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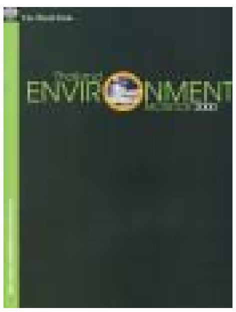
Thailand ENVIRNMENT MONITOR 2002

Air Quality

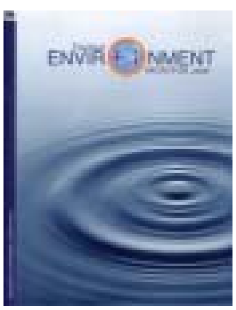
http://www.worldbank.or.th/monitor

CONTENTS

November
2002



Thailand Environment Monitor 2000
presented a snapshot of general environmental trends in the country.



Thailand Environment Monitor 2001
Assessed the status of water quality management in the country.

Preface	1
Abbreviations and Acronyms	2
Hot Spots Map	3
SUMMARY: Thailand's Air Quality: At Crossroads	4
SOURCES	7
Emissions Inventory	7
Mobile Sources: Transport	8
Stationary Sources: Industry	9
Stationary Sources: Power	10
Area Sources: Waste Burning	11
MONITORING	12
POLLUTANTS	13
Particulates	13
Nitrogen Oxides	15
Lead	16
Ozone	17
Carbon Monoxide	18
Sulfur Dioxide	19
Greenhouse Gases	20
Ozone Depleting Substances	21
IMPACTS	22
Public Health	22
Health/Non-Health	25
Public Perception	26
RESPONSES	27
MANAGEMENT	30
Legislation	30
Institutions	31
Budget	33
CHALLENGES	34
Glossary of Terms	39
Useful Websites on Air Quality Management	41
Acknowledgements	43
Thailand-at-a-Glance	44

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Preface

The Thailand Environment Monitor series tracks key environmental trends in the country. Its aim is to engage and inform stakeholders on key environmental changes and challenges as they occur. The 2000 Monitor benchmarked general environmental indicators, while the 2001 Monitor focused on water quality. This year, the Monitor concentrates on air quality.

Vehicles, power plants, factories, forest fires, agricultural burning and open cooking all contribute to air pollution in Thailand. While air pollution certainly has regional and global implications, its most severe impacts are felt by people living in cities, where concentrations are higher. Air quality monitoring measures the principal pollutants, including particulate matter, nitrogen oxides, ground-level ozone, carbon monoxide, sulfur dioxide, and lead. Much of the air quality monitoring information used in this document is drawn from the Pollution Control Department's monitoring network.

Economic and other activities in and around transport corridors result in a high incidence of pollution-related health problems in Thailand's cities. Several studies demonstrating the ill effects of air pollution on human health in Thailand have served as an important wake-up call. A decade ago, the health costs of exposure to lead, particulate matter, and carbon monoxide in Bangkok were estimated to be equivalent to between 8 and 10 percent of urban annual income.

The many commendable initiatives taken by the country include: enacting the environmental law in 1992; completing the phase-out of leaded gasoline by 1995; improving fuel quality and engine specification; curbing pollution from power plants; moving enterprises to cleaner production practices; tightening construction standards; improving public transport; and substantially reducing the use of ozone depleting substances. As a result of the improvements in air quality, air pollution costs to the national economy are now estimated to be equivalent to 1.6 percent of the GDP, down from 2.6 percent five years ago. On the global level, Thailand has demonstrated its commitment by ratifying the Kyoto and Montreal Protocols, among other conventions.

The Constitution of 1997 provides opportunities for civil society and the private sector to play an expanded role in environmental protection, including air quality management. Government agencies should harness this additional capacity while improving coordination among themselves. A multi-stakeholder partnership approach would benefit Thailand as it begins tackling the next set of challenges in attaining bluer skies.

The 2002 Environment Monitor comprises seven sections. The *first two* sections after the summary deal with the sources of pollution, and the monitoring of air quality. The *third* section describes the trends for different pollutants. The *fourth* section estimates health and non-health impacts of air pollution along with the public perception, while the *fifth* section deals with various policy responses taken to address air quality issues. The *sixth* section focuses on environmental management (legislation, institutions, and budget) pertaining to air quality management. The *final* section presents the main air quality challenges.

This Monitor is the outcome of a joint exercise. The Pollution Control Department provided data, reviewed the analysis, and coordinated inter-agency cooperation. The United States-Asia Environment Partnership supported the public perception survey undertaken by the Thai Society of Environmental Journalists. The World Bank team was responsible for analysis, report writing, and quality assurance. In addition, several national agencies, academics, civil society, and researchers participated in preparation of the Monitor. The information contained herein has been compiled from a variety of sources, including published and unpublished data and reports of Government agencies, universities, nongovernmental organizations, individuals, the World Bank, and international partners.

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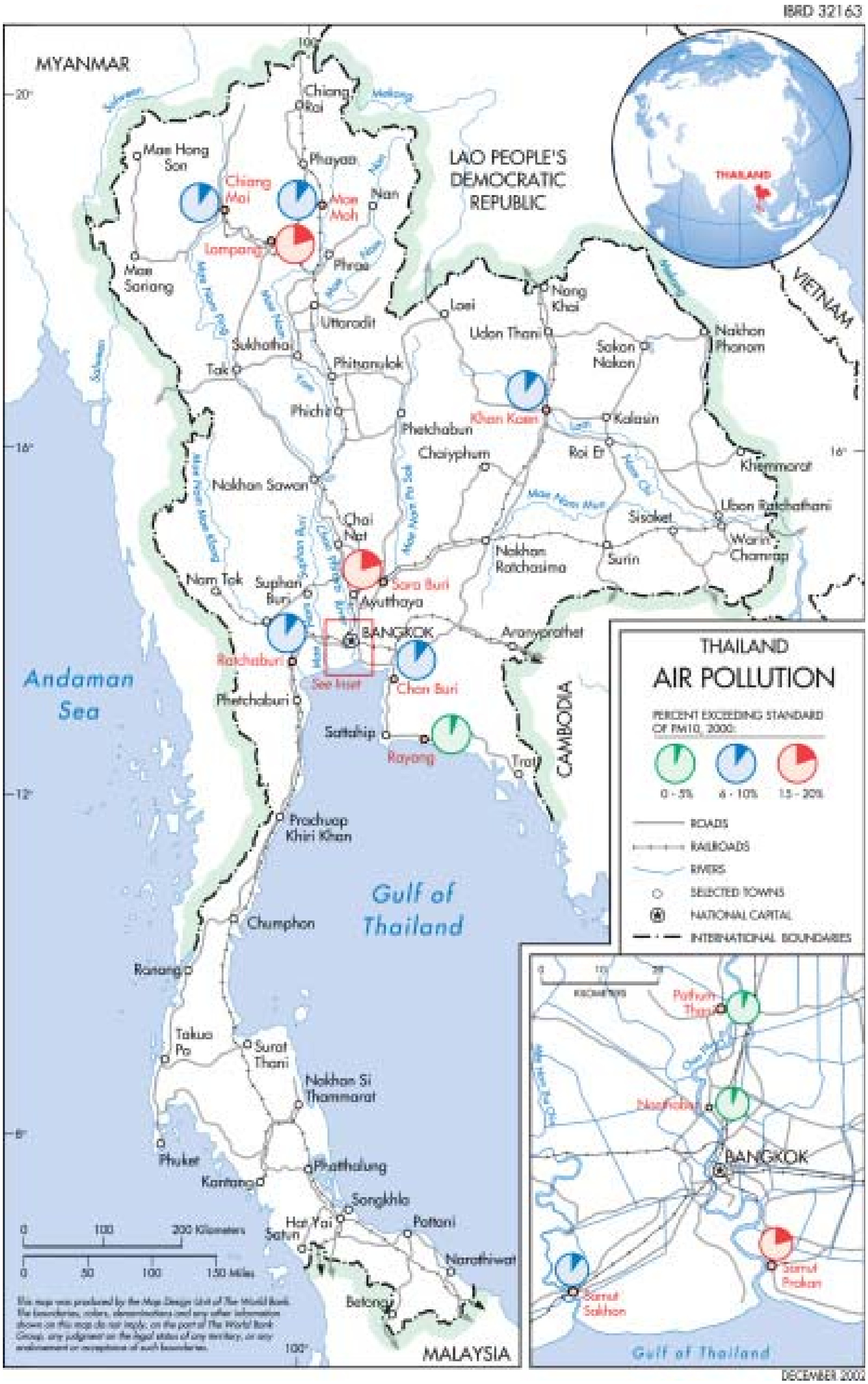
Abbreviations & Acronyms

AQI	Air Quality Index
BMA	Bangkok Metropolitan Administration
BMR	Bangkok Metropolitan Region
BMTA	Bangkok Metropolitan Transit Authority
BTS	Bangkok Transit System
CDM	Clean Development Mechanism
CFC	Chlorofluorocarbons
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
DEDP	*former* Department of Energy Development and Promotion
DIW	Department of Industrial Works
EGAT	Electricity Generating Authority of Thailand
ESP	Electrostatic precipitators
FGD	Flue Gas Desulfurization
GDP	Gross Domestic Product
Gg	Giga grams = 1015 grams
GHG	Greenhouse gas
HC	Hydrocarbon
HOV	High Occupancy Vehicle
I/M	Inspection and maintenance
IPP	Independent Power Producers
LTD	Land Transport Department
LPG	Liquefied petroleum gas
mg	Milligrams
mg/m^3	Milligrams per cubic meter
MLF	Multilateral Fund (GEF)
MoE	Ministry of Energy
MoIND	Ministry of Industry
MoNRE	Ministry of Natural Resources and Environment
MoPH	Ministry of Public Health
MoSTE	*former* Ministry of Science, Technology and Environment
MoTC	*former* Ministry of Transport and Communications
MP	Montreal Protocol
MT	Metric tons
NEB	National Environment Board
NEPO	*former* National Energy Policy Office
NEQA	National Environmental Quality Act
NO	Nitric oxide
NO_X	Nitrogen oxides
NO_2	Nitrogen dioxide
NGO	Nongovernmental organization
O_3	Ozone
ODS	Ozone depleting substances
OPPMO	Office of the Permanent Secretary, The Prime Minister's Office
Pb	Lead
PCD	Pollution Control Department
PM_{10}	Particulate matter smaller than 10 microns
$PM_{2.5}$	Particulate matter smaller than 2.5 microns
POP	Persistent organic pollutants
ppb	Parts per billion
ppm	Parts per million
SO_2	Sulfur dioxide
SPP	Small power producers
TSP	Total suspended particulates
µg	Micrograms
$\mu g/m^3$	Micrograms per cubic meter
ULG	Unleaded gasoline
UNFCCC	United Nations Framework Convention on Climate Change
US-AEP	United States – Asia Environmental Partnership
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
VOC	Volatile organic compounds

Exchange Rate: US$ 1 = Baht 43.58
(as of November 30, 2002)


IBRD 32163
THAILAND
AIR POLLUTION
PERCENT EXCEEDING STANDARD OF PM10, 2000:
0 - 5%
6 - 10%
15 - 20%
ROADS
RAILROADS
RIVERS
SELECTED TOWNS
NATIONAL CAPITAL
INTERNATIONAL BOUNDARIES
MYANMAR
LAO PEOPLE'S DEMOCRATIC REPUBLIC
VIETNAM
CAMBODIA
MALAYSIA
Andaman Sea
Gulf of Thailand
BANGKOK
Chiang Mai
Mae Moh
Lampang
Khon Kaen
Sara Buri
Ratchaburi
Chon Buri
Rayong
See Inset
Pathum Thani
Nonthaburi
Samut Sakhon
Samut Prakan
0 100 200 Kilometers
0 50 100 150 Miles
DECEMBER 2002

SUMMARY

Thailand's Air Quality : At Crossroads

Thailand has made remarkable progress over the past decade in combating air pollution. Today, Bangkok's air quality ranks ahead of Beijing, Jakarta, New Delhi, and Manila, but lags behind other cities such as Hong Kong, Singapore, Taipei, and Tokyo. While overall air quality has improved, it is still a problem in traffic corridors and urban centers like Bangkok.

Key air pollutants include dust, small particulate matter (PM_{10} and $PM_{2.5}$), sulfur dioxide (SO_2), lead (Pb), carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons (HC), and ground-level ozone (O_3). Other transboundary air pollutants such as ozone depleting substances (ODS), greenhouse gases (GHG), and some persistent organic pollutants (POPs) have caused long term impacts on the regional and global environment.

In Thailand, motor vehicles, power plants, factories, construction, forest fires, agricultural burning and open cooking all contribute to the emission of these pollutants. Among transport sources, two-stroke motorcycles, diesel trucks and aging buses are contributing significantly to air pollution in urban areas. The Central Region in Thailand accounts for 60-70 percent of all industrial emissions in the country. Fossil fuel-powered thermal sources continue to generate SO_2, NO_2 and carbon dioxide (CO_2) emissions, while PM emissions from power plants have been curbed. In non-urban areas, sources such as agricultural burning also contribute significantly to particulate pollution.

Trends in the ambient levels of these air pollutants can be gauged through appropriate and systematic monitoring. In Thailand, the air quality monitoring system is well developed. The Pollution Control Department (PCD) has taken the lead in monitoring key air pollutants, establishing ambient standards, and recommending policy measures to reduce air pollution in critical areas. The PCD's monitoring network consists of 71 sites nationwide—37 located in Bangkok and 11 in the suburbs. Much of the information presented in this report is based on PCD data.

Results of air quality data captured at these monitoring stations reveal that most air pollutants are declining.

Table 1. Thailand's National Primary Ambient Air Quality Standards in µg/m^3

Pollutant	Averaging time	Standard or Guideline µg/m^3		
		Thailand	USEPA	WHO
TSP	Daily	330		–[2]
	Annual	100 [1]		
PM_{10}	Daily	120	150	–[2]
	Annual	50 [1]	50	
Pb	1-month	1.5		
	Annual			0.5
O_3	1-hour	200		
	8-hours			120
SO_2	Daily	300	365	125
	Annual	100	80	50
NO_2	1-hour	320		200
	Annual		100	40
CO	1-hour	34.2 K	40 K	30 K
	8-hour	10.26 K	10 K	10 K

Source: *PCD, WHO/SDE/OEH/00.02, Geneva 2000.*

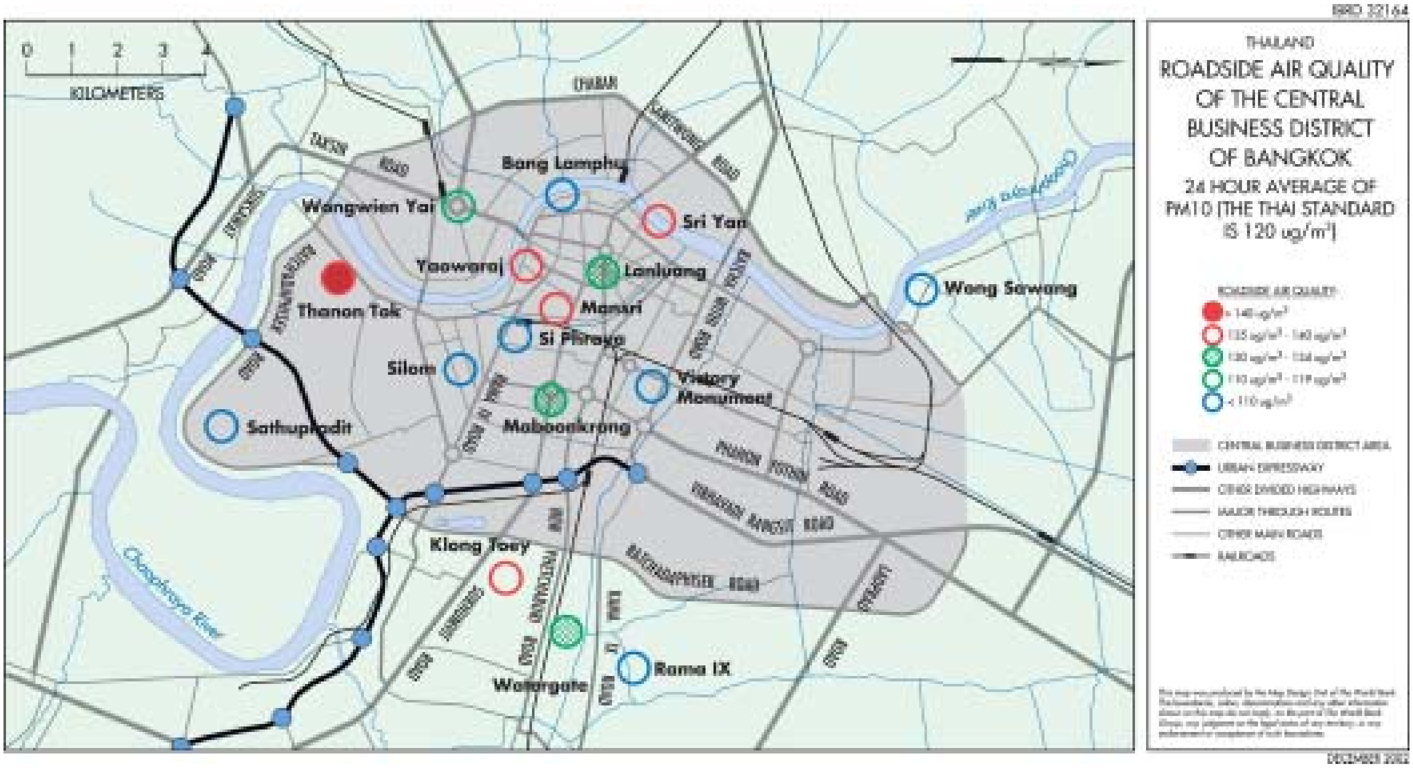
Notes:

1. Geometric mean.
2. WHO no longer recommends air quality guideline for PM because there is no safe lower limit for PM.

- Values of USEPA are for primary standards.
- Annual average -- average of daily measurements taken over one year.
- µg/m^3 is a unit of measurement and refers to one millionth of a gram of a pollutant in a cubic meter of air at 25 degrees Celsius at 1 atmosphere.
- Guideline refers to the safe level of a pollutant, for the given averaging time, to protect the public from acute health effects.
- CO values are in 1000 (K) of µg/m^3.

With the Government's efforts and leadership, the ambient levels of key pollutants—Pb, particulates, SO_2 and CO—in Bangkok and other urban centers have fallen dramatically. With the exception of particulates and O_3, all pollutants now comply with the country's air quality standards (Table 1).

Ambient PM, the pollutant with the most serious health impacts, still exceeds standards along traffic corridors. This is particularly serious along roadsides in urban areas such as Bangkok (See Map).



Visibility measurements at Don Muang airport in Bangkok have improved since 1996, even as improvements are reported in PM_{10} levels. Concentration levels of NO_x and CO are stable and declining, respectively. SO_2 levels too have declined substantially as new technology is installed at the country's power plants. Ozone levels are causing concern, with maximum values exceeding the standard.

In terms of GHGs, CO_2, methane (CH_4) and nitrous oxide contribute 68, 27 and 5 percent of total GHG emissions. Among sources, the energy sector in Thailand accounts for 51 percent of total emissions. Consumption of ODS has declined significantly over the last decade.

The presence of pollutants in the air contributes to numerous health effects ranging from irritation and odor to acute and long-term lung impairment and cardiac problems. This then translates into health costs associated with mortality and morbidity from respiratory and other cardiopulmonary diseases. The drop in most pollutant levels in Thailand has resulted in declining health costs. Health costs are estimated to have halved in Bangkok during the past five years, but they still cost the equivalent of 1.6 percent of the Gross Domestic Product (GDP) annually.

Benefit-cost ratios on health issues associated with air pollution are encouraging. One study of air pollution management in Thailand has estimated that under a medium investment scenario, the total annualized costs of implementing air pollution controls would be US$660 million in 2005 and US$1.5 billion in 2020, with corresponding benefits of US$4.7 billion and US$25 billion, respectively.

Indoor air pollution, however, remains a concern. A recent study of indoor and outdoor exposure to small particulates in Bangkok concluded that daily fluctuations of PM concentrations are correlated with PM concentrations at both near and ambient locations. However, most indoor environments, including shops, living rooms, and bedrooms, had levels higher than ambient levels of both $PM_{2.5}$ and PM_{10}

Improvements in air pollutant levels in recent years can be attributed to the foresight and leadership of a few champions, policy corrections (e.g. engine and fuel quality standards and a shift to natural gas in the power sector), massive public spending in infrastructure, stepped-up enforcement, and the market's response to advanced technologies.

In the transport sector, new cars pollute very little and motorcycles are increasingly four-stroke, though there remains a large fleet of older two-strokes. While newer EURO II buses have begun to ply the Bangkok streets, a very large fleet of older diesel buses and trucks still emits large amounts of carcinogenic particulate pollution.

The power sector is shifting more to natural gas and low-sulfur coal as fuel sources, and now requires sulfur dioxide scrubbers. At the same time energy efficiency measures and demand-side management are improving emissions from this sector. Many industrial units have embraced cleaner production to reduce air pollution, but emissions from small and medium-sized enterprises still remain a major problem. Crematoriums are being upgraded to reduce their contributions.

Area sources remain a major concern. In the countryside, open agricultural and forest burning is estimated to emit over 350,000 tons of PM annually. This smoke not only causes local impact, but is also a major source of cross-border pollution, especially from February to April. Open burning of garbage in Bangkok has decreased with the establishment of sanitary landfills.

The many improvements in pollutant levels do not seem to have changed the public's perception about air quality. A recent survey reported that three in four Bangkok residents viewed air pollution as the most significant pollution problem they faced. While air quality measurements reveal, and experts report, that Bangkok's air quality is getting better, the public remains skeptical. Such skepticism implies that public disclosure of Government programs and public participation in managing air quality may be inadequate or ineffective.

With several successes in addressing air pollution, the Government should now build on recent gains through an integrated program that involves all segments of society. Comprehensive environmental legislation in Thailand also contains specific articles and clauses addressing air quality. However the enforcement of laws remains weak due to inadequate political will, capacity constraints at the local level, lack of incentives and poor coordination among agencies.

In October 2002, a new Ministry of Natural Resources and Environment (MoNRE) was created to oversee environmental management, including air quality. This new Ministry creates an opportunity for improving coordination, integrating environmental functions across agencies, and enhancing service delivery.

In summary, Thailand needs to address the following major challenges in order to better manage its air quality over the coming decade:

- *Focusing on fine PM in Bangkok*. A recent action plan estimates that a 20 percent reduction from 1997 levels can be achieved by targeting diesel buses, and trucks at a cost of about US$80 million, with corresponding benefits estimated at over US$200 million.
- Improving air quality management by *strengthening analytical capability* in emissions inventory and health impact assessment, stepping up enforcement, and expanding monitoring and modeling.
- *Improving public transport and traffic management* by increasing the number of priority bus lanes, controlling smoke emissions from buses, and encouraging the use of the Skytrain.
- *Strengthening institutional effectiveness* by improving coordination among agencies and building capacity at the local level.
- *Broadening public involvement* in air quality management activities and improving public participation and disclosure.
- *Harnessing global opportunities* for local good by employing the Clean Development Mechanism (CDM) in the country.

Tackling these challenges, accompanied by better enforcement of environmental legislation and adequate budgets, will put Thailand on the right path towards attaining bluer skies.

The major sources of air pollution in Thailand are industry, power plants, transport (primarily automobiles), and area sources that include agricultural waste, and other biomass burning.

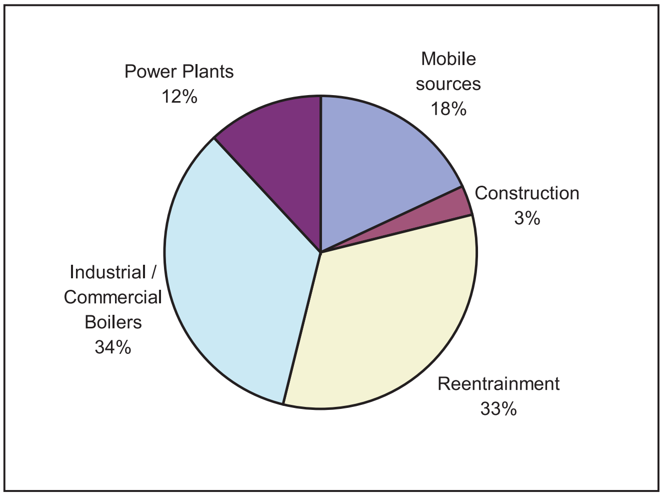
Source emissions inventory is needed. The establishment of a reliable pollutant inventory by type of source and economic sector is the first major step in effective policy formulation and enforcement. While the major sources of pollution are easily identifiable (Figure 1), the relative contribution of each of these sources is highly uncertain. The PCD has been estimating emissions for Bangkok (Figure 2) and other regions of Thailand. The Department of Energy Development (DEDP) has applied emissions factors to estimated fuel use by sector (Table 2). Special studies have also estimated emissions in Bangkok and Thailand from major sectors. There are, however, significant discrepancies in these inventories as discussed in Box 1.

Box 1. Getting the Inventories Right!

Emissions inventories prepared and reported by different organizations differ sometimes by a factor of 20! This is a major shortcoming and a clear indication that better estimates are needed for designing cost-effective actions. For example, the existing inventories in the Bangkok Metropolitan Region (BMR) do not account for pollution generated outside its airshed, contributions from open burning of agricultural residues or open cooking. Re-suspension of dust and other PM due to construction and traffic activity can change dramatically. PM emission from reentrainment and power plants for BMR today is probably lower than the 1997 estimates in Figure 2, as these sources have been controlled over the last few years.

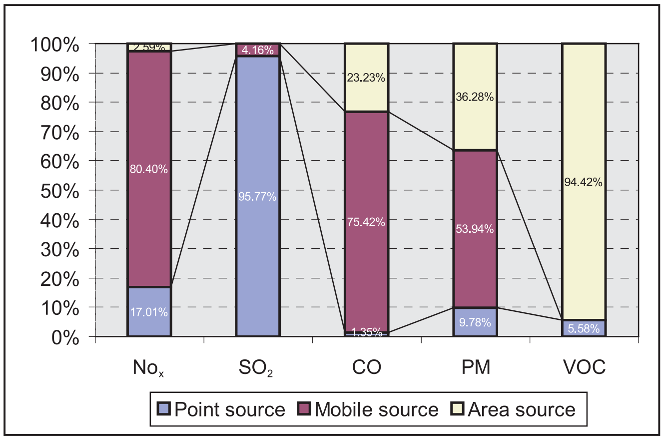
The actual number of vehicles on the road is off by a factor of two. The emissions factors used for vehicles may not be accurate as these have not been developed for vehicles and conditions prevalent in Thailand. The number of kilometers traveled for each class of vehicle also needs to be estimated with greater accuracy. With so much uncertainty the emissions should be estimated using more than one method to have confidence in these inventories.

Figure 1. Sources of PM_{10} in BMR, 1997



Source: *Radian, 1998.*
Note: Reentrainment estimates have been added by the World Bank.

Figure 2. Emissions Inventory for BMR for Five Major Pollutants, 1997



Source: *PCD Air emission source database update, 2000.*
Note: Total NO_x is 329,161. SO_2 is 240,016. CO is 463,775. PM is 38,192. VOC is 35,909. (Unit: ton/year)

Table 2. Pollution Emission Estimates, 2000 (*1000 Tons)

Pollutant	Industry	Transport	Power	Res. & Com.	Other	Total
TSP	6	16	153	0	10	185
CO	136	453	31	2,051	88	2,759
NO_x	137	208	161	28	106	640
SO_2	220	21	341	1	4	587
CO_2	30,922	46,401	57,788	4,306	7,143	146,560
CH_4	3	4	4	43	1	55

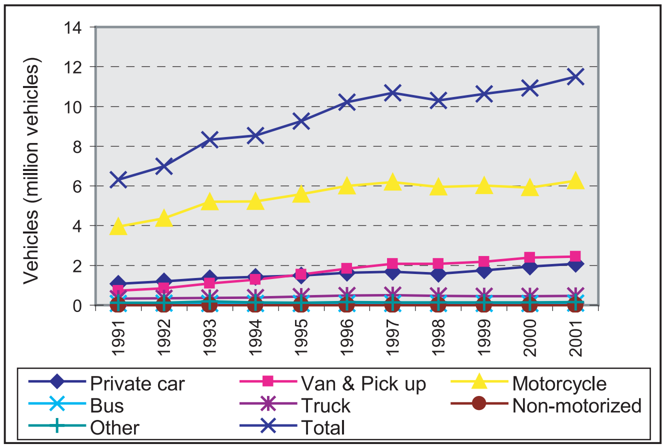
Source: *DEDP, 2000.*

Motorcycles dominate Thai roads. Thailand has recorded an annual vehicle growth of 15 percent—nearly 1000 vehicles daily—for the past two decades (Figure 3). In 1999, there were about 10 million vehicles on the road, of which 2.1 million were in Bangkok. It needs to be noted that the annual data published by the Land Transport Department (LTD) provide cumulative registrations and not the number of vehicles on the road. For Bangkok, it is estimated that in-use vehicles (on the road) are about 53 percent of the LTD reported values.[1] Motorcycles account for 39 percent of the vehicles plying Bangkok streets, followed by cars, vans and pickup trucks, and buses and trucks. Nationally, motorcycles account for three quarters of the vehicle fleet (Figure 4).

Vehicles[2] emit many pollutants, but PM is the most critical. Cars are major sources of CO, HC, and NO_x. Two-stroke motorcycles are a dominant source of HC and also contribute significantly to PM and CO emissions. Diesel trucks, both heavy and light duty, are responsible for high emissions of PM, NO_x, HC, and CO. Aging bus fleets in urban areas, including Bangkok, are large emitters of PM. The vehicle types contributing to PM_{10} are listed in Table 3. The extent of health impact is determined by the amount of population exposure, which in most urban centers is dominated by the transport sector. For this reason, air quality action plans for urban areas focus on the transport sector.

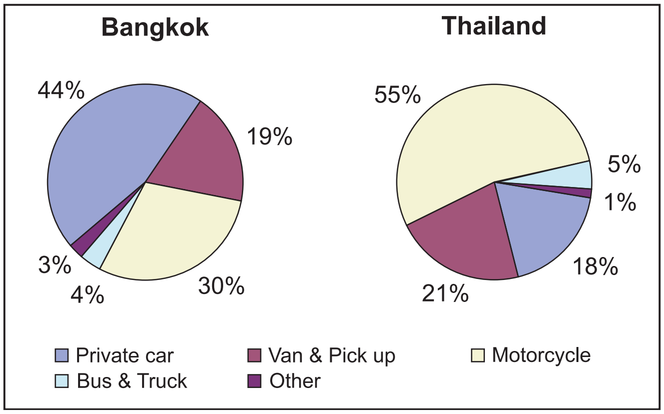
Diesel emits carcinogens. Diesel exhaust contains over forty substances that are regarded as toxic; some are considered carcinogenic by the USEPA. Almost all diesel PM emissions are fine particles less than 2.5 microns in diameter ($PM_{2.5}$). The principal sources of PM pollution in the BMR are the older light and heavy duty diesel powered vehicles that lack emissions control. Elsewhere, the large fleet of diesel-powered pickup trucks contributes to PM emissions.

Figure 3. In-use Vehicle Growth in Thailand



Source: LTD, 2002

Figure 4. In-use Vehicle Composition in Bangkok and Thailand, 2001



Source: LTD, 2002.
Note: Total vehicle count is 2,751,982 for Bangkok and 11,497,194 for Thailand.

Table 3. Estimated PM_{10} from Mobile Sources, 2000

Type of mobile sources	Percentage
Light duty trucks	31%
City buses	30%
City trucks	23%
Motorcycles	10%
Long haul trucks and buses	5%
Passenger cars	1%

Source: Parsons Internationals final report for the Air Quality Management Project to BMA, 2001.
Note: Total emissions from mobile sources are estimated to be 10,000 t/y.

[1] Based on re-registration data calculating emissions for 1999.

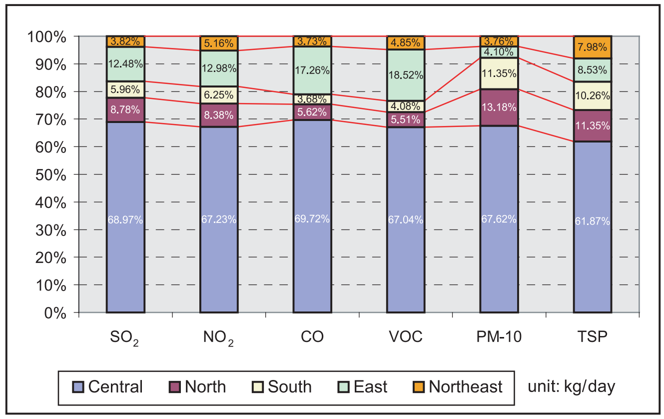
[2] Vehicles include cars, buses, trucks, motorcycles, and vans.

As large sources such as power plants and refineries have been controlled over the last decade, small and medium industries have risen in importance as major sources of PM and NO_x pollution.

The Central Region is the most industrialized. The Central Region, with 45,000 factories (including those in Bangkok), accounts for 60 to 70 percent of all industrial emissions in Thailand (Figure 5). Within the Central Region, BMR alone accounts for more than half of SO_2, volatile organic compounds (VOCs), and CO emissions, and over a third of all NO_2 emissions from industry. The eastern seaboard is also a major industrialized area with high emissions.

Key industrial contributors of PM, SO_2 and NO_2 within the Central Region are cement, lime and plaster manufacturing; iron and steel making; and other medium to heavy industries as listed in Table 4. Though emissions from industrial sources are much lower in other regions of Thailand, major contributors to emissions there are cement, lime and plaster manufacturing; sugar mills; sawmills; iron and steel manufacturing; industrial chemicals production; and pulp and paper manufacturing.

Figure 5. Industrial Emissions in Thailand, 2000



Source: Environmental Institutions Development Technical Assistance, The World Bank, Estimate of Industrial Emissions Thailand, 2000.

Note: Total industrial emission of SO_2 is 1,352,126. NO_2 is 830,273. CO is 817,475. VOC is 526,125. PM_{10} is 468,929. TSP is 600,572.

Table 4. Top Five Industrial Sources of Emissions, Central Region, 2000

Pollutant	Largest Source by Industrial Sector In Rank Order
TSP	Cement, lime and plaster (36.9%); Oil and fats (8.8%); Non-metallic mineral products (8.6%); Iron and steel (5.6%); Sugar factories and refineries (4.7%)
PM_{10}	Cement, lime and plaster (74%); Iron and steel (7.8%); Oil and fats (6.4%); Non-metallic mineral products (3.7%); Pulp, paper and paperboard (1.5%)
NO_2	Cement, lime and plaster (23.6%); Spinning, weaving and finishing textiles (10.98%); Synthetic resins, plastics materials and manmade fibers (9.3%); Pulp, paper and paperboard (7.6%); Iron and steel (7.0%)
CO	Iron and steel (24.5%); Chemical products NEC (18.9%); Pulp, paper and paperboard (16.3%); Non-ferrous metals (11.2%); Industrial chemicals except fertilizer (4%)
SO_2	Cement, lime and plaster (30.4%); Non-ferrous metals (14.7%); Iron and steel (9.6%); Pulp paper and paperboard (8.7%); Spinning, weaving and finishing textiles (4.8%)
VOC	Synthetic resins, plastics materials and manmade fibers (10.7%); Motorcycles and bicycles (7.3%); Motor vehicles (7.2%); Industrial chemicals except fertilizer (6.6%); Distilled spirits (6.2%)

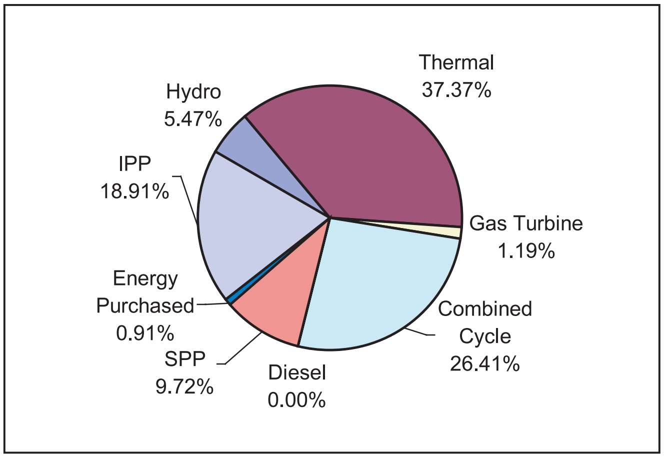
Source: Environmental Institutions Development Technical Assistance, The World Bank, Estimate of Industrial Emissions, Thailand, 2000.

Fossil fuel-powered thermal sources dominate. In Thailand, electricity is generated primarily from burning fossil fuels such as lignite, oil, and natural gas. Figure 6 illustrates electricity generation by process type. Fossil fuel-based electricity generation results in significant emissions of PM, SO_2, NO_2, and CO_2 (Table 2).

The Government's national energy policy promotes the use of natural gas, the combustion of which releases approximately half the amount of CO_2, and a small fraction of the PM and SO_2 produced by conventional fuels such as oil and coal.[3] The use of lignite has decreased slightly in recent years. Figure 7 illustrates the trend toward increased use of natural gas as a fuel source. Bang Pakong power plant has been retrofitted with electrostatic precipitators (ESP) to control PM emissions

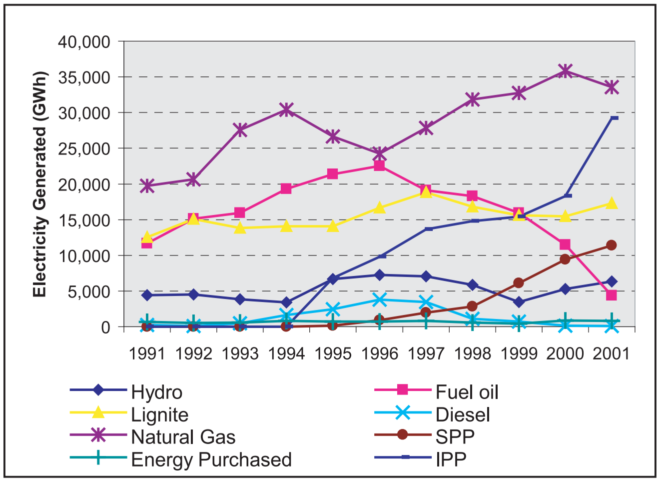
Sulfur dioxide emissions have been curbed. A critical problem for power plants in Thailand a decade ago was excessive SO_2 emissions. This was particularly true for plants operated in Mae Moh Valley in north of Thailand by the Electricity Generating Authority of Thailand (EGAT). SO_2 emissions had severely impacted human health and damaged crops and livestock in the area. In 1992 the situation reached crisis levels when the ambient 1-hr average SO_2 concentration level hit 3,418 $\mu g/m^3$, more than four times the current standard of 780 $\mu g/m^3$. There were considerable chronic respiratory problems and many people in the vicinity of the power plant needed to be hospitalized. Today this is no longer the case as many of the plants are now fitted with Flue Gas Desulfurization (FGD) systems to control emissions.

Figure 6. Electricity Generation by Process Type



Source: EGAT, 2002.
Notes: 1. Energy Purchased means electricity from Lao and Malaysia. 2. SPP = small power producers. 3. IPP = independent power producers.

Figure 7. Electricity Generation by Fuel Source



Source: EGAT, 2002.
Notes: 1. Energy Purchased means electricity from Lao and Malaysia. 2. SPP = small power producers. 3. IPP = independent power producers.

[3] Natural gas releases approximately 44 percent less CO_2 than coal, and oil produces 16 percent less CO_2/kWH than coal.

Area sources are underreported. Important area sources include re-suspended road dust; open cooking using fossil fuels; and forest fires and agricultural burning. These sources of pollution are widespread, difficult to cover in inventories, and thus often overlooked.

The occurrence of re-suspended road dust is highly correlated with building activity. However, even with moderate levels of construction, streets in urban areas get dusty and traffic activities resuspend this dust repeatedly. Regular cleaning of road surfaces is a cost-effective way of reducing roadside PM emissions.

Haze is a transboundary problem. In the South East Asia region post-logging burning is an established practice, and has transboundary implications for Thailand. The forest fires in Thailand in 2000 were estimated to have generated approximately 40,000 tons of TSP (equivalent to total emissions for Bangkok for all sources). The burning of agricultural residues generated 319 tons of TSP, causing widespread sub-regional haze. This haze impacts Bangkok and other cities (Table 5). Emission estimates from an ongoing PCD study confirm that forest fires are a major source of TSP and CO in urban areas such as Chiang Mai Municipality (Table 6).

Other pollution sources that are usually overlooked are residential and commercial open cooking and refuse burning. Estimates for Chiang Mai show that CO and VOC emissions from these sources are estimated to be high; they contributed 693 tons of CO and 627 tons of VOC in 2001 (Table 6).

Table 5. Estimates of Thailand's TSP Emissions from Agricultural Burning 2000, Tons

Region	Crops*	Forest Fires	Total
Northeast	60,171	NA	NA
North	136,589	NA	NA
Central	120,614	NA	NA
South	1,754	NA	NA
Total	**319,128**	**39,933**	**359,061**

Source: *PCD, 2002.*
Note: This is an overestimate as it assumes that all crop waste is burned. The contributions of different crops in order of significance are sugar cane (30.5%), corn (29.8%), cassava (11.0%), rice (9.8%), mungbean (8.3%), soybean (6.4%), and other (4.3%). Calculations were made using USEPA emission factors.

Table 6. Estimated Emissions from Selected Area Sources, Chiang Mai Municipality 2001, Tons

Source	CO	CH_4	NO_x	PM_{10}	SO_2	TSP	VOC
Residential/ commercial	693	-	19	8	3	1	627
Refuse burning	205	-	15	-	24	38	72
Agricultural burning	168	16	-	-	-	16	-
Forest Fires	10,280	-	294	-	-	624	1,767
Total	**11,346**	**16**	**328**	**8**	**27**	**679**	**2,466**

Source: *PCD, 2002.*

Air MONITORING

Monitoring is central to implementing an effective air quality management program in any country. Thailand has established an extensive air quality monitoring network (Table 7) with the aim of providing up-to-date information on major atmospheric pollutants. It has also prescribed national ambient standards for all criteria air pollutants (Table 1).

The monitoring network expands. Thailand commenced air quality monitoring in 1983. The monitoring network has progressively evolved and expanded to cover a variety of pollutants. Air pollution monitoring assesses compliance with air quality standards. The majority of sites in all five regions (North, Northeast, East, Central, and South) monitor particulates, CO, NO_2, SO_2, and ground-level ozone. However, not all stations monitor all these pollutants, and some monitor other pollutants in addition to those mentioned here.

Table 7. Number of Monitoring Stations in Thailand

Region	Agency	Permanent Stations	Meteorological Stations
BMR	PCD	21	19
	MET	-	4
	BMA	1	-
Central	PCD	4	4
	EGAT	3	-
	MET	-	6
North	PCD	7	7
	EGAT	12	-
	MET	-	20
Northeast	PCD	2	2
	EGAT	-	-
	MET	-	16
East	PCD	7	7
	EGAT	20	-
	MET	-	12
South	PCD	3	3
	EGAT	-	-
	MET	-	21
Total		75	121

Source: PCD, MET, BMA, EGAT, MoPH – 2002
Notes: 1. BMA has 1 mobile station, EGAT has 2 stations, PCD has 7 stations (2 stand by in Mae Moh).and MoPH had 8 mobile stations which are no longer in use.

The primary responsibility for monitoring rests with the PCD. Its monitoring network currently consists of 71 monitoring sites nationwide, which are linked to PCD's central computer system located in Bangkok.

A fleet of mobile units is maintained by MoPH to respond to area-specific pollution complaints. The primary focus of MoPH monitoring is to study the health effects of air pollution.

Bangkok's City Government, the Bangkok Metropolitan Administration (BMA), has one permanent air and noise monitoring station and one mobile monitoring unit. Under the decentralization process mandated by the new Constitution, BMA and other city governments in Thailand will progressive assume responsibility for air quality monitoring functions, while policy making and standard setting will continue to remain in the purview of national level agencies such as PCD and MoPH.

Atmospheric particles originate from a variety of sources and possess a range of physical and chemical properties. Examples of particulates include combustion-generated diesel soot or fly ash, photochemically produced particles such as those found in urban haze, salt formed from sea spray, and soil-like particles from re-suspended dust.

Collectively, particulate pollution is often referred to as total suspended particulates (TSP). Fine particulates less than 10 and 2.5 microns in size are referred to as PM_{10} and $PM_{2.5}$, respectively. These have the most significant impact on human health because they can penetrate deep into the lungs. PM emissions are a key health concern with estimated economic damage costs much higher than for other pollutants.

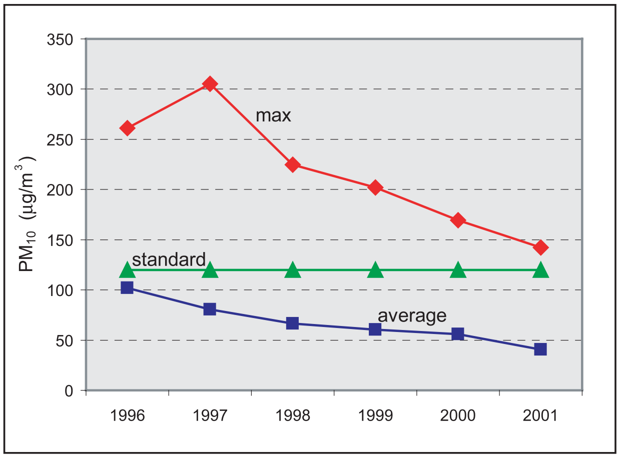
PM pollution sources are many and varied. Major sources of particulate pollution in urban areas of Thailand are vehicles, re-suspension of road and construction dust, and industry and commerce. In non-urban areas, sources such as agricultural burning contribute significantly to overall particulate pollution, and their impacts are also felt in urban areas.

Ambient PM_{10} is declining. Average ambient measurements of PM_{10} have declined steadily in recent years as shown in Figure 8. Control measures and the Asian economic crisis of 1997 contributed to this decline. Ambient PM_{10} in other urban areas has declined steadily of late. In general, average ambient PM_{10} concentrations are at a level similar to that of Bangkok (reflecting the choice of measurement sites that are usually near busy roads) in virtually all other urban areas for which measurements were taken, as shown in Figure 9 for the Northeast Region.

Moderate to high concentrations are experienced in and around Chiang Mai and Lampang. In Mae Moh, near one of Thailand's major power stations, the maximum PM_{10} concentrations recorded were more than double the standard (120 µg/m^3 averaged over 24 hours), with the value exceeded on more than 12 percent of occasions. There was, however, a slight improvement over the previous year.

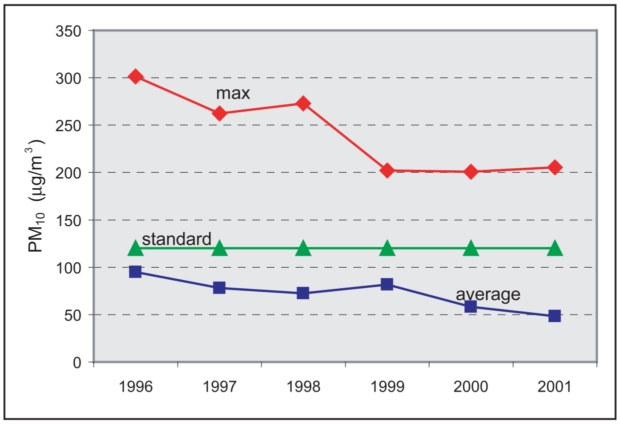
Although improvements have been reported in PM_{10} levels, standards have been exceeded on occasion in numerous cities in the North, Northeast, and Central Regions. In Bangkok, such occasions are becoming less frequent (Figure 10). There are few measured air pollution problems in Southern Thailand.

Figure 8. Annual Trends of PM_{10} Concentrations (24 hr average) in Bangkok, 1996 - 2001 (µg/m^3)



Source: PCD, 2002. Data came from 5 sites.

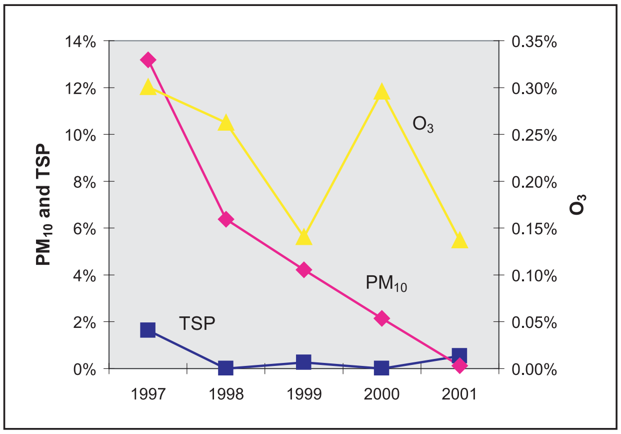
Figure 9. Annual Trends of PM_{10} Concentrations, (24 hr average) Northeast Region 1996 to 2001 (µg/m^3)



Source: PCD, 2002. Data came from 2 sites in Khon Kaen and Nakorn Ratchasima.

Note: Standard for figure 8 and 9 is daily standard.

Figure 10. Percentage of Air Exceeding Standards at All Sites (Ambient Air Quality in Bangkok)



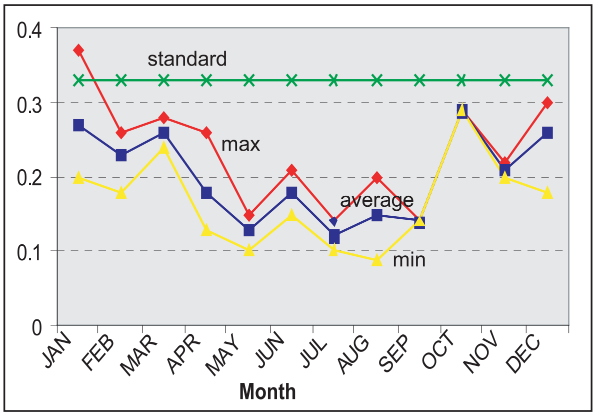
Source: PCD, 2002.

The exceedances, as measured by the percentage of observations exceeding the standard, are more likely to occur from November to April. Toward the end of the year, temperature inversions that trap pollutants close to the ground commonly occur due to the onset of the cool season. From February to April, the burning of rice paddy and other agricultural residues results in higher variability in TSP and PM_{10}concentrations in Bangkok and other urban areas (Figure 11).

Roadside air quality still exceeds standards. Maximum recorded concentrations, although lower than before, still exceed standards in many places. Longer-term trends in Bangkok's TSP concentrations (measured at the roadside) show that TSP spiked in the early 1990s, declined, and spiked again around 1996 (Figure 12). After 1997, levels declined further, mirroring trends in ambient PM_{10}.

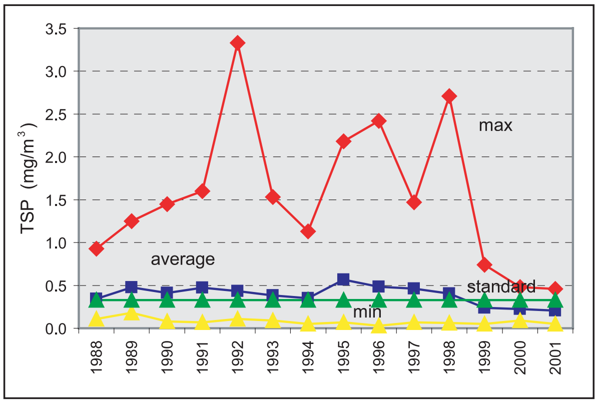
Visibility is improving. Visibility measurements recorded at Bangkok's Don Muang airport over the last four decades reveal an interesting story. While the visibility worsened steadily between the 1960s and mid 1990s, it has improved since 1996, as shown in Figure 13. Because air pollution and reduced visibility are related, the change in the trend of visibility is similar to the PM_{10} levels measured for Bangkok reported in Figure 8. The visibility and PM_{10} measurements corroborate each other and support the expert opinion that air quality has improved in BMR in recent times. However, it also shows that there is a long road ahead which will need sustained efforts to reach visibility levels enjoyed in the 1960s and 1970s.

Figure 11. Variation in Ambient TSP Concentrations by Month, 1999, Huaykwang, Bangkok (mg/m³)



Source: PCD, 2002.

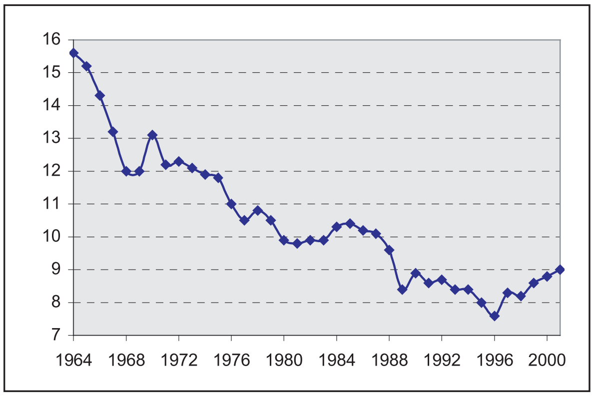
Figure 12. Annual Trends of Roadside TSP Concentrations, (24 hr average) Bangkok, 1988 to 2001 (mg/m³)



Source: PCD, 2002. Number of sites varied from 9 sites to 21 sites from 1988 to 2001

Note: Standard for figure 11 and 12 is daily standard.

Figure 13. Annual Average Visibility in Kilometers at Bangkok's Don Muang Airport, 1964 to 2001



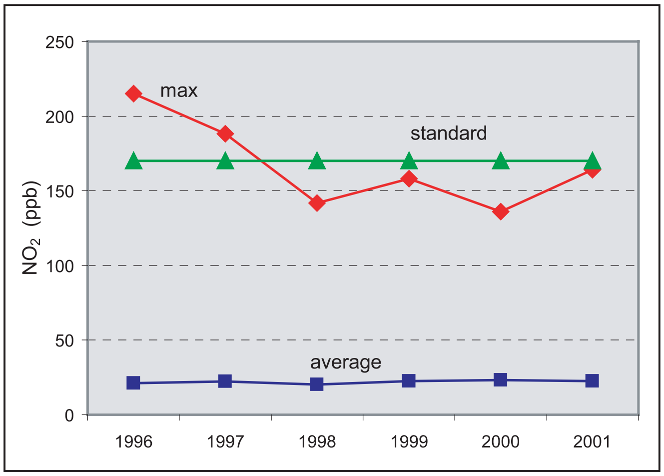
Source: Department of Meteorology, 2002.

Nitrogen oxides, including NO_2, are mainly produced by fossil fuel combustion in urban areas. They play a major role in the formation of ozone, PM, and acid rain. Short-term exposure, even less than three hours, to low levels of NO_2 may lead to changes in lung function in individuals with pre-existing respiratory illnesses and can increase respiratory illnesses in children. Long-term exposure to NO_2 may increase susceptibility to respiratory infections and cause permanent alterations in the lung.

Diesel combustion is a major contributor. Transport, in particular diesel-powered vehicles, is one of the major contributors to NO_x emissions in urban areas. Emissions from power generation and industry are also significant sources in Thailand.

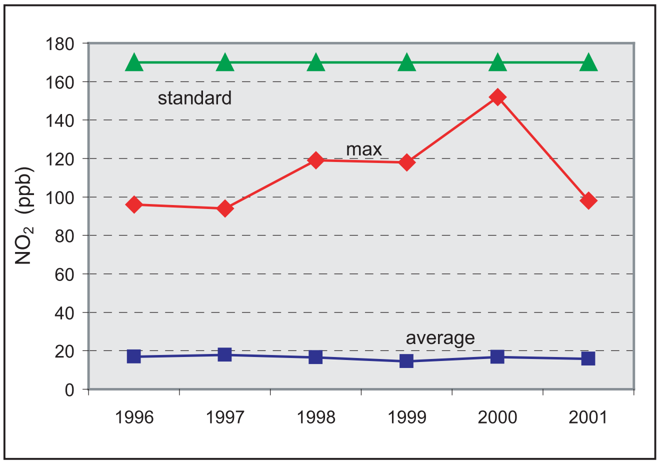
Nitrogen dioxide levels are stable. In 2000, ambient (Figure 14) and roadside measurements of NO_2 Bangkok were typically 20 percent of the national standard. From 1996 to 2000, ambient NO_2 measurements stabilized, although there is some evidence of growth in the recorded maximum during 2000 (Figure 15). NO_2 concentration levels in Bangkok's suburban provinces were similar to those recorded in the city.

Figure 14. Ambient NO_2 (1 hr average) (ppb) at All Sites in Bangkok, 1996 to 2001



Source: PCD, 2002. Data came from 10 sites.

Figure 15. Average Ambient NO_2 (1 hr average) (ppb) at All Sites in Northeast Region, 1996 to 2001



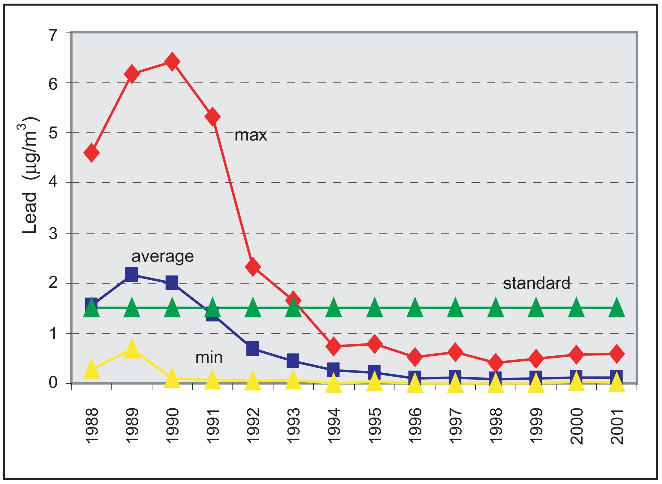
Source: PCD, 2002. Data came from 2 sites in Khon Kaen and Nakorn Ratchasima.

Note: Standard for figure 14 and 15 is 1 hr average standard.

Lead in ambient air is not an issue in Thailand any more. Lead is a highly toxic element that can result in damage to the brain, kidneys, blood, central nervous system, and reproductive system. Children who are exposed to high levels of lead may experience slowed cognitive development, reduced growth, and other health effects. Historically, the principal source of atmospheric lead has been the combustion of alkyl lead additives in gasoline.

Since Thailand's complete phase-out of leaded gasoline at the end of 1995 , observed lead levels have fallen to almost nil, as shown in Figure 16. A recent study found that since the early 1990s, there has been a statistically significant decrease in blood lead levels in school children and traffic police, two groups that face the highest risk of lead exposure (Box 2).[4]

Figure 16. Roadside Lead (24 hr average) (µg/m^3), 1988 to 2001, All Sites Combined, Bangkok



Source: PCD 2002. Number of sites varied from 9 sites to 21 sites from 1988 to 2001.
Note: Standard is monthly standard.

Box 2. Benefits of Unleaded Gasoline (ULG) Phase-out

A 1996 study on health benefits after the implementation of the ULG policy showed that blood lead levels in traffic policemen decreased dramatically from 28.14 µg/dl in 1988 to 5.33 µg/dl in 2000. Similarly, blood lead levels in school children also decreased from 8.56 µg/dl in 1993 to 5.58 µg/dl in 2000. Therefore, it is obvious that the leaded gasoline phase-out policy yielded health benefits to the population in Thailand.

This study also calculated the monetary value of health benefits resulting from reductions in IQ loss effect on lifetime earnings in children, and in hypertension, heart disease, stroke and premature mortality in adults. The monetary value of health benefits was calculated to be 7,000 million Baht, while the costs of the phase-out are only 200 million Baht. Therefore, the benefits outweigh the costs by more than 35 fold.

However, the study found that lead in paint is another important challenge. Both children and traffic policemen whose blood lead levels exceed the standard have one common risk factor - exposure to house paint. Therefore, it is recommended that Thailand initiate measures to limit or remove lead from other sources, particularly paint.

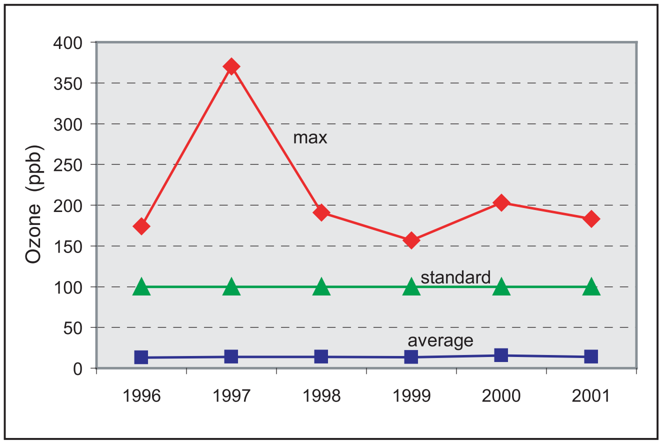
Source: The Study on "Unleaded Gasoline Policy: Health Benefits for School Children and Traffic Policemen in Bangkok Metropolitan Administration" done by Chulalongkorn University and PCD, 2002.

[4] PCD, *Unleaded Gasoline Policy: Health Benefits for School Children and Traffic Policemen in Bangkok Metropolitan Administration*, February 2002.

Ozone is a highly reactive gas, formed by the reaction of VOCs and NO_x in the presence of heat and sunlight. Ozone can cause a range of acute health effects including eye, nose and throat irritation, chest discomfort, coughing and headaches. Children who are active outdoors when ozone levels are high are most at risk. Ozone also affects vegetation and ecosystems, decreasing yields of commercial crops and plantations and lowering the aesthetic value of national parks.

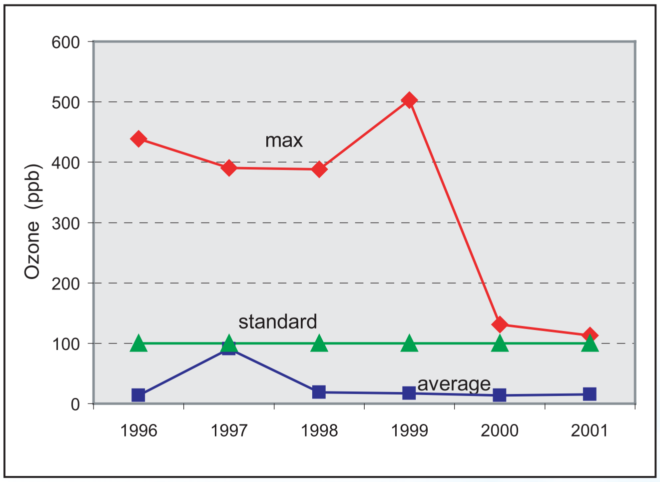
Ozone levels are a cause for concern. In 2000, measurements of ambient ozone in Bangkok showed that while average concentrations are low at all monitoring stations, maximum values exceeded the standards significantly and frequently (Figure 17).High ozone concentrations are normally observed in the suburb areas downwind from center of Bangkok. Similar trends have been observed in Bangkok's adjoining provinces and throughout other urban areas in Thailand, as shown in Figure 18. Rising emissions of VOCs and NO_x , which are precursors for O_3 along with meteorological conditions, are causes of increasing maximum levels downwind of urban centers. However, several studies indicated that O_3 problem in Bangkok is controlled by VOCs not by NO_x. This means that VOCs emissions will have to be reduced in order to lower the levels of O_3.

Figure 17. Average and Maximum 1-hour Ambient Ozone (ppb) at All Sites in Bangkok, 1996 to 2001



Source: PCD, 2002. Data came from 8 sites.

Figure 18. Average and Maximum 1-hour Ambient Ozone (ppb) at All Sites in North Region, 1996 to 2001



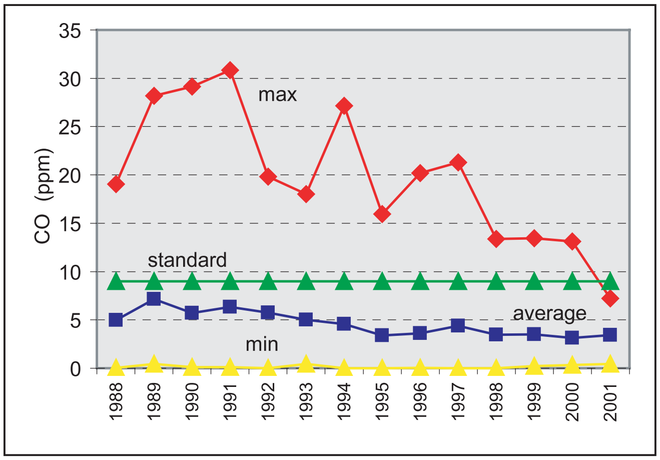
Source: PCD, 2002. Number of sites increased from 5 to 7 in 1999
Note: Standard for figure 17 and 18 is 1 hr average standard.

Carbon monoxide is an odorless, invisible gas, formed when carbon in fuel is not burned completely. The inhalation of CO can disrupt the supply of essential oxygen to the body's tissues – thus posing a major health risk. Those who suffer from cardiovascular disease are most at risk. At high levels of exposure, CO can be fatal.

Automobiles are the largest source of CO emissions. Lesser sources include industrial processes, non-transportation fuel combustion, and natural or manmade fires. Peak CO concentrations typically occur during the colder months of the year, when CO automotive emissions are greater and nighttime inversion conditions are more frequent.

Levels are steadily declining. Roadside measurements from 1988 to 2001 show a steady reduction in CO over the 13-year period (Figure 19). In Bangkok's adjoining provinces, average concentrations were similar to those observed in Bangkok. In the rest of Thailand, CO levels are very low and have exhibited a downward trend similar to that of Bangkok. This decline is due for the most part to the catalytic converters on automobiles, which were mandated in 1993 after introduction of ULG.

Figure 19. Roadside Carbon Monoxide (8 hr average) (ppm), 1988 to 2001, All Sites Combined, Bangkok



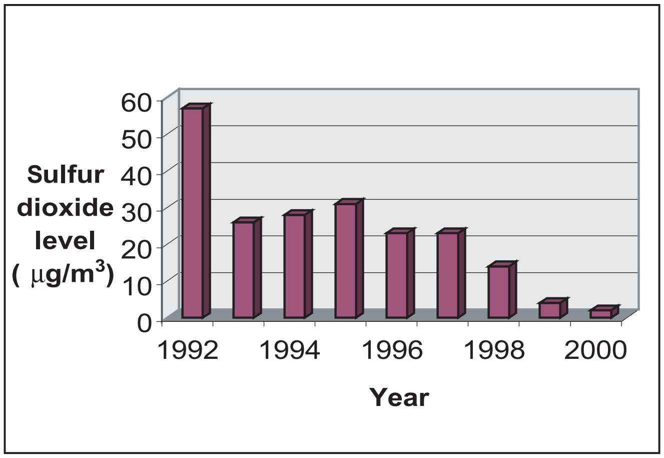
Source: PCD 2002. Number of sites varied from 10 sites to 21 sites from 1988 to 2001.
Note: Standard is 8 hr average standard.

Sulfur dioxide is a colorless gas with a choking odor that is formed when fuel containing sulfur (mainly coal and oil) is burned, and during other industrial processes. High concentrations of SO_2 can result in temporary breathing impairment for asthmatic children and adults who are active outdoors. Together, SO_2 and NO_x are the major precursors to acidic deposition (acid rain), which is associated with acidification of soils, lakes, and streams, and accelerated corrosion of buildings and monuments.

Fuel combustion, largely from lignite power plants, accounts for most of the total SO_2 emissions in Thailand. Industry is the next largest source of SO_2 emissions.

Levels have been substantially reduced. Ambient levels of SO_2 around cities have been within standards for a long time. Because power plants are the major source, measurements of SO_2 are made near power stations around the country. In 2000, average measurements were typically about one percent of the national standard. Since the 1992 pollution crisis, when SO_2 levels reached hazardous levels in the vicinity of the Mae Moh power station (discussed further in Response section), desulfurization technology has been progressively installed at power plants which has resulted in declining level of ambient SO_2 in Mae Moh (Figure 20). In 2000, ambient and roadside measurements in Bangkok showed that average measurements of SO_2 were well below the national standard, at around six percent, with the highest recorded maximum value being less than half of the standard. In Bangkok's adjoining provinces, SO_2 concentrations were similar to those of Bangkok.

Figure 20. Average Annual Ambient Sulfur Dioxide Levels in Mae Moh, 1992 to 2000



Box 3. Power Plants - Going Too Far?

High levels of ambient SO_2 during September 1992 caused severe damage to humans, crops, and animals in the Mae Moh valley. The maximum one hour SO_2 concentration recorded was 3,418 $\mu g/m^3$, several times higher than the standard value. This excessive level resulted because of expansion of a large number of power plants in the valley burning lignite coal (containing high levels of sulfur) during low dispersion conditions. The sulfur controls required and instituted at Mae Moh have resulted in controlling ambient pollution and are thus justified.

The ensuing public outcry caused the Government to tighten power plant controls requirements throughout Thailand. Since this incident, all coal-fired power plant, regardless of the level of sulfur in the coal or the location of the plant, appear to require desulfurization scrubbers (mostly as a result of public distrust). This could be costly to Thailand in the long term. It may be more prudent to ensure that cost-effective measures are proposed for each new plant, taking into account technology, location, and the carrying capacity of the environment. Public awareness and involvement in understanding the complex issues related to such decisions are very important.

Thailand has ratified international environmental agreements that aim to combat global warming. The United Nations Framework Convention on Climate Change (UNFCCC) obliges Thailand to develop, update, and publish information on inventories of GHG emissions. Thailand ratified the Kyoto Protocol in August 2002. Climate change caused by GHGs is likely to affect weather patterns and cause sea level rise. Thailand has an extensive coastline and Bangkok is particularly vulnerable, being located in a low-lying coastal area.

Greenhouse Gases. Emissions of GHGs in 1998 are estimated at 297,000 Gg.[5] Global GHG emissions from Thailand include CO_2, CH_4, and N_2O, O_3, direct emissions of which contribute 68, 27, and 5 percent of total emissions, respectively. Deforestation and the conversion of previously forested land to agricultural and urban use, combined with fossil fuel combustion, are major sources of GHGs. Deforestation and wet rice paddy production (90 percent of total rice under production) are major contributors to CH_4, an important GHG.

The energy sector contributes the most. The energy sector, which includes fuel consumed for transportation, accounted for 51 percent of total emissions in 1998. Agriculture contributed a net CO_2 equivalent of 23 percent of national emissions for 1998, and land use changes and the forestry sector contributed 17 percent (Table 8).

High per capita CO_2 emissions. CO_2 equivalent emissions are expected to increase by 2.3 percent per year during the current decade, and by 3.6 percent per year between 2010 and 2020. Thailand's CO_2 emissions per capita are relatively high compared to some of its neighbors, as shown in Table 9. In view of the dominance of the energy sector in GHG contributions, initial control measures should target energy efficiency.

Global Environmental Facility (GEF). This international, financial entity has been established by over 155 countries. GEF activities for Thailand fall into three areas—biodiversity, climate change, and international water. GEF funds can defray the added costs of making projects friendly to the global environment. GEF promotes conservation of biodiversity; improving forest, farmland, coastal, mountain, marine, and wildlife management; energy savings and renewable energy technology; and reduction of reliance on less efficient technologies that cause air pollution.

Table 8. Greenhouse Gas Emissions by Sector, 1998

Greenhouse Gas Emissions Sources	CO_2-equivalent Emissions (Gg) Total	%
Total Net National Emissions	297,611	100.0
1. Energy	151,953	51.1
A. Fuel Combustion	*144,096*	*48.4*
B. Fugitive Emissions	*7,858*	*2.6*
2. Industrial Process	10,752	3.6
3. Agriculture	69,214	23.3
4. Land Use Change & Forestry	50,666	17.0
5. Wastes	15,026	5.1

Source: ERM, 2001.

Table 9. Regional Comparison of CO_2 Emissions

Country	CO_2 Emissions (Million MT Carbon)[1]	CO_2 Emissions per capita[1]
Thailand	45	3.2
South Korea	107	10.3
Indonesia	64	1.1
China	669	2.5
World	6,144	3.9

Source: Millennium Development Goals Monitor for CO_2 Emissions per capita, 1999.

[5] GHG emissions are measured in CO_2 equivalent Gigagrams ;
1 Gigagram = 10^9 grams = 1 billion grams = 1,000 metric tons.

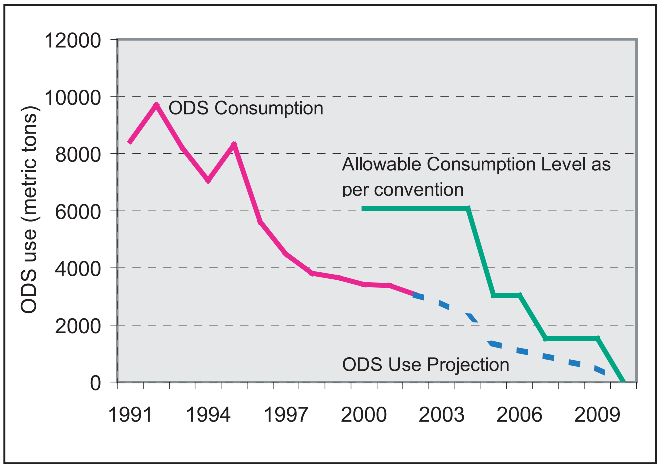
Ozone Depleting Substances. The Montreal Protocol (MP) on Substances that Deplete the stratospheric Ozone Layer, signed in 1987, has proven successful in progressively reducing the emissions of human-made ODS by phasing out their production and consumption. The stratospheric ozone layer provides a vital service in shielding the denizens of Earth from harmful ultraviolet radiation. This filter of ozone in the stratosphere is being stripped due to the use of manufactured chemicals (such as chlorofluorocarbons CFCs, methyl bromide, and halons), and natural chemicals (such as chloromethane, which originates from forest fires and rotting organic matter). CFCs are widely used as refrigerants, insulating foams, solvents, fire extinguishers, and insecticide.

A large "hole" was discovered in the ozone layer in 1985 over the Antarctic. Negative health effects of ultraviolet radiation (UV) include skin cancer, cataracts, weakened immune systems, and blindness in some animals. Other effects of increased UV include reduced crop yield (due to the disruption of the normal physiological properties of plants leading to increased plant disease and other problems), and reduced phytoplankton production - a key element in the marine food chain. Global response to ozone depletion led to the Vienna Convention and the implementation of the MP. The MP establishes the time schedule for the reduction and elimination of ODS and requires that all parties to the Vienna Convention ban exports and imports of controlled substances.

A Multilateral Fund (MLF) for implementation of the MP was established in June 1990. With the MP, the total consumption of CFCs worldwide has dropped from about 1.1 million tons of ODS in 1986 to about 150,000 tons in 1999. As of 2002, 160,401 metric tons of ODS had been phased out in developing countries Industrial countries, which consumed nearly 90 percent of ODS before the MP, stopped most ODS use after 1987, and Article 5 countries froze their consumption in 1999. Consumption of most ODS will be reduced to 50 percent of this by 2005, and to nothing by 2010. The benefits associated with the implementation of the MP add up to approximately US$ 460 billion in reduced damage to fisheries, agriculture, and materials. In addition, more than 20 million cases of skin cancer and nearly 130 million cases of cataracts will be avoided. The MP is often regarded as a model for global environmental cooperation arrangements.

Thailand has ratified the international environment agreements that aim to combat ozone depletion. Thailand is obliged to complete its ODS phase-out by 2010 (Figure 21).

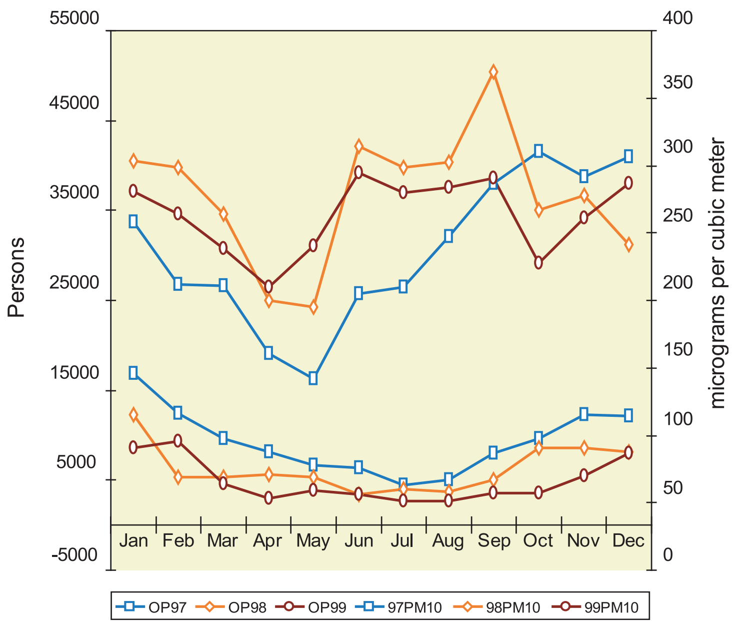
Figure 21. Consumption and Projection of ODS Use in Thailand, 1991-2010



Meeting ODS targets. Thailand is ahead of target, and is set to meet its 2010 obligations under the MP. Through grants amounting to US$35 million provided by the Multilateral Fund of the MP, the Department of Industrial Works (DIW) has assisted over 100 larger enterprises through the World Bank and UNDP. An additional US$15 million grant, administered by the World Bank, will support DIW to implement a national CFC Phase-out Plan covering small enterprises and service shops. However, meeting the phase-out targets for halons and methyl bromide will be difficult.

Health impacts of air pollution vary based on the type of pollutant, length of exposure, and extent of interaction among pollutants. Fine particulate matter such as PM_{10} poses a serious and direct threat to human health as the particles penetrate deep into lung tissue, conveying toxic substances. Figure 22 shows that the level of PM_{10} concentration and the number of outpatients with respiratory diseases peak during the dry season, from November until February. There is a positive correlation with the number of outpatients with respiratory diseases for these months. Although PM_{10} is not the only factor that leads to respiratory diseases, policy intervention to curb the concentration of PM_{10} during the dry season can be very beneficial and cost effective.

Figure 22. PM_{10} and respiratory patients



source: PCD and BMA.2002

Box 4. Methodology for Estimating and Forecasting Health Costs

- An increase in PM_{10} concentration by 1 $\mu g/m^3$ was estimated to increase the mortality rate by 0.084 percent, chronic bronchitis cases to 3.06 per 100,000, and incidence of respiratory symptoms to 18,300 per 100,000 adults.
- Health impacts were estimated by multiplying these dose-response coefficients with exposed populations and the PM_{10} levels above the safety threshold of 20 $\mu g/m^3$.
- In order to put a monetary value on human life, individuals in several countries are asked how much they would be willing to pay to avoid a certain symptom or illness. Per capita incomes are then used to adjust the unit values of statistical lives[1] in different cities. The corresponding value of statistical life in Bangkok and Nakorn Sawan is estimated at US$260,000 and US$43,000 respectively.
- The monetary values for health costs associated with morbidity and mortality are estimated by multiplying the health damages with the unit values.
- Projections for PM_{10} in Bangkok up to 2020 are based on assumptions made about population growth, per capita income change, and energy consumption changes, etc. Under the assumption of no new policy interventions, results indicate that PM_{10} concentration would be reduced from 60 $\mu g/m^3$ in 2002 to 50 $\mu g/m^3$ in 2020, largely due to

Table 10. Estimates of Thailand Health Impact and Costs by PM_{10} in Six Cities of Thailand for 2000

City	PM_{10} ($\mu g/m^3$)	Population (million)	Mortality Rate	Excess deaths	Chronic Bronchitis	Cost in million US$
Bangkok	64	5.7	0.0065	1,092	4,550	424
Chiang Mai	57	1.6	0.00985	390	1,080	56.8
Nakhon Sawan	51	1.1	0.0058	134	630	26.1
Khon Kaen	66	1.8	0.006	324	1,476	59.2
Nakhon Ratchasima	51	2.6	0.0055	286	1,426	56.8
Songkhla	41	1.2	0.0061	104	464	21
Total		**14**		**2,330**	**9,626**	**643.9**

Notes:
1. The PM_{10} data is the annual average and is from monitoring stations and estimates based on an air quality projection model.
2. Excess deaths and chronic bronchitis symptoms caused by PM_{10} are estimated based on simplified methodologies.
3. The total cost of deaths and chronic bronchitis caused by PM_{10} is estimated by first multiplying the unit costs with the respective cases and then adding up the costs for different categories. Since only PM_{10} related deaths and illness are included in the health damage estimation, the total costs presented in the table above are only lower bounds of the total costs caused by air pollution.

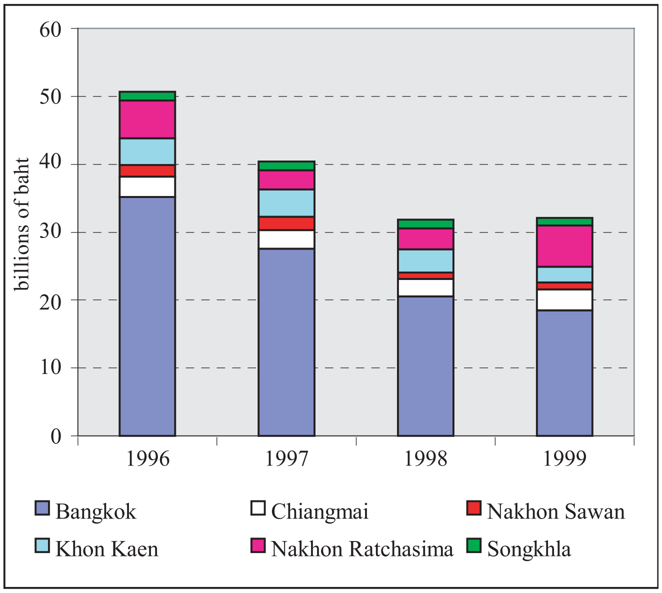
Numerous studies have attempted to estimate the health cost of PM_{10} emissions. Some of these have calculated costs on a value per ton basis, with figures ranging from US$20,000 per ton (for hospital costs only), to over US$500,000 per ton for total community costs in some high-income countries.[6] Others have attempted to put a value on mortality and morbidity, especially declining respiratory functions and other cardiopulmonary diseases.

Valuing health costs. An initial analysis of the cost of health impacts of PM_{10} in six major cities in Thailand—Bangkok, Chiang Mai, Nakhon Sawan, Khon Kaen, Nakhon Ratchasima, and Songkhla[7]—was undertaken for this Monitor (Table 10, Box 4). Based on earlier international studies, this analysis computed the numbers of excess deaths and incidence of disease due to impacts of PM_{10}. The total cost of the exposure to PM_{10} in these cities for excess death and bronchitis is estimated at US$ 644 million per year and is a lower bound of the health damage. The analysis covered the period 1996-1999, and revealed the following three important results:[8]

- *First*, the magnitude of total health costs was substantial, equivalent to 1 to 1.6 percent of the national GDP from 1996 to 1999. In 1999, for example, health costs were equivalent to the entire export value of footwear products.[9]

- *Second*, the health costs in Bangkok alone accounted for more than 65 percent of the total costs of all six cities. Since Bangkok accounts for roughly 35 percent of total GDP, the health impacts in Bangkok are equivalent to a significant proportion of the national GDP, i.e. 0.5 percent, in 1999. The average health costs of air pollution per person are estimated at US$46 (about 2,000 Baht) per year.

Figure 23. Health Costs of PM_{10} for Six Major Provinces (billion Baht)



- *Third*, the 1997 economic crisis has caused a sharp reduction in economic activities, energy demand, and levels of PM_{10}, which directly lowers health costs of PM_{10} exposure. However, since the economic recovery in 1999, health costs have stabilized (Figure 23).

Forecasting health costs. Recent research has found that long-term exposure to fine particulate air pollution is a vital environmental risk factor for cardiopulmonary and lung cancer mortality. Each 10 $\mu g/m^3$ elevation in fine particulate air pollution was associated with approximately 6 percent and 8 percent increased risk of cardiopulmonary and lung cancer mortality, respectively (see footnote 10).

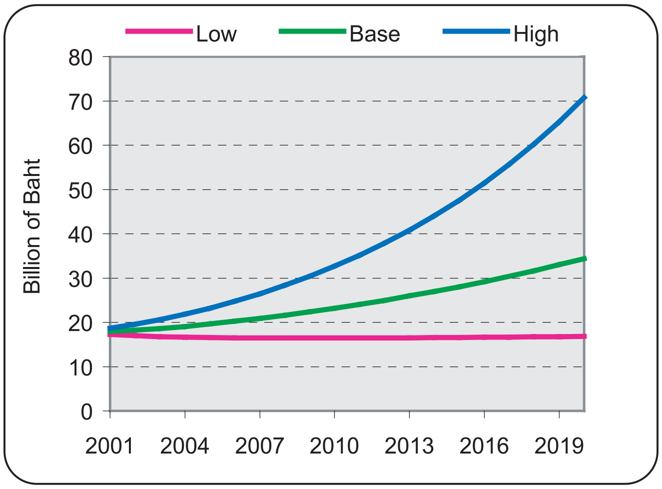
[6] Parsons Internationals final report for the Air Quality Management Project to BMA, 2001.
[7] The selection of these provinces is based on the availability of the ambient air quality data monitored by PCD
[8] The health costs comprise only the value of death and bronchitis costs caused by PM_{10}.
[9] In 1999, the total value of footwear export was 32.1 billions baht (BOT, Economics and Financial Statistics, January 2001).
[10] Pope, C. Arden, et. al. (2002), "Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution", Journal of American Medical Association, 287(9), pp. 1132-1141

Figure 24 shows trends in health costs associated with PM_{10} for Bangkok from 2001 to 2020, under different scenarios.[11] Health costs decline slightly until 2009, and gradually increase thereafter for the low cost scenario. This is because the declining rates of PM_{10} during the initial period are higher than the growth rates of Bangkok's GDP. After 2009, income growth as well as the growth in value of statistical life outpaces the declining rates of PM_{10}.

Another study on the benefits of air pollution management in Thailand estimated that under a medium investment scenario, the total annualized costs of implementing air pollution controls would be US$660 million in 2005 and US$1.5 billion in 2020, with corresponding benefits of US$4.7 billion and US$25 billion, respectively. The World Bank estimated benefit-cost ratio is higher for Thailand than for other countries in the East Asia region.[12]

The main purpose of such forecasting is to illustrate the potential health damage that may be prevented and substantial costs that may be saved. This can be done by designing and implementing appropriate policy interventions. These include: controlling PM emissions from buses, phasing out two-stroke motorcycles and older automobiles that lack catalytic converters, and providing appropriate fiscal and economic incentives to reduce traffic volume in cities, especially at peak hours.

Figure 24. Health Costs of PM_{10} for Bangkok, 2001-2020



[11] Low case: national GDP growth = 2 percent per annum and Bangkok GPP growth = 1.5 percent per annum.
- Base case: national GDP growth = 5 percent per annum and Bangkok GPP growth = 4.5 percent per annum.
- High case: national GDP growth = 8 percent per annum and Bangkok GPP growth = 7.5 percent per annum.

[12] World Bank (1999) Thailand: Building Partnerships for Environmental and Natural Resources Management.

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Indoor Air Pollution

Indoor air pollutants are recognized as a potential source of health risks to exposed populations throughout the world. Problems vary widely in industrialized and non-industrialized settings. In rural environments exposure to emissions from biomass burning for cooking or heating is the main problem. In urban areas such pollution can originate from cooking or heating, and be worsened by poor ventilation.

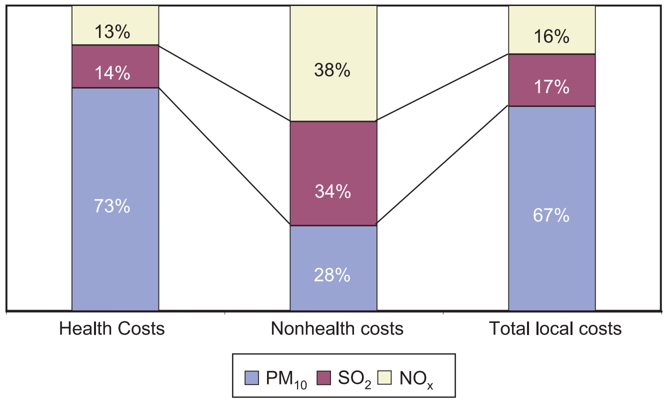
Epidemiological studies have indicated that women and children who spend large portions of the day in the home are often exposed to high levels of pollutants there. In addition, the location of the home is a major determinant of total exposure. Indoor air pollution and its impacts are not well studied in Thailand.

A recent study of indoor and outdoor exposure to small particulates in Bangkok concluded that daily fluctuations of PM concentrations are correlated with PM concentrations at both near and ambient locations. However, most indoor environments, including shops, living rooms, and bedrooms, had levels higher than ambient levels of both $PM_{2.5}$ and PM_{10}.[13]

Non-health Impacts

While health impacts are no doubt the most compelling reason to take action, non-health costs of pollution are also significant. These costs include those stemming from congestion and loss of productivity, and damage to ecosystems and physical infrastructure. One study estimates that in six international cities, including Bangkok, the non-health costs of NO_x and SO_2 outweigh health costs (Figure 25). In the case of particulate pollution however, health costs significantly outweigh non-health costs.

Figure 25. Contribution of Emissions of Various Pollutants to Local Damages from Fuel Burning in Six Cities, 1993 (percent)



Source: Environmental Costs of Fossil Fuels – A Rapid Assessment Method with Application to Six Cities, by K. Lvovsky et al., World Bank, 2000.
Note: Six surveyed cities are Mumbai, Shanghai, Manila, Bangkok, Krakow and Santiago.

Transboundary and global impacts include acid rain, global warming, and damage to stratospheric ozone. In Thailand, no studies have been done to value these impacts. Meanwhile, Thailand continues to contribute to and suffer from the regional haze problem. Typical impacts caused by some of the pollutants are described in Table 11.

Table 11. Non-health Impacts of Air Pollution

Pollutant	Receptor	Impacts
PM	Vegetation, materials, and structures	- Stunted growth - Soiling, deterioration, fading, chipping
NO_X, SO_2		- Leaf discoloration, spotting, increased susceptibility to pathogens - Corrosion, deterioration
O_3		- Leaf spotting, flecking - Cracking, fading

[13] Tsai, F.C., K. Smith, N. Vishit-Vadakan et al. 2000. "Indoor/outdoor PM_{10} and $PM_{2.5}$ in Bangkok, Thailand," Journal of Exposure Analysis and Environmental Epidemiology, Volume 10, pp. 15-26.

The Thai Society of Environmental Journalists, in collaboration with US-AEP and Mahidol University, surveyed 643 Bangkok residents between March and May 2002 to gauge their perception of air pollution (Box 5). The public views are consistent on the sources, causes, and impacts of air pollution across age and gender.

Vehicles are the main polluter. Nearly three in four Bangkok residents consider air pollution as the main environmental problem they face. Ninety percent identified transport as the main source of it, while road dust, construction dust, and industrial emissions were ranked next. Uncontrolled urbanization, over-population, inadequate city planning, poorly maintained vehicles, and the widespread use of two-stroke engines were thought to be the causes (Figure 26).

Bangkok residents remain skeptical. Bangkok residents were well aware of air pollution. Eighty five percent had witnessed what they believed were motor vehicle emissions violations. They did not report such violations to the authorities, either because they did not know how to make a report, or did not feel it was their duty. Thirty-one percent indicated that they did not believe the Government would take any action even if they did report a violation. The survey indicated that while Government authorities and air quality experts believe that Bangkok's air quality is improving, the public believes the situation has continued to deteriorate, or has remained the same.

Residents limit their exposure. More than 90 percent of the participants recognized that exposure to air pollution is a significant health risk. To guard against exposure, they avoid highly polluted areas, use air-conditioned vehicles, or hold their breath and cover their noses. Overall, women were more likely to guard themselves against exposure than men. Also, residents who were relatively younger (21 to 30 years of age), more educated, or worked in proximity to pollution sources took greater precautions to avoid exposure.

Control measures are perceived as inadequate. Citizens are aware of Government pollution control measures and campaigns and feel that these are on the right track, but see enforcement as weak and inconsistent. They would welcome more integrated policies and closer coordination among responsible authorities.

Everyone is responsible. The majority indicated that solving Bangkok's air pollution problem requires action not only from the Government, but also from citizens, civil society groups, and the private sector. Those with a relatively higher level of education believed more strongly that individual citizens have a greater responsibility in helping to develop solutions. Users of public transportation also believed that public transportation is an important component of any solution. In addition, while respondents recognized that effective solutions include mass transit and clean technologies, many cited the importance of creating the right incentives.

Box 5. Public Perception Survey

Conducted between March and May 2002, the survey reached 643 residents and commuters from a range of occupations, including those who face direct, daily on-the-job exposure to air pollution, such as traffic police, street vendors, bus drivers, and construction workers. To provide an in-depth understanding of respondent perceptions, interviews with forty residents from different occupations and educational backgrounds were also conducted.

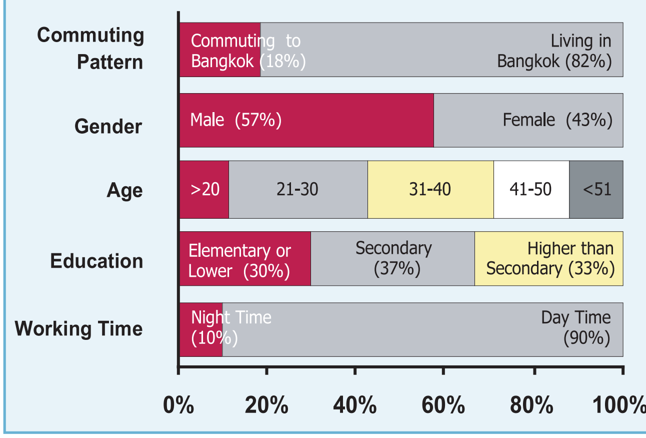
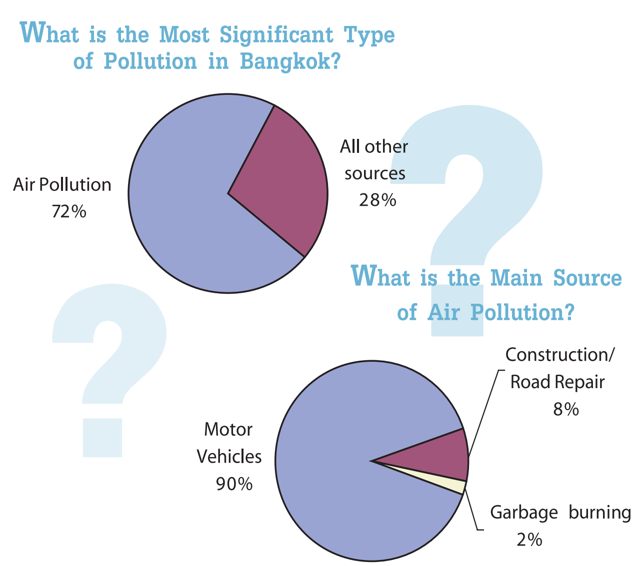


Figure 26. Public Perception in BANGKOK.



Since the early 1990s, Thailand has stepped up efforts to control air pollution. National and local agencies like the PCD, National Energy Policy Office (NEPO), LTD, BMA, city of Chiang Mai, and others have formulated policies, programs, and projects aiming to control air pollution. Similarly, the private sector and civil society also have undertaken several initiatives. A description of the different responses follows.

Pioneering leaded gasoline phase-out in the region. Thailand was the first developing country in the region to address the issue of lead in gasoline, phasing it out completely by 1995. (see Box 6). Thanks to this phase-out, the ambient lead levels in Thailand are negligible today. Thailand's remarkable success has inspired other countries in the region, such as Vietnam and Philippines, to give priority to phasing out leaded gasoline.

Achieving higher engine standards. The observed reduction in pollutant emissions from the transport sector in recent years has been due to a combination of new laws and regulations that have imposed higher emissions standards for new automobiles. Gasoline vehicle engines have become more efficient and less polluting through the use of technologies such as catalytic converters. These technologies have gone a long way in reducing emissions of NO_x, HC, and CO. Continued reductions in PM emissions can be achieved with effective implementation of more stringent mandated tail pipe emission standards for new diesel vehicles.

New diesel-fueled buses are required to meet Euro 2 standards. To meet the Euro 2 and Euro 1 standards, virtually all diesel engines require direct fuel injection and computerized engine maintenance systems. But many buses operating as Euro 2 buses do not employ such computer control technologies, and are unlikely to be operating to standard.

Box 6. Success of Lead Phase-out

Thailand's ambitious program to eliminate lead in gasoline was completed in 1995, after only four and a half years, and a year ahead of schedule. This achievement was the result of a collaborative approach involving key stakeholders such as Government agencies, representatives of oil companies, and automobile manufacturers.

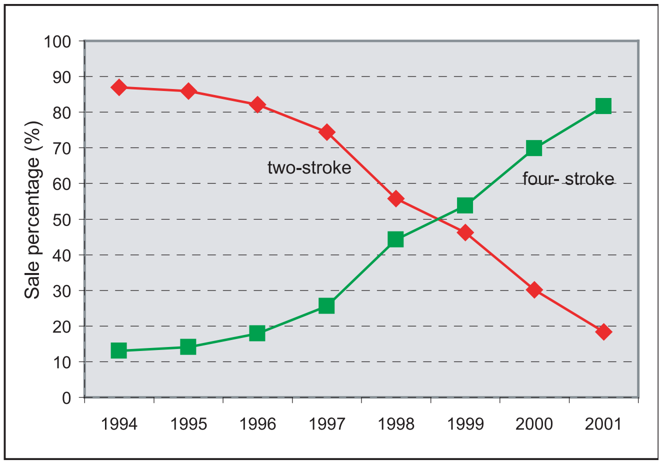
ULG was introduced as part of a broader strategy to reduce vehicular emissions. The Government began establishing more stringent ambient air quality standards and new emissions standards for motor vehicles, along with improved vehicle maintenance and inspection. New vehicles were required to be fitted with a catalytic converter.

As a result of this program, airborne lead dramatically declined from 1.55 $\mu g/m^3$ in 1991 to 0.1 $\mu g/m^3$ in 1996. The net costs of introducing the capability to refine ULG were estimated at less than US$0.02 per liter (Thai Baht 0.5). The slightly increased production cost of ULG has been offset by reduced maintenance costs, and by health benefits (estimated at US$0.12 per liter for a 20 percent reduction in airborne lead in Bangkok). The benefits from the 93 percent reduction actually obtained in ambient lead levels are commensurately greater.

Source: Successful Conversion to Unleaded Gasoline in Thailand, World Bank Technical Paper 410, 1998.

Shifting to four-stroke motorcycles. Responding to increasingly strict emissions standards, awareness raising campaigns, and motorcycle clinics, over 80 percent of Thai motorcycle production has shifted to four-stroke engines.(figure 27) These four-stroke motorcycles are less polluting, have better fuel efficiency and are priced similarly to the two-stroke. The Thai Federation of Industry and manufacturers may implement a program to phase out the highly polluting older two-stroke motorcycles to further encourage the switch to four-stroke. The legendry Tuk-Tuk used to be one of the biggest polluters in Bangkok; however, their numbers were reduced and the remainder required to run on liquefied petroleum gas (LPG) in the 1980s. There is discussion of requiring them to use clean four-stroke engines soon.

Figure 27: Sale percentage of two-stroke and four-stroke motorcycles in Thailand from 1994 - 2001



Source: PCD, 2002

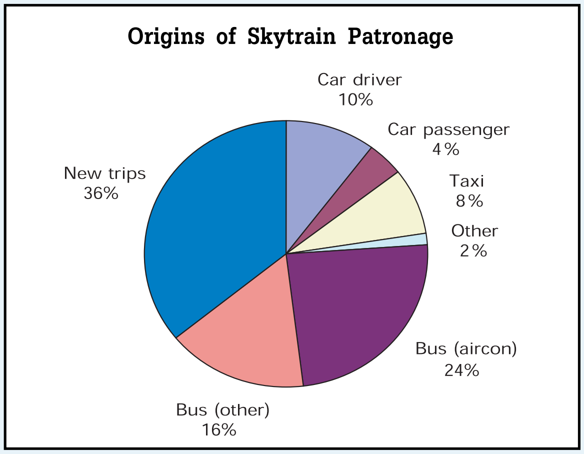
Improving public transport in Bangkok. In response to growing traffic snarls, congestion and pollution, traffic and transport management has been receiving attention at the highest levels of government in the country (see Box 7). Among the measures taken to improve public transport are: (a) adding Euro 2 buses to the fleet; (b) implementing bus lanes in busy one - way traffic corridors; (c) implementing mass rapid transit systems; and (d) building overpasses in major traffic arteries.

The light rail system, commonly known as Bangkok Transit System (BTS), became operational in December 2000. The underground metro system is at an advanced stage of construction and is expected to be completed in 2003.

Box 7. Bus Quagmire

The fleet of 10,000 buses, bus service obligations and fare levels of the Bangkok Metropolitan Transit Authority (BMTA) remain under Government control. BMTA is in a precarious financial situation and receives a large operating subsidy. However, subcontractors run 5,000 regular buses at the minimum fare without subsidy. These buses are in poor condition but the Government is in a difficult position to enforce stricter standards without BMTA making changes to the way it allocates subsidy payments.

Although BMTA's patronage declined by over 30 percent from 1995 to 2000, it continues to run exactly the same number of services it did in 1995. Bangkok's new urban rail system, Skytrain, has attracted over one-third of its patronage from buses. Pollution from buses could be reduced by some rationalization of services. However, BMTA is not run on a commercial basis and has no incentive to change. Nor is it under any Government pressure to do so.



Source: World Bank (1999) Bangkok Urban Transport: Options for Sustaining Mobility and for Sources of Skytrain Patronage: Policy Appraisal Services Pty Ltd and Economic and Policy Services (2001), Bangkok Mass Transit (Skytrain) Externalities Study, Final Report, prepared for the International Finance Corporation.

Requiring factories to cut back pollution. Industrial emissions have grown despite the introduction of fairly stringent emissions standards during the 1990s. In response to these standards, many large factories have adopted cleaner production, energy efficiency and advanced emissions control technologies. However, small and medium-sized industries are less able to afford new technologies. They are also difficult to regulate because of their dispersed locations.

Curbing SO_2 emissions from power plants. In addition to tightening industrial emissions standards and switching to natural gas, the Government has required power plants to control emissions, as discussed in Box 3. EGAT began installing FGD systems in its Mae Moh power plants in 1995. The results are obvious a dramatic reduction in ambient SO_2 concentrations, as shown in Figure 20.

Requiring contractors to control dust at construction sites. BMA and other local governments have issued a code of practice to the construction industry to control dust, which has resulted in reduced dust on the street. Bangkok also has an extensive street cleaning program to reduce road dust.

Reducing garbage burning. The practice of garbage burning has significantly declined in recent years in Bangkok but continues to be a problem in other urban centers. In Bangkok, two sanitary landfills receive the bulk of Bangkok's waste, and this largely relieved the problem. However, localized burning still takes place.

Controlling haze. Thailand is a signatory to the Regional Haze Action Plan that was adopted by the South East Asian countries in 1999, after the regional haze problem of 1997 that affected 20 million people in the region. The Governments also adopted a "zero burning" policy in the same year. Action plan is being developed. The challenge now is their implementation.

Legislation had an early beginning. The first comprehensive legislation on environmental protection was the Enhancement and Conservation of National Environmental Quality Act (NEQA), which was enacted in 1975. This act was superceded in 1992 by a newer act with the same title. The Constitution of 1997 deepened the state's commitment to environmental protection by including specific articles.[14] The 1992 Act includes specific clauses on air quality.[15] A catalogue of other relevant laws can be found in Table 12.

There is a sound basis but weak enforcement. Although there are sufficient laws and regulations on the books, their effective enforcement remains a problem. Political will, capacity constraints at the local level, lack of incentives, cumbersome procedures and lack of coordination among agencies contribute to weak enforcement. For example, roadside enforcement on black smoke remains low (Table 13).

New institutional arrangements – A new Ministry takes over. On October 2, 2002, the Government announced the reorganization of its public sector after several years of preparatory work. The new MoNRE was created to oversee environmental management, including air quality. In addition, a new Ministry of Energy (MoE) was also established. MoNRE fills an important void, and is expected to improve coordination and integration of environmental functions across agencies and enhance service delivery. Previously, the Ministry of Science, Technology and Environment (MoSTE) was responsible for implementing NEQA under the auspices of the National Environment Board (NEB), the apex environment policy making body. The Government is currently finalizing the roles and responsibilities of the Ministries and agencies, and a clearer picture will emerge once formal notification is announced in due course. A preliminary listing of agencies and their role in air quality management follows (Figure 28).

[14] Article 270.

[15] Part 4, NEQA: Air and noise pollution.

Table 12. Air Pollution Legislation and Responsible Ministries

Legislation	Regulated Activities	Responsible Ministry
Enhancement and Conservation of National Environmental Quality Act 1992	Regulates air emissions from mobile and point sources	MoSTE MoNRE (new)
Factories Act 1992	Regulates industrial emissions: air pollutant discharges and concentrations from factories	MoIND
Public Health Act 1992	Regulates nuisance activities which impact public health such as fumes, odor, discharges	MoPH
Energy Conservation Act 1992	Promotes energy conservation in factories, buildings and equipment. Established the Energy Conservation Fund	MoSTE MoE (new)
Traffic Act 1979	Provides compliance and enforcement regulations for traffic emissions	MoInterior
Land Transport Act 1979	Provides in-use vehicle standards and periodical inspection for commercial vehicles	MoTC MoT (new)
Motor Vehicles Act 1979	Regulates small vehicles and in-use vehicle standards and periodical inspection for commercial vehicles	MoTC MoT (new)

Source: World Bank Task Team Review of Thai Environmental Legislation

Table 13. Roadside Enforcement on Black Smoke in Bangkok

Year	Vehicles
1998	71,305
1999	105,763
2000	112,972
2001	88,240
2002	104,365 [1]

Source: Royal Thai Police Department, 2002.
Note 1: Projected figure, actual between January and September 2002 is 78,274

Figure 28. New Institutional Arrangements

	Environment	Transport	Industry	Energy	Area Sources
Policy	NEB; MONRE (NREPPO, PCD)	MOT (LTD, OCMLT)	MOIND (IEAT, DIW); NREPPO	MOE (EPPO)	MOINT (DOLA); BMA; PCD
Regulation	PCD	LTD, PCD, RTP	IEAT, DIW	EPPO, DMF, DOEB	DOLA, BMA
Standards	PCD	LTD, PCD, MOIND (TISI)	IEAT, DIW, PCD	PCD, DMF	PCD
Enforcement		LTD, PCD, RTP	IEAT, DIW, PCD	DMF	BMA, PAO, TAO
Monitoring	PCD, MOICT (MET), BMA	LTD, PCD	IEAT, DIW, PCD	DIW, MOE (EGAT), PCD	BMA, PAO, TAO
Awareness	PCD, DEQP	LTD, PCD	IEAT, DIW, PCD	EPPO, EGAT, DIW, PCD	BMA, PAO, TAO, Private
Investment	Private, EF	Private, BMTA	IEAT, Private	EGAT, IPP / SPP, ECF	

BMA - Bangkok Metropolitan Administration; **BMTA** – Bangkok Mass Transit Authority; **DIW** – Department of Industrial Works; **DMF** – Department of Mineral Fuels; **DOEB** – Department of Energy Business; **DOH** – Department of Health; **DOLA** – Department of Local Administration; **ECF** – Energy Conservation Fund; **EF** – Environment Fund; **EPPO** – Energy Policy and Planning Office; **EGAT** – Electricity Generating Authority of Thailand; **IEAT** – Industrial Estate Authority of Thailand; **IPP** – Independent Power Producer; **LTD** – Land Transport Department; **MET** – Meteorological Department; **MoE** – Ministry of Energy; **MoICT** – Ministry of Information and Communications Technology; **MoIND** – Ministry of Industry; **MoINT** – Ministry of Interior; **MoNRE** – Ministry of Natural Resources and Environment; **MoPH** – Ministry of Public Health; **MoT** – Ministry of Transport; **NEB** – National Environment Board; **NREPPO** – Natural Resources and the Environment Policy and Planning Office; **OCMLT** – Office of the Commission for the Management of Land Traffic; **PAO** – Provincial Administration Organization; **PCD** – Pollution Control Department; **Private** –Private Sector; **RTP** – Royal Thai Police; **SPP** – Small Power Producer; **TAO** – Tambon Administration Organization; **TISI** – Thai Industrial Standards Institute

Varying degree of capacity. A preliminary assessment was made to determine the existing capacity for monitoring and enforcement functions. A combination of input, output and outcome indicators were chosen. The summary of analysis is presented in Table 14. The findings indicate varying degrees of staff capacity and utilization of facilities that have been procured over the years.

It could be broadly stated that human resources capacity in the three key agencies—PCD, LTD and DIW—remains low. For example, one DIW inspector has to cover nearly 400 enterprises, while one LTD staff has to inspect over 40,000 vehicles.

Table 14: Indicators of Institutional Capacity for Air Quality Management in Thailand

	Capacity Determinant	Indicator	Value
Monitoring	PCD monitors air quality. There are 48 monitoring sites in BMR and 23 sites in other 13 cities,[1] which cober a land area of 4,410.38 sq km[2]	Monitoring station per 1,000 sq.km	16
	Traffic police in Bangkok has 18 testing equipment for diesel vehicle and 45 for gasoline vehicle, while there are 1,937,217 in use vehicles (excluding motorcycle) in Bangkok[3]	Number of traffic police's testing equipment per million vehicles in Bangkok	33
Enforcement	**Vehicles:** Traffic police received 1,776 complaints on black smoke and loud noise between December 2001 and September 2002, while there are 2,751,982 in use vehicles in Bangkok[4]	Number of complaints per million vehicles in Bangkok	645
	Number of violations prosecuted by Traffic Police and LTD were 88,240 and 811 cases in 2001 in Bangkok	Percentage of vehicles prosecuted for violation in Bangkok	2
	2,022,913 vehicles were inspected. Of which, 30,615 were unable to meet emissions standard.	Percentage of inspected vehicles not meeting emission standard.	1.5
	Industries: DIW received 1,913 complaints on air pollution from industries, while there are 125,499 factories	Number of complaints per 1,000 factories	15
	There were 19 air violations while there are 186 factories inspected on air emission	Number of violations per 100 factories	10
	Amount of fine from industries for air pollution violation was ThB 24,000 in 1999 and ThB 7,000 in 2001, while no industry was fined in 2000	Percentage decrease in fines from 1999 to 2001	71
Staffing	DIW inspects air pollution from factories. 332 inspectors cover 125,499 factories	Number of DIW inspectors per 10,000 factories	26
	LTD inspects air pollution from vehicles 523 inspectors cover 22,589,185 vehicles	Number of LTD inspectors per million vehicles	23
	PCD monitors air quality. 56 PCD officers (belonging to Air Quality and Noise Management Division) who operate 71 monitoring sites	Number of PCD staff per 10 monitoring stations	8
	EGAT monitors air pollution from power plants. 52 staff work on air related issues while EGAT generates 103,050.03 GWh of power	Number of EGAT air quality staff per 10,000 GWh power generated	5

Source: *The World Bank – compiled from a variety of sources, including personal communication with agencies*

Note: 1. PCD monitoring sites consist of 10 permanent, 7 semi-perminent, 20 temporary sites in Bangkok, 11 permanent sites in BMR (excluding Bangkok, and 23 permanent sites in other 13 cities)
2. Land area refers to the municipal area of the 19 provinces which have air monitoring stations.
3. According to the law, it gives the authority to traffic police to prosecute vehicles on air violation cases in Bangkok only. Consequently, testing equipment is provided to traffic police in Bangkok area only. In addition, testing equipment cannot be used to inspect motorcycle. Therefore, number of motorcycles is excluded.
4. Vehicle complaint program of Traffic Police began in December 2001.

Spending on air pollution control has increased. Government spending for pollution reduction, prevention, and control has steadily increased since 1992. In 2000, the budget allocated to the key central agencies[16] and BMA was Baht 8,965 million (approximately US$200 million), up from Baht 1,254 million in 1992 (US$50 million).[17] No reliable estimates are available of investments and expenditures made by the private sector, petroleum refineries or EGAT, although these are likely to have been substantial as well (between 1992 and 2000).

Of the total budget reported, air pollution control has received the lowest share, when compared to water pollution and hazardous wastes (See Figure 29). In 2000, it was 2 percent (Baht 158 million) of the total amount allocated by the relevant agencies. It should be noted that some expenditures, such as street sweeping and washing, are not reported as expenses to improve air quality. Therefore, total expenditure is understated.

However, it is interesting to note that public complaints are higher for air pollution than for other types of pollution (Figure 30).

It is important for PCD to systematically track expenditures for air quality management, as it will enable it to better assess the cost-effectiveness of Government interventions.

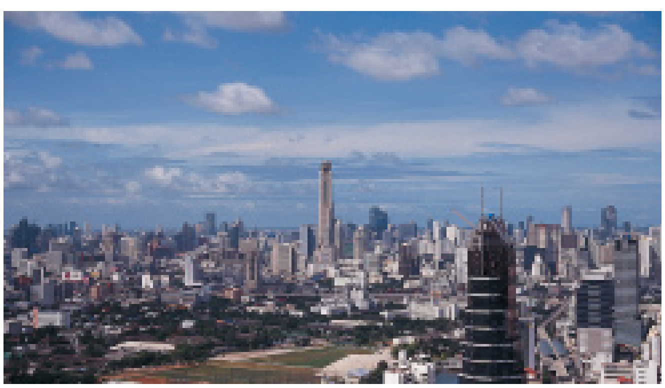


Figure 29. Expenditures for Pollution Control

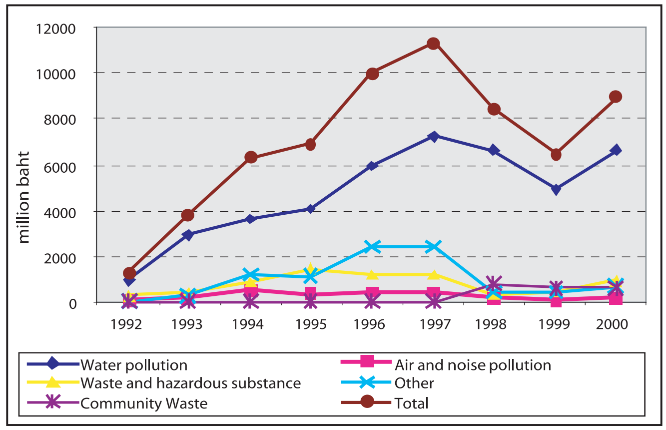
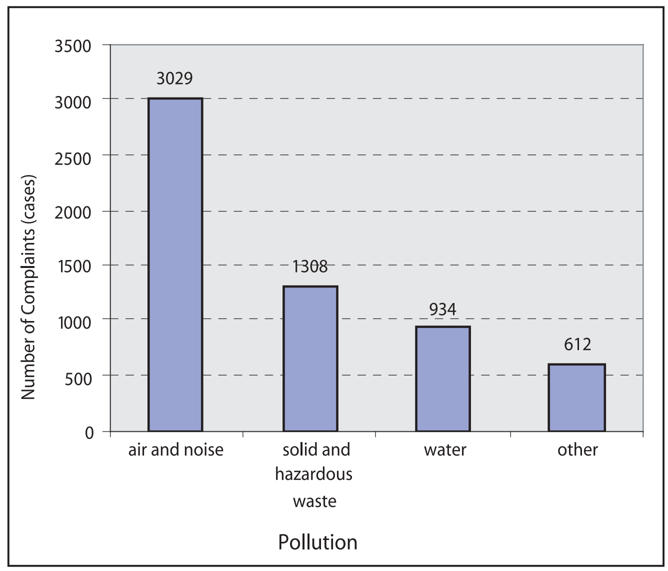


Figure 30. Causes of Complaints



[16] Former MoSTE (PCD, OEPP, DEQP); MoPH, MoT, Ministry of Interior, Ministry of Industry, Ministry of Agriculture and Cooperatives, *former* Ministry of University Affairs.

[17] US$1 = 25 Thai Baht.

Thailand has made remarkable progress in improving air quality and combating pollution as compared to Manila, Jakarta, Beijing, Dhaka, Delhi, and other cities in Asia. It has passed critical laws and regulations, created monitoring systems, strengthened enforcement capacity, and shown improvements in ambient air quality and airport visibility.

Champions in many agencies have been persistent in their vision to improve air quality and have fought special interests over the years. Examples of success include introduction of ULG, improvements in fuel quality, control of power plant sulfur emissions, regulations for motor vehicles, and the monitoring systems.

While overall air quality has improved, it is still a problem in traffic corridors and urban centers like Bangkok. The public perception that air quality has not improved is due, in part, to traffic congestion and poor air quality in urban areas. This perception is often a deterrent to tourism and foreign investment.

The economy has bounced back since the crisis of 1997, and congestion is beginning to re-emerge in Bangkok. Consequently, pollution problems can worsen and set back the recent gains. So, the challenge for Thailand is to consolidate these gains and tackle more complex problems that include reducing $PM_{2.5}$, NO_x, and ground-level ozone in Bangkok and containing GHGs like CO_2 and CH_4. The challenges outlined below are based on the foregoing analysis and feedback received during the preparation stage of this Monitor. They cover both immediate actions needed in hotspots like Bangkok; and longer-term reforms required for strengthening the policy and institutional framework.

1 Tackling the unfinished agenda in Bangkok. PM remains a major public health threat in Bangkok, with concentration levels exceeding standards by two-and-a-half times. There are several million gross polluters—very old diesel vehicles that are continually rebuilt (such as the green mini-buses) or older two-stroke motorcycles—that need to be taken off the roads. Attempts to deal with these gross polluters have not been very successful. There are social and political problems associated with implementing technical solutions, for example in the case of pollution caused by Bangkok's bus fleet (Box 5).

A recent study undertaken by BMA[18] lays out an action plan for the next five years that targets motor vehicles, traffic management, public transport, road dust, crematoriums, and industrial and utility boilers. The implementation of this US$150 million-plan (Table 15) is estimated to reduce PM_{10} emissions by 6,000-8,000 tons annually, representing a 20 percent reduction from 1997 levels[19]. The benefits (health and productivity) of implementing this plan are estimated to be over US$500 million. The main features of the plan follow.

- *Inspection and Maintenance (I/M)*. A large part of the bus and diesel vehicle fleet in Bangkok is old and has uncontrolled emissions. Improved I/M would go very far in reducing vehicle emissions. However, I/M requires significant institutional capacity and sustained effort by both Government and the private sector. The Government should improve its own I/M activities while providing incentives for the private sector to improve its services.

- *Two-stroke Motorcycles*. New motorcycle production is dominated by four-stroke engines, but the older two-stroke motorcycles continue to be a major source of particulate emissions. The Government (mainly BMA) and the manufacturers and traders should join hands to introduce incentive schemes for users to replace their two-stroke motorcycles with four-stroke.

- *Control of Road Dust*. A source apportionment study done in 1995 indicated that a significant portion of the PM loading in Bangkok is re-entrained dust, and therefore it is necessary for BMA to give this a priority.

[18] Bangkok Air Quality Management Plan, February 2001, BMA/Parsons.

[19] In 1997, over 38,000 tons of PM_{10} were emitted in Bangkok. This represents a 20 percent reduction.

Table 15. Targeting PM_{10} Reduction in Bangkok - An Action Plan for 2001-2006

Action	PM Reduction (Tons)	Costs (Baht million)	Benefits (Baht million)
Transport Source Control - Upgrading I/M program for all diesel vehicles, taxis and Tuk-Tuks - Upgrading test procedures for light-duty gasoline vehicles and motorcycles - Introducing catalytic converters in BMA and BMTA diesel vehicles and partial conversion to LPG/diesel bi-fuel system -Upgrading 15,000 2-stroke motorcycles to 4-stroke	20,000	3,200	9,000[1]
Transport Management - 12 corridor-type bus lanes of 110 km - 9 central area one-way circulation type bus lanes of 40 km - Testing electric hybrid buses - Traffic improvements	Not estimated	1,100	7,800[2]
Road Dust Control - Sweeping, cleaning and washing of 544 roads of 540 km length	11,000-20,000[3]	170-450	2,800-5,000
Other Sources - Upgrading crematoriums - Updating emissions inventory for non-point sources of pollution - Studies to examine the feasibility of switching to natural gas in utility and commercial and industrial boilers	Not estimated	600	Not estimated
Air Quality Management - Improving air quality monitoring - Institutional capacity building of BMA, PCD, LTD and others		200	
Total	**31,000-40,000**	**5,270-5,550**	**21,800**

Source: Bangkok Air Quality Management Plan – Final Report; February 2001; BMA/Parsons.

Notes:

1. Primarily health benefits; does not include economic savings realized through fuel efficiency and lower maintenance. Based on Monitor Team calculations.
2. Mainly savings in travel time and reduced operating costs.
3. Lower value is for sweeping while the higher value includes washing as well.

- *Financing of the Plan*. Thailand should tap private sector resources to finance the implementation of the plan, especially the operation of I/M facilities. This would require the Government to put in place some incentives; at the same time, it will need to tighten the enforcement of its laws. Thailand can also investigate imposing a targeted tax on gasoline to control air pollution from the transport sector and promote mass transit.

2 Improving air quality management. Thailand does better than most countries on monitoring and transparent reporting of data, but analysis of monitoring data is limited. A more organized approach is needed to integrate monitoring and analytical capacity with decision-making.

- *Update of Emissions Inventories*. Emissions inventories for major sectors and source-contribution to human exposure need to be updated (Table 16). Currently, large uncertainties about estimates make cost effectiveness analysis of action plans impossible. An updated source inventory is needed in Bangkok on a priority basis, to target cost-effective solutions for gross polluters. The role of area sources, such as waste, and agricultural and forest burning, should be quantified and control options identified.

Table 16. Who Pollutes What in Bangkok? 1997

Source	PM	NO	CO	SO_2	HC	CH_4
Power & Industry	10	17	1	95		
Transport	54	80	75	4	100	
Area	36	3	24	1		100
Total	**100**	**100**	**100**	**100**	**100**	

Source: PCD, 2000.

- *Strengthened Enforcement*. Thailand has made impressive advances in managing air quality by setting standards and using the latest technology. Continued progress will require more effective and sustained management and enforcement of large as well as scattered, small industrial and transport sources. Better enforcement requires clarity in laws and regulations, appropriate incentives and fines for infringement, and a dedicated, trained corps of officers with adequate resources. Further, the Government needs to go beyond the command-and-control approach and build in incentives like economic instruments and public disclosure programs to encourage better polluter behavior.

- *Expanded Health-Causality Studies*. Thailand was among the first countries in Asia to link air pollution impacts to health, when research studies vividly demonstrated the debilitating effects of lead in children. However, this has not been replicated for other pollutants. The effects of air pollution in terms of costs associated with morbidity and mortality, and linkages with poverty, need to be studied and publicized. Health impact costs are currently based on estimated pollution and exposure, and not confirmed by epidemiological surveys. Quantifying and disclosing health and non-health costs of air pollution is an effective way of generating public and political support for difficult, and sometimes expensive, actions.

- *Control of Unconventional Sources*. Local and central governments have to address agricultural waste and forest burning, which contribute significantly to air pollution, and which are carried over long distances. Existing control measures have tended to focus on pollution from industry and transport sources in urban areas.

3 Improving public transport and traffic management. Bangkok traffic has improved over the last decade thanks to better management of traffic, introduction of priority bus lanes, and expansion of the highway system. However, as noted earlier, traffic congestion that had considerably eased after 1997 is worsening again. Without appropriate and timely actions, these increasing traffic problems could potentially negate the gains made in the late 1990s.

Current regulations provide short-term solutions, however, in the long term, Bangkok needs to improve the coverage and efficiency of its public transport system to ensure sustained improvements in air quality. The following areas of focus can help in easing congestion and increasing vehicle speeds, thereby reducing pollution, enhancing pedestrian safety, and encouraging the use of non-motorized transport.

- *Priority Lanes and Traffic Management*. In Bangkok, the use of High Occupancy Vehicle (HOV) lanes and the provision of adequate sidewalks and bicycles lanes will encourage people to use public transport, carpool, bicycle, or simply walk shorter distances.

- *Smoke-belching Buses and Trucks*. PM levels along the traffic corridors exceed air quality standards. Despite many years of discussion and policy alternatives, local buses, trucks, and other high mileage vehicles remain gross polluters. Young children and the poor continue to face the highest health risks, while the sight of traffic police covered in clouds of black bus smoke is still common in Bangkok and other cities. Efforts should target these gross polluters through appropriate technology and policy changes.

- *Skytrain (BTS)*. The Skytrain was an effort to displace bus use, and encourage a less-polluting mass transit option. However, ridership remains low (40 percent utilization capacity). The privately operated BTS is handicapped by a large debt burden, and this prevents it from offering incentives to passengers. Options need to be considered to increase mass transit capacity and ridership.

4 Strengthening institutional effectiveness.

In October 2002, the new MoNRE was created with the overall responsibility of environmental management, including air quality. At the same time, the Government has also put into place an ambitious program to decentralize functions to local governments. Given this, efforts need to focus on:

- *Improved Inter-Agency Coordination*. In Thailand, the various agencies with functions relating to air quality management need to be able to work cooperatively. For example, an assessment of Thailand's vehicle inspection, which is managed by LTD, reports that the current system is inadequate in controlling vehicle emissions. The inspection of motorcycles for smoke required by PCD is not being carried out by LTD because of implementation difficulties. Through better coordination, the monitoring, enforcement and licensing systems can be more effective.

- *Expanded Local Government Role*. While the central Government requires air quality monitoring on a regional level, there are few urban (local) authorities with such monitoring responsibilities due to capacity and budget restraints. Two exceptions, however, are BMA and the Chiang Mai Municipality. BMA, Thailand's largest local government, has several departments and divisions with responsibilities related to air quality management. Implementation and enforcement is being carried out through fifty district offices. The experience of Chiang Mai (see Box 8) demonstrates the ample opportunity for local government involvement. Expansion of the local government role can be achieved in stages, in which selected local governments are strengthened. The initial set of responsibilities could include: (a) monitoring smoke emissions from belching vehicles; (b) conducting local awareness activities; (c) regulating small point-sources; and (d) managing existing ambient air quality monitoring stations.

Box 8. Chiang Mai Air Quality Management Initiative

Over the past decade, the northern city of Chiang Mai has become increasingly aware of air pollution impacts on the health, livelihood, and quality of life of its residents and its many tourists. In late 1999, the City of Chiang Mai, PCD, and the Maryland Department of the Environment (MDE) of the US agreed to work together to undertake the Chiang Mai Air Quality Initiative. In June 2002, the City released its first air quality management (AQM) plan.

With assistance from a team that included MDE and the USEPA, Chiang Mai and PCD staff first participated in on-the-job trainings focused on all aspects of AQM. Over the next two years, a multi-stakeholder group took part in nine workshops in Bangkok and Chiang Mai to develop the action plan. The process included the creation of a detailed emissions inventory, which served as an important scientific building block. At the end of the planning effort, stakeholder representatives committed to continuing their leadership and involvement in protecting and improving the City's air quality through discrete actions, such as bicycling to work and turning off taxi and Tuk-Tuk engines while idling and fueling. The local media has picked up on these commitments, reaching out to residents through the radio, internet and newspaper.

In July 2002, a workshop by Government, media and NGO representatives from over 26 Thai municipalities discussed ways to develop similar programs focusing on concrete actions in other Thai cities. Air quality master plans provide a foundation for broad-based programs that result in cleaner air for the citizens of cities such as Chiang Mai. This newly completed plan can also serve as a model that can be replicated in Thailand and other Asian countries.

5 Broadening public participation. While the level of awareness of air pollution is high, the level of public participation in pollution control programs is low. Surveys show that while 72 percent of the population is aware of pollution and existing regulations, they believe that enforcement is weak and that agency coordination is a bottleneck. Given the limited capacity of national and local institutions, the public and private sectors have important supplemental roles to play.

Involvement of local communities is a critical part of an integrated air quality management framework. The best technical plans may fail without community buy-in. Disseminating data and creating stakeholder awareness is important in building political support for rational air quality management approaches. However, people also have to be willing to contribute on an individual level to reduce pollution.

Examples of how the public can contribute include car-pooling or using mass transit, reporting smoke-belching vehicles to the relevant authorities, conserving electricity, composting instead of burning yard waste, and planting trees.

6 Harnessing global opportunities for local good. Recently, Thailand ratified the Kyoto Protocol. While Thailand, as a developing country, has no emission reduction obligations under the Kyoto Protocol, MoSTE established a national goal of reducing CO_2 emissions by 3 million metric tons annually or approximately 2 percent of total emissions.

The primary funding mechanism is the CDM, which allows developing and developed countries to work together toward achieving Kyoto Protocol targets. Once the Kyoto Protocol has been ratified internationally and the CDM is operational, developing countries will be able to obtain funding for projects aimed at GHG emission reductions, while developed countries can use these emission reductions towards their Kyoto compliance limitations. Thailand's GHG emission is expected to nearly double by 2020 to 535,000 Gg CO_2 equivalent emissions.

Energy, agriculture, and waste sectors form the bulk of GHG emissions, and therefore will be the focus of CDM initiatives. MoSTE recently prepared a National CDM Strategy, which reviews different options and identifies opportunities in: (a) reducing CO_2 in the energy sector; (b) converting CH_4 from waste to energy; and (c) sequestering CO_2 through reforestation and afforestation activities.

For Thailand to engage and draw benefits from the CDM market, it will need to do the following: (a) designate a national CDM authority and approval process; (b) institutionalize eligibility criteria and a transparent process to identify eligible investments; (c) establish a public participation mechanism; (d) ensure that the identified CDM investments comply with the country's environmental impact assessment requirements; and (e) reach a "distribution" agreement for Certified Emission Reduction with project sponsors.

Abatement: The reduction or elimination of pollution.

Acid Rain: Rain which is especially acidic (pH <5.2). Principal components of acid rain typically include nitric and sulfuric acid. These may be formed by the combination of nitrogen and sulfur oxides with water vapor in the atmosphere.

Adverse Health Effect: A health effect from exposure to air contaminants that may range from relatively mild temporary conditions—such as eye or throat irritation, shortness of breath, or headaches, to permanent and serious conditions—such as birth defects, cancer or damage to lungs, nerves, liver, heart, or other organs.

Air Monitoring: Sampling for and measuring of pollutants present in the atmosphere.

Air Pollution: Degradation of air quality resulting from unwanted chemicals or other materials occurring in the air.

Alternative Fuels: Fuels such as methanol, ethanol, natural gas, and liquid petroleum gas that are cleaner burning. These may be used for powering motor vehicles.

Ambient Air Quality Standards: Health- and welfare-based standards for outdoor air that identify the maximum acceptable average concentrations of air pollutants during a specified period of time.

Carbon Dioxide (CO_2): A colorless, odorless gas that occurs naturally in the Earth's atmosphere. Significant quantities are also emitted into the air by fossil fuel combustion.

Carbon Monoxide (CO): A colorless, odorless, poisonous gas produced by incomplete fossil fuel combustion. The inhalation of CO can disrupt the supply of essential oxygen to the body's tissues—thus posing a major health risk. Those who suffer from cardiovascular disease are most at risk. At high levels of exposure, CO can be fatal.

Chlorofluorocarbons (CFCs): A family of inert, non-toxic, and easily liquefied chemicals used in refrigeration, air conditioning, packaging, insulation, or as solvents and aerosol propellants. Because CFCs are not destroyed in the lower atmosphere they drift into the upper atmosphere where their chlorine components destroy ozone.

Climate Change (also referred to as "global climate change"): Used to imply a significant change from one climatic condition to another. In some cases "climate change" has been used synonymously with the term, "global warming;" however, scientists tend to use the term in the wider sense to also include natural changes in climate.

Dose-Response: The relationship between the dose of a pollutant and the response (or effect) it produces on a biological system.

Emission Standard: The maximum amount of a pollutant that is allowed to be discharged from a polluting source such as an automobile or smoke stack.

Exceedance: A measured level of an air pollutant higher than the national or state ambient air quality standards.

Exposure: The concentration of the pollutant in the air multiplied by the population exposed to that concentration over a specified time period.

Fossil Fuels: Coal, oil, and natural gas; so-called because they are the remains of ancient plant and animal life.

Global Warming: An increase in the temperature of the earth's troposphere. Global warming has occurred in the past as a result of natural influences, but the term is most often used to refer to the warming predicted by computer models to occur as a result of increased emissions of GHGs.

Greenhouse Effect: The warming effect of the Earth's atmosphere. Light energy from the sun which passes through the Earth's atmosphere is absorbed by its surface and re-radiated into the atmosphere as heat energy.

Greenhouse Gas: Gases, such as CO_2, CH_4, NO_2, and others that increase global temperatures by trapping solar electromagnetic radiation.

Hydrocarbons (HC): Compounds containing various combinations of hydrogen and carbon atoms. They may be emitted into the air by natural sources (e.g., trees) and as a result of fossil and vegetative fuel combustion, fuel volatilization, and solvent use. Hydrocarbons are a major contributor to smog.

Indoor Air Pollution: Air pollutants that occur within buildings or other enclosed spaces, as opposed to those occurring in outdoor or ambient air. Some examples of indoor air pollutants are NO_x, smoke, asbestos, formaldehyde, and CO.

Glossary of Terms

Lead: A gray-white metal that is soft, malleable, ductile, and resistant to corrosion. Sources of lead resulting in concentrations in the air include industrial sources and crustal weathering of soils followed by fugitive dust emissions. Health effects from exposure to lead include brain and kidney damage and learning disabilities.

Mobile Sources: Sources of air pollution such as automobiles, motorcycles, trucks, off-road vehicles, boats, and airplanes.

Morbidity: Rate of disease incidence.

Mortality: Death rate.

Nitrogen Oxides (NO_X): A general term pertaining to compounds of nitric oxide (NO), nitrogen dioxide (NO_2), and other oxides of nitrogen. NO_x are typically created during combustion processes, and are major contributors to smog formation and acid deposition. NO_2 is an air pollutant.

Ozone (O_3): In the stratosphere (the atmospheric layer 7 to 10 miles or more above the Earth's surface) ozone is a natural form of oxygen that provides a protective layer shielding the Earth from ultraviolet radiation. In the troposphere (the layer extending up 7 to 10 miles from the earth's surface), ozone is a chemical oxidant and major component of photochemical smog. Ground-level ozone forms readily in the atmosphere, usually during hot summer weather, and is a major contributor to smog.

Ozone Depletion: Destruction of the stratospheric ozone layer that shields the Earth from ultraviolet radiation harmful to life. This destruction of ozone is caused by certain chlorine- and/or bromine-containing compounds (CFCs or halons), which break down when they reach the stratosphere and then destroy ozone molecules.

Particulate Matter (PM): Fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in air or emissions.

PM_{10}: Particulates smaller than 10 microns. Small particulates are of special concern because of their ability to penetrate deep into the lungs and cause major health impacts.

$PM_{2.5}$: Tiny particles with an aerodynamic diameter less than or equal to a nominal 2.5 microns. This fraction of PM penetrates most deeply into the lungs.

Pollutant: Something which makes the environment physically impure or unclean.

Scrubber: An air pollution control device that uses a high energy liquid spray to remove aerosol and gaseous pollutants from an air stream. The gases are removed either by absorption or chemical reaction.

Smog: A combination of smoke and other particulates, ozone, hydrocarbons, NO_x, and other chemically reactive compounds which, under certain conditions of weather and sunlight, may result in a murky brown haze that causes adverse health effects.

Stationary Sources: Non-mobile sources, such as power plants, refineries, and manufacturing facilities, which emit air pollutants.

Sulfur Dioxide (SO_2): A heavy, pungent, colorless, gaseous air pollutant formed primarily by processes involving fossil fuel combustion.

Volatile Organic Compounds (VOCs): Carbon-containing compounds that evaporate into the air (with a few exceptions). VOCs contribute to the formation of smog and/or may themselves be toxic. VOCs often have an odor, and some examples include gasoline, alcohol, and the solvents used in paints.

Adapted from various air quality glossaries.

Organization	Website address	Description & Contents
Asian Development Bank (ADB)	www.adb.org/vehicle-emissions/	Provides an overview of environment but focuses more on transport related pollution
Bangkok Metropolitan Administration (BMA)	www.bma.go.th	Provides comprehensive overview of projects and royal-initiated projects regarding traffic and transportation management in Bangkok
Clean Air Initiative (World Bank, ADB and others)	www.worldbank.org/cleanair/caiasia/	Provides information on all topics under air quality management and also linkages to various ongoing environmental activities in the region. Has discussion space on various topics to exchange ideas in the region
Department of Alternative Energy Development and Efficiency (DEDE) (*former* DEDP)	www.dedp.go.th	Presents overview information on energy and related laws and focus more on alternative and renewable energy.
Department of Environmental Quality Promotion (DEQP)	www.deqp.go.th	Presents information on environment including environmental standards, laws, interesting articles, projects and also list of environmental NGOs
Department of Health	www.anamai.moph.go.th/factsheet/index_en.htm#envi	Provides articles and research regarding environmental health, including health impacts from air pollution
Department of Industrial Works (DIW)	www.diw.go.th	Provides extensive information on industry including industrial laws, statistics, services and related links
Department of Land Transport (LTD)	www.dlt.motc.go.th	Provides information on land transport including vehicles, tax, fine statistics. Projects, plans and budget also presented
Electricity Generating Authority of Thailand (EGAT)	www.egat.or.th	Provides information on energy and power plants, including environmental concerns and environmental management policy of EGAT
Energy Policy and Planning Office (EPPO) (*former* NEPO)	www.nepo.go.th	Provides extensive information on energy including energy plan and policy, conservation, database, international cooperation, and useful links

USEFUL WEBSITES

Organization	Website address	Description & Contents
Federation of Thai Industries (FTI)	www.fti.or.th	Provides overview of environmental information, including environmental laws and standards, clean technology, reports, and links to environmental agencies
Kenan Institute Asia (KIASIA)	www.kiasia.org	Provides overview information on its environmental projects and partnerships
Office of Natural Resources and Environmental Policy and Planning (*former* OEPP)	www.oepp.go.th	Provides overview of environmental management in Thailand, plan and policy, multilateral environment agreement and also EIA process
Office of the Commission for the Management of Land Traffic (OCMLT)	www.ocmlt.go.th	Presents comprehensive information on traffic including its plans and project, online traffic report and traffic information center
Pollution Control Department (PCD)	www.pcd.go.th/	Provides comprehensive overview of programs and projects that help protect, preserve and enhance the natural resources of Thailand.
Thai Environment Network	www.thaienvironment.net	Provides information on environment and pollution, including news, articles and related laws
Thailand Environment Institute (TEI)	www.tei.or.th	Provides information on its accomplished and ongoing environmental projects. Environmental news and publications are also available
United Nations Development Program (UNDP)	www.undp.org/energy/index.html	Provides information on energy and environment related to sustainable development
US Asia Environmental Partnership (US-AEP)	www.usaep.org/	Provides links to recent development in environment and its own projects in region
US Environmental Protection Agency (USEPA)	www.epa.gov/	Provides extensive information available on all technical and legal aspects of environment, including air pollution

This Monitor is a joint effort of several Government agencies, private sector and civil society organizations at both the national and local levels. A consultation workshop was held in Bangkok on October 21, 2002 to discuss a draft of the document. The following representatives from government, academia, NGOs and media attended the workshop and provided valuable comments and inputs, which is gratefully acknowledged:

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Pollution Control Department (PCD)

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Video of Thailand Environment Monitor 2002 was produced by Kitti Singhapat (Producer of World of Environment Program)

THAILAND - AT - A - GLANCE

GEOGRAPHY	ECONOMY/SOCIETY
Area: *total:* 514,000 sq km *land:* 511,770 sq km *water:* 2,230 sq km **Land boundaries**: *total:* 4,863 km *border countries:* Myanmar 1,800 km, Cambodia 803 km, Laos 1,754 km, Malaysia 506 km **Coastline:** 3,219 km **Maritime claims:** continental shelf: 200-m or to depth of exploitation exclusive economic zone: 200 nm territorial sea: 12 nm **Climate:** tropical; rainy, warm, cloudy southwest monsoon (mid-May to September); dry, cool northeast monsoon (November to mid-March); southern isthmus always hot and humid. **Terrain:** central plain; Khorat Plateau in the east; mountains elsewhere. **Elevation extremes:** *lowest point:* Gulf of Thailand 0 m *highest point:* Doi Inthanon 2,576 m **Mineral resources:** tin, natural gas, tungsten, tantalum, timber, lead, fish, gypsum, lignite, fluorite. **Land use:** *arable land:* 32.62 percent *permanent crops:* 7.82 percent *pastures:*0.22 percent *forests and woodland:* 25.28 percent *other:* 34.06 percent (1998) **Irrigated land:** 49,600 sq km (1999) **Environment—international agreements**: *party to:* Climate Change, Endangered Species, Hazardous Wastes, Marine Life Conservation, Nuclear Test Ban, Ozone Layer Protection, Tropical Timber 83, Tropical Timber 94. *signed, but not ratified:* Biodiversity, Law of the Sea	**GDP:** US$115 billion (2001) **GDP growth rate:** 1.8 percent (2001) **GDP**—composition by sector: *agriculture:* 10.2 percent *industry:* 40 percent *services:* 49.4 percent (2000) **Inflation rate—consumer price index**: 1.7 (2001) **Unemployment rate:** 1.7 percent (2001) **Gross Domestic Investment/GDP:** 23 (2001) **Exports of good and services/GDP**: 66.3 (2001) **Gross domestic savings/GDP**: 30.1 (2001) **Gross national savings/GDP**: 28.7 (2001) **Industrial production growth rate**: 2.8 percent (2000) **Agricultural production growth rate**: 2.2 percent (2000) **Agriculture—products:** rice, cassava (tapioca), rubber, corn, sugarcane, coconuts, soybeans. **Exports:** *total value:* US$76.2 billion (2001) **Imports:** *total value:* US$69.2 billion (2001) **Population:** 61.2 million (2001) **Population growth rate**: 0.7 percent (2001) **Urban population** (percent of total population): 20 (2001) **Birth rate:** 12.5 births/1,000 population (2001) **Death rate:** 5.9 deaths/1,000 population (2000) **Infant mortality:** 28 deaths/1,000 live births (2001) **Access to safe water** (percent of population): 92.7 (2000) **Access to sanitation** (percent of population): 97.7 (2000) **Life expectancy at birth:** Male 67.0 years (latest single year, 1994-2000) Female 71 years (latest single year, 1994-2000) **Literacy:** 96 percent (2001) **Gross primary enrollment** (percent of school-age population): Male 105, Female 103 (2001) **National capital**: Bangkok **Administrative divisions**: 76 provinces (*changwat*) **Independence:** 1238 (traditional founding date; never colonized)

Source: The World Bank - complied from various government and international data sources.

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