) or operate at SO_2 emission rate less than 0.6 per million Btu with 70% SO_2 removal of potential SO_2 emission.

Later these emission rates were extended to existing coal-fired power plants (through Title IV of Clean Air Act 1990). 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. However, high cost of operation was reported for the power plants using coal with low sulfur content as compared to the plants using high sulfur coal (Ellerman et al., 2000).

In Europe, the Integrated Pollution Prevention and Control (IPPC) Directive of the EU required each member states to issue emission permits or technical measures based on the best available technology (BAT) (European Parliament and the Council of the European Union, 2008).

While the practice of technology based standards with fuel taxes is also available, according to Peszko and Lenain (2001), 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 (MBIs) (also called economic instruments) can include direct instruments, e.g., emission charge (based on the level of emission), and emission permits (with or without emission trading) as well as indirect instruments such as environmental tax (e.g., sulfur tax based on sulfur content of the fuel), fuel tax (e.g., gasoline tax) and energy tax (i.e., tax per unit of heat content) and subsidy on cleaner fuel or efficient technologies. These market based instruments are discussed in the following sections.

3.3.2.1 EMISSION CHARGE

An emission charge is a fee or tax per unit of pollutant emission and is based on the polluters' pay principle. The charge is levied on the level of pollutant emitted. It requires the regulator to monitor emissions. However, fixing a charge has been mostly a debated issue as this has direct implication for the emission abatement cost for a firm as the firm may reduce emission to the point where its marginal abatement cost is equal to the charge or tax rate (Stavins, 2003). Theoretically, an economically efficient emission tax rate should be equal to the marginal benefits of cleanup at the efficient level of cleanup (Stavins, 2003, Tietenberg, 2003). In some cases, these taxes are used in conjunction with fines or non-compliance fees in order to comply with the maximum permitted emission level (so called "emission ceiling"). These fees are intended to provide incentive to reduce pollution to the permitted levels and therefore play a compliance function (Speck et al., 2000).

3.3.2.2 EMISSION CHARGES 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 20-30% of the NO_x emission and up to 90% of the VOC emission during an entire flight would occur during the landing and take-off cycle (LTO). The aircraft engine emission charge is expressed as a percentage of the regular landing fee and 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 for 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 on 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 emission reduction measures at the airport (Carlsson, 1999). Similar emissions-related charge scheme was applied at 10 Swedish airports in 1998 and in France in 2003. UK has introduced emission charges at two of its airports in 2004 and Germany is going to introduce it in 2008 (Fleuti, 2007; ECAC, 2005).

SO_2 and NO_x charges in European countries

In Poland, Czech Republic, Estonia, Latvia, Lithuania, and Slovakia, SO_2 and NO_x charges were introduced in conjunction with a permit system (SIEI, 2000). A base charge rate is applied to all pollution within the permitted level and a penalty rate is added for pollution above that level (the so-called non-compliance fee). Large point source polluters (combustion plants, heavy industry) are subject to these charges. The charges are intended to raise revenues and encourage cost-effective abatement below the permitted level. The fines, non-compliance fees, are intended to provide incentive to reduce pollution to permitted levels and play a compliance function. Such revenues are largely earmarked for expenditure through national and regional/local environmental funds (SIEI, 2000; Speck et al., 2000).

Denmark, Sweden, Italy and France also have emission tax on SO_2 and NO_x emission. However, the taxes vary from country to country. Emission taxes for SO_2 emission in Denmark, France, Italy and Sweden were Euro 2,700 per ton of Sulfur[14], 27.4 per ton of SO_2, 53.2 per ton of SO_2 and 3,470 per ton of Sulfur respectively (Speck et al., 2000). Emission taxes for NO_x in France, Italy and Sweden were Euro 22.9, 105, 4630 per ton of NO_x respectively (Speck et al., 2000). Norway has also introduced taxes on NO_x emission since January 2007.

Emission taxes as a pollution damage levy in Japan

In Japan, emission tax was charged to polluting firms in order to collect revenue to compensate the victims of designated diseases (NCEE, 2004). It was implemented under a framework of the Pollution-Related Health Damage Compensation and Prevention Law, which was established in 1973. Under the framework, areas having a certain level of pollution were designated as Class I and people living in the area for certain period of time and suffering with designated diseases were defined as air pollution victims. Eighty percent of the revenue was

[14] *1 ton Sulfur is equivalent to the 64/32 ton of SO_2.*

obtained by collecting pollution levies from polluting firms based on their emissions of sulfur oxides (SO_x) and the remaining 20% was collected from vehicle tax charged to polluting motor vehicles (Azora Foundation, 2005). Significant reduction in emissions was reportedly achieved. However, it was not clear how much reduction was due to the tax (NCEE, 2004).

Refund based tax system for NO_x and sulfur tax in Sweden

An innovative approach called "Refund Based Tax System" has been in practice in Sweden (SIEI, 2000; Roseveare, 2001; NCEE, 2004). The approach is not intended to raise revenue. It is designed to provide an incentive to the participants to reduce emissions. The system imposes tax on the emitting sources based on their emission and then redistributes the revenue so collected to the sources in proportion to their energy production.

A charge of 40 SEK/kg NO_x ($ 4.4/kg) has been imposed in Sweden since 1992. The charge is applied to large heat and power plants, which produce more than 25 GWh/yr (Roseveare, 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. That is, the plants, which produce more energy with less emission, would benefit more from this system. At the beginning of every year, large plants report their NO_x emission and energy production for the previous year to Swedish Environmental Protection Agency (SEPA). On the basis of these reports, SEPA calculates the total taxes and refund rate per unit of energy generated (MWh). SEPA has mentioned that the target has been achieved with significantly reduced emission per unit of produced energy in Sweden (Roseveare, 2001).

Since 1991, Sweden also has imposed the sulfur tax of 30 SEK/kg S ($ 3.3/kg S), which is applicable to fuel oils and coal having more than 0.1% sulfur. It is reported that a remarkable reduction (i.e., below the allowable limit) in the sulfur content of oil products was achieved due to the sulfur tax (Hammer and Lofgren, 2001).

3.3.2.3 FUEL AND ENVIRONMENTAL TAXES

Fuel and environmental taxes are indirect instruments that are based on the users pay principle, where the user of a polluting fuel pay a fee, which is either per unit use of the fuel or per unit output of the polluter's activity consuming the fuel (e.g., per unit electricity generation based on coal) (Blackman & Harrington, 2000). Historically, fuel taxes are the most used market mechanism internationally. These taxes are applied as an indirect tax charged on the polluting fuel so as to increase the prices of these fuel and the products or services using the polluting fuel. On the other hand, environmental taxes are either charged to the goods used as an input in polluting activity or products associated with pollution or content of polluting substance contained in the inputs. Other forms of indirect taxes are annual vehicle tax/registration tax, sales tax, scrappage tax, parking fees, city tolls, road pricing, congestion pricing etc. These affect the 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 AND ENVIRONMENTAL TAXES IN PRACTICE

In countries like Finland, Mexico and Australia fuel taxes are levied in the form of excise duty[15]. In Germany, eco-tax is levied along with excise duties. The eco-tax is similar to the environmental tax, which is intended to achieve an environmental effect. These taxes are intended to influence the consumption of scarce resources by changing the price that users have to pay. In Germany, eco-tax was introduced in 1999 as a part of its Environmental Tax Reform. It was designed to make energy and resource consumption more expensive, while lowering the cost of labor (Diefenbacher et al., 2006). The taxes raised the price of electricity by 2 Pfennigs[16]/kWh, price of mineral oil by 6 Pfennig/liter, price of heating oil by 4 Pfennig/liter and gas price by 0.32 Pfennig/liter. Labor costs were cut by reducing pension contributions. By the end of 2002, tax collected had a significant contribution in lowering the pension contributions. In addition, some of the eco-tax revenue, up to €150 million a year, was used to promote renewable energy (Diefenbacher et al., 2006). The level of eco-tax on fuel varies with sulfur content (IEA, 2002). In other European countries like in Finland, Belgium, Denmark, France, Norway, Portugal, Sweden, Switzerland and United Kingdom, differential fuel tax rates are applied according to the sulfur content of fuel with higher tax applied for fuels having higher sulfur content (SIEI, 2000). But it is unclear whether these taxes, as in the case of eco-tax in Germany, are utilized for an environmental objective other than revenue generation. In Finland there are special tax (environmental damage tax) systems as oil pollution fee on oil imports besides excise tax, (IEA, 2007) (Table 3.1).

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 either on the basis of the ambient air standard in the region or based on the necessity of reducing emissions from a reference level. These permits are also known as emission permits. If a source or firm reduces emission below the level required, the extra reduction is credited to the source. The credits so earned can be used by the same firm or another firm to comply with the emission allowance. As the cost of pollutant abatement may be

[15] *Excise duty is a form of tax applied on goods produced and sold within a particular region, country or state.*
[16] *2 Pfennigs is roughly equivalent to one Euro cent.*

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

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 (ET). The emission trading mechanism can result in a lower total cost of emission abatement by all the firms taken together than that under the Command and Control (CAC) approach.

3.3.2.6 EMISSION REDUCTION CREDIT AND EMISSION TRADING IN PRACTICE

SO_2 allowances trading in the United States

In the case of sulfur emission allowances trading mechanism in the US under its Acid Rain Program, emission permits are issued to the polluting sources. The emission permits have been based on the reduction requirement with reference to a baseline emission projection. In the trading program, some proportion of the surplus allowance is also auctioned to the public (USEPA, 2007a). Agencies lobbying for environment protection and other public ventures concerned on environmental conservation have been buying the credits (surplus allowances) in the auction. These credits could be retired physically[17] so that the emission is permanently reduced. In this case, it is observed that the cost to the society of emission reduction has been lowered (Tietenberg, 2003; Stavins, 2003).

[17] *Buyer of the credit terminates the allowances so that that allowance is neither traded nor transferred in the following year.*

SO_2 emission trading in Slovakia

In 2002, Slovakia started issuing the SO_2 emission permits (quotas) based on the combination of historical emissions, future plans and programs of power plants on an annual basis (EEA, 2005). It is applied to power plants with capacity above 50 MW, which represented about 90% of emissions in 1998. The country's Ministry of Environment decides an overall envelope of allowances on an annual basis. This overall allowance is then divided into district-wise allowances and a district may transfer the unused quota to other districts under certain circumstances. However, few such trades have been noted (EEA, 2005).

NO_x emission trading in the 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 government is regulating the electricity generation sector for NO_x emission as a part of national policy to comply with the EU Directive on National Emission Ceilings (NEC Directive) (VROM, 2007). 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 on emission (through permits) is issued as per the obligatory participant's commitment to monitor the emission adhering to the monitoring protocol[18]. The participant then needs to monitor, report and verify the emissions every year. These emissions are registered against emission permits. If the emissions registered are lower than the allowance, credits are issued accordingly by the Dutch Emission Authority (DEA, 2007). All participants are allocated an annually declining performance standard rate (PSR)[19] (which declines from NO_x emission of 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 for 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 in the US (originally they were developed for SO_2 emission trading in the US) (Stavins, 2003; Tietenberg, 2003). The mechanisms are as follows:

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. Thus, the emission

[18] Issued by Netherlands Emission Authority
[19] It is the standard rate at which NOx emission is allowed per unit of electricity generation

by new sources can be offset by using the emission reduction credits earned by the existing sources. It is also in practice in Netherlands for ammonia (Roseveare, 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. The mechanism is also in practice for NO_x and SO_2 emission in Netherlands and SO_2 emission in United Kingdom (Roseveare, 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 plantwide 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 the United States and Netherlands, certain proportion of total surplus allowances is allowed for banking (Tietenberg, 2003; Roseveare, 2001).

3.3.3 APPROACHES 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 the command and control approach, in Poland, there is a practice of publishing the names of top 80 worst national polluters. This has informally influenced firms to comply with the standard in the country (Peszko and Lenain, 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 widely used strategies for controlling air pollution is switching to the use of cleaner fuels. For example, use of low sulfur fuel has been widely adopted in several developed countries in Europe and North America. Switching to the use of cleaner fuel vehicles (like CNG and electric vehicles) are also examples of such strategies. 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 India and Pakistan, public passenger transport system has made a 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) in the form of Electric Trolley Buses were introduced in Kathmandu in 1975 with the support of the Chinese government. In early 1996, a group of private investors started a company with 7 EVs. Currently, there are over 600 electric three wheelers (called "Safa Tempos") plying on the streets of the Kathmandu valley and five EV manufacturers in the country. EVs in Nepal have almost no emission as electricity in the country is produced almost solely from hydro resources (CAI-Nepal, 2007). In cases where 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 additional charge or tax and the level of the charge depends upon the time of day, vehicle type etc. Such a system has been put into practice successfully in Singapore, Stockholm, Dubai and London. Though the main purpose of the congestion charge 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 vehicular operation by issuing license permits and banning the vehicles from operating in designated days of a week are some of the approaches used primarily for traffic management in practice, which also have potential to reduce air pollutant emissions. Some of the schemes in practice are as follows:

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 passing through a designated region based on the degree of congestion. The major focus of the charge was to reduce traffic congestion in the designated 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 km^2 in the heart of the capital. Certain vehicles, for example motorcycles, buses (having 9 or more seats), emergency vehicles like ambulances, fire engines, police vehicles and alternatively fuelled vehicles are exempted from the charge, while some users, for example, residents in the zone and the disabled, benefit with discounts (TFL, 2007).

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 charge varies each half-hour of a day and varies in the range of 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 (LTA, 2007a).

License Permits in Singapore

The License Permit policy is aimed at reducing the congestion related pollution from vehicles in designated time. A user is required to acquire a permit in order to run his/her vehicle. Vehicle Permits are used for regulating the vehicular operation.

In Singapore, a vehicle quota scheme (VQS) was introduced in 1990. Under the scheme, the government issues certain number of quota for new users as well as quota for renewing for the existing users for limiting the vehicles on road. The quota was called as Certificate of Entitlement (COE), which was required to operate the vehicles on road. The government issues the quota through a bidding process. 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. The bidding process was conducted twice a month (LTA, 2007a).

License Permits in Chile

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

Banning of vehicles from running in designated days in Mexico

In Mexico city, the city administration imposed a regulation in 1990 that banned running of cars on specific days, which was determined by the last digit of the license plate of cars. The regulation was called Hoy No Circula (known in English as "One Day without a Car"), It consisted of prohibiting the circulation of 20% of vehicles from Monday to Friday depending on the last digit of their license plates (Answer, 2008). Vehicles with certain ending numbers[20] on their license plates are not allowed to circulate on certain days in an attempt to cut down on pollution and traffic congestion. Initially the program had a good result in curbing air pollution

[20] *Corresponding digits for Monday is 5 or 6, 7 or 8 for Tuesday, 3 or 4 for Wednesday, 1 or 2 for Thursday and 9 or 0 for Friday (http://www.answers.com/topic/hoy-no-circula).*

in the city. However, later, it was reported to be controversial since it had resulted in many better-off households buying extra cars reducing the program's benefits; also, newer vehicles are exempt from complying with the program. This policy is considered as a failed attempt to anticipate behavior reactions in longer run (Tietenberg, 2003).

Banning of vehicles from running in designated days in China

The Mexican practice has been followed in China recently (Philly News, 2007). Cars with even-numbered license plates are ordered off roads on Fridays and Sundays, and vehicles with odd-numbered plates are banned on 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 based on the lesson learnt from the experience of Mexico City. In Mexico City during the initial phase, such program was a success, but after few years, it proved to be a mistake in that it led to an over investment in vehicles (Tietenberg, 2003).

3.3.6 CO-BENEFITS OF GREENHOUSE GAS EMISSION REDUCTION POLICIES AND TECHNOLOGIES

Several measures to abate greenhouse gas (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 often simultaneously emitted from the same sources. Any measure that modifies the activity level of a source also influences emissions of both local/regional air pollutants and greenhouse gases simultaneously. And the benefits in terms of reduction of local/regional pollutants resulting from a GHG emission reduction measure are attributed as co-benefits of the GHG mitigation measure. In this sense, promotion of renewable energy by using a Renewable Portfolio Standard (RPS) and implementing GHG reduction technologies are some of the practices, which not only help reduce GHH emissions but also reduce local/regional pollutant emissions. The policy of RPS and some GHG reduction technologies are discussed next.

3.3.6.1 RENEWABLE PORTFOLIO STANDARD POLICY

Electricity from renewable energy sources is being promoted in several European countries through a wide array of instruments (feed-in tariffs, tradable green certificates (TGCs), bidding/tendering schemes, investment subsidies, fiscal/financial and green pricing schemes) (Rio, 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 CO_2 emission from electricity generation sector, it has co-benefits in terms of reduced fossil fuel consumption. In cases, where coal use is reduced as a result of such policy, there can also be a reduction in sulfur emissions.

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 several pollutant emissions. Thus, measures aimed at the reduction of one pollutant may lead to reductions of other pollutants, e.g. efficiency improvement of coal fired power plants would not only reduce coal use and GHG emission but they also simultaneously reduce sulfur emissions too. It is, however, also possible for some pollutants to increase with the implementation of controlling measures, e.g., use of SO_2 scrubber reduce SO_2 emission but it may increase fuel consumption and 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 NH_3 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 CO_2 emissions, could reduce NO_x emissions at the same time. Selective catalytic reduction (SCR) on gas boilers reduces not only NO_x, but also N_2O, CO and CH_4. The three-way catalysts on cars reduce emissions of NO_x, CO and CH_4. Regular inspection and maintenance programs on oil and gas production and distribution facilities would reduce losses of CH_4 and other VOCs (EEA, 2004).

Some technologies in controlling air pollutants might increase the emission of other pollutants. Desulfurization techniques involving $CaCO_3$ increase CO_2 emissions, and catalysts that are used to reduce NO_x, VOC and CO emissions from vehicles tend to cause higher N_2O and NH_3 emissions. In general, emission control measures, which increase energy consumption (e.g. scrubber mechanism reducing SO_2 or NO_x from flue gases) would also increase some greenhouse gases emissions.

Chapter IV | Good practices on prevention and control of transboundary air pollution

4.1 Introduction

According to the United Nations Development Programme (UNDP), good practices are defined 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 good practices are those practices that have succeeded in achieving the target and these may be transferable in part, or as a whole, to other regions/ countries (ADB, 2006c). Transfer of good practices to other countries/regions requires consideration adaptation or modification as the success of a particular practice depends the country/region specific factors and conditions which varies widely among different countries/regions. Some good practices may not be transferable at all and often it is difficult to know impacts of some good practices over time (ADB, 2006c). However, important lessons can be learnt from the study of the good 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 giving brief references to the actual examples of their applications. In this chapter, more detailed descriptions of the successful practices under different approaches are presented. The good 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 the public passenger transport system to the use of compressed natural gas (CNG) in New Delhi and environmental measures, NO_x tax system in Norway, solar water heater systems in Asian countries, vertical shaft brick kiln in Asian countries, alternative fuel vehicle promotion in Kathmandu Valley and the Ozone Transport Commission (OTC) NO_x Budget Program in Eastern States of the US.

4.2 NO_x 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 generating utilities
Implemented by	:	Swedish Environmental Protection Agency (SEPA)

Description

In 1990, the 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 based on measurements. However, the charge is redistributed among the plants in the proportion of energy production by these plants. So, the NO_x charge is not taken as tax (IISD, 1994). In this system, a plant that produces more energy per unit of emission benefits more. 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 the firms (i.e., liable operations) in the same proportion as their 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 redistribution of tax collected among the participants based on their rate of energy production implies that the plants that produce more energy with less emission will benefit more from this system.

Since 1992, large combustion plants are subject 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. In 2001, around 400 units were covered by the charge (Roseveare, 2001). It was 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) was deducted from the pay-out (IISD, 1994).

Smaller combustion plants are not liable because of the higher relative cost of continuously measuring the emissions (IISD, 1994). Most of the liable combustion plants are involved in energy production, that is, plants producing heat and power. Besides, industrial firms like the pulp and paper, chemical and metal industries that have combustion plants for energy production and waste incineration plants producing energy are similarly liable to the charge.

The unique feature of the system is the refund system, which was necessary in order to achieve a fair system. The competition between small (non-liable) 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 its acceptance. A positive side effect is that the less polluting plants are favored 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 the flexibility on choosing the technology type, the number of NO_x emission reduction technologies after implementation of such system is observed to have significantly increased.

Major Activities

The utilities (or liable operations) are not forced to adopt any specific technology for NO_x reduction. They are left on their own to choose the most cost effective NO_x reduction technology.

Impact on Air Pollution

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

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

• The number of combustion plants with NO_x-reduction technologies increased by a factor of about 16 between 1982 and 1994. A sharp increase is noted after the introduction of the charge scheme, and further installations are planned (IISD, 1994).

• SEPA has noted that NO_x emissions 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 40 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 (SO_2) 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 (World Bank, 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 (EIA, 2007b). 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) related pollution (World Bank, 2003). The combustion sources include small domestic stoves as well as large industrial plants and power plants. The major sources of SO_2 emissions are facilities burning fossil fuels, 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. Most of the major cities in China are heavily polluted by SO_2 and PM emissions (Yi et al., 2007). In 2006, acid rain affected about 32.6% (occurrence of acid rain over 5%) and 15.4% (occurrence[21] of acid rain over 25%) of the total land in China (SEPA, 2006).

The "Two Control Zone (TCZ)" Plan, as the name suggests, classified two control zones, of which the 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 km^2 of area and were responsible for two-third of sulfur emission of the country (World Bank, 2003). Closing of mines producing high-sulfur coal, limiting the sulfur content of coal in use and emission control in power plants and large industries were the measures taken to control the sulfur pollution. Most major cities in China were required to comply with the SO_2 pollution requirement and SO_2 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 a policy has been put into practice for the first time in developing countries (World Bank, 2003).

Major Activities

• Gradual phasing out of mining of coal containing 3% or more sulfur

• Prohibition of construction of coal fired power stations (except coal fired cogeneration plants with primary purpose of supplying heat for household use) inside large and medium-sized cities and surrounding suburbs.

• Mandatory use of coal with sulfur content not exceeding 1% in new and renovated old coal fired power stations

• Requirement to adapt SO_2 reduction measures including installation of flue gas desulfurization by the existing coal fired power plants using coal more than 1% sulfur content.

• Implementation of sulfur emission charges by major sulfur emitters.

Impact on Air Pollution

SEPA (2002, 2004 and 2005) has reported significant reduction in SO_2 emission during 1998-2005.

[21] *Frequency of incidence of acid rain.*

In the Sulfur Dioxide Pollution Control Zone, the major achievement was 12.3% point increase in cities meeting Grade II and 16.5 % point decrease in the cities not meeting Grade III standard in terms of SO_2 annual average concentration. The cities meeting Grade III 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 SO_2 annual average concentration and 3.3% point increase in the cities witnessing annual SO_2 average concentration meeting Grade II[22] quality standard. The cities reaching Grade III was increased by 7.9 % point

Table 4.1: Percentage of cities in Two Control Zones meeting SO_2 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, 2004 and 2005)

[22] *The grades are defined as follows. Grade I: This grade is set as the standard in natural conservation, resort, or tourist areas, and in those with historic monuments (SO_2 <0.02mg/m^3); Grade II: This grade is set as the standard in areas that are urban residential, commercial/residential, cultural, or rural (0.02 mg/m^3 < SO_2 < .06 mg/m^3); and Grade III. This grade is set as a standard in interim administrative measure for environmental management in industrial districts and traffic centers (0.06 mg/m^3 < SO_2 < 0.1 mg/m^3) (SEPA, 2004 and 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_2 and NO_x
Year of Introduction	:	Since 1990
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

The main purpose of Acid Rain Program in the US was to reduce the adverse effects of acid deposition by reducing its key precursor pollutants SO_2 and NO_x. The program is a market based approach to control the SO_2 and NO_x emissions and was created by the US Government in 1990 through the Title IV of Clean Air Act Amendment 1990. However, controlling SO_2 emissions through the Clean Air Act Amendments (CAAA) could be traced back in 1970s; for the first time, the CAAA in 1970 had established national maximum standards for ambient concentrations of SO_2, CO, NO_2, particulates, ozone and lead. While the CCAA of 1970 are largely based on the command and control approach, CAAA in 1990 has introduced market based, cap and trade approach and has also targeted NO_x reduction.

SO_2 Reduction

Title IV of the Clean Air Act has set a goal of reducing annual SO_2 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. Additional 182 units joined Phase I of the program as substitution or compensating units[23] in 1997, 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, high emitting plants and also set restrictions on smaller, cleaner coal, oil, and gas fired plants fired by, encompassing over 2,000 units in all. The program affects existing utility units with an output capacity of greater than 25 megawatts and all new utility units.

[23] During Phase I of the of the Acid Rain Program, a unit not originally affected until Phase II may elect to enter the program early as a substitution unit or a compensating unit to help fulfill the compliance obligations for one of the 263 units initially targeted by Phase I. A unit brought into Phase I as a substitution unit can assist one of these 263 units in meeting its emissions reductions obligations. Utilities may make cost-effective emissions reductions at the substitution unit instead of at the initially targeted unit, achieving the same overall emissions reductions that would have occurred without the participation of the substitution unit (USEPA, 1998).

The program is an innovative cap and trade approach, in which a permanent cap is allocated on the total amount of SO_2 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, 2007a). Currently, one allowance provides a regulated unit a limited authorization to emit one ton of SO_2. The total allowances allocated for each year equal the SO_2 emission cap.

SO_2 Allowance Trading Mechanism

Reductions in SO_2 emissions are facilitated through a market-based system for capping and trading—the centerpiece of US EPA's Acid Rain Program (USEPA, 2007a). 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 amount allowed (according to the allowances they hold) may trade the surplus allowances with other units in their system, sell them to other utilities in the open market or through EPA auctions, or bank them to cover emissions in future years (USEPA, 2007a).

The USEPA holds an annual auction of SO_2 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, 2007b). The allowances are awarded to the highest bidder. Typically environmental groups[24] 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 SO_2 allowances is provided as the Conservation and Renewable Energy Reserve (CRER). Utilities could apply for these allowances if they have employed efficiency or renewable energy measures to produce early emission reductions before their generating became subject to the Acid Rain Program (USEPA, 2007a).

NO_x Reduction

The Clean Air Act Amendment 1990 had also set a target to reduce 2 million tons of NO_x emission below the 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 SO_2 emission

[24] 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)

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 SO_2 emission reduction program, but it does not "cap" NO_x emissions as the SO_2 program does, nor does it utilize an allowance trading system.

Emission limitations for the NO_x boilers provide flexibility to for the electric 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 of the emission limitations are provided:

- 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 was applied to two types of boilers (which were already targeted for Phase I SO_2 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. It
- 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).

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: USEPA (2007a), USEPA (2005) and USEPA (2004)

The Acid Rain Program is flexible in allowing a utility to select its own methods of emission control for SO_2 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).

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 SO_2, NO_x, and CO_2, as well as volumetric flow and opacity. A continuous emission monitoring (CEM) system is used for this purpose (USEPA, 2007c). 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 emissions 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 SO_2.

Major Activities

With the implementation of the Acid Rain Program, utilities have adapted one or more options that include blending low-sulfur coal, installing SO_2 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 was also an increased use of efficient advanced combined cycle generation units using natural gas as the fuel source.

Impact on Air Pollution Scene

The program had made the following achievements by the end of Year 2005 (USEPA, 2007a):

SO_2 emission was reduced by more than 5.5 million tons from the 1990 level and by more than 7 million tons from the 1980 level; these figures were about 35% and 41% of the total power sector emissions in 1990 and 1980 respectively (USEPA, 2005).

Similarly, the program was able to reduce NO_x emissions by 3 million tons from the 1990 level. The NO_x emissions in 2005 were less than half the level anticipated in the absence of the Acid Rain program (USEPA, 2005).

The program led to the initiation of the following other emission reduction policy programs in 2005:

- Clean Air Interstate Rule (CAIR) to address transport of fine particles and ozone in eastern United States,
- the Clean Air Visibility Rule (CAVR) to improve visibility in national parks and wilderness areas, and
- the Clean Air Mercury Rule (CAMR) to reduce mercury emission from power plants.

4.5 Urban Transportation Planning and 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_2, 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

A major source of air pollution in most of the countries is the vehicular emissions. As such, reduction of vehicular emission has been a major issue. Exhaust emissions from vehicles are controlled in many countries utilizing technological options. However, the control of air pollution using the traditional command and control policies that curtail travel demand has been a difficult task, though it has been tried in several countries (Dhakal, 2003). The transport policies of Singapore provide good examples of the government authority being able to limit the air pollution by limiting private vehicle growth with a series of demand management measures (Chin, 1996), while sustaining rapid economic growth for over four decades (Willoughby, 2001). Though the initial purpose of the transport demand management measures was the reduction of the growing traffic congestion thereby reducing the travel time and not reduction of environmental pollution but the secondary effect of the policies 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. For example, the 24-hr average air quality of Singapore is found to be within the acceptable limit of the USEPA Annual Mean Ambient Air Quality Standard for the pollutants SO_2, NO_x, Carbon Monoxide, Ozone and PM_{10} measured (National Environmental Agency, 2007).

Since its independence in 1967, the approaches taken by Singapore for transportation management were a mix of command-and-control policies initially and market-based-instruments later on. The policies were effective in managing the traffic congestion and also the related environmental problems. A series of the policies was introduced in order to curb the travel demand in the past. Also there were quick enforcements of the revised policies after sensing the undesired impact of policy, which has resulted better later. It is argued that the policy was largely focused on limiting the vehicle ownership rather than maximum utilization of the transport infrastructure and pointed out the disadvantage of the policy instrument as it could lead to under-utilization of the road infrastructure because of the high tax rate (Willoughby, 2001). 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 in policy from that targeted to limiting the vehicle ownership limiting to the one focused on higher usage of road infrastructure.

Major Activities

The evolution of road transport management policy instruments and activities implemented in Singapore since its independence are listed chronologically as follows:

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

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 the 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, 2003). ARF/PARF proceeds were the largest single source of government revenue from the road transport sector in the 1980s. In addition to the registration fee of S$ 140, two tier system ARF is in place (LTA, 2007a):

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

The PARF has the following structure (LTA, 2007a):

Table 4.3: Preferential Additional Registration Fee (PARF) Structure

Age of Vehicle at De-registration	Graduated PARF Rebate (For cars registered with COEs[25] 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, 2007a

B) AREA LICENSE SCHEME (ALS)

It is a license required for a vehicle to enter a designated area. ALS was introduced for the first time in 1975. It involves a road tax charged to users on pay-as-you-use principle and required a license for 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

[25] Certificate of Entitlements

displayed and an observer was stationed in the entry posts (22 entry posts) 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 charge (which was approximately double the cost of commuting to work by car (Willoughby, 2001)), the car traffic volume in the peak morning hours fell beyond expectation, while the traffic volume was found to have 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[26] and goods vehicles[27] 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 week-days. Later in 1998, to overcome the difficulty in observing and recognizing the different types of license issued according to vehicle type, and in order to make the system efficient, the system was replaced by electronic road pricing (ERP).

C) VEHICLE QUOTA SCHEME (VQS)

Under the vehicle quota scheme, 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 one needs to buy the COE in closed bidding in an auction conducted quarterly initially (twice a month in later years). 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, 2007a). This lowest price offered is called the Quota Premium (QP) (Table 4.4). In the initial auctions, the Quota Premium was modest but later in 1994 it increased steadily and reached above S$ 27,000 for medium sized cars and above US$ 45,000 for larger cars (Willoughby, 2001). Prevailing quota premium (PQP) was also introduced so that vehicle owners could renew the COE

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	

Source: LTA, 2007b

[26] Car pooling is the shared use of a car by the driver and one or more passengers.
[27] Vehicles that carry goods.

for the next period. The PQP[28] was based on the monthly average of the QP for 3-months. In 2002, open bidding process replaced with the closed bidding process. In 2007, the bidding process was conducted twice a month (LTA, 2007b).

D) ELECTRONIC ROAD PRICING (ERP)

ERP is an electronic tax system, which replaced ALS in 1998. The ERP was in effect during 7.30 a.m. to 7.00 p.m. in all areas, which had been covered by ALS; it was also extended to few other expressways. The ERP scheme is similar to ALS but its enforcement is automatic and electronic equipments like sensors, cameras with short-range radio communication system are utilized to sense vehicle entries. Vehicles are equipped with an electronic In-vehicle Unit (IU), in which a general-purpose smart card (cash card) with positive cash balance is inserted. The toll applicable at the 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 a vehicle category. Charges are different for motorcycles, cars, good vehicles, taxies and buses. Half of the approximately US$125 million total cost of the ERP scheme was incurred in the fitting of IUs, provided free to the vehicles on first come first serve basis during the initial period of its implementation. Total cost per vehicle for the scheme was less than US$190 in the then existing fleet (Willoughby, 2001). Since February 2003, graduated ERP was implemented in order to avoid vehicles speeding up or slowing down to avoid paying higher ERP charges during few minutes before and after the restricted hours. The ERP varies every half-hour of a day and varies by type of vehicle and by time of day (e.g. peak and off-peak) (LTA, 2007b).

E) FLEXIBLE SCHEMES (OFF-PEAK CAR SCHEME)

The Off-Peak Car (OPC) Scheme was introduced on 1 October 1994 and replaced the Weekend Car Scheme. Under the Weekend Car Scheme, special permits were issued to cars allowing them to run during weekends only. 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. In 2007, an upfront rebate of S$17,000 was provided to be offset against COE Quota Premium and Additional Registration Fee (ARF) (LTA, 2007c). The rebate was used to offset against the COE premium payable first. If there was any surplus (unused) rebate after that, it was used to offset against the ARF payable. Also a flat discount of S$ 800 on annual road tax was provided, subject to a minimum road tax payment of $50 per year. Normal car was also allowed to be converted to Off-Peak Car

[28] PQP is the amount required to extend or renew the COE for a vehicle already in use. Unlike buying a new vehicle, one does not need to bid for COE when buying a used vehicle; instead, all you need to do is to pay the PQP and the COE will be extended or renewed. The COE may be renewed for a period of either 5 or 10 years. COEs which have been renewed for a period of 5 years are not eligible for another renewal and will have to be de-registered after they expire. Otherwise, there is no limit to the number of times for renewal.

after paying an additional fee of S$ 100 (LTA, 2007c).

In addition to the above policy instruments for demand management, the following were the other measures and approaches undertaken (Chin, 1996):

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

Impact on Air Pollution

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)[29]

	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

*Note: * Average of AM Peak (8am - 9am) and PM Peak (6pm - 7pm)*
Source: LTA, 2007a

The air quality of Singapore has been meeting the 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.

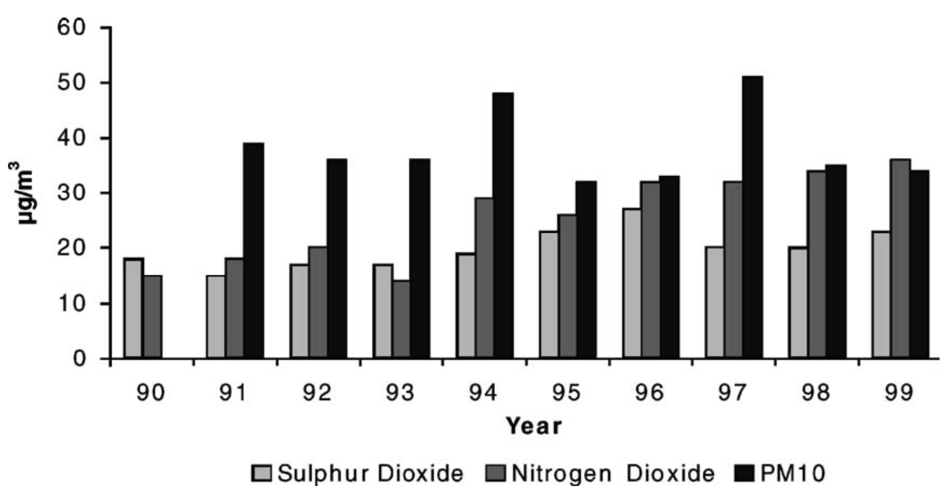


Figure 4.1: Annual average levels of sulfur dioxide, nitrogen oxide and PM_{10} in Singapore (Quaha et al., 2003)

[29] Downloaded on 26 July 2007

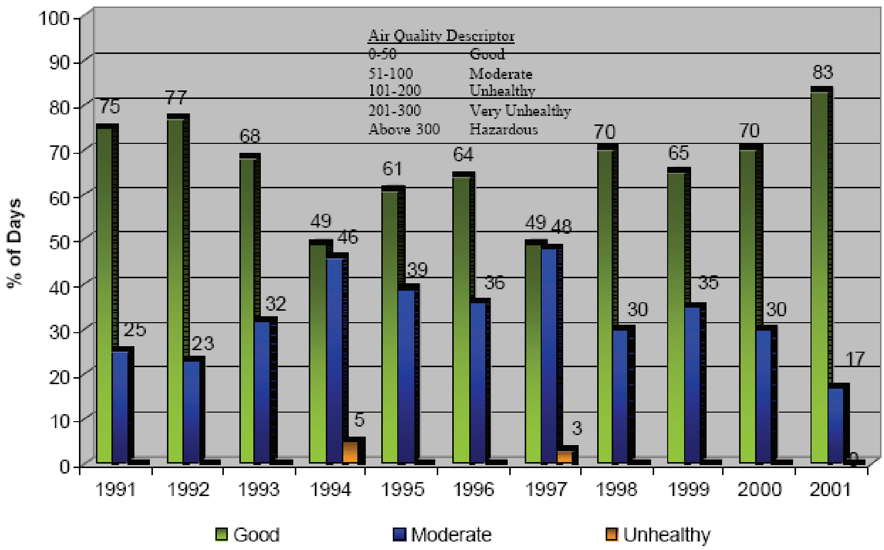


Figure 4.2: Annual average Pollutant Sub Index (PSI) in Singapore (Yong, 2002)

Table 4.6 presents the air quality data in Singapore as an illustration. It shows that air quality to be good all over Singapore.

Table 4.6: 24-hr PSI[30] at 4pm, 25 July 2007[31]

Region	24-hr Sub-Index at 4pm, 25 July 2007					PSI*	Air Quality Descriptor	Responsible Pollutant
	Sulfur Dioxide	PM_{10}	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: National Environmental Agency, 2007
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.*

[30] *PSI is Pollutant Sub Index based on highest indices in accordance with USEPA guidance*
[31] *Downloaded on 26 July 2007 (http://app.nea.gov.sg/psi/psi2mthv1.asp)*

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

Description

The transport sector is the major polluter in Delhi (DPCC, 2003). In response to a writ petition filed in 1985, the Supreme Court of India issued in 1998 directives to the Delhi Government to convert entire public transport system (comprising of auto rickshaws, taxies and buses) to use compressed natural gas (CNG) by March 31, 2001 . This was a historic decision in which the 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).

Measures to reduce vehicular pollution include the use of improved fuel quality (like low sulfur 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 considered as the one of the world's 10 most polluted cities (Mumbai Newsline, 1998). While the role played by other sectors can not be undermined, the ruling of Supreme Court

> 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.

of India played the major role. Moreover, the court was active in issuing a series of directives to the implementing agencies and in many occasions, it even criticized them for their slow responses with excuses of not having the necessary infrastructures available (UNEP, 2006). On July 28, 1998, 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 that the entire city bus fleet be converted to CNG with an objective to expand the city's public transport system as well as 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.

Delhi had the largest fleet of CNG buses in the world in 2005. There were 2,394 buses, over 27,000 autos and 14,000 other vehicles running on CNG by 2005. More than 146 fueling stations (till March 2006) have been established (IGL, 2006b).

Major Activities

The major activities conducted could be traced back to early 1990s. Major activities that led to the implementation of the historic court decision into reality include the following (Bell et al., 2003):

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 Delhi Transport Corporation (DTC) buses should be converted to CNG.

1995:

The SC ordered and agreed to a schedule to convert government cars to CNG or retrofitting of 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 for doing so. 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 gave directives for switching over of the entire public transport system (comprising of autos, taxies and buses) to the compressed natural gas (CNG/clean fuel mode) as per schedule specified by the court.

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 DTC[32] on a trial basis.

1999:

A committee was formed to devise the implementation plan of SC directives. CNG was made available at 9 dispensing stations in the capital.

[32] state owned transport company

The Motor Vehicles Act was amended to include CNG.

That all 7,500 DTC buses plying in the capital would be converted to CNG by March 31, 2001 – was announced. Further, 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 of the buses), 17,000 rickshaws, and 1,200 taxis -- which were all over 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 of Petroleum and Natural Gas 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 request 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 auto-rickshaws 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, 2006a).

Impact on Air Pollution

Improvement in air quality of Delhi in recent years is widely acknowledged. The 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 the average concentration of SO_2 is drastically reduced to the safe limit. Further, the concentration of NO_x meets the criteria of the annual average national standard value (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

SO_2							
Area	1998	1999	2000	2001	2002	2003	2004
Sarojini Nagara	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
NO_x							
Area	1998	1999	2000	2001	2002	2003	2004
Sarojini Nagara	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
Suspended Particulate Matter (SPM)							
Area	1998	1999	2000	2001	2002	2003	2004
Sarojini Nagara	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

b - Data from 1998-2003 is from Shahadra
All units are in yearly average µg/m³.

Annual Average National Ambient Air Quality Standard:
SO_2/NO_x – 80 µg/m³ for industrial and 60 µg/m³ for residential.
SPM – 360 µg/m³ for industrial and 140 µg/m³ for residential.

Source: CPCB, 2007b and 2007c

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 endorsed a tax policy on emission 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 from ships, fishing vessels, air traffic and diesel railways, and also engines, boilers and turbines in the manufacturing industries. The large units in these categories are applicable for the tax system. Large units are defined as units with capacity higher than 10 MW for boilers and 750 kW for propulsion engines. 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 (NPCA, 2008).

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 %)
NMVOC	294 875	196 345	195 000	1 000 tonnes (1 %)
Ammonia (NH_3)	20 375	22 610	23 000	Emission ceiling reached at the moment

Source: NPCA, 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) and the tax system is expected to help in meeting this obligation (NPCA, 2008).

Major Activities

ENVIRONMENTAL REGULATION

Under the Pollution Control Act, the regulation relating to the pollution control was introduced in 1981 (NPCA, 2007). The scope of the regulation covers emission of particulate matters ($PM_{2.5}$ and PM_{10}), nitrogen dioxide and nitrogen oxides, Sulfur dioxide, lead, benzene, carbon monoxide, arsenic, cadmium, nickel, benzo(a)pyrene (as a marker for polycyclic aromatic hydrocarbons) and mercury. The regulation considers only the locally-created contributions in determining whether a source contributes substantially to exceeding individual limit values (Table 4.9). Emission from road traffic is seen as a whole, regardless of who owns the roads. Similarly, contiguous port area with different owners is treated as once emission source. Furthermore, emissions from small heating plants as a whole are taken as one source.

The limit values for the concentration of outdoor air pollution for different 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 owners of smaller heating plans to comply with the regulation. Also they are given authority to order/issue directives to plant owners to comply with the regulation even when such plants do not contribute significantly to the concentration of the pollutant.

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 4.9: Maximum Allowable Limit on Concentration of pollutants in outdoor air and the date by which the limit value is 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/m³	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/m³	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/m³		4 October 2002
Nitrogen dioxide and oxides of nitrogen				
1. Hourly limit value for the protection of human health	1 hour	200 µg/m³ 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/m³ NO_2		1 January 2010
3. Annual limit value for the protection of vegetation	Calendar year	30 µg/m³ NO_x		4 October 2002
Particulate matter PM_{10}				
1. Daily limit value for the protection of human health	1 day (fixed)	50 µg/m³ 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/m³ 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 (PM_{10})	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)

Source: NPCA, 2007

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 cumulative installed engine rating of over 750 kW or motors, boilers and turbines with a total installed capacity of more than 10 MW. If the installed propulsion power rating exceeds 750 kW, NO_X emissions from other auxiliary machinery are also subject to tax in addition to the tax on the propulsion machinery (NMD, 2007). 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) based on the maximum rotations per minute (rpm) template if 'a' and 'b' are non-existent.

Application of (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') while (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 (c) requires documentations based on rotation speed recorded or main engine manufacturer's certificates (continuous onboard monitoring).

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

The policy has a provision to refund the tax based on the difference between emissions before and after the installation[33] of cleansing equipments, measuring equipments. In the absence of such information, the policy also has a provision to fix source specific emissions factors by competent authority[34] In such a case, the tax is calculated on the basis of source emission factors relevant to fuel consumption (DOCE, 2007)

Impact on Air Pollution

In 2007, Norwegian NO_x emissions were reduced by 8.7% as compared to 1990. In 2007, the total NO_x emission was about 190,000 tonnes. This was 0.6% lower than the NO_x emission in 2006 (NPCA, 2008). Emissions from the road transport, sea transport and fishing decreased, whereas the emissions from liquefied natural gas (LNG) plant and industries increased. The decrease in emissions from the road transport was mainly due to the requirements of exhaust gas purification, increasing share of petrol run cars with catalytic converters.

[33] There is restriction of such provision. Applicant has to agree to install cleansing or fixing source specific emission factor before 1 July 2007. In the case of measuring equipment installation, the applicant has to agree on the installation before 31 December 2007.
[34] It is an authority to determine the specific emission factors. (e.g., Norwegian Pollution Control Authority for land based activities; Civil Aviation Authority for aircraft; Norwegian Maritime Director for ships/vessels)

4.8 Solar Water Heater System (SHWS) Development and Promotion Policies

Country/Region	:	Several countries
Area of coverage	:	Several countries
Sectoral category	:	Energy
Type of approach	:	Policy/Technology
Pollutant Type	:	SO_2, NO_x, particulate matter
Year of introduction	:	1960s onward
Participants	:	Manufacturers, suppliers, industries, households

Description

It was estimated that around 10 million solar water heating systems (SWHs) were already installed in developing countries by 2001 (Refocus, 2005). Countries in Asia like China, India and Nepal are using solar energy significantly for water heating purpose. China's SWHs cumulative installations were over 60 million m^2 by the end of 2004, more than 70% of the total world market (Refocus, 2005). SWHs have provided hot water supply for more than 35 million families competing with water heating technology options fueled by electricity and natural gas. In India, over 500,000 m^2 solar collector area was already installed by 2000 (Refocus, 2004). Solar water heater (SWH) for domestic water heating purpose is one of the most successfully used water heating systems in Nepal (Bajracharya et. al, 2003). Over 308,000 m^2 of collector area was already installed in the country by 2004 (OGARTA and Himal Energy, 2004). Every year, over 2000 SWHs are installed in Nepal (Shrestha et. al, 2002). There are approximately 60,929 households using SWHs (approximately 16% of the total households) in the country, of which more than 80% live inside the Kathmandu Valley (OGARTA and Himal Energy, 2004). This shows that one SWH is installed in every 5 households inside the Kathmandu Valley.

Major Activities

Direct grants, subsidies are the most prevalent schemes, whereas tax incentives while importing SWHs and their components are other indirect schemes used for promoting SWHs the most countries using SWHs. Accelerated depreciation schemes for commercial and public applications are also other schemes used in few of the countries. In India deployment of a further one million SWHs is aimed for domestic use by 2012 (Refocus, 2004).

New constructions of government-owned housing in Namibia are not allowed to install water heaters other than SWHs (Refocus, 2004). In Mexico, rather than giving direct financial incentives, the policy is targeted towards creating an enabling environment with roundtable talks between the sellers and potential users and developing a virtual marketplace.

In Florida (USA), under the 'Solar Weatherization Program', low income households were given free SWHs to replace electrical water heaters so as to lower the share of the energy cost in their budget. The average cost of the SWH was around 1500 Euro. Each SWH saves on average 130 Euro of electricity bill per year. The programme is operated by local program agencies and other non-profit agencies in cooperation with local volunteer groups (Refocus, 2004).

Australia has policies to promote the use of SWH to reduce the electrical load under the Renewable Portfolio Standard, under which, all SWHs replacing electrical water heaters are allowed to have green certificates. These certificates are marketable. Electricity suppliers are obliged to purchase a certain share of electricity from renewable energy sources and they can buy these green certificates to meet their obligation. Typically, a SWH will receive between 10 and 35 certificates with an electricity equivalent of 1 MWh over its lifetime. The market value of one certificate is reported to be between 18 and 20 Euro. About one fourth of the issued green certificates in 2001 in Australia were from SWHs (Refocus, 2004).

SWHs in Barbados are supported through different mechanisms. The Fiscal Incentive Act of 1974, which made provisions for import preferences and tax holidays, 30% consumption tax on electric water heaters are some of the mechanisms that helped to make SWH competitive (Refocus, 2004).

In Nepal, the development of solar thermal conversion devices started in the early 1960's. After several improvements, an experimental SWH was installed in a school in 1975, which was the first unit installed for public use. With its market growth, a number of local manufacturers are involved into the commercial business. There are already more than 200 local manufacturers in such business (REDP/UNDP/AEPC, 2002). More manufacturers get into the business during the winter season (approx 4 months) when the sale of SWHs is high (OGARTA and Himal Energy, 2004).

Impact on Air Pollution

In the Indian northern state of Himachal Pradesh, every rural household uses 720 kg of firewood for heating water every winter and solar water heaters have been used in small villages to replace the demand for wood (Refocus, 2004). In Gujrat, daily consumption of firewood for water heating purpose in domestic use has been decreased by the use of SWHs. Each household previously used 5-7 kg of firewood per day for water heating. By replacing it with solar water heaters, households save the corresponding amount of firewood reducing carbon dioxide emissions (SPRERI, 2002). Solar energy is renewable and zero emission device, thus there is a strong possibility of earning carbon credits when it replaces fossil fuels generated electricity. It is estimated that the use of SWHs would save nearly 200 million kWh of electricity each year in Nepal (OGARTA and Himal Energy, 2004). SWHs could also reduce the consumption of fossil fuels like diesel and kerosene used in industrial boilers. In Nepal, it was estimated that the use of SWHs would reduce approximately 9,974 tCO_2 every year and significant amount of other pollutants would also be reduced (ASTED, 2006).

In China, solar-powered water heaters provided 7.2 million tons of coal equivalent (tce) of heat (calculated at 120 kgce per year/m^2 collector) in 2004, providing approximately 12% of China's renewable energy. The application of SWH in China is estimated to reduce around 12 million tons of CO_2 emission and associated other regional pollutants emissions in 2004 (Refocus, 2005).

The island of Barbados has over 35,000 solar water heaters installed and this is equivalent to about one in every three households (Refocus, 2004). Solar water heaters are also widely used in the hotel industry and each unit saves about 4,000kWh per year, which results in a cumulative electricity saving of 140 million kWh (i.e., equivalent of 227,000 barrels of oil) if use of diesel is considered to generate electricity in place of solar. A substantial quantity of emissions, such as carbon dioxide, Sulfur dioxide and the oxides of nitrogen are avoided with the use of SWHs (Refocus, 2004).

4.9 Vertical Shaft Brick Kiln Technology Promotion in Asia

Country/Region	:	South and South East Asia
Area of coverage	:	South and South East Asia
Sectoral category	:	Energy
Type of approach	:	Policy/Technology
Pollutant Type	:	SO_2, particulate matter
Year of introduction	:	1990s onward
Participants	:	Brick manufacturing industries, The Energy Resources Institute (TERI), SKAT, Swiss Agency for Development Cooperation (SDC), Center for Pollution Control Board (CPCB) of India and Ministry of Environment, Science and Technology of Nepal

Description

Vertical Shaft Brick Kiln (VSBK) technology is an energy efficient brick manufacturing technology originally developed in China. The design of the VSBK resembles to an intermittent updraft kiln with a unique method of continuous firing clay bricks (VSBK Nepal, 2007). The first version of VSBK originated from traditional updraft intermittent kilns in China during the 1960s. During the 1970s, this kiln became popular in several provinces of China and it was reported that there were more than 50,000 installations in China. Attempts to encourage the use of the VSBK technology outside of China started in early 1990s. The VSBK technology was promoted to several Asian countries such as India, Nepal, Afghanistan, Pakistan, Vietnam and Bangladesh (APEIS, 2003a).

Major Activities

INDIA

In India, the brick manufacturing is very labor-intensive, since bricks are usually hand-molded and sundried before firing in the kiln (APEIS, 2003a). The firing of the bricks is the mostly done in either Bulls' Trench Kilns (BTKs) or in clamps. BTKs are generally the choice of medium and large projects and account for about 70 % of the total production in the country, while clamps are often used in operations with smaller production capacities. Coal and biomass are used for firing the bricks in the kilns. Estimated coal consumption in the brick sector of the country is about 24 million tonnes per year (APEIS, 2003a). With such a large consumption of coal, the brick industry is the cause of significant air pollution in terms of suspended particulate matter (SPM).

The emission standard enforced by the Government of India in April 1996 limited stack emission to 1,000 mg/Nm^3 of emissions for small capacity kilns and 750 mg/Nm^3 for medium and larger kilns. The use of moving chimney BTKs were banned after June 2002. The various state pollution control boards are now enforcing the ban on this technology. While kilns with the higher production levels had the option to switch to fixed chimney type BTKs, small and medium capacity brick makers are required other options to meet the enforced standards on SPM emissions (APEIS, 2003a). The government regulations have therefore been a vital instrument that provided a framework for the adoption and dissemination of VSBK technology for small and medium brick makers in India.

With the support from Swiss Agency for Development and Cooperation (SDC), in the action research phase (1996-2000), VSBKs are introduced and demonstrated. Major activities carried out under the research phase included providing training, developing technology options to suit different regions of the country and conducting awareness seminars, and study tours. There were no government-supported demonstrations/ subsidies for the adoption of VSBK technology. In India there were 45 VSBK installations by 2004 and it was reported that the installations are over 100 by 2007 (SDC, 2008).

VIETNAM

In Vietnam, the VSBK technology was introduced under UNDP Project funded by the Small Grant Programme of the Global Environment Fund. The adoption of the new VSBK was growing rapidly all over the Vietnam. Approximately, around 200 VSBKs were already constructed in Vietnam by 2004 (Kim et. al, 2004). It is reported that over 300 VSBKs are constructed in Vietnam (SDC, 2008). Raising awareness among the local authorities on the possibility of air pollution reduction while retaining the livelihood of the brick-makers was one of the major achievements of the project. The project also made an effort to involve local policymakers from the beginning of the project. The national government had placed deadlines for the phase-out of the traditional brick kilns, which provided a push to find efficient technologies such as VSBKs to meet the needs of the very large number of small scale brick producers throughout the country. However, some VSBKs failed because of monetary losses incurred by them. This was due to the dissemination of wrong information about VSBKs and managerial problems.

NEPAL

In Nepal, joint efforts between the government and local entrepreneurs have boosted the development of VSBK technology. A strong lobby from local community resulted banning of BTK citing heavy air pollution in the nearby vicinity (Heierli and Maithel, 2008). For the first time VSBK was introduced in Nepal in 1992 as a demonstration project. SDC, through its VSBK Program executed by Skat consulting (Swiss Resources Centre and Consultancies for Development), has been providing technical support to interested entrepreneurs to install VSBK. Currently, over 10 VSBKs are in operation in the Kathmandu Valley (SDC, 2008). Establishment of VSBK Entrepreneurs Forum was one of the major achievements of the program. In the Second VSBK Entrepreneurs Workshop, the forum was established in order to address various issues related to VSBK technology. This forum had established a good network among all VSBK entrepreneurs (VSBK Nepal, 2007).

In Pakistan and Bangladesh, some pilot projects are ongoing in VSBK technology transfer.

Impact on Air Pollution

VSBK technology is environmentally friendly. SPM emissions from VSBKs are very low compared to the environmental requirements (80 to 250 mg/Nm^3 as against about 750 mg/Nm^3 for medium and large capacity BTKs and 1,000 mg/Nm^3 for small capacity BTKs). Apart from the obvious stack emissions, other fugitive emissions are also significantly lower.

For clamp type kilns, the comparison with VSBK is even more dramatic. These kilns generally do not have a stack for the dispersion of flue gases, which are usually let out into the surroundings. On a global level, the energy savings resulting from VSBK (20 to 50 %) would help considerably in reducing CO_2 emissions if the technology were adopted on a wide scale.

4.10 Alternative Fuel Vehicle Promotion in Kathmandu Valley[35]

Country/Region	:	Nepal/South-Asia
Area of coverage	:	Kathmandu Valley
Sectoral category	:	Energy
Type of approach	:	Policy/Technology
Pollutant type	:	SO_2, NO_x, particulate matter
Year of introduction	:	1995-2000
Participants	:	Donor supported (USAID/US-AEP) demonstration project, private investment, and government-provided facilitation and benefits

Description

Motor vehicles have been identified as the major source of air pollution in the Kathmandu Valley. A sudden surge of diesel-operated three-wheelers was observed during 1989-92. These vehicles emit a thick black smoke and were noisy. With the growing problem of air pollution and due to public outcry, the government put a ban on further registration of these vehicles in 1992 (APEIS, 2003b). Despite growing public awareness over air quality and pressure from NGOs and other civic groups, a ban on these vehicles from operating on the streets could not be enforced in the early days due to a number of local economic and political difficulties. Policy makers failed to create any incentive mechanism to motivate the owners to abandon their three-wheelers. In 1995, the prohibition of the use these vehicles on the street was put into effect. Then the combined effort of the government, the private sector and civil society (mainly NGOs and advocacy groups) produced synergy effects to promote and expand the use of battery-operated electric three-wheelers on a commercial basis in the valley, to fill the vacuum created by the restriction on diesel three-wheelers. These vehicles were promoted as zero-emission vehicle since over 90% of the electricity produced in Nepal is hydropower (Nepal Electricity Authority, 2006). Currently over 600 electric vehicles (popularly named as 'Safa[36]' tempo) are running inside the Kathmandu Valley.

Major Activities

The key activities behind the successful introduction of electric vehicles in the Kathmandu Valley are given below:

MAJOR INSTITUTIONAL EFFORTS

As a major institutional effort to improve environment, the government of Nepal set

[35] The material in this section draws heavily on RAPIDC (2008).
[36] 'Safa' in Nepali language means clean.

emission standards in 1994 and formed the Ministry of Environment in 1995. It passed the Environmental Protection Act 2056 in 1997. The ministry attempted in late 1998 to start the phase out of non-complying vehicles within two years and in early 1999 formulated a phase-out program in association with the Department of Transport Management and local municipalities, and in consultation with the private sector and NGO groups. Unfortunately, these efforts did not succeed.

PUBLIC PRESSURE AND CREATING AWARENESS ON THE ENVIRONMENT

The non-governmental sectors like the tourism, industry, cine-artists associations, local clubs, NGOs and civil society fueled the anti-diesel three-wheeler movement which peaked in 1995 (Dhakal, 2004). The movement led to street protests and road blockades against three-wheelers. Finally, the government provided an incentive for the owners to replace their diesel three-wheelers, in the form of a 75 % customs holiday on the import of 12- to 14-seater public transportation vehicles (Dhakal, 2004). Consequently, diesel three-wheelers were banned from operating in the valley, starting in July 1999.

DEMONSTRATION OF TECHNOLOGICAL AND ECONOMIC FEASIBILITY OF ELECTRIC THREE-WHEELERS

Initially, Global Resource Institute conducted a pilot project for the demonstration of the technological feasibility of an electric vehicle, which was converted from a diesel three-wheeler. By 1995, a total of eight electric three-wheelers had been designed and pilot-tested on one of the major routes in the valley for six months (Dhakal, 2004). This demonstration project, apart from designing vehicles, also created awareness of the new vehicles and encouraged their acceptance by the government, private sector and the public.

EMERGENCE OF A NEW INDUSTRY

The demonstration project showed that the battery-operated three-wheelers were technologically and economically feasible in the valley. As a result, the private sector was attracted to invest in this industry. Since then, the private sector has been the main impetus for the growth of the electric vehicles in Kathmandu. There were 600 safa tempos operating in Kathmandu, servicing 100,000 people daily in 17 routes and employ over 70 women drivers by 2004 (ADB, 2006a and Dhakal, 2004). There were also 37 charging stations. These safa tempos were assembled in Kathmandu using body and chassis parts from India and electronic parts and batteries from the other countries (e.g., United States). These vehicles can carry an average load of 12 persons and one set of batteries. The government has been providing tax incentives on vehicle parts importation and there were no fees for annual registration of electric vehicles (ADB, 2006a). The EV industry in the valley principally consists of three major groups: vehicle manufacturers, vehicle owners and charging station operators. Currently, there are about five major manufacturers, 38 battery-charging centers, and about 450 owners. Each charging centre owns about 5 to 10 vehicles, and individuals own the rest.

The demand for electric vehicles is likely to grow as an alternative to fossil-fuel based vehicles (Tiwari, 2007). The private sector has been interested in manufacturing four-wheeled electric vehicle with an alternating current drive system. Recently, five electric cars (REVA) were imported from India into the country through private organizations. Hulas Motors, the only automobile manufacturer in Nepal, came out with its first five to ten passenger electric van in 2007. Other local electric vehicle manufacturers are also working on four wheel and alternating current drive-based electric vehicles (Tiwari, 2007).

ROLE OF PRIVATE SECTOR ASSOCIATION

The Electric Vehicle Association of Nepal is an umbrella organization of the electric vehicle (EV) industry. It integrates the charging station operators' association, the manufacturers' association and the owners' association, and also represents the EV industry when dealing with the government, the media and the public.

DONORS' INTEREST

The support of foreign donors in promoting electric three-wheelers is also one of the important factors behind the growth of EVs in the valley. Two donors, the US Agency for International Development (USAID) and Danish International Development Agency (DANIDA), played instrumental roles: The USAID supported the demonstration programs and DANIDA provided support at the later stages. Since donors are influential in many of the governmental policies, such donor involvement helped to create a favourable response from Nepal's policy makers (Dhakal, 2004).

LOWER ELECTRICITY TARIFF AND TAX BENEFIT

The state-owned Nepal Electricity Authority provided electricity at low tariff (NRs 2.95-4.70/kWh for transport as compared to NRs 4 - 6.55/kWh for industries) for electricity use for battery charging in electric vehicles in 2006 (Nepal Electricity Authority, 2006). Since most of the electricity in Nepal is generated from run-of-the-river hydro power plants, the charging of batteries could use the surplus and unutilised energy during off-peak periods (i.e., night-time charging) at reduced tariffs. Indeed, electric vehicles provided a new market for the electric utility. The EV sector also enjoys benefits offered to manufacturing industries that deal with energy efficiency, energy conservation and pollution abatement as announced by the Industrial Enterprises Act 2049 (Article 15e). Under this, they are entitled up to a 50% discount from taxable income for a period of seven years.

Impact on Air Pollution Scene

Although air quality data are not available, banning of the diesel-three-wheelers had improved the visibility in the region. Vehicular smoke was reduced to some extent and pollution during hours of traffic congestion was reduced.

4.11 The OTC NO_x Budget Program, the NO_x SIP Call and NO_x Trading Program in the Eastern States of the U.S.

Country/Region	:	United States (US)
Area of coverage	:	22 states in US
Sectoral category	:	Energy
Type of approach	:	Policy/Emission Trading
Pollutant type	:	NO_x
Year of introduction	:	1999
Participants	:	Electric power plants, large industrial boilers and turbines, Ozone Transport Commission (OTC)

Description and Major Activities

THE OTC NO_x BUDGET PROGRAM

It is a program implemented in the Northeast and Mid-Atlantic region of the United States to meet the air quality standard for ground-level ozone under the Clean Air Act Amendments of 1990. The Ozone Transport Commission (OTC) was established for this purpose. Under this program, a regional cap (budget) on NO_x emissions was set for emissions from electric power generating facilities, large industrial boilers and turbines during the "ozone season" (from May 1st through September 30th) beginning in 1999. The ozone season covers the summer months, during which the formation of ozone was found to be of greatest concern. To meet the cap, the sources were required to reduce emissions significantly below the 1990 baseline levels, and could use emissions trading to achieve the most cost-effective reductions possible.

Each state within the OTC was allowed to design and implement its own trading program consistent with the state conditions and needs. However, all participating states have agreed to adopt guidelines for applicability, duration of the control period, targeted NO_x emissions monitoring and record-keeping, and electronic reporting. States have the authority to establish individual enforcement procedures and penalties. Accurate monitoring of all emissions and timely reporting ensured that a ton of NO_x emitted from one budget source is equal to a ton from any other source. This has maintained the integrity of the budget and the states have accurate and comprehensive compliance information. Transparency was maintained keeping all emissions and allowance data from the budget sources publicly available on the EPA Web site (USEPA, 2007d). States work with the federal Environmental Protection Agency (EPA), which reviewed and approved the State Implementation Plans (SIPs) as well as developed and operated allowance and emissions tracking systems.

EPA´S NO_x SIP CALL

EPA issued a regulation in 1998 to reduce the regional transport of ground level ozone since the OTC NO_x Budget Program did not bring the region (the Northeast and Mid-Atlantic) into compliance, due to the transboundary flow of NO_x across state boundaries. The regulation was commonly known as State Implementation Plans (NO_x SIP Call). SIP was issued to

- reduce seasonal NO_x emissions in 22 states and the District of Columbia by 2003 and
- to create a Federal NO_x Budget Trading Program.

In the 2003 ozone season the NO_x SIP Call superseded the OTC NO_x Budget Program. The NO_x SIP Call did not mandate which sources must reduce emissions; rather, it required states to meet an overall emissions budget and gave them flexibility to develop control strategies to meet the budget. All affected states chose to meet their NO_x SIP Call requirements by participating in the NO_x Budget Trading Program.

THE NO_x BUDGET TRADING PROGRAM

Under the SIP Call, EPA developed NO_x trading program known as the OTC NO_x Budget Trading Program. Under this program, budget sources were allocated allowances by their state government. Each allowance would permit a source to emit 1 ton of NO_x during the control period.

As in US Acid Rain Program, these allowances could be bought, sold, or banked. Any person was allowed to acquire allowances and participate in the trading system. In 2006, more than 2,500 units were involved under the NO_x Budget Trading Program (NBP). These include electricity generating units with output capacity of 15 MW or more. These also includes large industrial units with fossil fuel fired boilers or indirect heat exchangers having maximum rated heat input capacity of 250 million British thermal units per hour or more (USEPA, 2007e).

States were given broad discretion as to how they could allocate allowances from their trading budget to affected sources.

Impacts

CHANGES IN NO_x

In 2006, under the NO_x Budget Program, the budget sources emitted 491,483 tons, which means a reduction of NO_x by more than 38,000 tons, or 7 % from the emission in 2005 and 74 % from 1990 emissions (USEPA, 2007e). However, there were also contributions of other programs under the Clean Air Act such as the Acid Rain NO_x Reduction Program and other state, local, and federal programs on NO_x reduction. The significant decrease in NO_x emissions after 2000 largely reflects reductions achieved by the OTC Budget Trading program, and the NO_x Budget Program. Over 99.7% of the total affected sources had achieved compliance with the NO_x Budget Trading Program in 2006 (USEPA, 2007e).

CHANGES IN GROUND-LEVEL OZONE

Like NO_x emissions, ozone concentrations in urban and rural areas had decreased during 2004-2006 (after implementation of the NO_x Budget program) in comparison to that during the period 2000-2002 (i.e., before implementation of NO_x Budget Program). The average reduction in ozone concentrations in states participating NO_x Budget Program was estimated as 5% (USEPA, 2007e).

Chapter V | Summary and concluding remarks

With the increasing dependence on fossil fuels and heavy use of biomass, the countries in South Asia are increasingly facing the problem of air pollution. Three sectors, i.e., power, industry and transport are reported to be mainly responsible for air pollution in the region. The power sector is reported to be the largest emitter of SO_2, while transport sector, biomass burning and agriculture (crop residues and live stocks) are considered to be the largest contributors to NO_x, NMVOC and CH_4 emissions respectively in the region (Garg et al., 2001 and 2006; Shrestha et al, 1998; Varshney et al., 1999).

The use of coal is increasing in the region (especially in India) to meet the growing demand for electricity. As a result, SO_2 emission is also expected to rise in the region in the future. In addition, the problem of SO_2 emission is getting aggravated by the deteriorating quality of coal, inefficient coal preparation and coal cleaning mechanisms in the region. Low efficiency of the thermal power generation (especially from coal fired power plants) is another factor resulting in higher SO_2 emission and offer potential for significant coal and SO_2 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 emissions from the urban transport sector. On the other hand, the rural areas in the region are facing the indoor air pollution problems related to biomass burning due to their high dependence on such fuels.

Most countries in the region 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.

The Declaration for Prevention of Transboundary Air Pollution ("The Malé Declaration") adopted by the Environment Ministers of South Asian Countries in 1998 is a milestone in the process of fostering regional cooperation towards the control and prevention of transboundary air pollution (TAP) in the South Asia region. However, the region is yet to adopt specific 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 reviewed various existing international treaties and agreements that address the problem of TAP 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 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). It adopted 8 protocols targeting emission reduction of major transboundary air pollutants. Likewise, the US has taken an initiative to control transboundary air pollution under Title IV of Clean Air Act 1990 Amendment. The Act requires the states in the US to achieve stipulated SO_2 and NO_x emission reductions within a specified 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 present report has also discussed the approaches used by different countries to control air pollution so that appropriate lessons could be learned for controlling TAP in the region.

The major approaches used for environmental management in general and air quality management particular can be 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 present report has presented in greater detail several examples of good practices existing in different countries in the world for the control of transboundary air pollution, which 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 the European Union for each of its member states to adopt best available technology (BAT); in that sense the directive sets technology based standards. In the case of the US, an emission standard is imposed on new power plants in terms of SO_2 emission per unit of heat content of fuel burned.

Economic or market based approaches for environmental management employ either an 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 the use of emission charges in practice. A tax on NO_x emission is in use in several countries (e.g., France, Italy, Norway, Sweden and Switzerland). Similarly, a tax on SO_2 emission has been introduced in a number of countries (e.g., Denmark France, Norway, Sweden and Switzerland). In Switzerland, there is a tax on volatile organic compounds (VOCs) from the emission of aviation engines. In Japan, emission tax was charged as a pollution levy to polluting firms in order to collect revenue to compensate the victims of designated diseases.

Historically, fuel taxes are the most used market mechanism. In general, it is levied in the form of excise duty. In Finland, a special tax (Environmental Damage Tax) system and oil pollution fee for the imported oil are in effect besides an excise tax. Differentiated fuel tax rates based, on the amount of sulfur content of fuel, are also applied in European countries. In Germany eco-tax is levied along with the excise duty. The eco-tax was in the form of an environmental tax designed to make energy and resource consumption more expensive.

A refund based tax system is followed in Sweden, which is not intended to raise revenue but to provide an incentive to the participants for emission reduction. The system imposes tax on the emitting sources based on their SO_2/NO_x emission. However, in the case of NO_x, the tax is refunded to the participants based on the level of electricity produced so that the tax system benefits the participants generating more energy output with less NO_x emission.

The system of allowing emission reduction credits (ERC) and emission trading is in practice in the United States and also in some European countries. In this system, firms are issued an emission permit (allocated to their 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 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 include publication of top worst polluters (e.g., in Poland) and green electricity pricing that are in practice in some countries in Europe and US.

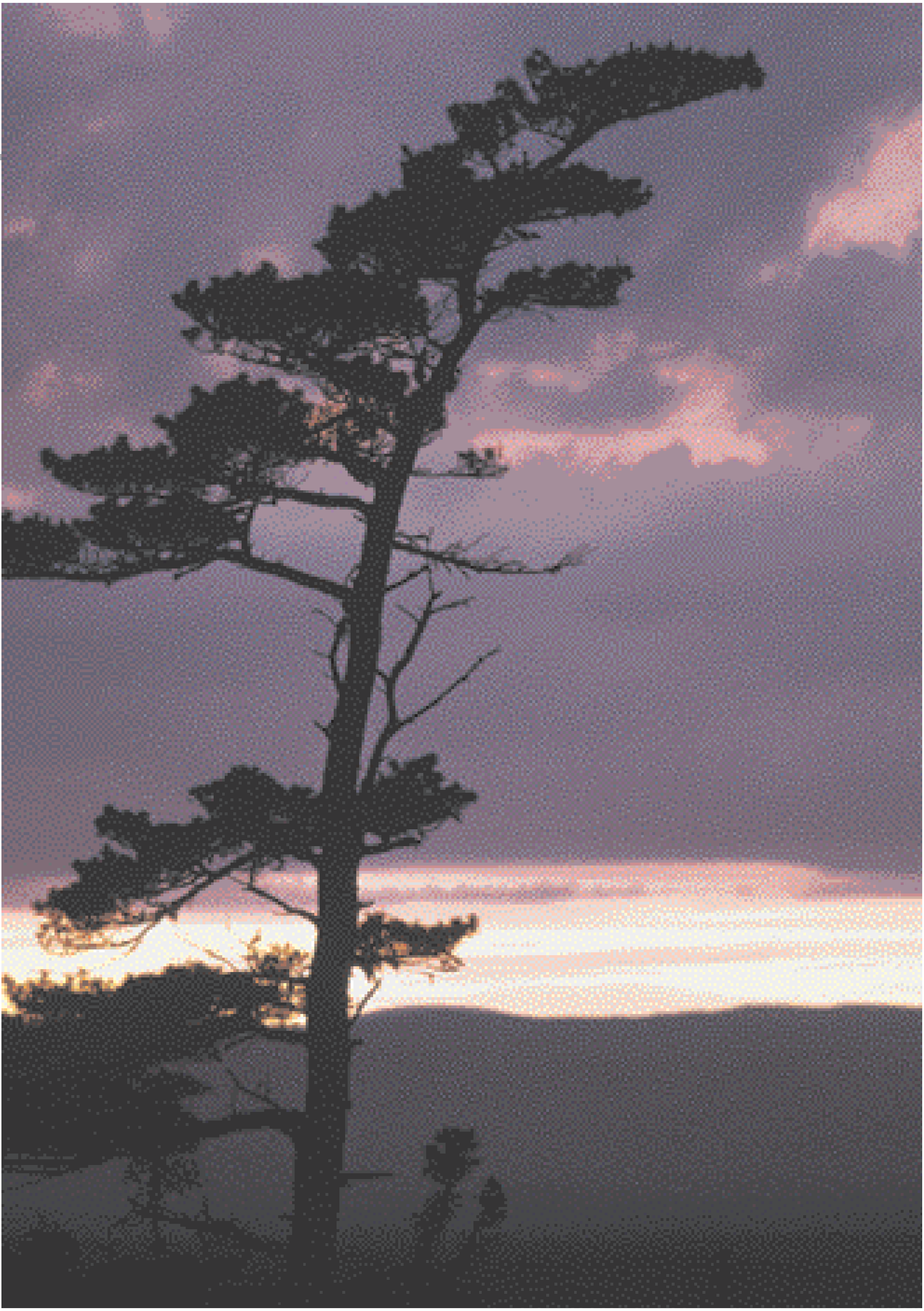
Congestion charges have been applied successfully in Singapore, Hong Kong and London on the vehicles entering the designated regions based on the degree of congestion. Though the major focus of this practice is to reduce traffic congestion rather than environmental benefits, it is believed to have also contributed to the improvement of air quality in the cities. Similarly, the license quota system that requires 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 introduced in Mexico. However, the scheme does not seem to have the desired effect and is reported to be economically inefficient.

Apart from the economic approaches, other emission control measures adopted in different countries include switching to the cleaner energy sources/fuels e.g., hydrogen fuel cell, compressed natural gas (CNG) and electricity. The switch of public passenger transport vehicles in India and Pakistan from Diesel/gasoline to compressed natural gas (CNG) is such 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 have been introduced in public passenger transport system. In developing countries like India, China and Nepal, solar water heaters are extensively used for water heating purpose. Similarly, in several countries in Asia: India, Nepal, Bangladesh, Pakistan, Vietnam, China, energy efficient technology for brick making like Vertical Shaft Brick Kiln (VSBK) has been implemented as an alternative to traditional brick kilns.

In many cases emissions of pollutants like CO_2, SO_2 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 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 primarily at reducing CO_2 emission from electricity generation from thermal power plants, it also can yield co-benefits in the form of reduced SO_2 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.

Upscaling of these good practices requires several pre-requisites. Among them are: i) political will, iii) an institution framework with good technical and human resources to carry out the measures; appropriate rules and regulation that help to carry out such measures; and iii) Awareness and networking among the stakeholders. Demographic characteristics such as population, geography and economy are some factors which need to be considered during the process of upscaling. A reliable information system on emissions and their effects/impacts and the costs of abatement measures are some of the important requirements for upscaling process.



References

Aardenne, J. A. V., Carmichael, G. R., Levy, H., Streets, D. and Hordijk, L., 1999, Anthropogenic NO_x emissions in Asia in the period 1990-2020, Atmospheric Environment, Vol. 33, pp. 633-646.

ADB, 2006a, Country Synthesis Report on Urban Air Quality Management – Nepal, Discussion Draft Report, Asian Development Bank (ADB), Clean Air – Initiative, Manila.

ADB, 2006b, Best Practices notes on Small-and Medium-sized Enterprises Support, Asian Development Bank, Manila.

ADB, 2006c, Urbanization and Sustainability in Asia: Case studies of good practices, Asian Development Bank, Manila.

ADB, 2007, Energy Strategy Draft Paper, Asian Development Bank, Manila.

Answer, 2007, Hoy No Circula, Answer Corporation, New York (http://www.answers.com/topic/hoy-no-circula downloaded on 8 July 2008).

APEIS, 2003a, Adaptation of Vertical Shaft Brick Kiln (VSBK) technology for Indian brick industry, Research on Innovative and Strategic Policy Options (RISPO), Good Practices Inventory,

Asia-Pacific Environmental Innovation Strategies (APEIS), Japan (http://www.iges.or.jp/APEIS/RISPO/inventory/db/pdf/0028.pdf downloaded on 20 May 2008).

APEIS, 2003b, Introduction of Electric Three-Wheelers in Kathmandu, Nepal, Asia-Pacific Environmental Innovation Strategies (APEIS), Japan (http://www.iges.or.jp/APEIS/RISPO/inventory/db/pdf/0018.pdf downloaded on 9 June 2008).

AQMP, 2006, Report on Roadside Vehicle Emission Testing Program in Dhaka, Air Quality Management Project (AQMP), Ministry of Environment and Forest, Government of Bangladesh, Dhaka.

ASTED, 2006, Project Idea Note (PIN) developed for Nepal Industrial Solar Water Heater Project, Association for Solar Thermal Energy Development (ASTED) Nepal, Kathmandu.

Aziz, J. A., 2006, Towards establishing air quality guidelines for Pakistan", Eastern Mediterranean Health Journal, Vol. 12, No. 6, pp. 886-893. (http://www.emro.who.int/Publications/EMHJ/1206/PDF/article21.pdf)

Azora Foundation, 2005, Japan's Pollution Experience, Azora Foundation, (http://www.aozora.or.jp/newenglish/eindex.htm downloaded on 28 August 2007)

Bajracharya, T. R., T. H. Ghimire and R. Rimal, 2003, Elementary Findings of End Users Assessment of Solar Water Heater (SWH) in Kathmandu Valley, Proceedings – RETRUD-03, Center for Energy Studies, Nepal Solar Energy Society, Kathmandu.

BBS, 2005, Compendium of Environment Statistics of Bangladesh 2005, Bangladesh Bureau of Statistics (BBS), Dhaka.

Bell, G R, Mathur, K, Narain, U., Simpson, D, 2003, Clearing the Air: Why air quality reforms finally took hold in Delhi, Jawaharlal Nehru University, Delhi and Resources for the Future, Washington, D.C.

Bergin, M. S., West, J. J., Keating, T. J., Russell, A. G., 2005, Regional Atmospheric Pollution and Transboundary Air Quality Management, Annual Review of Environment and Resources, Vol. 30, pp. 1-35. (doi:10.1146/annurev.energy.30.050504.144138).

Blackman, A. and Harrington, W., 2000, The use of economic incentives in developing countries: lessons from international experience with industrial air pollution, Journal of Environment and Development, Vol. 9, pp. 5-44.

Boaz, A., 2007, Presentation on "Environmentally Sustainable Transport (EST) in South Asia", Asian Mayor's Policy Dialogue for promotion of EST in cities, Kyoto, 23-24 April, 2007.

Bose, R. and Sperling, D, 2001, Transportation in Developing Countries: Greenhouse Gas Scenarios for Delhi, India, Institute of Transportation Studies, University of California, Davis.

CAI– Asia, 2007, Clean Air Initiative for Asian Cities, CAI-Asia Center, Manila. (http://www.cleanairnet.org/caiasia downloaded on 15 July 2007).

CAI-Asia, 2006, Country Synthesis Report on Urban Air Quality Management (Discussion Draft), Asian Development Bank, Manila.

CAI-Nepal, 2007, News Bulletin 2007, Clean Air Initiative – Nepal (CAI-Nepal), Clean Energy Nepal, Kathmandu.

Carlsson, F., 1999, Incentive-based environmental regulation of domestic civil aviation in Sweden, Transport Policy, Vol. 6, pp. 75–82.

CEPA, 2002, Guidelines for Volatile Organic Compounds in Consumer Products, Canadian Environmental Protection Agency (CEPA), Canada.

Chin, A. and Smith P., 1997, Automobile Ownership and Government Policy: The Economics of Singapore's Vehicle Quota Scheme, Transportation Research, Vol. 31, No. 2, pp.129-140.

Chin, A. T.H., 1996, Containing air pollution and traffic congestion: Transport policy and the environment in Singapore, Atmospheric Environment, Vol. 3. No. 5, pp. 787–801.

CPCB, 2007a, Environmental Standards for Thermal Power Stations, Central Pollution Control Board (CPCB) Website (http://cpcb.nic.in/Industry-Specific-Standards/Effluent/ThermalPowerPlant.pdf downloaded on 4 July 2008).

CPCB, 2007b, Central Pollution Control Board (CPCB) Website, India (http://envfor.nic.in/cpcb)

CPCB, 2007c, Data extracted from Central Pollution Control Board Website, India (http://www.cpcb.nic.in/oldwebsite/as.htm)

CSE, 2006, Winter woes: Delhi headed for air pollution disaster, Press Release, Center for Science and Environment (CSE), Delhi (http://www.cseindia.org/campaign/apc/press_20061114.htm download on 25 July 2007)

DEA, 2007, Dutch Emission Authority (DEA) Website, Netherland (http://www.emissieautoriteit.nl/english downloaded on 1 August 2007).

Dhakal, S., 2003, De-coupling of urban mobility need from environmental degradation in Singapore, Institute for Global Environmental Strategies, Japan (http://www.iges.or.jp).

Dhakal, S., 2004, Role of Government, private sector and civic society in promoting battery operated electric three-wheelers in Kathmandu, Nepal, Institute for Global Environmental Strategies, Japan (http://www.iges.or.jp).

Diefenbacher, H., Teichert, V. and Wilhelmy, S., 2006, How have ecotaxes worked in Germany?, FIESTA Review, Vol. 2 (http://www.foes.de/en/downloads/ FactsandFeatures/ ecotaxes_how_they_work.pdf downloaded on 8 July 2008).

DOCE, 2007, Tax on Emission of NO_x (Translated from Norwegian), Circular No. 14/2007S, Directorate of Customs and Excise (DOCE), Oslo, (http://www.toll.no/upload/ Dokumenter/avgiftsrundskriv/2007NOx_english.pdf downloaded on 15 June 2008).

DOE/BMEP, 2003, A Compilation of Environmental Laws of Bangladesh, Department of Environment and Bangladesh Environmental Management Project (DOE/BMEP), Dhaka.

DOEMTI/TERI, 2005, Bhutan Energy Data Directory 2005, Department of Energy Ministry of Trade and Industry (DOEMTI), Thimpu, Bhutan and The Energy and Resources Institute (TERI), New Delhi.

DPCC, 2001, Towards cleaner air: A case study of Delhi, Department of Environment, Government of NCT of Delhi and Delhi Pollution Control Committee (DPCC), India, (http://dpcc.delhigovt.nic.in/down/cleanerair.pdf downloaded on 25 June 2007).

DTI, 2000, Review of technology requirements of the coal preparation sector in India, Department of Trade and Industry (DTI), India.

ECAC, 2005, Current Status of Emission Related Landing Charges in Europe, European Civil Aviation Conference (ECAC) (http://www.mdcr.cz/NR/rdonlyres/FE76CF68-1098-4C57-BFC1-9F8D8B2338BD/0/ANCAT65IP8.pdf downloaded on 15 August 2007).

EEA, 2004, Air pollution and climate change policies in Europe: exploring linkages and the added value of an integrated approach, European Environment Agency (EEA), Copenhagen.

EEA, 2005, Market-based instruments for environmental policy in Europe, European Environment Agency (EEA), Copenhagen.

EIA, 2007a, Bangladesh: Country Analysis Brief – 2006, Energy Information Administration (EIA), Department of Energy, USA.

EIA, 2007b, International Energy Outlook 2007, Energy Information Administration (EIA), Washington DC.

Ellerman, A. D, Joskow, P. L., Schmlensee, R., Montero, J. P. and Bailey, E.M., 2000, Markets for clean air: The US Acid Rain Program, Cambridge University Press, Boston.

ESCAP, 2003a, Tax incentive schemes for anti-pollution equipment, ESCAP Virtual Conference, Economic and Social Commission for Asia and the Pacific (ESCAP), Bangkok.

ESCAP, 2003b, ESCAP Virtual Conference, Good Practices, Economic and Social Commission for Asia and the Pacific (ESCAP), Bangkok. (http://wwww.unescap.org/drpad/vc/ conference/ ex_pk_4_tis.htm).

European Parliament and the Council of the European Union, 2001, Directive 2001/81/ec of the European Parliament and of the Council, European Parliament and the Council of the European Union (http://ec.europa.eu/environment/air/pdf/necd_consolidated.pdf downloaded on 14 September 2007).

European Parliament and the Council of the European Union, 2003, National Emissions Ceiling for EU 27, Environmental Protection Agency (http://ec.europa.eu/environment/air/pdf/eu27_nat_emission_ceilings_ 2010.pdf).

European Parliament and the Council of the European Union, 2008, Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control, The European Parliament and the Council of The European Union, (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0001: EN:NOT downloaded on 7 July 2008)

Faiz, A., Sinha, K., Walsh, M. and Varma, A., 1990, Automotive Air Pollution: Issues and Options for Developing Countries, World Bank, Washington, D.C.

FAO, 2006, Summary Report Workshop on Up-Scaling Good Practices for Sustainable Agriculture and Rural Development (SARD), Food and Agriculture Organisation, Rome.

Field, B. C. and Field, M. K., 2002, Environmental Economics: An Introduction, Third Edition, Mc Graw-Hill, New York.

Fleuti, E., 2007, Local Emission Charges in Europe, ICAO Colloguium on Aviation Emissions with Exhibition, 14-16 May 2007.

Foell, W., Green, C., Amann, M., Bhattacharya, S., Carmichael, G., Chadwick, M., Cinderby, S., Haugland, T., Hettelingh, J.-P., Hordijk, L., Kuylenstierna, J., Shah, J., Shrestha, R., Streets, D. and Zhao, D., 1995, Energy use, emissions, and air pollution reduction strategies in Asia, Water, Air and Soil Pollution, Vol. 85, No. 4, pp. 2277-2282.

Garg A., Shukla, P. R and Kapshe Manmohan, 2006, The sectoral trends of multigas emissions inventory of India, Atmospheric Environment, Vol. 40, pp. 4608-4620.

Garg, A., Shukla, P.R., Bhattacharya, S., Dadhwal, V.K., 2001, Sub-region (district) and sector level SO_2 and NO_x emissions for India: assessment of inventories and mitigation flexibility, Atmospheric Environment, Vol. 35, pp. 703-713. UNEP, 2007, GEO Data Portal, United Nations Environment Programme (UNEP), Nairobi.

GOI, 2006, Integrated Energy Policy: Report of the Expert Committee, Government of India, Planning Commission, India.

Gozun, B., 2006, Ambient Air Quality Standards in Asia; Is there a Trend towards Stricter Standards?, Better Air Quality Conference, 13-15 December, 2006, Yogyakarta, Indonesia.

Guttikunda, S. K., Carmichael, G. R., Calorib, G., Eckc, C., Wood, J. H., 2003, The contribution of megacities to regional sulfur pollution in Asia, Atmospheric Environment, Vol. 37, pp. 11–22.

Hammer, H. and Lofgren, A., 2001, The determinants of Sulfur emissions from oil consumption in Swedish Manufacturing Industry, 1976-1995, The Energy Journal, Vol. 22, No. 2, pp. 107-126.

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

Hayashi Y., Doi K., Yagishita M., and Kuwata M., 2004, Urban Transport Sustainability: Asian Trends, Problems and Policy Practices, European Journal of Transport and Infrastructure Research, Vol. 4, No.1, pp.27-45.

Heierli U. and Maithel S., 2008, Brick by brick: the Herculean task of cleaning up the Asian brick industry, Swiss Agency for Development and Cooperation (SDC), Natural Resources and Environment Division, Berne.

ICIMOD, 2007, Kathmandu Valley Environment Outlook, International Center for Integrated Mountain Development (ICIMOD), Kathmandu.

IEA, 2002, Energy Policies of IEA Countries: Germany 2002 Review, International Energy Agency (IEA), Paris.

IEA, 2004, Energy Policies of IEA Countries, The Netherlands 2004 Review, International Energy Agency, Paris.

IEA, 2006a, Country Analysis Brief, South Asia Overview, International Energy Agency, Paris.

IEA, 2006b, World Energy Outlook 2006, International Energy Agency, Paris.

IEA, 2006c, Energy Balances of Non-OECD Countries - 2006 Edition, International Energy Agency, Paris.

IEA, 2007, Energy Prices and taxes, 2nd Quarter, International Energy Agency, Paris.

IGL, 2006a, Survey in 2006 conducted by Indraprasth Gas Limited (IGL), India

IGL, 2006b, Annual Report 2005-06, Indraprastha Gas Limited (IGL), India

IISD, 1994, Making budget Green: Leading practices in Taxation and Subsidy Reform, International Institute for Sustainable Development (IISD).

India Times, 2006, Going the CNG way, India Times (http://www.iglonline.net/newsdetail.asp?fol=news&f=news4)

IPCC, 1998, Aviation and Global Atmosphere, Intergovernmental Panel on Climate Change (IPCC).

IPCC, 2001, Climate Change 2001: The Scientific Basis, Intergovernmental Panel on Climate Change (IPCC).

Kim T. V. T., Tung D. V., Thieu V. V., Luong D. V., Tu B. T., Priester M., 2004, International VSBK Conference, 2004, Kathmandu, Nepal.

Knaus, E. M. and Klarer, J., 1997, Switzerland: Worldwide first aircraft engine emission charge introduced at Zurich airport, Newsletter on Green Budget Reform, Issue 1, (http://www.rec.org/REC/Programs/SofiaInitiatives/EcoInstruments/Green Budget/GreenBudget1/Swiss.html downloaded on 5 August 2007).

Koh, W. T.H., 2003, Control of vehicle ownership and market competition: theory and Singapore's experience with the vehicle quota system, Transportation Research Part A, Vol 37, pp. 749–770.

LTA, 2007a, Vehicle Ownership, Land Transport Authority (LTA), Singapore (http://www.lta.gov.sg/motoring_matters/index_motoring_vo.htm downloaded on 18 July 2007).

LTA, 2007b, Land Transport Authority Website (http://www.lta.gov.sg downloaded on 18 July 2007).

LTA, 2007c, Vehicle Policies and Schemes (http://www.lta.gov.sg/motoring_matters/motoring_vo_policynschemes_offpeak.htm downloaded on 26 July 2007).

MoEF, 2006, Annual Report 2006-2007, Ministry of Environment and Forests (MoEF), Government of India, New Delhi.

Mumbai Newsline, 1998, Smog city to clean capital: How Delhi did it (http://cities.expressindia.com/fullstory.php?newsid=85665).

National Environmental Agency, 2007, PSI Reading of 20 September 2007, National Environmental Agency (http://app.nea.gov.sg/psi/ downloaded on 25 July 2007).

NCEE, 2004, International experiences with economic incentives for protecting the environment, National Center for Environmental and Economics (NCEE), United States Environmental Protection Agency, Washington DC

NECS, 2006, Bhutan Environmental Outlook 2006 (Draft Report), National Environment Commission Secretariat (NECS), Royal Government of Bhutan, Thimpu.

Nepal Electricity Authority, 2006, Annual Report 2005/6, Kathmandu, Nepal.

Nepal Electricity Authority, 2007, White Paper, Kathmandu, Nepal.

NMD, 2007, Guideline on the NOx Tax, Norwegian Maritime Directorate (NMD) (http://www.sjofartsdir.no/upload/Fart%C3%B8y%20og%20sj%C3%B8folk/Nox-avgiften/Guideline%20on%20NOx%20rev%206.pdf downloaded on 15 July 2008).

NPCA, 2007, Unofficial translation of the Norwegian regulation laid down pursuant to sections 5, 9, 39, 49, 51 and 81 of Act no. 6 of 13 March 1981 concerning protection against pollution and concerning waste (the Pollution Control Act),

Norwegian Pollution Control Authority (NPCA) (http://www.sft.no/artikkel____34960.aspx downloaded on 15 July 2008).

NPCA, 2008, Emissions of NMVOC, nitrogen oxides and ammonia: 1990-2007, Statistics of Norway, Norwegian Pollution Control Authority. (http://www.ssb.no/english/subjects/01/04/10/agassn_en/ downloaded on 14 July 2008).

OECD, 1998, Lessons from existing trading systems for international greenhouse gas emission trading, Organisation for Economic Cooperation and Development (OECD), Paris.

OGARTA and Himal Energy, 2004, Report on Solar Water Heating System Database in Nepal, OGARTA Private Limited and Himal Energy Development Company Private Limited, Alternative Energy Promotion Center, Kathmandu, Nepal.

PEPA, 2000, National Environmental Quality Standards Regulations, Pakistan Environmental Protection Agency (PEPA), Pakistan.

PEPA, 2001, Pollution Charge for Industry (Calculation and Collection) Rules, 2001, Pakistan Environmental Protection Agency, Pakistan.

PEPA, 2005, State of Environment Report-2005, Pakistan Environmental Protection Agency, Pakistan.

Peszko G. and Lenain P., 2001, Encouraging environmentally sustainable growth in Poland, Organisation for Economic Cooperation and Development (OECD), Paris.

Philly News, 2007, Traffic ban cleared the air, (http://www.philly.com/philly/wires/ap/news/nation_world/20070821 _ap_beijing trafficbanclearedtheair.html downloaded on August 23, 2007)

Quaha, E. and Boon, T. L., 2003, The economic cost of particulate air pollution on health in Singapore, Journal of Asian Economics, Vol. 14, pp. 73–90.

RAPIDC, 2008, RAPIDC Handbook on Policy Options for Air Pollution Prevention and Control in South Asia, (Draft Copy), Regional Air Pollution in Developing Countries (RAPIDC) Program, Stockholm Environment Institute, York, UK.

REDP/UNDP/AEPC, 2002, Solar water Heater in Nepal, Rural Energy Development Programme (REDP), United Nations Development Programme (UNDP) and Alternative Energy Promotion Centre (AEPC), July 2002.

Refocus, 2004, Solar Water Heating: A Viable Industry in Developing Countries, Refocus, May/June 2004, pp.18-21.

Refocus, 2005, Solar Thermal in China: Overview and Perspectives of the Chinese Solar Thermal Market, Refocus, September/October 2005, pp.25-27.

Rio, P., 2004, A European-wide harmonised tradable green certificate scheme for renewable electricity: is it really so beneficial?, Energy Policy, Vol. 33, Issue 10, pp. 1239-1250

Roseveare, D., 2001, Encouraging environmentally sustainable growth in Sweden, OECD Working Paper, Organisation for Economic Cooperation and Development (OECD), Paris.

SDC, 2008, Regional Brick Programme in Asia, Swiss Agency for Development and Cooperation (SDC) (http://www.deza.admin.ch/en/Home/Projects/Regional_Brick_Programme_in_Asia downloaded on 20 May 2008).

SEPA, 2002, State of Environment in China, State Environmental Protection Agency, Beijing.

SEPA, 2004, State of Environment in China, State Environmental Protection Agency, Beijing.

SEPA, 2005, State of Environment in China, State Environmental Protection Agency, Beijing.

SEPA, 2006, State of Environment in China, State Environmental Protection Agency, Beijing.

Shrestha R. M. and Bhattacharya S.C., 1998, Technological and policy options to reduce acid rain causing emissions in Asia, First National Workshop on Acid Rain and Emissions Reduction in Asia, UNEP, Bangkok.

Shrestha, J. N., R. Rimal, S. Pradhan, and S. R. Shakya, 2002, Solar Hot Water System - The Nepalese Prospect, The International Energy Journal, Special Issue: Renewable Energy Sources in Nepal, Vol. 3, No. 2.

Siddiqi, T. A., 2007, Developing Integrated Energy Policies in South Asia, Discussion Paper, Global Energy and Environment in 21st Centuries (GEE-21), Hawaii

SIEI, 2000, Database of Environmental Taxes and Charges in Central and Eastern Europe, Newsletter on Green Budget Reform, Issue 7, Sofia Initiative for Economic Instrument (SIEI), Szentendre, Hungary.

Siyambalapitiya, T. and Samarasinghe, A. K., 1993, Power generation in Sri Lanka: status and future options, Power Engineering Journal, IEEE, February 1993, pp. 29-36.

Speck, S., McNicholas, J. and Jackson, N., 2000, Energy Taxation and Green Tax Reform in Central and Eastern Europe, UN-ECE/OECD Workshop on Enhancing the Environment by Reforming Energy Prices, Czech Republic, 14 to 16 June 2000 (http://www.env.cz/www/zamest.nsf/62c5044df2e98482c12564ce0052d352/7187728e3737a957c12568fc004cac35?OpenDocument downloaded on 8 July 2008).

SPRERI, 2006, Transformation of Users of Conventional Water Heaters to Solar Water Heaters, Project implemented by Sardar Patel Renewable Energy Research Institute (SPRERI) under the GEF Small Grants Programme, UNDP.

Stavins, R. N., 2003, Experience with Market-based Environmental Policy Instruments, Handbook of Environmental Economics, Edited by Mäler, K. G. and Vincent, J. R. Vol 1, North-Holland.

Streets G. D., Tsai, N. Y., Akimoto, H., 2001, Trends in Emission in Acidifying Species in Asia, 1985-1997, Water, Soil and Air Pollution, Vol. 130, pp. 187-192.

Streets, D. G., Bond, T. C., Carmichael, Fernandes, G. R., S. D., Fu, Q., He, D., Klimont, Z., Nelson, S. M., Tsai, N. Y., Wang, M. Q., Woo, J.-H., and Yarber, K. F., 2003, An inventory of gaseous and primary aerosol emissions in Asia in the year 2000, Journal of Geophysical Research, Vol. 108, No. D21, 8809, pp. 30-1 to 30-23, (doi:10.1029/2002JD003093)

TFL, 2007, Discounts and Exemptions, Transport for London (TFL), UK, (http://www.tfl.gov.uk/roadusers/congestioncharging/6713.aspx downloaded on 8 July 2008).

Tietenberg, T, 2003, Environmental and Natural Resource Economics, 6th Edition, Addison Wesley, Boston, USA.

Tiwari M., 2007, Electric Vehicles in Nepal, Tiempo Climate Newswatch, May, 2006, Edited by Mick Kelly and Sarah Granich, Stockholm Environment Institute and the International Institute for Environment and Development.

TREC, 1998, Reduction of SO2 and Particulate Emissions, Synthesis Report, Sofia Initiative in Local Air Quality, The Regional Environmental Center for Central And Eastern Europe (TREC), Szentendre, Hungary.

UNECE, 2007a, The convention on Long Range Transboundary Air Pollution, United Nations Economic Commission for Europe (UNECE). (http://www.unece.org/env/lrtap downloaded on 20 August 2007).

UNECE, 2007b, Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at Least 30 per cent, The convention on Long Range Transboundary Air Pollution, United

Nations Economic Commission for Europe (UNECE) (http://www.unece.org/env/lrtap/full%20text/1985.Sulphur.e.pdf downloaded on 20 August 2007).

UNECE, 2007c, Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Further Reduction of Sulphur Emissions, The convention on Long Range Transboundary Air Pollution, United Nations Economic Commission for Europe (UNECE). (http://www.unece.org/env/lrtap/full%20text/1994.Sulphur.e.pdf downloaded on 22 August 2007).

UNECE, 2007d, Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution Concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes (http://www.unece.org/env/lrtap/full%20text/1988.NOX.e.pdf downloaded on 22 August 2007).

UNECE, 2007e, Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution Concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes (http://www.unece.org/env/lrtap/full%20text/1991.VOC.e.pdf downloaded on 22 August 2007).

UNECE, 2007f, Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication and Ground-Level Ozone, (http://www.unece.org/env/lrtap/full%20text/1999%20Multi.E.Amended.2005.pdf downloaded on 22 August 2007)

UNEP RRCAP, 2002, Maldives: State of the Environment 2002, United Nations Environment Programme/Regional Resource Centre for Asia and the Pacific (UNEP/RRCAP), Bangkok.

UNEP RRCAP, 2007, National Views on air pollution, Sri Lanka (Downloaded on 21 May 2007), Bangkok.

UNEP, 2001, State of Environment of India, United Nations Environment Programme (UNEP), Bangkok.

UNEP, 2006, CNG conversion: Learning from New Delhi, United Nations Environment Programme (http://ekh.unep.org/?q=node/1737 downloaded on 25 May 2007).

USEPA, 1998, 1997 Compliance Report: Acid Rain Program, United States Environmental Protection Agency (USEPA), Washington DC.

USEPA, 2004, Acid Rain Progress Report: 2004, United States Environmental Protection Agency, Washington DC.

USEPA, 2005, Acid Rain Progress Report: 2005, United States Environmental Protection Agency, Washington DC.

USEPA, 2007a, Clean Air Markets, United States Environmental Protection Agency, Washington\ DC. (http://www.epa.gov/airmarkets).

USEPA, 2007b, Acid Rain Program Allowance Auction Fact Sheet, United States Environmental Protection Agency, (http://www.epa.gov/airmarkets/ trading/factsheet-auction.html downloaded on 5 July 2007).

USEPA, 2007c, Clean Air Markets, United States Environmental Protection Agency, Washington DC, (http://www.epa.gov/airmarkets/emissions/continuous-factsheet.html downloaded on 5 July 2007).

USEPA, 2007d, Introduction to the OTC NOx Budget Program, United States Environmental Protection Agency, Washington DC, (http://www.epa.gov/airmarkets/progsregs/nox/docs/otcreport.pdf downloaded on 15 July 2008).

USEPA, 2007e, NOx Budget Trading Program: 2006 Program Compliance and Environmental Results, United States Environmental Protection Agency, Washington DC.

Varshney, C. K. and Padhy, P. K., 1999, Emissions of Total Volatile Organic Compounds from Anthropogenic Sources in India, Journal of Industrial Ecology, Vol 2, No. 4., pp. 93-105.

VROM, 2007, NOx Emission Trading, VROM International, Netherlands Ministry of Housing, Spatial Planning and the Environment (http://international.vrom.nl/pagina.html?id=10327 downloaded on 1 August 2007)

VSBK Nepal, 2007, Vertical Shaft Brick Kiln: Clean Building Technologies for Nepal, VSBK Technology Transfer Programme. (http://www.vsbknepal.com/technology/vsbk_tech.htm downloaded on 20 May 2008).

WAPDA, 2007, Website, Water and Power Development Authority (WAPDA) , Government of Pakistan (http://www.wapda.gov.pk/htmls/pgeneration-index.html downloaded on 5 August 2007).

WCI, 2006, A Focus on India, ECOAL, July 2006, World Coal Institute (WCI), London (http://www.worldcoal.org/assets_cm/ files/PDF/ecoal_focus_on_india.pdf downloaded on 8 August 2007).

Willoughby C., 2001, Singapore's motorization policies 1960-2000, Transport Policy, Vol. 8, pp. 125-139.

World Bank, 2003, China: Air Pollution and Acid Rain Control: The Case of Shijiazhuang City and the Changsha Traingle Area, Energy Sector Management Assistance Program (ESMAP), World Bank, Washington, D.C.

Yi, H., Hao, J. and Tang, X., 2007, Atmospheric environmental protection in China: Current status, developmental trend and research emphasis, Energy Policy, Vol. 35, pp.907-915.

Yong, K.C., 2002, Air quality monitoring in Singapore, Better Air Quality in Asian and Pacific Rim Cities (BAQ 2002), Hong Kong.

UNEP