



**Bangkok**  
Assessment Report  
on Climate Change **2009**

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The Green Leaf Foundation was officially founded and registered on 17 March 1998. It was jointly established by organizations with the same determination and responsibility, with support, funding and sponsorship from various local and international organizations. GLF has organized several training seminars on environmental education, environmental standards and energy efficiency since 1999. Its main objective is to promote knowledge and to support studies and research for creating good understanding of environmental conservation.

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The Bangkok Metropolitan Administration (BMA) is organized in accordance with the Bangkok Metropolitan Administration Act 1985 to be responsible for the management of the city of Bangkok. It is the sole organization at the local authority level responsible for its duties and it provides services for the well-being of Bangkok residents.

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## FOREWORD

Climate change is a global issue which is of concern to the entire international community. In view of the rapid increases in urbanization that have occurred in countries of Asia, including Thailand, over the past several decades, the impacts of climate change are starting to occur and are expected to be especially serious in the not too distant future. Thus, they are worthy of increased study and vigorous remedial action.

The main cause of this critical problem is the emission of greenhouse gases; unfortunately Bangkok plays a role in this regard. As the capital of Thailand, Bangkok has reached mega-city status. It annually releases tremendous amounts of greenhouse gases into the atmosphere, thus contributing to the acceleration of global warming and the other deleterious impacts that will be the outcome of that warming, such as flooding, higher temperatures and disease outbreaks.

The Bangkok Metropolitan Administration (BMA) recognizes that it has a responsibility to try to reduce the climate change problems threatening the living conditions of the people of Bangkok. Therefore, BMA in cooperation with UNEP has published this Bangkok Assessment Report on Climate Change 2008 to increase the knowledge and understanding of climate change globally, nationally and locally. This report also focuses on the mitigation and adaptation measures that must be implemented by BMA and all the other sectors concerned.

The reduction of greenhouse gas emissions will require cooperation from every sector. In addition to the initiatives of BMA, the general public must play an essential role in solving the problem, since several of the efforts to reduce greenhouse gas emissions depend on public cooperation, with several of them being totally reliant on the awareness of the people of Bangkok and their wholehearted participation. While the people make adjustments in their daily activities or lifestyle, BMA will provide them with the knowledge and support they need so that these improvements can be realized as efficiently and painlessly as possible.

We strongly believe that the cooperation of every responsible sector in society is required in order to reduce the impacts of climate change. Our communal action in combating climate change and making adjustments in the way we live will bring about benefits not only now but also to future generations of people at home and abroad.

BMA is serious about climate change mitigation and adaptation actions. We are committed to helping to foster sustainable urban environmental management. Our ultimate goal is to improve the environment, human health and the quality of life of those living in Bangkok, while contributing to making the world a better place to live.

**Dr. Pongsak Semson**  
Permanent Secretary for Bangkok Metropolitan Administration



## FOREWORD

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The United Nations Environment Programme (UNEP) is mandated to regularly assess major environmental developments and trends. This mandate is implemented through the Global Environment Outlook (GEO) process, which involves global, regional, subregional, national and city-level assessments.

The GEO process is participatory and consultative, with capacity-building at its core. The result is scientifically authoritative information for environmental management and policy development tailored to a wide target audience.

The Bangkok Assessment Report on Climate Change 2009 is one of the outputs of this capacity-building programme, and the first UNEP endeavour conducted in partnership with a city authority to assess climate change impacts, to support decision makers in understanding the need for urgent action and to mobilize public awareness and participation.

Built on a swampy floodplain along the Chao Phraya River near the Gulf of Thailand, Bangkok is home to more than 10 million people. The Bangkok Assessment Report on Climate Change 2009 reveals that the city is already experiencing the impacts of climate change. Bangkok and its suburbs are experiencing more severe and frequent flooding as well as an increase in the number of days hotter than 35°C. This may have serious implications for the country's economy, including its tourism industry.

The report also points out that 87 per cent of Bangkok's annual greenhouse gas emissions come from the electricity, transportation, waste and wastewater sectors. In this context, I congratulate the Bangkok Metropolitan Authority for being proactive in taking actions to reduce its greenhouse gas emissions by at least 15 per cent by 2012 in comparison with projections under a "business-as-usual" scenario.

However, for Bangkok and cities like it, adaptation to climate change remains the most urgent priority. The Bangkok Assessment Report on Climate Change 2009 sets out a number of adaptation options for climate-proofing the city. These include improving the local public health infrastructure and disease surveillance and prevention programmes; creating early warning systems for extreme weather events; and implementing stricter zoning and building codes to minimize damage from storms and sea level rise.

The Medium-term Strategy (2010-2013) of UNEP directs the organization to strengthen the ability of countries to integrate climate change responses into their national development processes that are supported by scientific information, integrated climate impact assessment and local climate data. I believe this report fulfils this mandate and provides the necessary information and options for BMA to sustain the quality of life and livelihoods of the city's residents.

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A handwritten signature in black ink, reading 'Achim Steiner'.

Achim Steiner

United Nations Under-Secretary-General and Executive Director  
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# Contents

	Page
I-II Foreword	4-5
IV Figures	7
V Tables	7
V Boxes	7
VI Executive Summary	8-11

12

## 1. Introduction

- Climate Change Perspective
- The Thai Context
- Introducing Bangkok

26

## 2. Observed Climatic Trends and Variability

- Temperature Trends Past and Present : The Global Perspective
- Thailand and Bangkok Perspectives

36

## 3. Greenhouse Gas Emissions : Baseline Inventory and Projections

- Global and Regional Overview
- Thailand
- Bangkok

48

## 4. Assessment of Vulnerability and Impacts of Climate Change

- Climate Change Projections
- Vulnerability and Local Adaptation Practices

60

## 5. Mitigation Policies and Measures

- Cooperation for Mitigating Carbon Emissions in Bangkok
- Public Awareness

65

## 6. Bangkok's Adaptation to Climate Change

- General Theme of Adaptation Actions
- Selecting Appropriate Adaptation Responses

74

## 7. Options for Action

- Achieving Goals
- Actions for Bangkok
- Conclusion and Recommendations

## Bibliography and References

Page

### Annexes

I. Tools and Approaches for Climate Change Assessing	82
II. Glossary	83
III. Acronyms, Chemical Symbols, Scientific Units	87

## Figures

## Page

1.1	An idealised model of the natural greenhouse effect	14
1.2	Top 15 countries, by population exposed today and in the 2070s, showing the influence of future climate change vs. socioeconomic change	17
1.3	Top 10 countries, by assets, exposed today and in the 2070s, showing the influence of future climate change vs. socioeconomic change	17
1.4	Map of Bangkok	19
1.5	Land subsidence rate of Bangkok in 2002 (a) and in 1981 (b)	20
1.6	Meteorological data of Bangkok Metropolis, averaged monthly over 10 years (1993–2002)	21
1.7	Population trends of Bangkok	23
1.8	Land Use Patterns of Bangkok	23
1.9	Trend of Tourists Arrival in Bangkok, 1998–2007	24
1.10	Number of newly registered vehicles in Bangkok	25
2.1	Global temperature land–ocean index, 1880–2000	27
2.2	Annual mean temperatures in Thailand	31
2.3	Annual mean and maximum temperatures in Thailand, 1951–2005	31
2.4	Annual mean and minimum temperatures in Thailand, 1951–2005	32
2.5	Observed changes in precipitation Thailand, 1951–2005	32
2.6	Observed number of rainy days in Thailand	33
2.7	Average maximum temperatures in Bangkok, 1961–2007	34
2.8	Average minimum temperatures in Bangkok, 1961–2007	34
2.9	Number of days exceeding 35°C in Bangkok, 1961–2007	35
2.10	Variations in monthly rainfall in Bangkok	35
3.1	Emissions of carbon dioxide by 27 selected economies in Asia	38
3.2	Emissions of carbon dioxide per capita by selected economies in Asia	38
3.3	Emissions of carbon dioxide by Thailand	39
3.4	Emissions of carbon dioxide per capita by Thailand	39
3.5	Final energy demand per sector in the business-as-usual case	40
3.6	Gasoline consumption by the transport sector in BMR and Bangkok	42
3.7	Gasohol consumption by the transport sector in BMR and Bangkok	42
3.8	Diesel consumption by the transport sector in BMR and Bangkok	43
3.9	Biodiesel consumption by the transport sector in BMR and Bangkok	43
3.10	Annual roadside and ambient carbon monoxide (CO) levels in Bangkok, 1992–2005	44
3.11	Percentage of energy sales within Metropolitan Electricity Authority areas by category in 2007	45
3.12	Solid waste composition at BMA Transfer Station in 2007	45
4.1	Asian cities at risk due to climate change	49
4.2	Sea level rises by 0 metres above mean sea level in Bangkok and vicinity	53
4.3	Sea level rises by 2 metres above mean sea level in Bangkok and vicinity	53
4.4	Sea level rises by 4 metres above mean sea level in Bangkok and vicinity	53
4.5	Sea level rises by 6 metres above mean sea level in Bangkok and vicinity	54
4.6	Sea level rises by 8 metres above mean sea level in Bangkok and vicinity	54
4.7	Sea level rises by 10 metres above mean sea level in Bangkok and vicinity	55
4.8	Monthly rainfall variations in Bangkok	56
4.9	Cases of malaria in Bangkok	57
4.10	Spread of dengue fever in Bangkok	57
4.11	Cases of influenza in Bangkok	58
4.12	Average temperature trends of the two hottest months in Bangkok 1999–2006	59

## Tables

1.1	Climate of Bangkok	22
3.1	Comparison of carbon dioxide emissions of Bangkok and selected cities in developed countries (2005)	41
3.2	Greenhouse gases emission inventory of Bangkok city in 2007	41
3.3	Electricity consumption in Bangkok	44
3.4	Solid waste generation and collection in Bangkok	46
6.1	Adaptation measures for Bangkok	70–71

## Boxes

1.1	The industrial Age	13
3.1	Estimated emissions of carbon dioxide	37
3.2	Global emissions of carbon dioxide per capita	37
5.1	ASEAN+6 City Forum on Climate Change	62
5.2	BMA receives ASEAN Environmentally Sustainable Cities Award on Clean and Green Land	63

# Executive Summary

Thailand has long been actively participating in the global efforts to prevent or at least ameliorate the effects of climate change. Now its capital city, Bangkok, is starting to participate in these efforts since it is a significant source of greenhouse gases emitted into the atmosphere, and as the nation's economic hub it has a lot to lose.


This report attempts to explain why and how climate change is affecting Bangkok, while giving some idea of the likely trends that may be expected and what action will have to be taken in order to make the predicted outcomes less severe.

Bangkok contains close to 15 per cent of the entire population of Thailand, or close to 10 million people in real terms. Thailand's capital, communications hub, and administrative and business centre produced emissions of carbon dioxide totalling 43 million tons in 2005—a much greater volume than that of Toronto (24 million tons). Although they were lower than the total carbon dioxide emissions of New York City (58 million tons), they were about the same as those of London (44 million tons). Those data are enough to put Bangkok in the ranks of major sources of greenhouse gas emissions. In per capita terms, Bangkok was responsible for producing 7.1 tons of carbon dioxide per annum in 2007, that is, the same level of emissions as produced by New Yorkers (7.1 tons per capita), and considerably higher than the annual emissions of Londoners (5.9 tons per capita) but lower than the levels produced by residents of Toronto (9.6 tons per capita).

In 2007, the principal sources of greenhouse gas emissions in Bangkok were transportation (37.68 per cent) and electricity generation (33.37 per cent) (see table 3.2). The Department of Energy Business, Ministry of Energy, indicated that the transport sector in Bangkok emitted almost 23.07 million tons of carbon dioxide per annum from consuming 8,948,683 million litres of gasoline and diesel oil. Electricity used was as high as 29,180 GWh which caused the emission of 20.43 million tones of carbon dioxide, accounting for 33.37 per cent of total annual emissions. Solid waste and waste water emitted 12.16 million tones of carbon dioxide, equivalent to 19.86 per cent of total annual emissions. These three sources contribute 90.91 per cent of the total emissions of greenhouse gases annually. The remaining 9.09 per cent comes from other sources, such as agriculture.

The impacts of greenhouse gas emissions and the resulting climate change on Bangkok are likely to be quite severe. Bangkok is naturally prone to flooding and, owing to the rapid urbanization in recent decades, many long-existing watercourses, such as canals, ditches and ponds, were filled in and replaced by roads, buildings and other structures, thus exacerbating the effects of heavy rains. Although flood protection projects were established and improved after two particularly devastating floods, Bangkok is still at increasing risk of flooding. A case study of Bangkok provides a macro picture of likely flooding and its socio-economic impacts, using various scenarios of mean sea level rise in the twenty-first century. The simulated outcomes of the flood model used in the study indicate that almost 55 per cent of Bangkok would be affected by floods if the mean sea level were to rise by 50cm, and 72 per cent of the city would be affected if the mean sea level were to rise by 100cm.





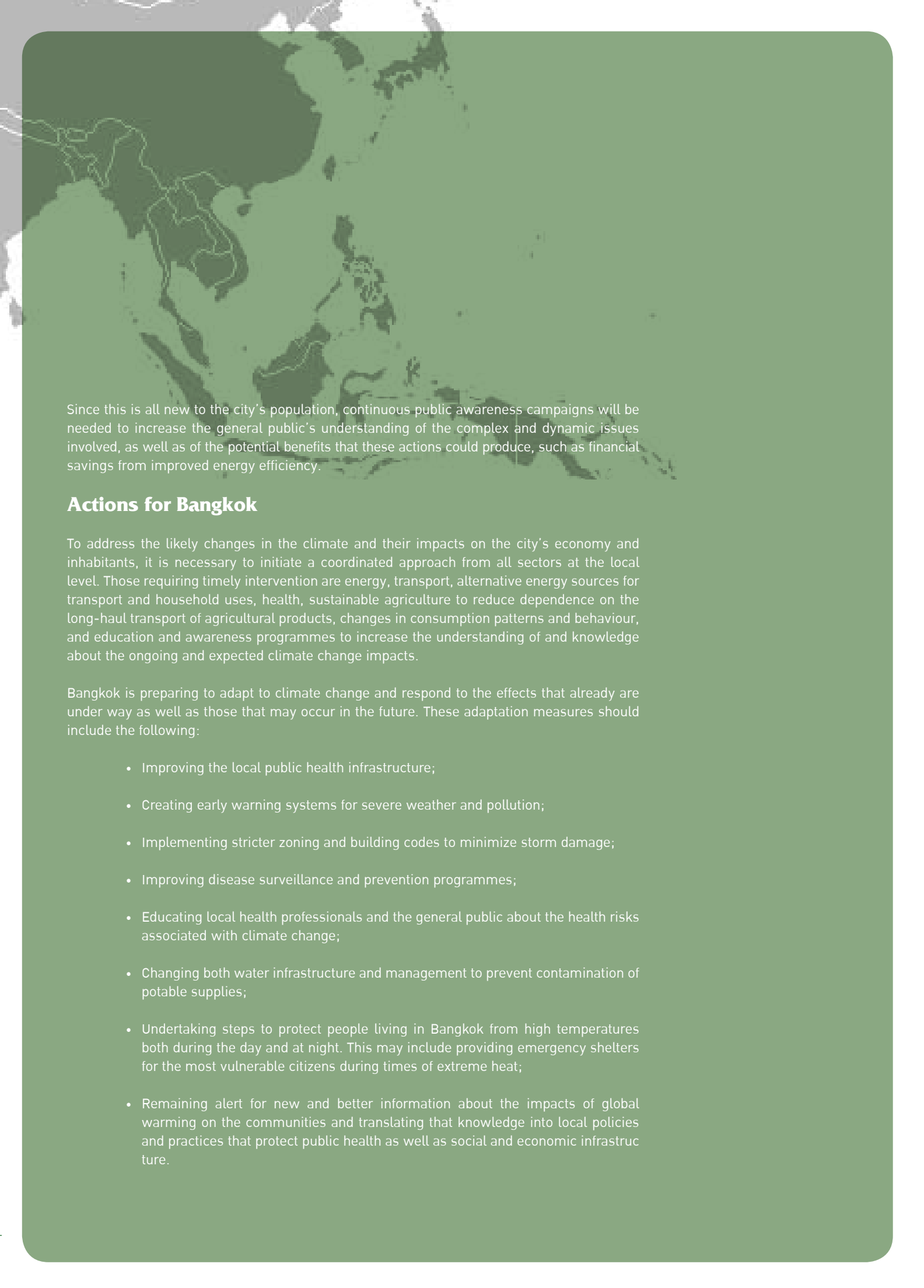
Bangkok also suffers from the effects of land subsidence caused by over-pumping of groundwater and by the nature of the thick, soft clay on which the city is built. Other results of subsidence include ground water contamination with saline intrusion, nitrates, coliform bacteria and volatile organic compounds.

Since Bangkok is expected to continue to grow over the next 10 years, the problems of water supply and contamination of both surface and ground waters are also likely to be exacerbated. By the end of the current century, increasing temperatures are expected to boost the demand for water for agricultural purposes between 2 and 13 times in the lower and medium warming ranges, respectively, as well as the demand for water for household purposes owing to the continued urbanization of the city.

Climate change will also affect the health of Bangkok residents due to the increases in the frequency, duration and intensity of the conditions conducive to air pollution and oppressive heat. However, the primary concern is the projected increase in extreme conditions that are responsible for most serious health consequences. Climate change has the potential to influence the incidence and spread of infectious disease transmitted by mosquitoes, ticks, fleas, rodents and contaminated food. Based on projected increases in the temperature for the period from 1998 to 2050 under a climate change scenario, the number of cases of malaria infection would rise substantially. Besides the likely human impact, a preliminary estimate of the potential financial damage suggests it could be in the thousands of millions of Baht. Similar impacts would be caused by outbreaks of dengue fever and other health conditions.

Another adverse impact is that of increased atmospheric temperature on crop production, because it influences crop growth through its impact on photosynthesis and respiration, as well as the length of the growing season and the amount of water used. Rising temperatures may therefore have a significant impact on the crops and other plants grown in and around Bangkok, as well as the rest of the country, which is currently one of the world's important food exporters.

To deal with these threats, the Bangkok Metropolitan Administration has adopted the Action Plan on Global Warming Mitigation 2007-2012, which calls for it to: expand mass transit and improve traffic systems; promote the use of renewable energy; improve electricity consumption efficiency; improve solid waste management and wastewater treatment efficiency; and expand park areas. The Action Plan is aimed at bringing about a reduction in Bangkok's greenhouse gas emissions over a period of five years, that will be 15 percent below the levels currently projected for 2012.



Since this is all new to the city's population, continuous public awareness campaigns will be needed to increase the general public's understanding of the complex and dynamic issues involved, as well as of the potential benefits that these actions could produce, such as financial savings from improved energy efficiency.

## **Actions for Bangkok**

To address the likely changes in the climate and their impacts on the city's economy and inhabitants, it is necessary to initiate a coordinated approach from all sectors at the local level. Those requiring timely intervention are energy, transport, alternative energy sources for transport and household uses, health, sustainable agriculture to reduce dependence on the long-haul transport of agricultural products, changes in consumption patterns and behaviour, and education and awareness programmes to increase the understanding of and knowledge about the ongoing and expected climate change impacts.

Bangkok is preparing to adapt to climate change and respond to the effects that already are under way as well as those that may occur in the future. These adaptation measures should include the following:

- Improving the local public health infrastructure;
- Creating early warning systems for severe weather and pollution;
- Implementing stricter zoning and building codes to minimize storm damage;
- Improving disease surveillance and prevention programmes;
- Educating local health professionals and the general public about the health risks associated with climate change;
- Changing both water infrastructure and management to prevent contamination of potable supplies;
- Undertaking steps to protect people living in Bangkok from high temperatures both during the day and at night. This may include providing emergency shelters for the most vulnerable citizens during times of extreme heat;
- Remaining alert for new and better information about the impacts of global warming on the communities and translating that knowledge into local policies and practices that protect public health as well as social and economic infrastructure.

In addition, the following actions will be undertaken by the BMA together with relevant partners:

- Create partnerships with various stakeholders to create momentum, continuity, longevity and success for the various programmes upon which it embarks;
- With regard to municipal buildings, retrofit city buildings with energy efficient lighting and appliances, collaborate with the Ministry of Energy in establishing energy efficient standards for new municipal construction and major renovations, and perform energy audits for existing buildings;
- Work with the Ministry of Transport to install light-emitting diode (LED) traffic signals and traffic flow management systems, update street lighting to a high-efficiency level, increase wastewater utilities and establish landfill-gas energy projects;
- Reduce the emissions of its vehicle fleets, using hybrids, alternative fuel vehicles and idle-engine reduction policies and campaigns, as well as establishing programmes to reduce driving on duty by city employees. BMA will also modify school buses, waste haulers and ambulances to use compressed natural gas (CNG) and biofuels;
- Establish purchasing programmes to procure energy-efficient appliances and purchase materials that require less energy and reduce the amount of waste that such appliances and materials produce;
- Continue working with the Thai Industrial Standards Institute to create efficiency standards for office equipment, adopt recycled salvaged product use policies and develop local purchasing programmes;
- Support public and private transport by making the city pedestrian- and bicycle-friendly, providing better access to public transport, creating more park-and-ride facilities, providing incentives for hybrid or low-emission vehicle use and installing plug-in facilities for electric hybrid vehicles.

Existing and new technologies and initiatives yet to be developed will enhance the ability of Bangkok to reduce its emissions of greenhouse gases and adapt to climate change. These investments and efforts should yield a triple dividend, for the economy, for the environment and for society, primarily for the people of Bangkok but also of Thailand and the planet as a whole, as well as contributing to mitigating climate change.



# Introduction

## Climate Change Perspective

The phrase “climate change” has generated its share of headlines in recent years, with predictions of frightening impacts on people and economies around the world, as well as globally.

However, the likely impacts often seem to concern those living in far off lands in colder latitudes. Does climate change hold any implications for people living in an already warm tropical climate like that of Thailand and its capital city, Bangkok ?

Unfortunately, the answer is “yes”; thus, this report will attempt to explain why and how climate change is affecting and might further affect Bangkok, while giving readers some idea of the likely trends they can expect to see and what action they and others can take in order to reduce the predicted impacts.

## Real but not natural

Climate change is real. That the earth’s climate is warming is an “unequivocal” fact, according to a recent report of the Intergovernmental Panel on Climate Change (IPCC, 2007). The change is clearly evident from the increases observed around the globe in air and water temperatures, which are causing widespread melting of snow and ice, along with a concomitant rise in the average sea level, among other impacts (IPCC, 2007).

Are these not just natural changes? The IPCC report states that, for the first time in history, climate change is happening now largely as a result of human activity (IPCC, 2007).

Scientists have long known that the earth’s climate has experienced periodic changes. For millennia before recorded history began, climate changes have occurred at wide intervals: sometimes the change was characterized by heat and other times by cold. But this time the climate warming is not due to natural variability - it is due to human activity (IPCC (WG. 1), 2007).

Specifically, the burning of fossil fuels for industrial production and modern transport, among many other purposes, results in abnormal quantities of carbon dioxide and other “greenhouse gases” being pumped into the atmosphere (see box 1.1 for historical details). Adding to the problem are deforestation and changes in land use, driven by population growth and the increasing need for more land. These factors are rapidly changing the air above us and the surface beneath our feet, and they are the main causes of climate change in today’s world.



## The Industrial Age

From the end of the last Ice Age thousands of years ago, the concentration of carbon dioxide in the atmosphere increased to about 100 parts per million (ppm) in the eighteenth century, or an average increase of 1.25 ppm per century.

Since then, following the start of the Industrial Revolution in the 1700s, the rate of increase of this greenhouse gas has accelerated markedly. Carbon dioxide levels increased to 379 ppm in 2005. In the 10-year period leading up to 2005, atmospheric carbon dioxide increased by 19 ppm, the highest average growth rate recorded for any decade since direct measurements of atmospheric carbon dioxide began in the 1950s.

This increase is due to the burning of fossil fuels, such as coal, oil and natural gas, to produce energy, as well as to the burning of forests and other vegetation to clear land for agriculture, the construction of cities and other human activities.

The outlook for the future is worrying. It has been estimated that, in the next 100 years, the concentrations of carbon dioxide in the atmosphere might increase to 600 ppm, or even as high as 900 ppm.

It has also been estimated that there could be a doubling in the level of another greenhouse gas, methane, released into the atmosphere, from the current level of 1,750 parts per billion (ppb) to 3,500 ppb in 2100 (IPCC, 2007).

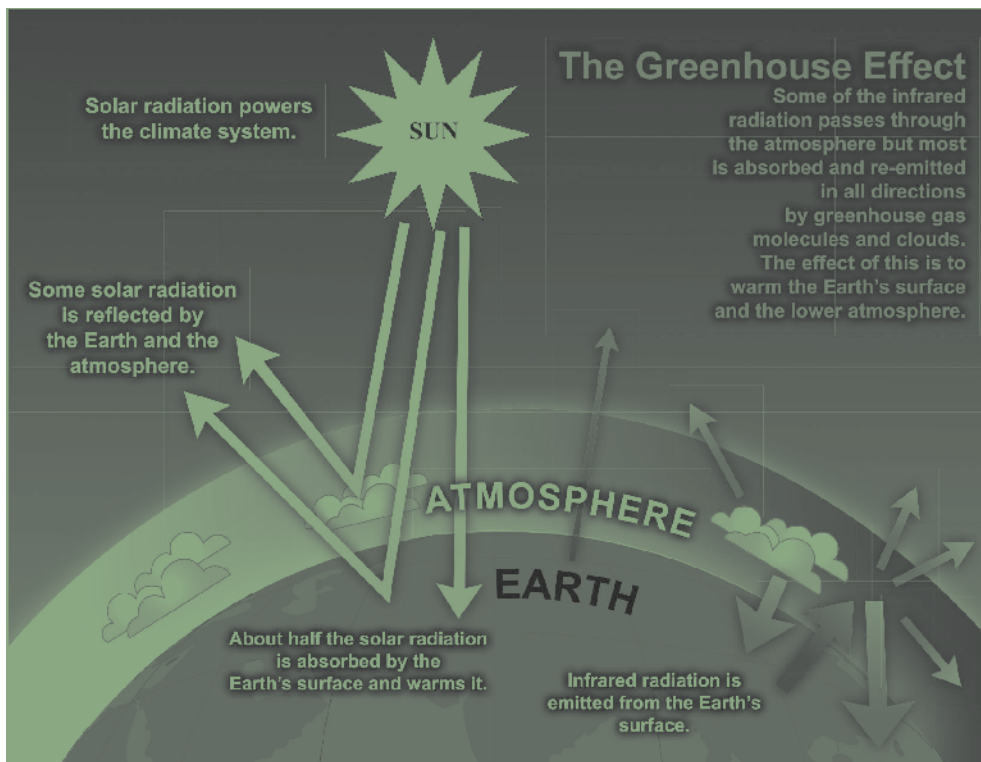
## The heat trap

How does climate change occur? The large volumes of greenhouse gases—mainly carbon dioxide, methane and nitrous oxide—produced by human activity act like a “greenhouse” or an invisible blanket covering the earth in addition to the covering of clouds and less visible water vapour. That layer of gas allows sunlight to reach the earth and warm its surface, but it traps some of the heat that ordinarily would be reflected out of the atmosphere as infrared radiation (see figure 1.1). Since the levels of greenhouse gases have become unusually high compared with the historical record, the absorbed heat builds up over time. This phenomenon is disrupting natural patterns of climate around the world, including in Thailand.

In terms of how hot it is getting, experts predict that the world faces an average temperature rise of 3°C within this century if greenhouse gas emissions continue to rise at the current rate (UNFCCC, 2007). But higher temperatures are not the only concern.

Experts think that the climate change which we are currently witnessing is likely to increase even more dramatically. The emerging scientific consensus is that climate change will not be experienced in a steady progression. Rather, changes are more likely to be observed through increases in the intensity and frequency of natural variations in the global climate system (IPCC, 2007).

Figure1.1: An idealised model of the natural greenhouse effect



Source: [http://ipcc-wg1.ucar.edu/wg1/FAQ/wg1\\_faq-1.3.html](http://ipcc-wg1.ucar.edu/wg1/FAQ/wg1_faq-1.3.html)

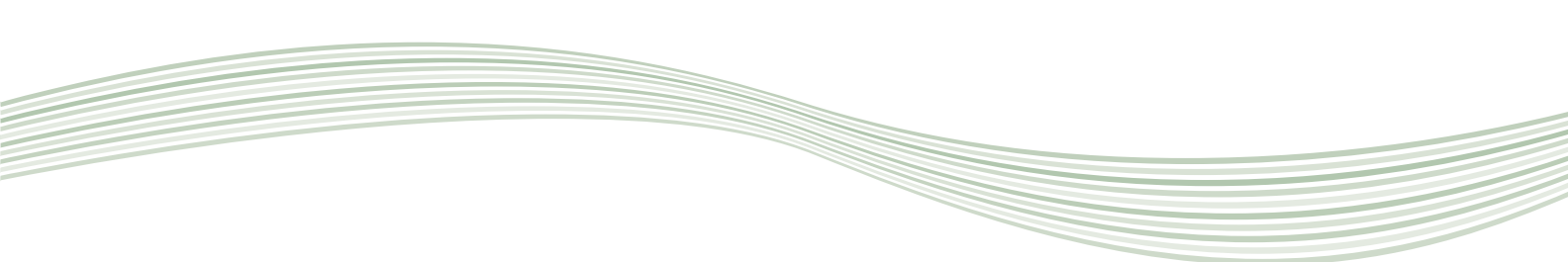
## Natural disasters

What this means is that humanity will suffer from harsher weather patterns, such as the alternating El Niño and La Niña events (see annex II for details). As the concentrations of greenhouse gases continue to increase, it is expected that many of the world's major storm tracks could shift significantly and "natural" disasters could become more deadly and more frequent (Pew Center for Global Climate Change, 2006). In addition to severe storms, flooding, heat waves, droughts and water shortages as well of the spread of diseases into new territory are also among the expected outcomes of the ongoing process of climate change (Pew center for Global Climate Changes 2006).

Although there may be some benefits, overall there are likely to be more negative impacts. For example, although people living in cold countries such as Greenland may actually be able to grow a wide range of crops for the first time, thus benefiting from the higher temperatures, people elsewhere will struggle to cope with the adverse effects of the heat, even though they may have contributed little to the emission of greenhouse gases causing the problem.

For the world as a whole, the picture is equally pessimistic. The frequency of major natural disasters is already three times what it had been in the 1960s. "Our climate is warming at a faster rate than ever before recorded", according to Mr. James Baker, speaking as Administrator of the United States National Oceanic and Atmospheric

Administration (NOAA). "Ignoring climate change and the most recent warming patterns could be costly to the nation. Small changes in global temperatures can lead to more extreme weather events, including droughts, floods and hurricanes" (NOAA, 2000).



Some scientists state that, in order to stabilize the climate, it will be necessary to reduce the emissions of carbon dioxide and other greenhouse gases by 60-80 per cent below current levels. However, doing so will not be easy. The remedy will require drastic increases in energy efficiency and the use of renewable forms of energy, including perhaps a shift away from hydrocarbons towards carbohydrates, for example (California Environmental Protection Agency (CEPA) 2006)

Even meeting the targets established under such hard-won international agreements as the Kyoto Protocol may not be enough to solve the climate change problem. Achieving the cuts called for by that agreement would only delay the doubling of greenhouse gas concentrations by a decade or two. Because climate change may be happening faster than models have predicted, fundamental changes in human activities need to be made urgently if the world is to avoid the adversity that the current course will bring about (Union of Concerned Scientists, 2006).

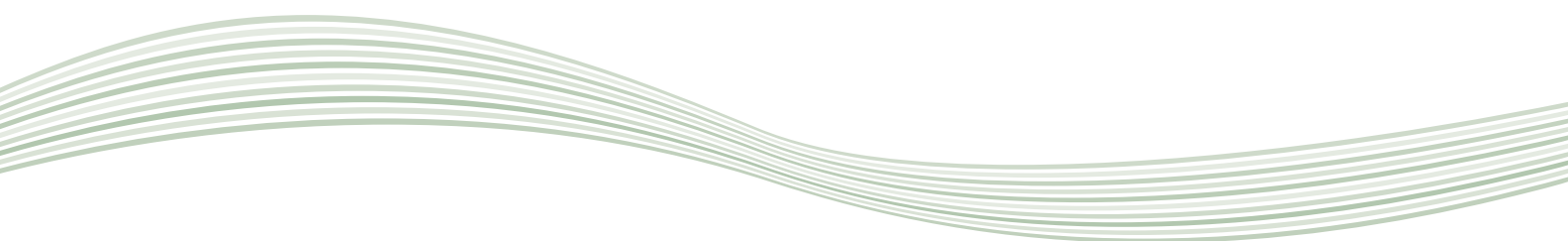
## The Thai Context

Thailand recognizes that it, too, must play an active role in the world's search for solutions, since it shares with others the challenges posed by this unprecedented climate change. The country has much at stake. Thailand's livelihood, culture and lifestyle are related to its climate. Moreover it is one of the few net exporters of food and fish in the world.

Thailand covers an area of more than 513,000 square kilometres in the humid tropics of South-East Asia. The country is divided into four regions. The mountainous Northern Region borders Myanmar and the Lao People's Democratic Republic. During the cool season, crops normally cultivated in temperate zones, such as strawberries and grapes, are grown in the region's well-watered valleys.

The Northeastern Region, or Korat Plateau, which borders both the Lao People's Democratic Republic and Cambodia, is quite different. It is characterized by much drier weather and frequent droughts, although the construction of reservoirs and other such facilities has helped in alleviating these harsh conditions. Researchers have also been trying to identify crops that would thrive in the soil of this region, which is characterized by an elevated salt content.

The Central Plains Region is among the most productive rice-growing areas in the world. It stretches in the west from the border with Myanmar to Cambodia in the east, and enjoys a long coastline along the Gulf of Thailand, which is rich in fisheries. The nation's capital, the mega-city Bangkok, is located near the mouth of the famous Chao Phraya River, which empties into the Gulf.



The Southern Region is a long narrow peninsula bordering Myanmar to the west and Malaysia to the south. Famous for its picturesque mountains and beaches along the Gulf and the Indian Ocean, it is also a major producer of natural rubber, a wealth of fruit, and coconut and palm oil products.

For the country as a whole, the climate is monsoonal. Except for the Southern Region where rain can fall throughout the year, Thailand's rainy season extends generally from May to early November. The rest of the year is relatively dry. While the period from November to January and sometimes February is comparatively cool, the months between March and May are the hottest, with temperatures reaching from the mid to high 30s to the mid-40s (Meteorological Department of Thailand, 2008).

## Vulnerability to climate change

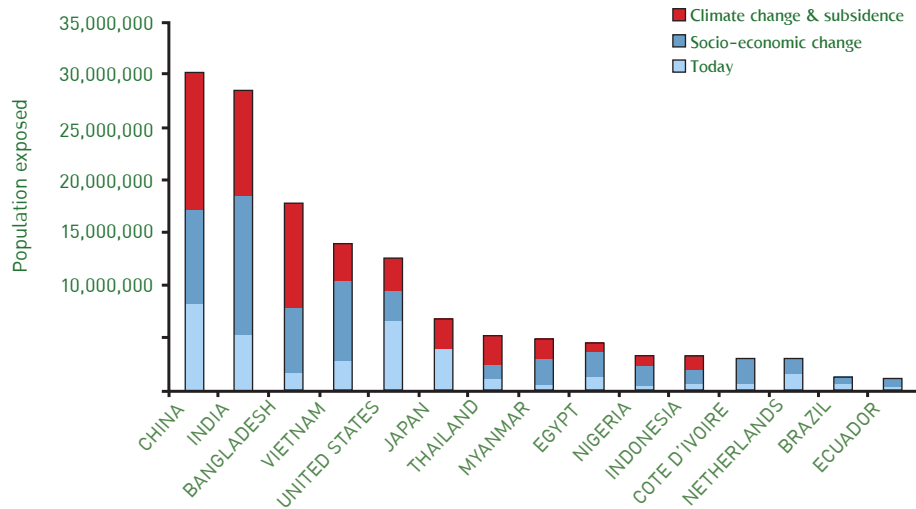
Thailand's long coastline (a total of 2,615 km) makes it especially vulnerable to the effects of climate change. In this regard, the country's capital and major port are especially at risk. A recent study ranking the cities of the world most exposed to coastal flooding today and in the future provides interesting insights into this vulnerability (OECD, 2007). The analysis indicates that by the 2070s almost all (90 per cent) of the total asset exposure of large port cities will be concentrated in only eight countries, one of which is Thailand (see figure 1.2). Thailand ranks sixth in terms of the severity of the projected effects.

The same study also assessed the impact on the population of countries exposed to coastal flooding. Figure 1.3 shows that 90 per cent of the exposure of people in the 2070s will be in 11 countries and Thailand will rank fifth in terms of the negative impacts projected (OECD, 2007).

Parts of Thailand are already quite susceptible to extreme weather events, such as tropical storms, floods and drought. In 2005, the weather nationwide was characterized by both severe drought and flooding. Several cities and extensive stretches of farmland in six provinces of the Northern Region were inundated by flood waters; 6 deaths were recorded and about 50,000 people were severely affected. In the same year, heavy rainfall and devastating floods inundated eight provinces in the Southern Region, destroying bridges, roads, houses and agricultural land and wiping out large populations of livestock. Yet, 2005 was also marked by critical water shortages in many other parts of the country, particularly in the east (IGES, 2005).

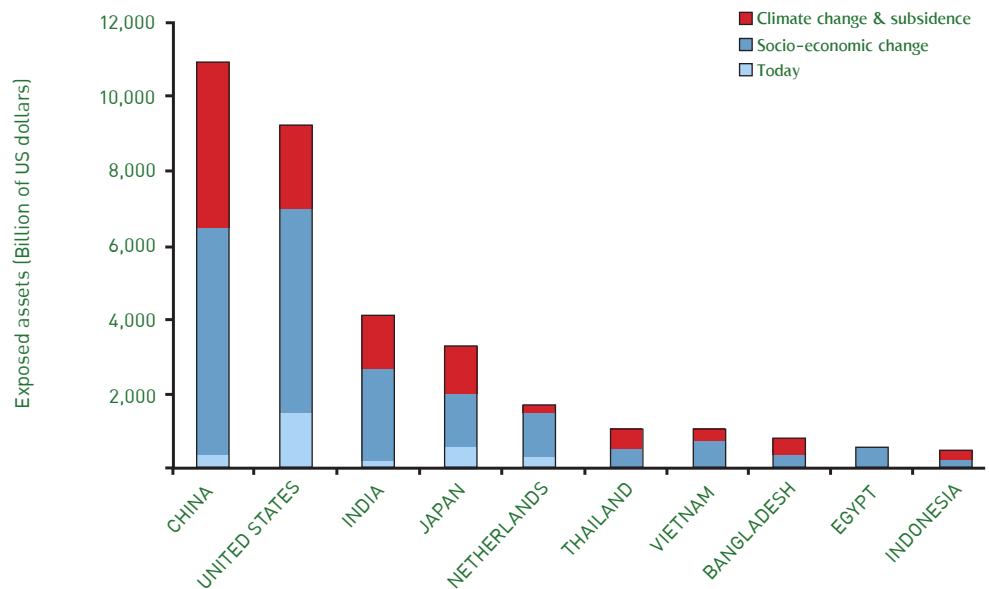


Figure 1.2: Top 15 countries by population exposed today and in the 2070s, showing the influence of future climate change vs. socioeconomic change



Source: Nicholls et al, Paris, OECD (2007)

Figure 1.3: Top 10 countries by assets exposed today and in the 2070s, showing the influence of future climate change vs. socioeconomic change



Source: Nicholls et al, Paris, OECD (2007)

Further evidence is provided in the meteorological data record for the 40-year period between 1951 and 1991 during which 145 tropical depressions occurred. Since 1991, however, Thailand has been affected almost every year by at least two tropical storms powerful enough to cause considerable loss of life and damage to property. The areas of the country affected by such violent weather also appear to be expanding (Wangwacharakul 2002)

Although such weather is beyond the ability of government authorities to control, many people believe that the severity of the damage could be reduced if local ecological systems were conserved and managed better. As an example of a positive intervention, they point to the ban the Government imposed on logging in 1989 following a massive landslide in the Southern Region (FAO, 2000).

More specific details about these and other matters relating to climate change will be provided in subsequent chapters.

## Climate change policy

In order to cope with the potential and real threats posed by climate change, the Government is taking into account the principles of the United Nations Framework Convention on Climate Change in the formulation of policies. Such policy dimensions are being integrated into the country's economic and social development plans. The first to undergo this process was the Seventh National Economic and Social Development Plan, covering the period 1992-1996 (MOSTE, 2000). These principles have also been incorporated into Thailand's environmental policies and plans.

Currently, the Office of Natural Resources and Environmental Policy and Planning, under the Ministry of Natural Resources and Environment, is in the process of drafting a strategy to address climate change issues as they relate to Thailand. The strategy will outline the mechanisms and measures that will have to be undertaken by various agencies of the Government. Such measures will include those for reducing greenhouse gas emissions and enabling the country to adapt to the adverse impacts of climate change. These measures will be in addition to those incorporated within the country's five-year plans.

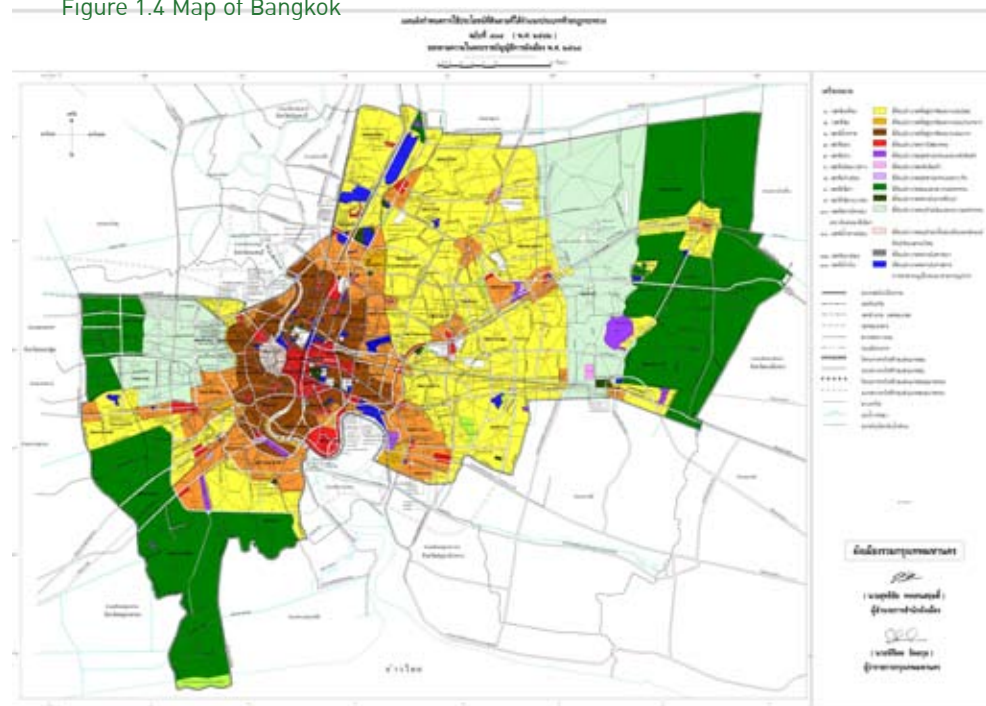
In general, the measures also call for promoting the awareness of the general public about climate change and the need for community action to implement them. Efforts to build or strengthen capacity will also be undertaken, especially in the area of research and development (ONEP, 2008).



## Introducing Bangkok

What applies to the entire country also applies especially to Bangkok, Thailand's capital and most heavily populated city-close to 15 per cent of the entire population lives or works there. Although the population of greater Bangkok is close to 10 million in real terms, the number of people officially registered there is closer to 6 million. Besides its large population size, the city is also enormous in its physical dimensions, sprawling over an area much larger than that of many European and North American capitals.

Figure 1.4 Map of Bangkok



Source: BMA, 2008

Bangkok is not only the political, administrative, economic and cultural capital of Thailand, but it is also the focal point for the national road, railway, aviation and communications services. In a very real sense, all roads do seem to lead to Bangkok. Employment opportunities in government, industry and commerce exceed those offered elsewhere in the country, as do the educational opportunities available.

The city is also a transit hub for the rest of Asia, with its proximity to major destinations on the continent and its strategic location between the growing markets of China and India. It serves not only as a gateway to Thailand but also to other Asian destinations for businessmen, professionals and tourists numbering in the millions.

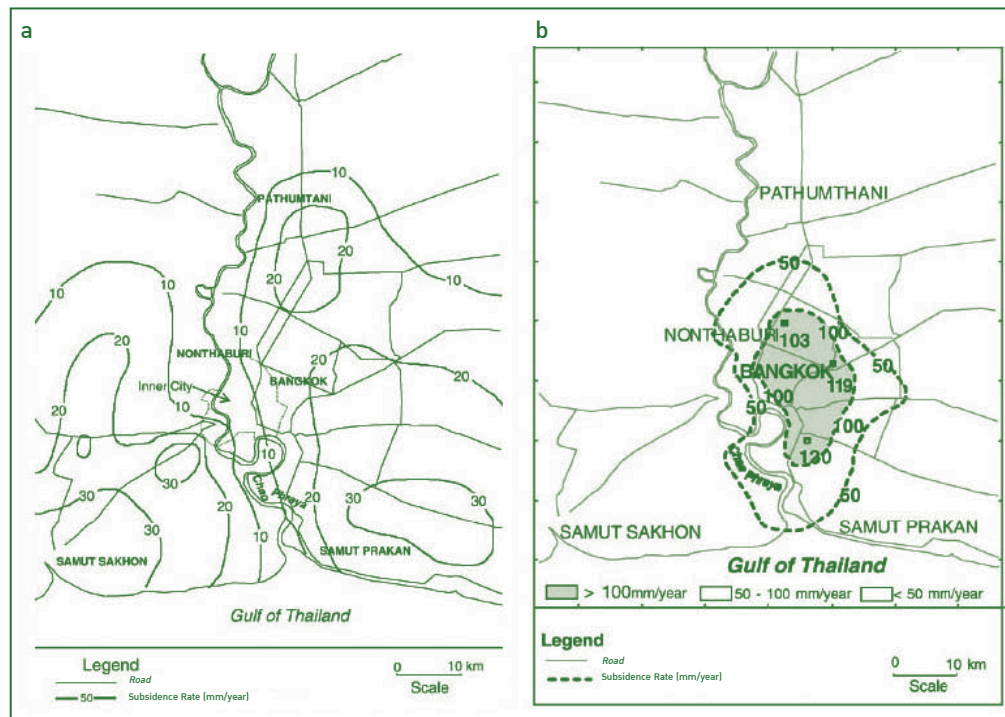
## Geography, topography and climate

Although Bangkok may be at the summit for almost every aspect of modern life in Thailand, it is virtually flat, rising little more than 2 metres above mean sea level at its highest point.

As the Chao Phraya River flows to the Gulf of Thailand, it divides Bangkok; simultaneously numerous canals flow into the river, which has given rise to the city's appellation as the "Venice of the East". Although many of the canals were filled in during the past several decades to make roads, sometimes immediately after particularly heavy rain it may seem as if the roadways have reverted to their former use. However, the Bangkok Metropolitan Administration has installed giant pumps and instituted other measures that prevent much of the flooding that used to be an annual event in the city.

While such measures benefit pedestrians and motorists, they have had a negative and far-reaching effect. Land subsidence is occurring in several areas of the city owing to overpumping of groundwater from the thick clay on which the city is built. The average rate of subsidence has reached 5-10 mm per year in much of the city and has reached 30 mm per year in the outlying southeastern and southwestern areas (see figure 1.5) (Phien-wej and others, 2006). Such rates of subsidence when combined with a rising sea level could leave Bangkok under 50-100 cm of water by 2025 (Phien-wej and others, 2006).

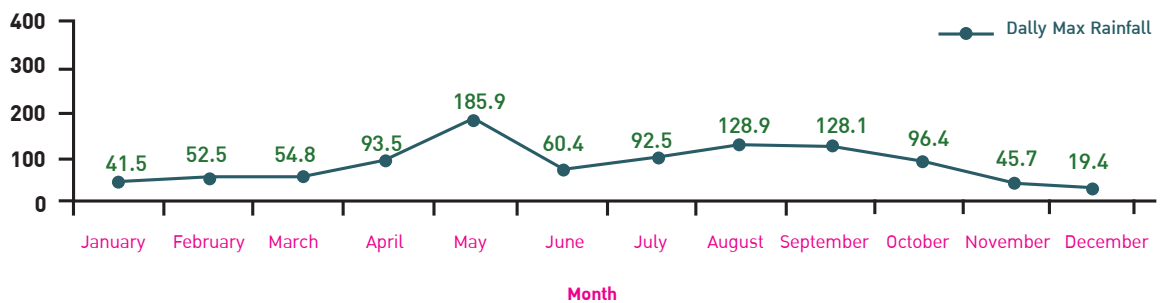
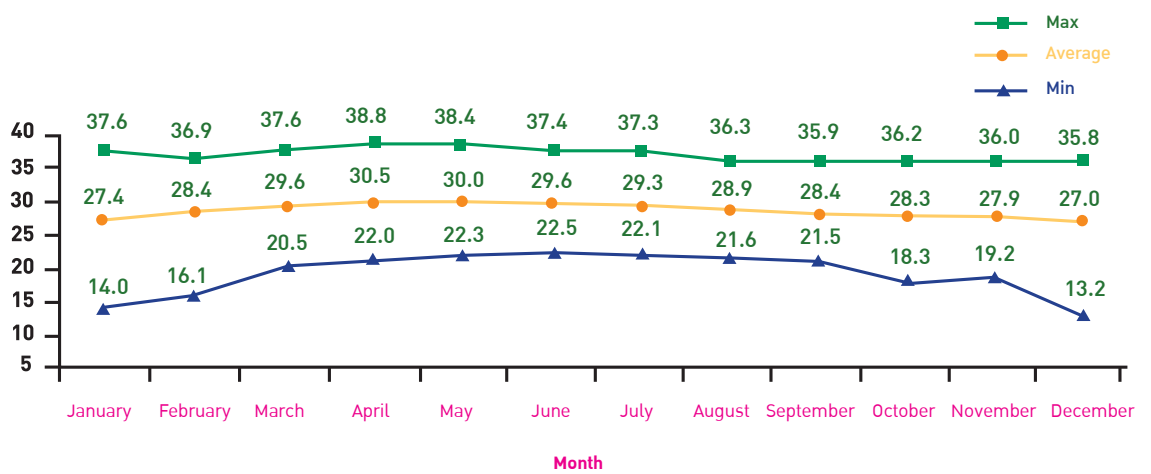
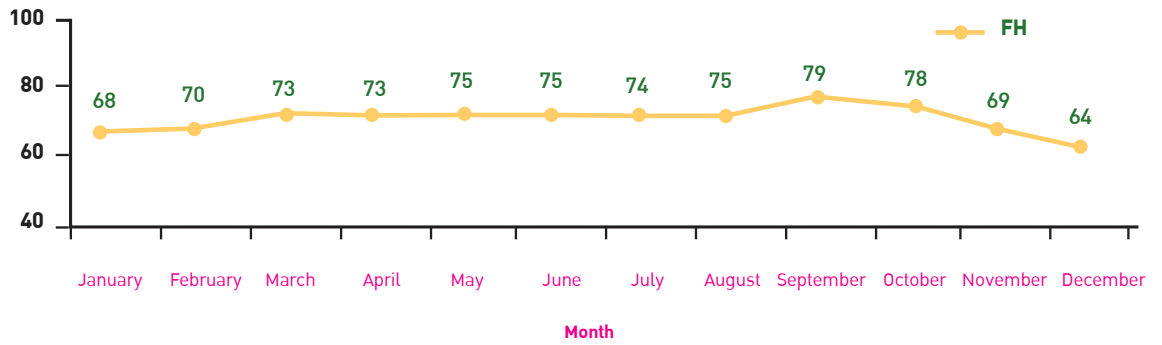
Figure 1.5 : Land subsidence rate of Bangkok in 2002 (a) and in 1981 (b)



Source: Phien-wej et al., 2006

The city has a number of advantages in the form of generous water endowments and generally benevolent weather patterns. With an average annual temperature of 29.2°C (the extremes ranging from the high teens to the low forties), it is easy to see why the city's founders established the nation's capital there in 1782 (see table 1.1 and figure 1.6) (BMA, 2006).

Figure 1.6: Meteorological data of Bangkok metropolis, averaged monthly over 10 years (1993 - 2002)



Source: Department of Meteorology

Table1.1. Climate of Bangkok

MONTH	January	February	March	April	May	June	July	August	September	October	November	December
Average daily maximum Temperature (oC)	32	33	34	35	34	33	32	32	31	31	31	31
Average daily minimum Temperature (oC)	20	22	24	25	25	24	24	24	24	24	22	22
Average total rainfall (mm)	8	20	36	58	198	160	160	175	305	206	66	5
Average number of rainy days	11	3	3	9	10	13	13	15	5	14	5	1

Source: BMA 2005 Refer to BBC Weather Centre, 2005

However, a study by the Department of Meteorology on the variations in maximum and minimum temperatures in Bangkok during the previous 10 years, compared with long-term averages, found that from 1991 to 2000 the maximum average temperature in the summer months was significantly higher than the long-term average. Conversely, the lowest temperatures in the winter months were warmer than the long-term average (Department of Meteorology, 2008). This aspect will be considered further in other sections of the present report Particularly in Chapter 2.

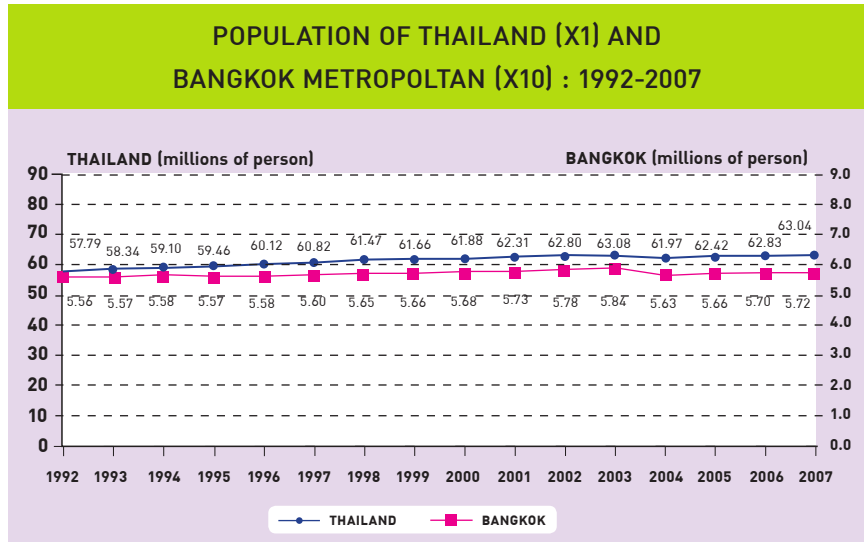
## Urbanization and demographic trends

Since 1960, Bangkok has been undergoing rapid urbanization and industrialization in line with the overall development of the Thai economy. Several factors have contributed to Thailand's rapid economic growth. The country has an abundance of natural resources and has been blessed with large expanse of fertile land, ideal conditions for tropical agriculture and an enterprising population capable of exploiting such resources.

With the Government providing infrastructural support in transport, communications and public utilities, among other sectors, the economy has attracted the attention of many domestic and international entrepreneurs who have helped to develop industry and agriculture to the point where Thailand has been considered among the "Asian Tiger" economies.

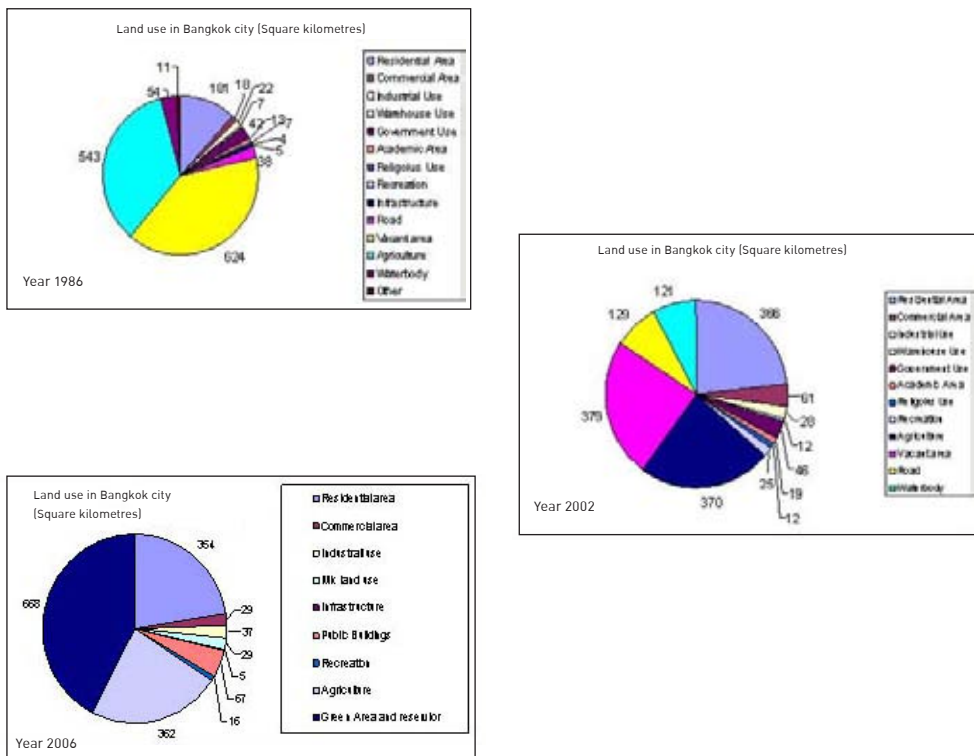
When Bangkok was founded two and a quarter centuries ago, the population was about 50,000 (Sternstein, 1982) Today it numbers about 10 million as previously mentioned. Although figure 1.7 shows the trend in population increase of the population registered as living in Bangkok over the last 15 years, it does not show the millions of others who are registered elsewhere but live and work in the city.

Figure 1.7 Population trends of Bangkok



Source: Statistical Profile of BMA, 2007

Figure: 1.8. Land Use Patterns of Bangkok



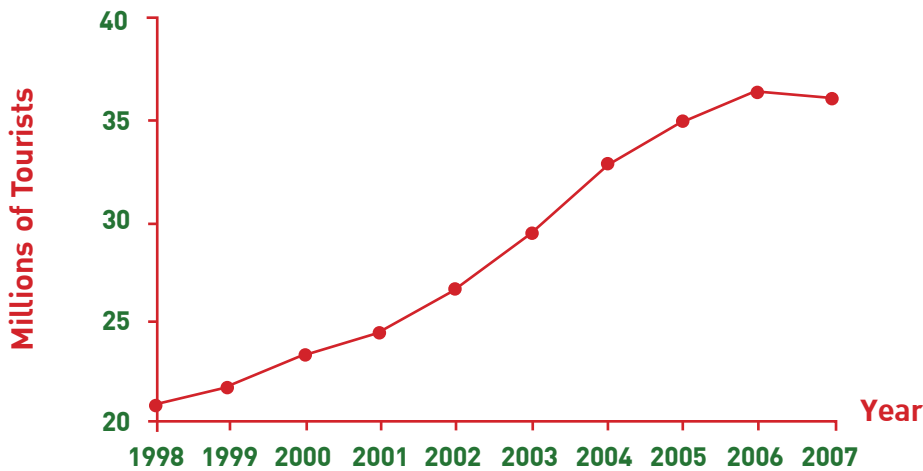
Source: Survey and Mapping Division, Department of City Planning, BMA, 2008

Economic development has not only changed the size of the population, but it has also contributed to massive expansion of the city and to major changes in land use patterns. Figure 1.8 illustrates these changes for three periods: 1986, 2002 and 2006. The increases in population, changes in land use patterns and the development of new road networks have also led to an increase in environmental pollution, especially from the emissions of motor vehicles.

Owing to such pressures in the more central parts of Bangkok, a large number of people have moved to suburban areas from where they commute daily to the business districts of the city. As a result, the population density in the inner city decreased from 15,270 people per square km in 1978 to 11,090 in 2000, or in other words, from 3.25 million to 2.86 million people. By contrast, in the outer areas of Bangkok population density increased during the same period from 770 people per square km to 1,280, that is, from about 670,000 to 1.12 million people. These statistics show that people now tend to live away from the inner city (Nitivattananon and Noonin, 2008).

However, central Bangkok does not seem to reflect much change in the population. This is partly due to the large influence of temporary visitors and tourists, whose numbers have increased dramatically in the past decade or so. The number of tourists visiting Bangkok increased at an average annual rate of 6.24 per cent during the period 1998-2007 (see figure 1.9). The average annual growth rate was 5.25 percent during the period 2003-2007, reflecting a drop to 3.38 per cent annually for 2005 and 2006.

Figure 1.9 Trend of Tourists Arrival in Bangkok 1998-2007



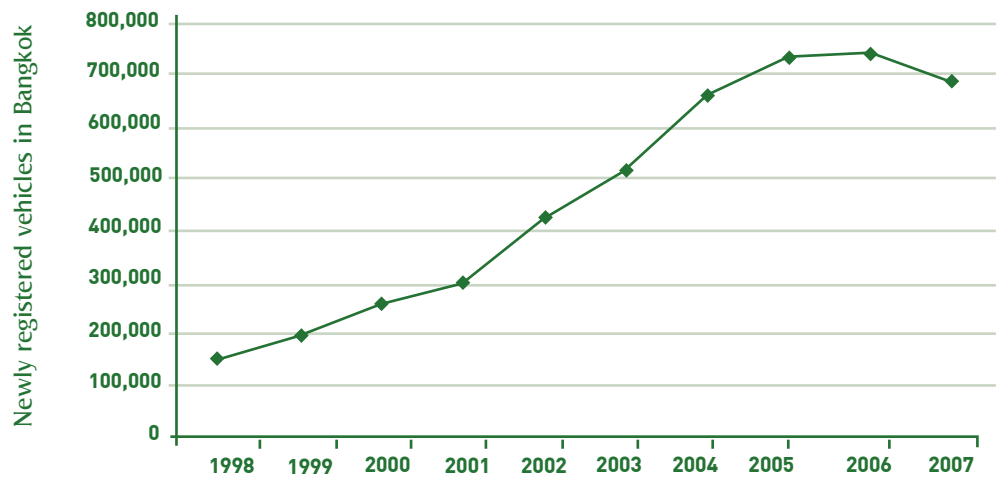
Sources: Tourism Authority of Thailand 2008

Residents or visitors walking and travelling around Bangkok face significant air pollution, the greatest source of which is the transport sector. Street-level concentrations of air pollutants along the city’s major roads can reach hazardous levels, owing to the large number of high-emission motor vehicles coupled with the long distances travelled and the extreme traffic congestion that characterizes the city. The reason is the number of motor vehicles registered in Bangkok, which has soared from 600,000 in 1980 to 4,163,000 at the end of 1999—a seven-fold increase.



Between 1999 and 2007, vehicle registration continued to rise as shown in figure 1.9. By the end of 2007, there were 5,614,294 vehicles choking Bangkok's inadequate street and roadway networks, comprising 3,208,462 passenger cars, 2,261,545 motorcycles, 110,571 trucks and 33,716 buses (Land Transport Department, 2008). However, it should be pointed out that, for several years, the situation has improved somewhat owing to the operation by BMA of an overhead rail system popularly known as the "Skytrain" and an underground system called the "Metro", or MRT for short. (UNHABITAT, 2008).

Figure 1.9 Number of newly registered vehicles in Bangkok



Source: Land Transport Department ,2007

As mentioned previously, Thailand faces serious challenges in terms of air pollution, water pollution, noise pollution, solid and hazardous waste problems and land subsidence. In governing the twenty-second largest city in the world, which is an active member of the international community, the city's administrators recognize that Bangkok will face further challenges in terms of the effects of climate change. The present report is an attempt to assess the possible impacts of climate change on Bangkok and to identify areas where interventions could make useful and timely contributions to the efforts to stem or adapt to the deleterious process.

# Observed Climatic Trends and Variability

## Temperature Trends Past and Present : The Global Perspective

Concern about climate change may seem to be a relatively new phenomenon, but it has been a subject of concern since the nineteenth century, when a few scientists began to realize that some gases in the atmosphere were causing a greenhouse effect that was raising temperatures on earth.

Carbon dioxide was the focus of the early investigators. When scientific instrumentation became reliable enough to produce meaningful results from atmospheric and oceanographic testing, scientists found that the levels of carbon dioxide were indeed rising fast.

Soon the scientists began to postulate whether carbon dioxide might have played a role in incidents of climate change known to have occurred in the distant past. To determine whether such events could predict future outcomes, holes were drilled into the Arctic ice cap to test the deeply buried ice. The cylinder ice cores that the researchers extracted from these holes showed that carbon dioxide from prehistoric times had indeed been preserved and could be measured.

Their investigations revealed that in the last Ice Age the levels of carbon dioxide had been up to 50 per cent lower than they were currently and that atmospheric temperatures had gone up or down in the past in line with the levels of carbon dioxide from natural sources such as volcanoes.

More recently a similar approach was used in other scientific analyses focused on underground temperatures. Scientists drilled more than 600 holes in all continents except Antarctica. Their efforts produced the following findings (Pollack and others, 2000):

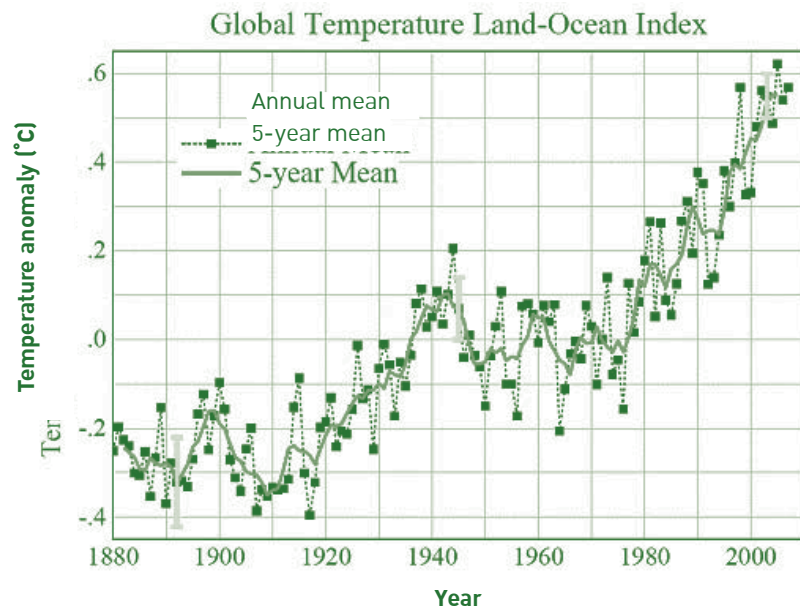
- The global average ground surface temperature increased by at least 0.5°C in the twentieth century. This is a conservative estimate of the century-long rate of warming because many of the holes had been drilled and their temperatures recorded prior to the extraordinary warming that took place in the final decades of the twentieth century;
- The twentieth century was the warmest of the past five centuries;
- The mean temperature was currently at least 1.0°C warmer than that of 500 years previously; about 80 per cent of the increase occurred since 1800 and half of the change occurred in the twentieth century alone.

## A special century

These specifics provide a historical and global perspective which indicates that the twentieth century was not “just another century” in terms of temperature change. In the context of the five-century interval investigated, the twentieth century was clearly unusual.

IPCC has stated that paleoclimatic data supported the interpretation that the warmth of the last half century was out of the ordinary, standing out uniquely in a period of at least 1,300 years. The last time that the polar regions of the earth were significantly warmer than they had been for about 125,000 years previously there were reductions in the volume of polar ice, which led to a rise in the sea level of between 4 and 6 metres (IPCC, 2007).

Figure 2.1. Global temperature land-ocean index, 1880-2000

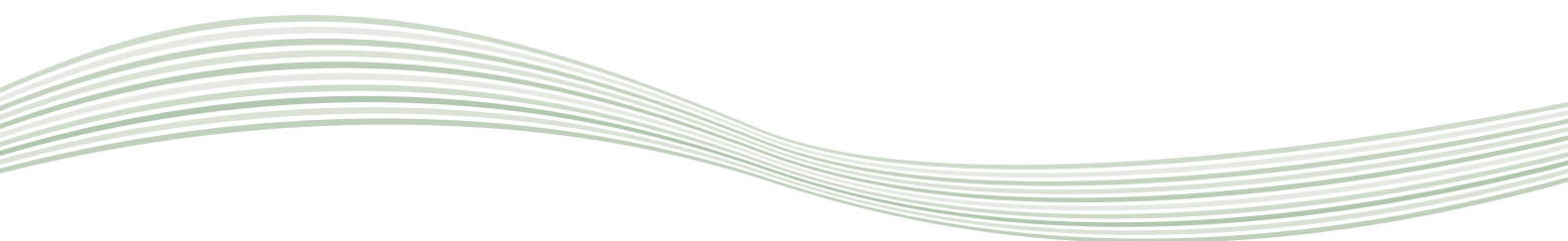


Source: Hansen and others, 2006; and <[www.columbia.edu](http://www.columbia.edu)> for 2007-2008.

## Changes in extreme events

That degree of change in the past notwithstanding, one of several pieces of evidence used to gauge climate change in the last several decades has been the increase in extreme climatic events (IPCC, 2007). Because such events have changed in frequency or intensity over the last 50 years, it is likely that:

- Cold days, cold nights and the incidence of frost are becoming less frequent over most land areas, while hot days and hot nights are becoming more frequent;
- Heat waves are becoming more frequent over most land areas;
- The frequency of heavy precipitation events (or the proportion of heavy rainfall from total rainfall is increasing over most areas;
- The incidence of extremely high sea levels is increasing at a broad range of sites worldwide and this has been happening since 1975 (IPCC, 2007).



As already mentioned, evidence from paleoclimatic data suggests that current temperatures are the warmest in the past millennium and even further back in time. More recent observations of global temperatures indicate that they have increased by approximately 0.6°C over the past 100 years. Embedded within the temperature records for 1997 and 1998 was a string of 16 consecutive months when the monthly global temperature broke the previous records for those months. In fact, during much of 1998 monthly records were broken that had just been set the previous year (IPCC, 2007).

The string of record-breaking temperatures in the period 1997-1998 is not consistent with a rate of warming of 0.2°C per decade (the so-called norm); the average warmer temperatures may thus signal an increase in the normal rate of change (IPCC 2002).

The increase in temperature is widespread globally and is greater at higher northern latitudes than lower ones. Average arctic temperatures have increased in the recent past at almost twice the global average rate recorded for the past 100 years. During this time, land areas have warmed at a faster rate than oceans. Nonetheless, observations since 1961 show that the average temperature of the ocean globally has increased to depths of at least 3,000 metres and that the ocean has been taking up over 80 per cent of the heat being added to the climate system (IPCC, 2007).

Such temperature rises have had impacts: melting ice and a rise in the average sea level. While the sea level rose globally by an average of 1.8 mm per year over the period 1961-2003, in the decade from 1993 to 2003 it rose by an average of about 3.1 mm annually. However, it remains unclear whether this accelerated rate for the period 1993-2003 reflects decadal variation or an increase in longer-term trends. What is clear however is that since 1993 thermal expansion (higher temperatures) of the oceans has contributed to more than half (about 57 per cent) of the total rise in the sea level. Decreases in glacial ice and the polar ice caps have contributed to more than a quarter (about 28 per cent) of the sea-level rise, with losses from polar ice sheets accounting for the remainder ((IPCC WG1 AR4 2007, Chapter-4).

From 1993 to 2003 these climatic events have been consistent with the total sea-level rise observed (IPCC, 2007). The monitored decreases in snow and ice are also consistent with warming of the atmosphere. Satellite data show that since 1978 the annual average coverage of arctic sea ice has shrunk at the rate of 2.7 per cent per decade. The largest decreases have occurred in the summer months at the rate of 7.4 per cent per decade (IPCC (WG1 AR4) 2007, Chapter-4).

Mountain glaciers and snow cover have declined on average in both hemispheres. Since 1900, the maximum area of seasonally frozen ground (as distinct from permafrost) has decreased by about 7 per cent in the northern hemisphere, with springtime decreases of up to 15 per cent having been recorded (IPCC (WG1 AR4) 2007, Chapter-4).

Temperatures at the top of the permafrost layer in the Arctic have generally increased by up to 3°C since the 1980s. Numerous long-term changes in other aspects of the earth's climate have also been observed in continental, regional and ocean basin areas (IPCC, 2007).



## Precipitation and storms

Changing trends from 1900 to 2005 have been observed in the amount of precipitation, most significantly in the eastern parts of North and South America, in northern Europe and in northern and central Asia. By contrast, precipitation declined in the Sahel, the Mediterranean area, southern Africa and parts of southern Asia (IPCC, 2007). Further, the areas affected by drought globally are likely to have increased since the 1970s. These phenomena are in line with the previously described extreme weather events that have changed in frequency or intensity over the last 50 years (IPCC, 2007).

Observational evidence verifies the increases that have occurred in intense tropical cyclone activity in the North Atlantic since the early 1970s. There is a suggestion also that increased intense tropical cyclone activity may also have occurred in some other regions, but greater concerns about data quality mean that firm conclusions cannot be reached. Multi-decadal variability and the quality of the tropical cyclone records prior to the time when routine satellite observations started around 1970 complicate the detection of long-term trends in tropical cyclone activity. Nonetheless, average northern hemisphere temperatures during the second half of the twentieth century were very likely to have been higher than during any other 50-year period in the last 500 years and the highest in at least the past 1,300 years (IPCC 2007, Technical Summary WG1).

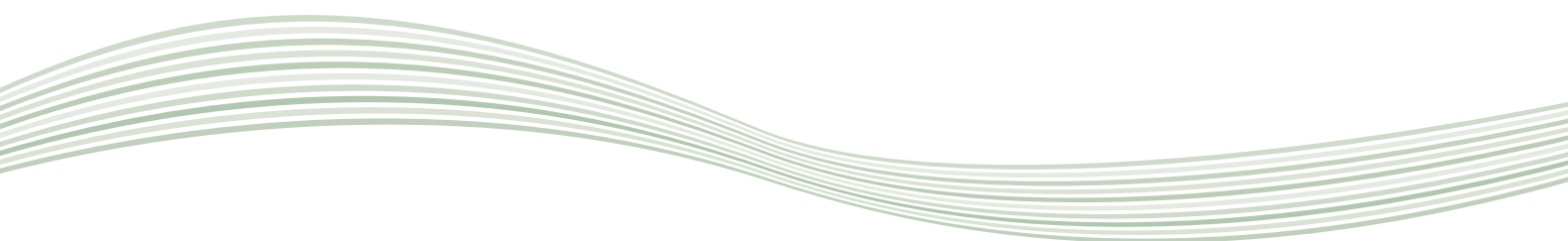
## Effects

Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases. There is high confidence that natural systems related to snow, ice and frozen ground, including permafrost, are being affected. Examples are as follows:

- Enlargement of glacial lakes and increases in their number;
- Increasing ground instability in permafrost regions and rock avalanches in mountain regions;
- Changes in some Arctic and Antarctic ecosystems, including those in sea ice biomes, and predators at high levels of the food chain (IPCC, 2007).

Based on growing evidence, there is high confidence that the following effects on hydrological systems are occurring: increased runoff and earlier spring peak discharge in many glacier- and snow-fed rivers, and the warming of lakes and rivers in many regions, all of which events affect thermal structures and water quality (IPCC, 2007: Summary for Policymakers)

There is very high confidence, based on more evidence from a wider range of species, that recent warming is strongly affecting terrestrial biological systems, including such changes as earlier timing of spring events, including leaf unfolding, bird migration and egg-laying activity, and shifts towards the poles of plant and animal species. Based on satellite observations since the early 1980s, there is high confidence that there is a trend in many regions towards earlier “greening” of vegetation in the spring linked to longer thermal growing seasons due to recent warming (IPCC, 2007: Summary for Policymakers).



There is also high confidence, based on substantial new evidence, that observed changes in marine and freshwater biological systems are associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels and circulation. These include the following: shifts in the ranges of, and changes in, algal, plankton and fish abundance in high-latitude oceans, increases in algal and zooplankton abundance in high-latitude and high-altitude lakes, and range changes and earlier fish migrations in rivers (IPCC, 2007: Summary for Policymakers).

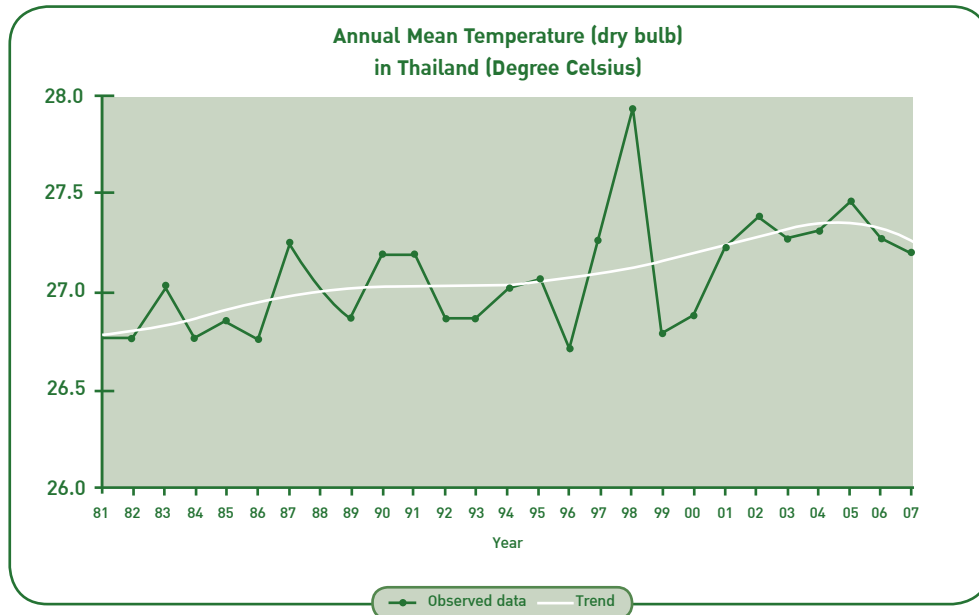
While there is increasing evidence of climate change impacts on coral reefs, separating the impacts of climate-related stresses from other stresses, such as overfishing and pollution, remains difficult. Other effects of regional climate changes on natural and human environments are emerging, although many of them are difficult to discern owing to adaptation and non-climatic factors (IPCC, 2007: Summary for Policymakers).

## Thailand and Bangkok Perspectives

### Temperature and rainfall trends

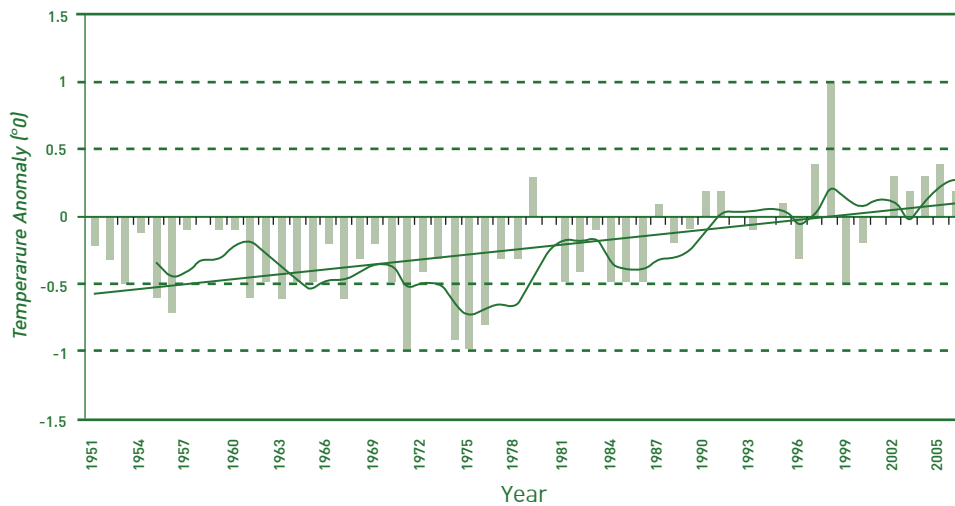
Figure 2.2 clearly illustrates that the observed annual mean temperatures in Thailand between 1981 and 2007 are increasing. Overall, the temperature rises demonstrate an upward trend during the same period. Annual mean minimum and maximum temperatures from 1951 to 2005 are shown in figures 2.3 and 2.4, which also show a rising trend. The observed increase in average temperatures since the middle of the twentieth century is very likely due to the observed increase in greenhouse gas concentrations caused by human activity (IPCC climate Change, 2007: Synthesis Report).

Figure 2.2. Annual mean temperatures in Thailand



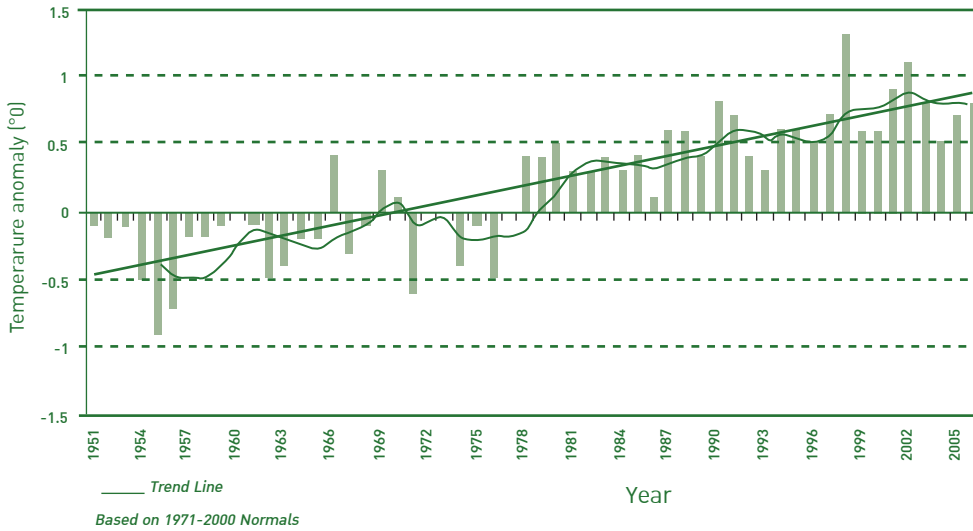
Source: Department of Meteorology, 2008.

Figure 2.3. Annual mean and maximum temperatures in Thailand, 1951-2005



Source: Department of Meteorology, 2008.

Figure 2.4. Annual mean and minimum temperatures in Thailand, 1951-2005



Source: Department of Meteorology, 2008.

It has also been observed that precipitation in Thailand has shown a decreasing trend since the middle of the twentieth century. This is clearly illustrated by the metrological data over the years from 1951 to 2005 (see figure 2.5). Similarly, the number of rainy days in Thailand has been decreasing since 1959, as shown in figure 2.6.

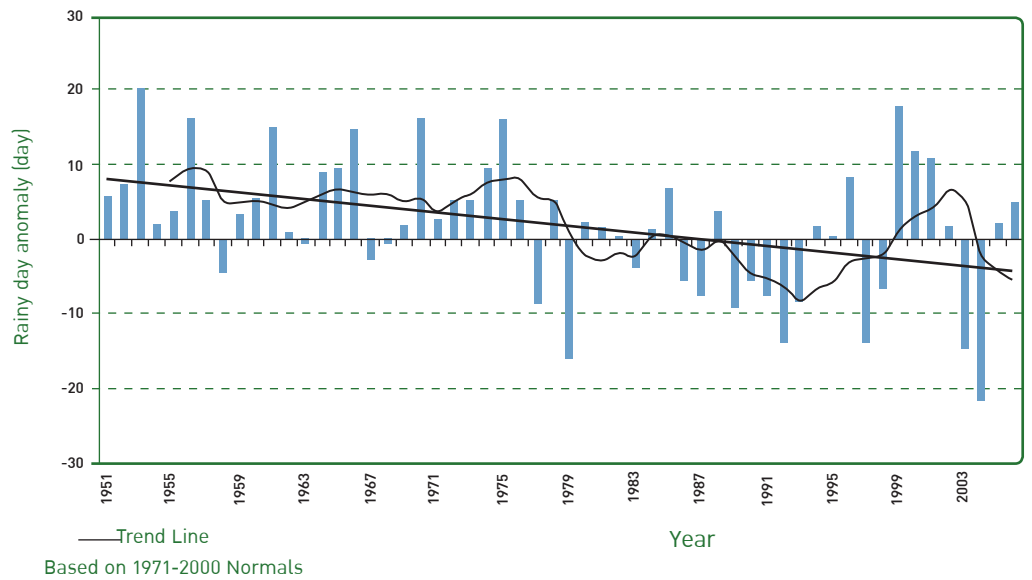
Figure 2.5. Observed changes in precipitation Thailand, 1951-2005



Source: Department of Meteorology, 2008.



Figure 2.6. Observed number of rainy days in Thailand



Source: Department of Meteorology, 2008.

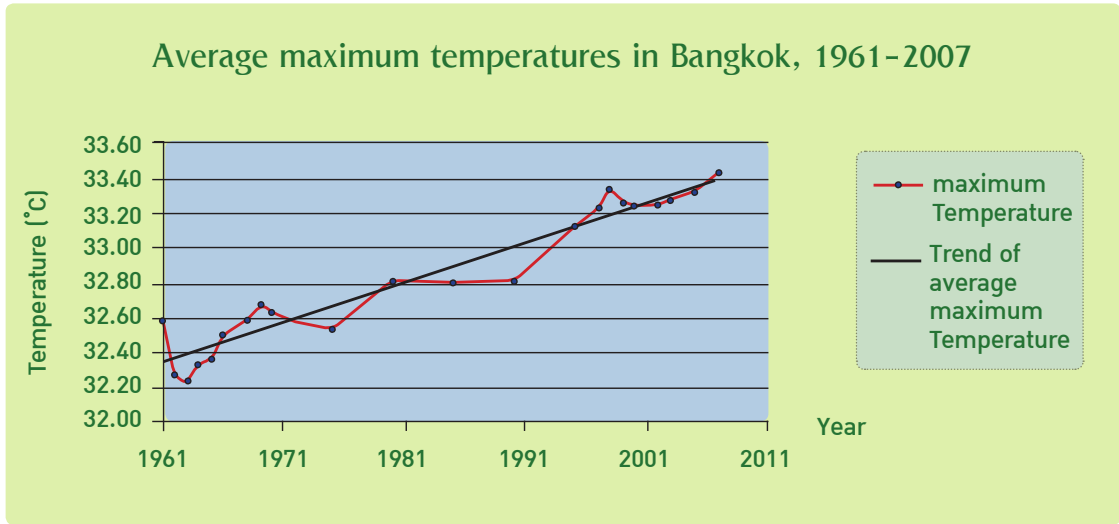
It is very likely that the results of human activity contributed to sea-level rises during the latter half of the twentieth century. There is some evidence of the impact of human influence on the hydrological cycle, including the observed large-scale patterns of changes in land precipitation during the twentieth century. It is highly likely that human influence has contributed to the global trend towards the increases in the areas affected by drought and the frequency of heavy precipitation events since the 1970s (IPCC Climate Change, 2007: Synthesis Report).

### Temperature and rainfall trends in Bangkok

The average maximum temperatures observed in Bangkok indicate an increasingly warming trend over the period 1961-2007 (see figure 2.7). The pattern of warming is also observed in the average minimum temperatures in Bangkok during the same period, as shown in figure 2.8.

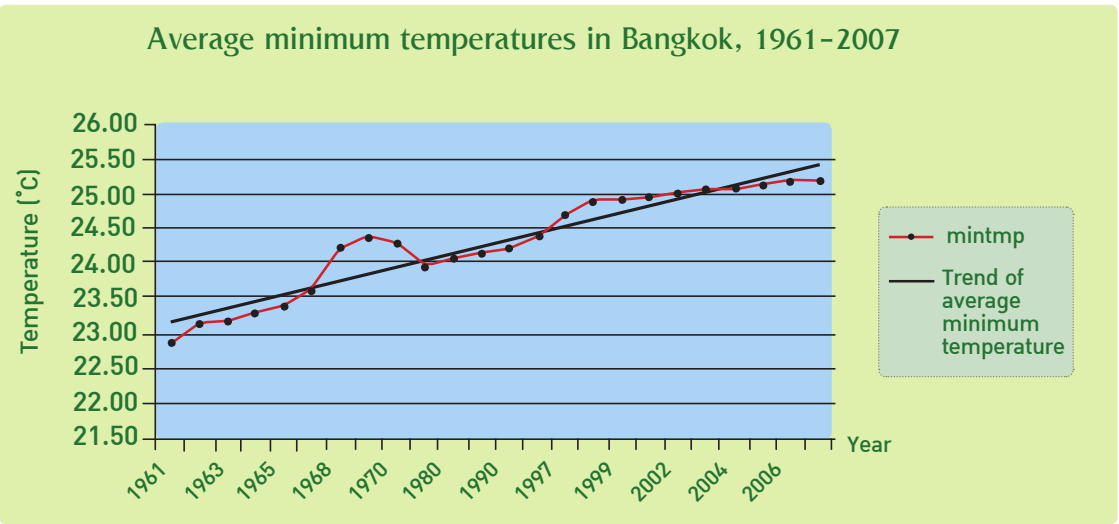
In urban Bangkok, the number of days exceeding 35°C is rising (see figure 2.9). The impacts of climate change on Bangkok have thus become increasingly visible and have been the subject of serious concern among residents since 1967, as they experience increasingly hotter weather (Department of Meteorology, 2008).

Figure 2.7. Average maximum temperatures in Bangkok, 1961-2007



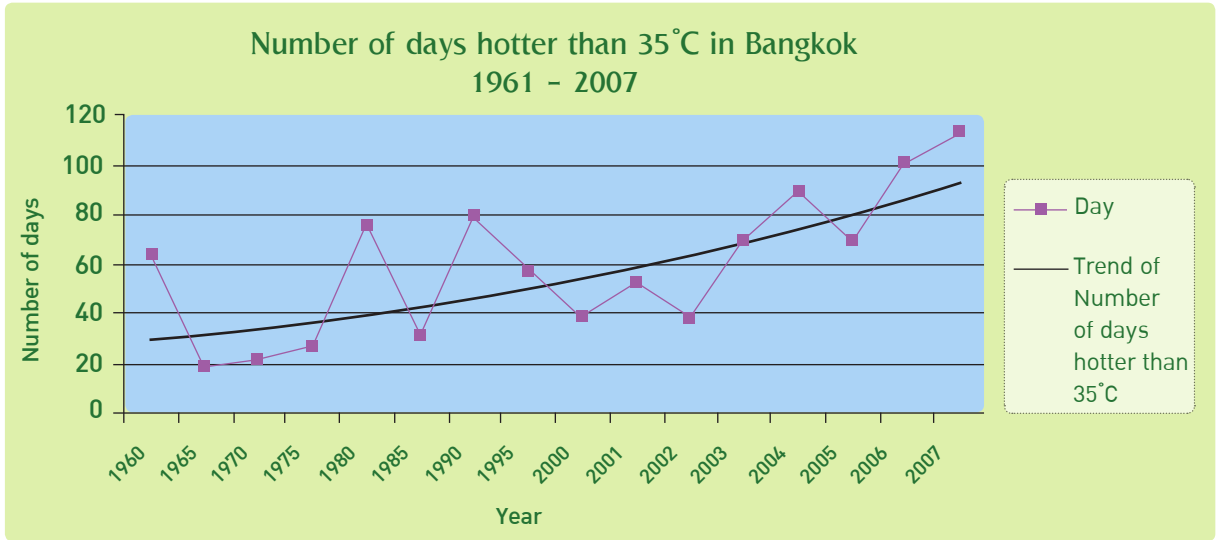
Source: Department of Meteorology, 2008.

Figure 2.8. Average minimum temperatures in Bangkok, 1961-2007



Source: Department of Meteorology, 2008.

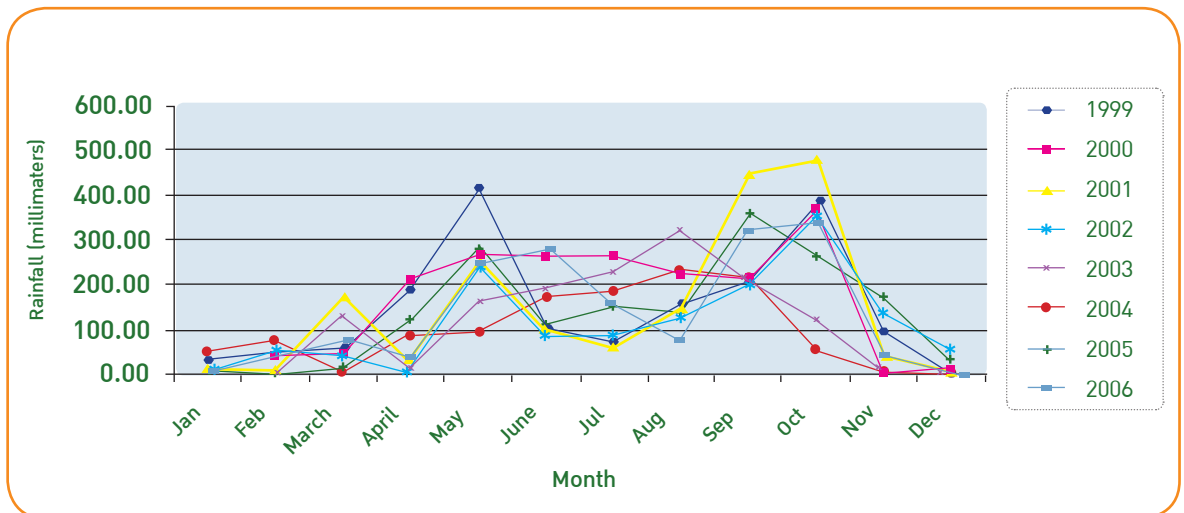
Figure 2.9. Number of days exceeding 35°C in Bangkok, 1961-2007



Source: Department of Meteorology, 2008

The average annual rainfall in Bangkok and vicinity is 1,482 mm. The observed monthly rainfall variation pattern for the entire year during the period 1999-2006 (see figure 2.10) shows that there are two peak rainfall patterns concentrated in the months of May-June and September-November. In 1999 the maximum rainfall peaked during May and in 2001 the peak was unusual, occurring during October. These rainfall patterns suggest extreme rainfall events occurring in certain months of the year.

Figure 2.10. Variations in monthly rainfall in Bangkok



Source: Department of Meteorology, 2008



# Greenhouse Gas Emissions: Baseline Inventory and Projections

## Global and Regional Overview

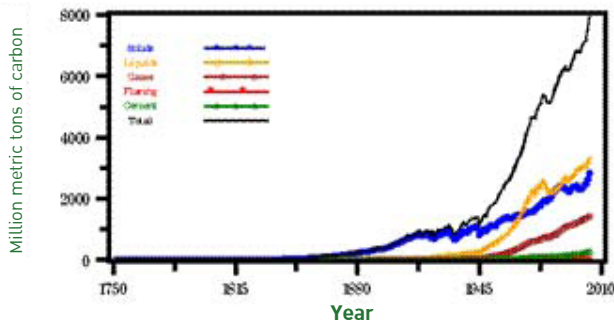
Past and present observations of climate change and its many impacts, and the collection of data from Thailand and other countries around the world form the basis for the scientific investigation of this phenomenon and the course it will likely take in the future.

While past and present data on the impacts of climate change are indispensable, equally important are data on its causes, especially on greenhouse gas emissions. Records that are kept around the world show that billions of tons of carbon in the form of carbon dioxide (CO<sub>2</sub>) are absorbed by oceans and the living biomass every year. We also know that these systems emit massive quantities of carbon dioxide into the atmosphere annually through natural processes, and that changes in land use and forestry practices can both emit carbon dioxide and act as a carbon sink.

If maintained in equilibrium, the carbon fluxes, or continuously changing amounts of carbon, among these various reservoirs would be roughly in balance. However, since the start of the Industrial Revolution equilibrium has been destabilized and seems unlikely to be restored in the near future. Global atmospheric concentrations of carbon dioxide increased from about 280 ppm in the mid-1700s to 379 ppm in 2005 (IPCC -GW1, 2007), principally due to the combustion of fossil fuels.

This means that globally in 2004 alone approximately 27,044 million tons of carbon dioxide were added to the atmosphere as a result of the combustion of fossil fuels; boxes 3.1 and 3.2 show the data for global and per capita emission respectively. Of that enormous quantity of carbon dioxide, Thailand accounted for only about 1.0 per cent (Carbon Dioxide Information Analysis Center (CDIAC), 2007), but its contribution is by no means innocuous, as will be demonstrated by the data on those emissions contained in the section below on Bangkok.

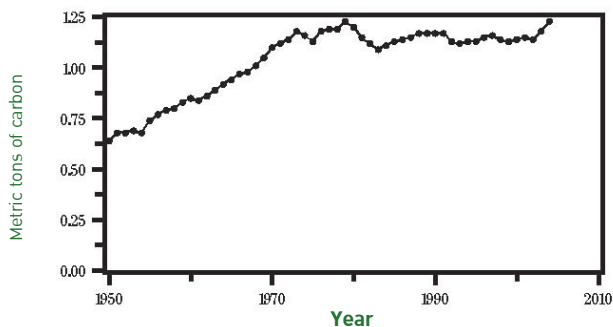
Box:3.1. Estimated emissions of carbon dioxide



Source: CDIAC 2008

Since 1751 roughly 315 billion tons of carbon have been released into the atmosphere owing to the combustion of fossil fuels and the production of cement. Half of the emissions have occurred since the mid-1970s. The 2004 global estimate of carbon dioxide resulting from fossil fuel combustion is 7,910 million metric tons<sup>2</sup> an all time high and a 5.4 per cent increase over that of 2003 (CDIAC, 2008).

Box:3.2. Global emissions of carbon dioxide per capita



Source: CDIAC 2008

Global carbon dioxide emissions per capita increased from 0.63 tons annually in 1950 to 1.23 tons in 2007, representing an average growth rate of 1.14 per cent annually.

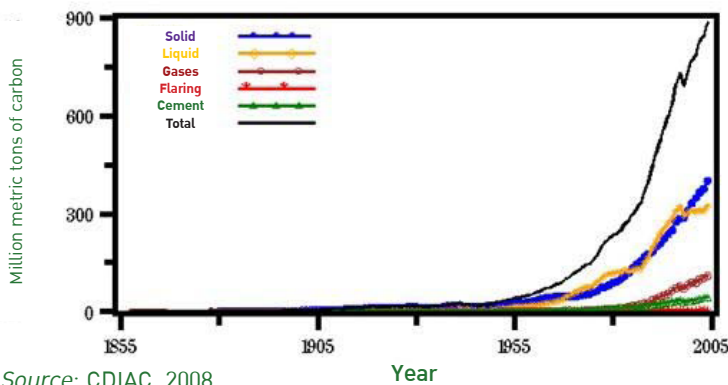
Emissions of carbon dioxide from the combustion of fossil fuels in 27 selected economies of Asia dropped in 1997 and 1998 for the first time since the post-Second World War level recorded in 1947 and 1948, ending a 50-year period of growth averaging approximately 7 per cent per year (CDIAC, 2008).

Such emissions rose to 885 million tons of carbon in 2004, a 31-fold increase over the levels in 1950. The increase in emissions of carbon dioxide since 1948 reflects not only the increased contributions of India, Indonesia and the Republic of Korea, but also of Malaysia, Pakistan, the Philippines, Singapore and Thailand, as well as that of other less populous economies in Asia (see figures 3.1 to 3.3).

India, Indonesia and the Republic of Korea were responsible for 64 per cent of the region's emissions of carbon dioxide from fossil fuel combustion in 2004. Per capita emissions in the region are as low as 0.01 tons of carbon per person per year in Afghanistan and Cambodia, and as high as 6.6 tons in Brunei Darussalam. Of the 22 economies in Asia selected for comparison, 15 have per capita emission levels below the global average of 1.23 tons of carbon per year (CDIAC,2008).

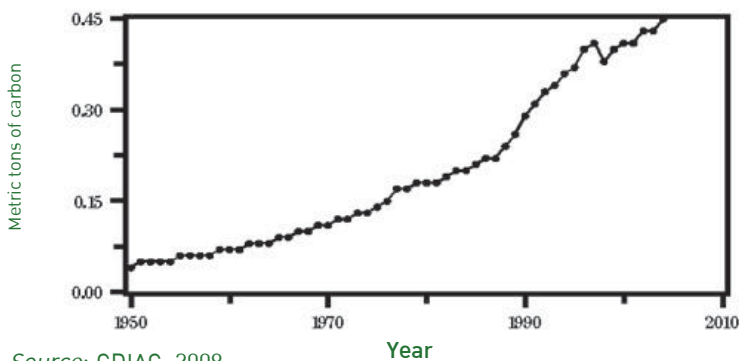
The burning of coal is the major source of carbon dioxide emissions from fossil fuel sources in the region. Over 63 per cent of the coal consumed in the region is burned in India; moreover, India, Indonesia and the Republic of Korea combined account for 61 per cent of the carbon dioxide emissions from the combustion of liquid fuel (CDIAC, 2008).

Figure 3.1. Emissions of carbon dioxide by 27 selected economies in Asia



Source: CDIAC, 2008

Figure 3.2. Emissions of carbon dioxide per capita of selected economies in Asia

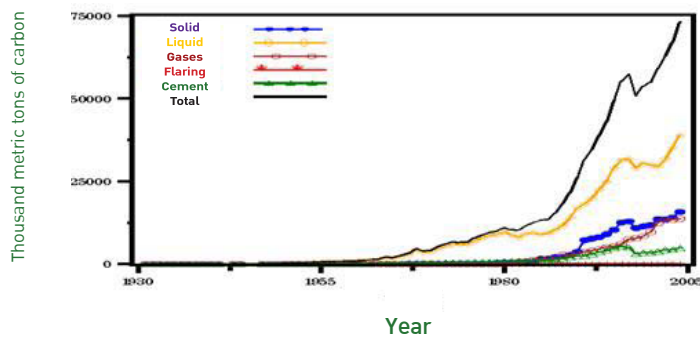


Source: CDIAC, 2008

## Thailand

As in other parts of Asia, the emissions of carbon dioxide in Thailand have shown an increasing trend in recent decades, rising from 1.6 tons per year in 1990 to 4.3 tons per capita per year in 2004 (ESCAP, 2007). Although the emissions dropped following the 1997-1998 financial crisis, they started climbing again from 1999 through 2007 (see figure 3.3 and 3.4).

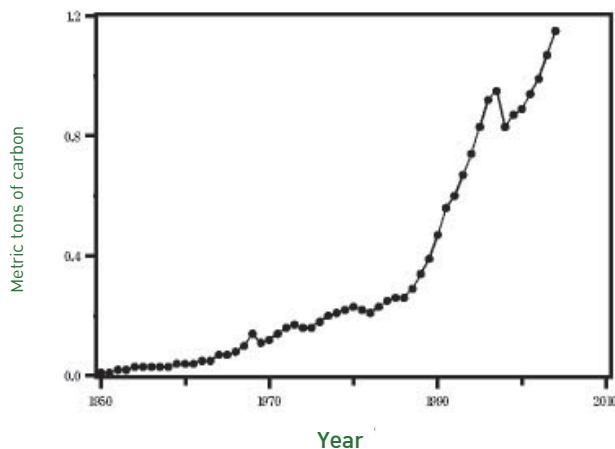
Figure 3.3. Emissions of carbon dioxide by Thailand



Source: CDIAC, 2008

In 2005, Thailand's Ministry of Energy indicated that energy end-use activities accounted for 56 per cent of the total emissions of carbon dioxide in 2003, while emissions resulting from agricultural activities accounted for 24 per cent. Changes in land use and forestry practices accounted for 7 per cent of Thailand's total carbon dioxide emissions, while industrial production accounted for 19 per cent of the total.

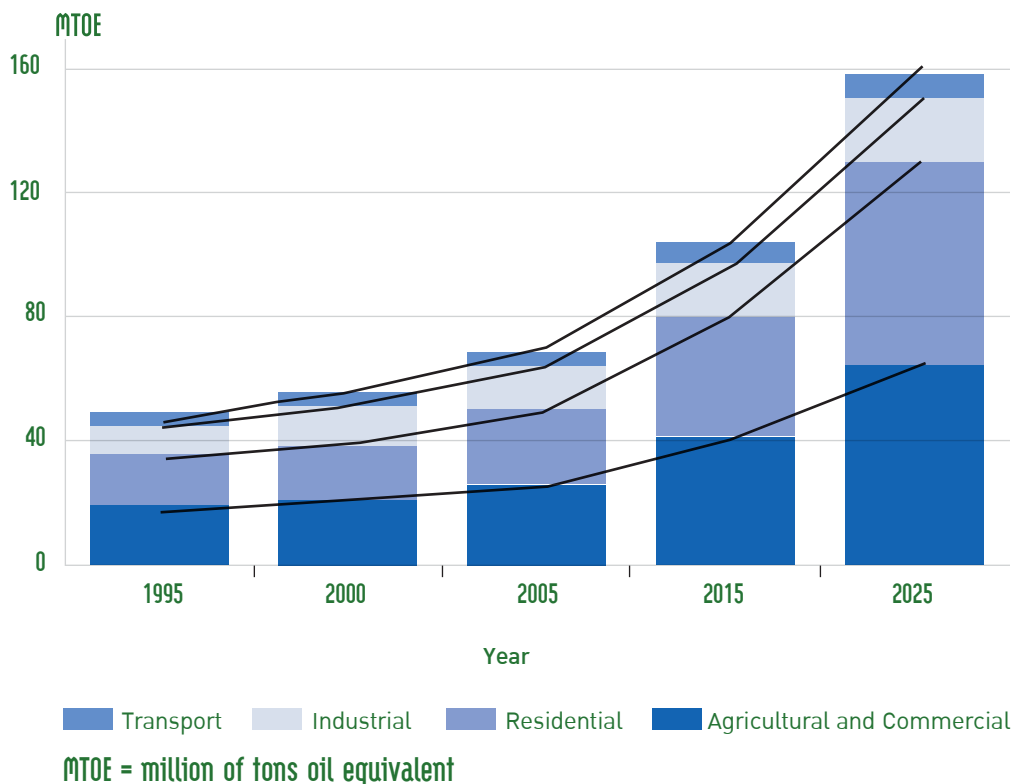
Figure 3.4. Emissions of carbon dioxide per capita by Thailand



Source: CDIAC, 2008

In Thailand, total energy consumption in 2003 was equivalent to 3.1 quadrillion British thermal units (BTUs), comprising oil (53 per cent), natural gas (33 per cent), coal (12 per cent), hydroelectricity (2 per cent), other renewables (1 per cent) (ADB-CAI-Asia 2006). Majority of the energy in Thailand is predominantly consumed in the transport sector which accounts for 79.4 per cent of all fuel consumption that year, or about 25.4 billion liters. Of this, total road based vehicles used more than 99 per cent of total fuel consumed. The main fuel types are gasoline, diesel oil, and jet fuel. In looking forward to 2025 (figure 3.5), the energy demand forecast shows that the demand of the transport sector is expected to reach 64.7 million tons of oil equivalent, nearly of 2.5 times increase from of that of 1995 (Srisurapanon, undated).

Figure 3.5 Final energy demand per sector in the business-as-usual case



Source: Energy Policy and Planning office, Ministry of Energy, 2006

Thailand is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and is listed under the non-Annex 1 countries, which includes developing countries that are especially vulnerable to the adverse impacts of climate change and includes countries with low-lying coastal areas, such as Thailand. Therefore, because the Convention emphasizes activities that take into account such countries' special needs and concerns, Thailand is not required to reduce its greenhouse gas emissions.

When compared with industrialized countries and developing economies, Thailand is not a major emitter; it is responsible for only a small fraction of total greenhouse gas emissions worldwide (about 1.0 per cent of the total). In addition, the average per capita emissions in Thailand are lower than the global average of 1.23 tons of carbon (CDIAC, 2008).

Nonetheless, Thailand will suffer the full impacts of climate change even though it contributes only a small amount of greenhouse gases. This is because the nature and severity of climate change impacts are dependent on a number of factors, including a country's geographic location, its local environment, its level of preparedness and the adaptive measures it undertakes.



## Bangkok

Owing to Bangkok's preeminent position as Thailand's capital, communications hub, and administrative and business centre, the city accounts for much of the country's emissions of carbon dioxide estimated to be 61.23 million tons in 2007. In 2005, those emissions totaled 43 million tons—a much greater volume than that of Toronto (24 million tons). Although they were lower than the total carbon dioxide emissions of New York City (58 million tons), they were about the same as those of London (44 million tons).

Greenhouse gas emissions per capita reveals that the residents of Bangkok were responsible for producing 7.1 tons of carbon dioxide per annum in 2005, that is, the same level of emissions as produced by New Yorkers (7.1 tons per capita), and considerably higher than the annual emissions of Londoners (5.9 tons per capita) but lower than the levels produced by residents of Toronto (9.6 tons per capita) (see table 3.1).

Table 3.1. Comparison of carbon dioxide emissions of Bangkok and selected cities in developed countries (2005)

City	Millions of tons of carbon dioxide	Tons per capita of carbon dioxide emissions
Bangkok	43	7.1
Toronto	24	9.6
New York	58	7.1
London	44	5.9

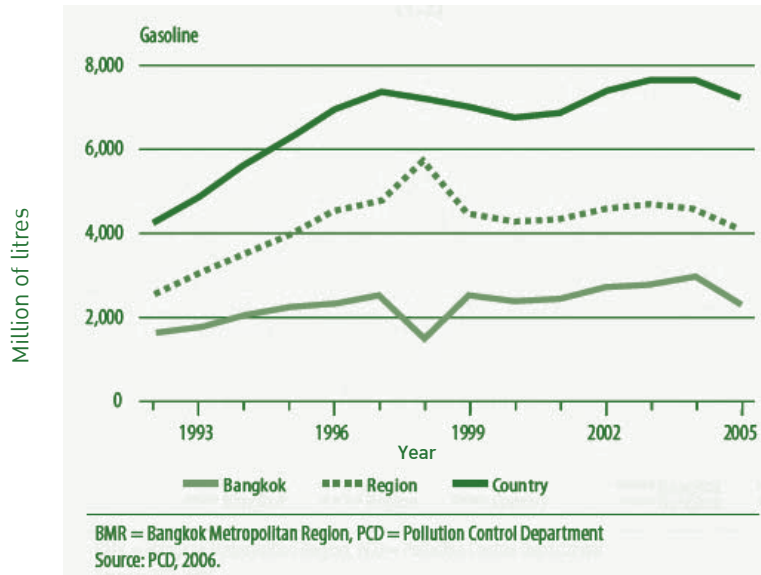
Source: Bangkok Metropolitan Administration, 2007

The principal sources of greenhouse gas emissions in Bangkok are transportation (37.68 per cent) and electricity generation (33.37 per cent) (see table 3.2). The Department of Energy Business, Ministry of Energy, indicated that, in 2007, the transport sector in Bangkok emitted almost 23.07 million tons of carbon dioxide per annum from consuming 8,948,683 million litres of gasoline and diesel oil. Electricity used was as high as 29,180 GWh which caused 20.43 million tons of carbon dioxide emissions, accounting for 33.37 per cent of the annual total. Solid waste and waste water emitted 12.16 million tons of carbon dioxide, equivalent to 19.86 per cent of total annual carbon dioxide emission. These three sources contribute 90.91 per cent of the total emissions of greenhouse gases annually. The remaining 9.09 per cent comes from other sources, such as agriculture.

Table 3.2. Greenhouse Gases Emission Inventory of Bangkok City in 2007

Source	Emission (Million tons per year)	Percentage
Electricity	20.43	33.37
Transportation	23.07	37.68
Solid waste and waste water	12.16	19.86
Other	5.57	9.09
<b>Total</b>	<b>61.23</b>	<b>100</b>

Figure 3.6 Gasoline consumption by the transport sector in BMR and Bangkok



Source: Bangkok Metropolitan Administration

Figure 3.7 Gasohol consumption by the transport sector in BMR and Bangkok

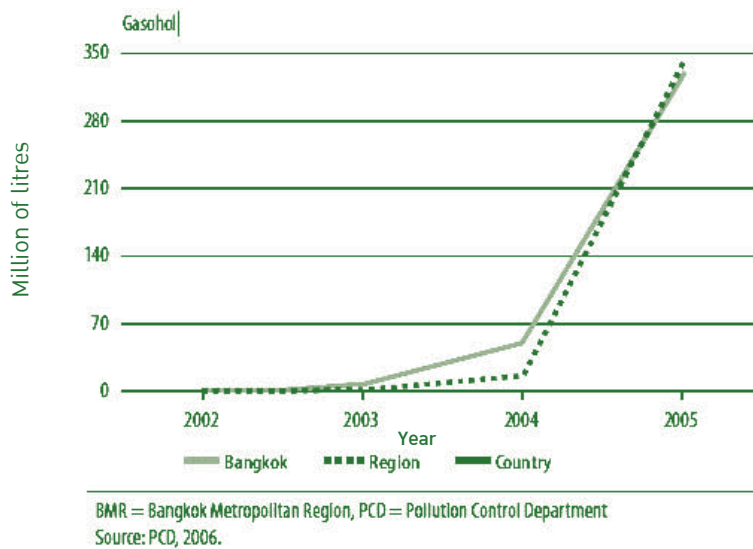
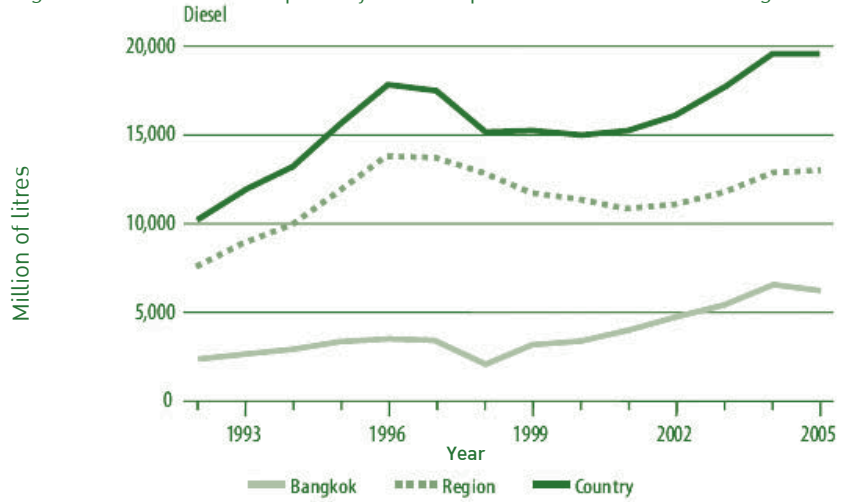
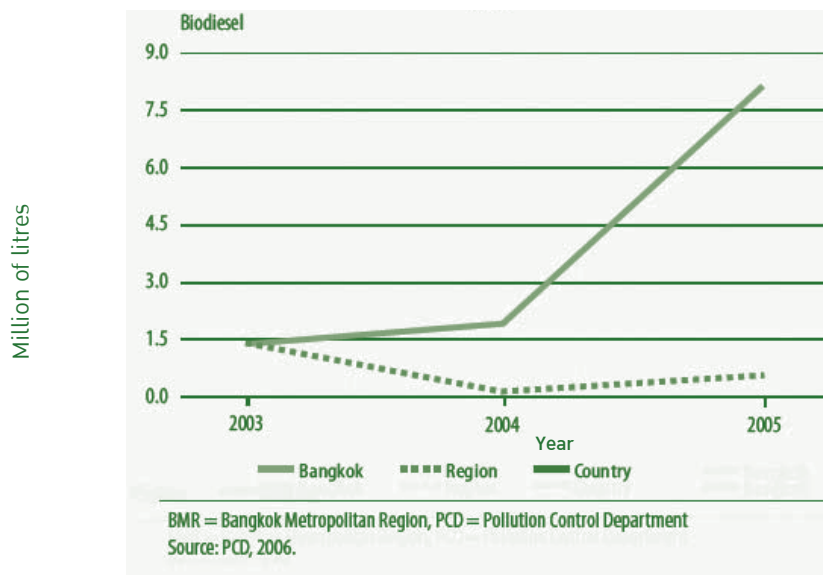


Figure 3.8 Diesel consumption by the transport sector in BMR and Bangkok



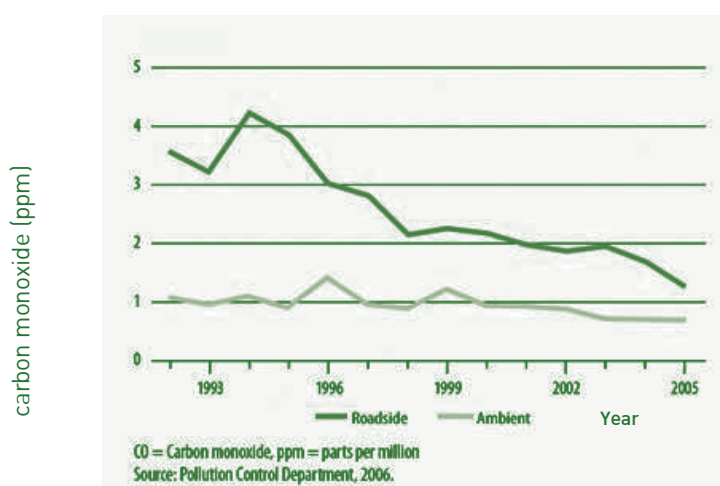
BMR = Bangkok Metropolitan Region, PCD = Pollution Control Department  
Source: PCD, 2006.

Figure 3.9 Biodiesel consumption by the transport sector in BMR and Bangkok



Cars are major sources of carbon monoxide (CO), hydrocarbons, and nitrous oxide (NO<sub>x</sub>). Two-stroke motorcycles are a dominant source of hydrocarbon emission and contribute significantly to particulate matters (PM) and CO emissions but this type of motorcycle is decreasing in number. Diesel trucks (both heavy and light duty) are responsible for high emissions of PM, NO<sub>x</sub>, CO and hydrocarbon. Despite huge increases in the number of vehicles, CO levels have declined slightly over the last few years due to fleet modernization, enforcement of emission standards, reduced traffic congestion and improvements in fuel quality. Roadside measurements of CO levels in Bangkok from 1992 to 2005 show a steady reduction over a 14-year period (Figure 3.10). Annual ambient levels were not very different from those for 2003 and 2004, while annual roadside level decreased over the same period (ADB and CEI-Asia,2006) .

Figure 3.10 Annual roadside and ambient carbon monoxide (CO) levels in Bangkok 1992-2005

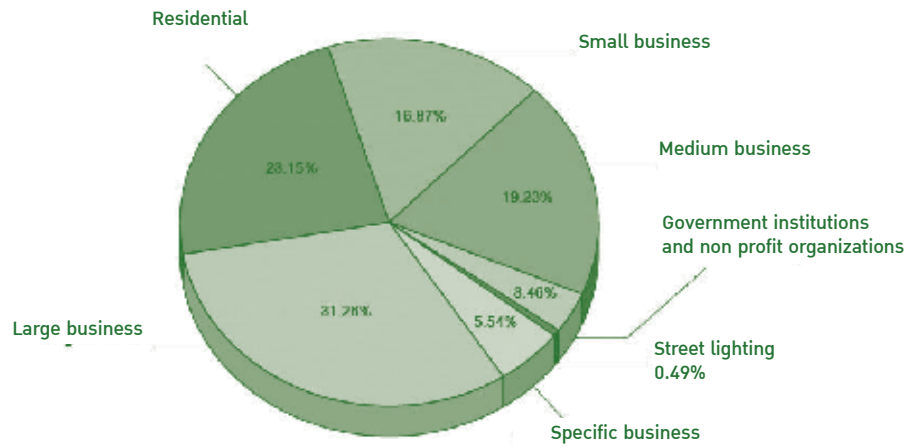


The Bangkok metropolitan urban area consumed approximately 29,200 Gigawatt hours (GWh) of electricity per annum in 2007. Producing this amount of electricity generated 14.86 million tons of carbon dioxide. Electricity consumption in Bangkok has risen from 20,129 GWh in 1998 to 29,180 GWh in 2007, or by an average annual increase of 4.2 per cent. The emission of carbon dioxide related to the consumption of electricity has also risen at the same rate (see table 3.3). Figure 3.11 depicts the share of electricity consumption by area. The residential category is the second largest after the large business category in Bangkok.

Year	kWh
1998	20,129,448,740
1999	19,614,191,609
2000	21,167,216,600
2001	22,174,739,013
2002	23,302,072,529
2003	24,281,953,324
2004	25,203,305,666
2005	25,674,575,714
2006	28,367,076,323
2007	29,180,095,754

Source: Metropolitan Electricity Authority, 2008.

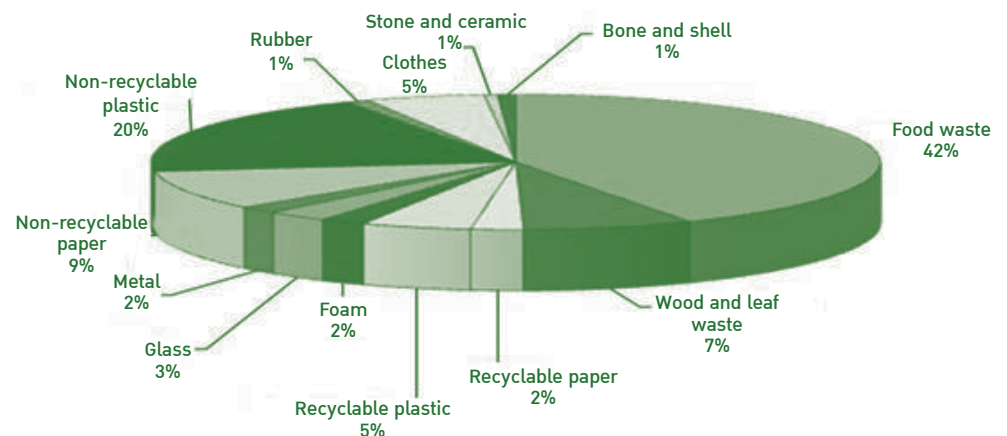
Figure 3.11 Percentage of energy sales within Metropolitan Electricity Authority areas by category in 2007



Source: Metropolitan Electricity Authority, 2007.

Solid waste and waste water are sources of 1.13 million tons of greenhouse gas emissions in Bangkok and account for 3 per cent of the city's total greenhouse gas emissions annually. It has been estimated that solid wastes in the city increased from 6,634 tons per day in 1995 to 8,718 tons per day in 2007, or an average increase of 0.6 tons per annum (see table 3.4). The composition of solid wastes from the Bangkok metropolitan area is shown in figure 3.13; it reveals that food waste accounts for the highest proportion, that is, over 42 per cent of the total (BMA, 2005).

Figure 3.12 Solid waste composition at BMA Transfer Station in 2007



Source: Office Presentation of Department of Environment, BMA 2008

As of 2007, the Bangkok Metropolitan Administration managed approximately 1,900 hectares of park area, including at least 3 million trees. These trees, together with trees on private land, are able to absorb about 100,000 tons of carbon dioxide per year. Thus, the net reduction of greenhouse gases in Bangkok through this means is equivalent to 42.65 million tons of carbon dioxide per year.

**Table 3.4 Solid waste generation and collection in Bangkok**

Year	Waste collected (tons/day)	Total (tons/year)
1995	6,633.71	2,421,304.15
1996	7,961.12	2,905,808.80
1997	8,694.79	3,173,598.35
1998	8,585.49	3,133,703.85
1999	8,772.49	3,201,958.85
2000	8,988.19	3,280,689.35
2001	9,162.32	3,344,246.80
2002	9,460.40	3,453,046.00
2003	9,349.97	3,412,739.05
2004	9,356.69	3,415,191.85
2005	8,495.97	3,101,029.05
2006	8,376.95	3,057,605.71
2007	8,717.78	3,182,353.68



# Assessment of Vulnerability to and Impacts of Climate Change

## Climate Change Projections

### Global and regional climate change

The IPCC report stated that warming of the climate system is unequivocal and that there is evidence of climate change around the world. There is therefore a need to assess how it will unfold further in the future and what will be its likely impacts on people's lives and the world as we now know it. The IPCC assessment has produced the following conclusions and projections about global climate change (IPCC, 2007):

- The evidence strongly suggests that most of the global warming that has been observed over the last 50 years can be attributed to human activities;
- The average warming will be between 1.1°C and 6.4°C in the period 2090-2099 relative to temperatures in the period 1980-1999;
- The average sea level will rise between 0.18 and 0.59 metres by the period 2090-2099 (these figures do not include the full effects of recent accelerated changes in ice-sheet flows);
- Increases in the amount of precipitation are very likely to occur at high altitudes, while decreases are likely in most subtropical land regions;
- Extreme climate events, characterized by heat waves and heavy rainfall, are very likely to become more frequent.

Regionally, all of Asia is very likely to witness warmer weather during the rest of the current century. The warming is likely to be well above the global mean average in Central Asia and the Tibetan Plateau, and in North, East, South and South-East Asia. It also is very likely that the heat waves and hot spells in East Asia will be of longer duration, more intense and more frequent than previously. Further, it is very likely that there will be fewer very cold days in East Asia and South Asia (IPCC, 2007).

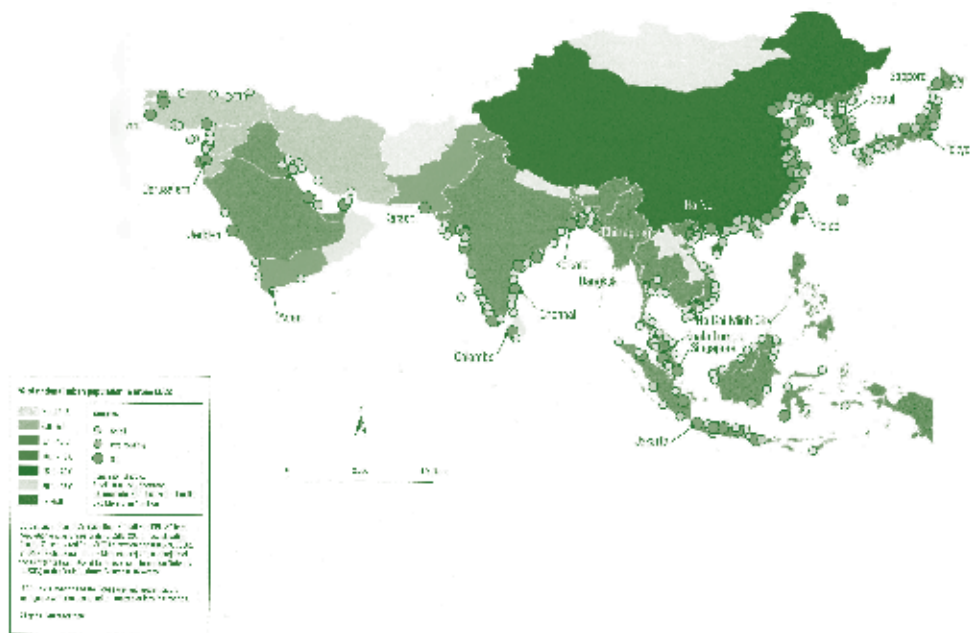
Precipitation in the summer months is likely to increase in North, East and South Asia and most of South-East Asia, but it is likely to decrease in Central Asia. The extreme rainfall and winds associated with tropical cyclones are likely to increase in East, South and South-East Asia (IPCC, 2007).

As monsoon winds are the main determinant of weather in the heavily populated areas of South and South-East Asia, the factors that influence the flow of these winds and the precipitation they produce are of central importance in understanding climate change in Asia (IPCC, 2007).



It should be pointed out that there are 3,351 cities in low-elevation coastal zones around the world. Of these cities, 64 per cent are in developing regions; Asia alone accounts for more than half of the most vulnerable cities (see figure 4.1). In Asia, 18 of the region's 20 largest cities are coastal, or located on a riverbank or in a delta. Of the total urban population in Asia, 17 per cent lives in the low-elevation coastal zones, while in South-East Asia, more than one third of the urban population lives in such a setting (UNHABITAT, 2008).

Figure 4.1. Asian cities at risk due to climate change



Source: UNHABITAT 2008

The volume of precipitation is affected both by the strength of the monsoonal currents and the amount of water vapour that they transport. Currently there is an emerging consensus that higher temperatures will enhance moisture convergence in the monsoons, resulting in increased precipitation in the regions where they prevail (IPCC, [AR4 WG1], 2007). There is even an association between the so-called El Niño Southern Oscillation (ENSO) and the strength of the summer monsoons, with the result that changes in ENSO will also have an impact on the monsoons (IPCC [AR4 WG1],2007).



## Vulnerability and Local Adaptation Practices

### Flooding

Flooding has long been recognized as the most damaging and costly natural hazard in many countries in Asia, in line with the frequency and extent of such events. Owing to global climate change and the rapid urbanization that is occurring in the floodplains of Asia, the frequency of devastating floods is tending to increase and the loss of human life and property is showing no signs of diminishing (Chen, 2007).

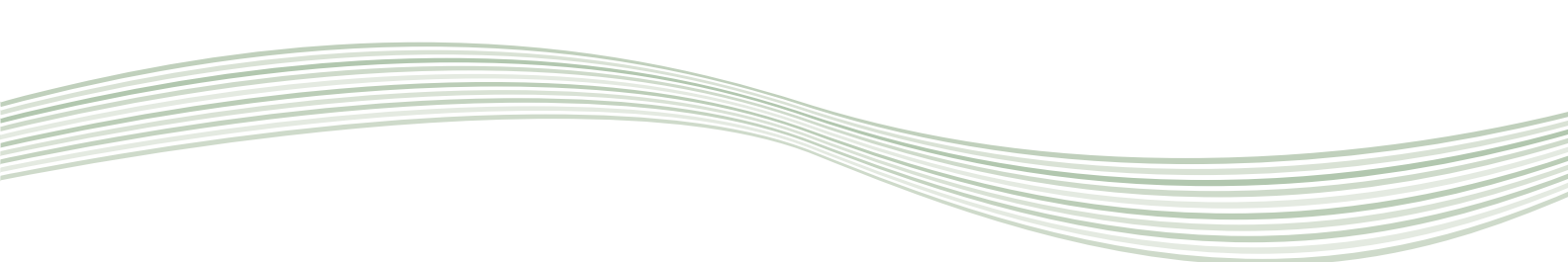
Bangkok is naturally prone to flooding. Following months of heavy downpours in the rainy season, the Chao Phraya River draining the northern and eastern parts of the country flows through the centre of Bangkok on its way to the Gulf of Thailand. At the same time, because the city is close to the sea, the direction of flow of the Chao Phraya River at high tides can be reversed and in the process the river can overflow its banks when tidal surges meet the heavy runoff from other parts of the country.

Due to the rapid urbanization of Bangkok in recent decades, many long-existing watercourses, such as canals, ditches and ponds, were filled in and replaced by roads, buildings and other structures. The effects of these changes were particularly apparent in 1983 and 1990, when Bangkok suffered remarkably severe flooding which had far-reaching effects on the social and economic activities in the nation's capital.

In order to assess what Bangkok might be like under a future flood scenario the Organisation for Economic Co-operation and Development (OECD) recently undertook the first-ever evaluation of its kind, ranking 136 coastal cities around the world with populations greater than 1 million people, by the impacts those cities would experience from a major flood (OECD, 2007).

The results give cause for concern. As described in a previous chapter, by the 2070s, Bangkok would rank seventh on the list of the top 10 cities in terms of population exposure (including all environmental and socio-economic factors) and tenth on a similar list in terms of the assets exposed to coastal flooding among cities around the world as a result of climate change and subsidence (OECD, 2007).

According to the report, approximately 900,000 people in Bangkok are currently at risk from flood events, and that number would increase to more than 5 million by 2070. The economic losses to the infrastructure that would be caused by such floods is estimated to be \$39 billion currently, but are expected to grow to a staggering \$1.1 trillion by 2070 (OECD, 2007). Although flood protection projects were established and improved after the two previous devastating flood events (Bangkok Metropolitan Administration, 2004), Bangkok is still at increasing risk of flooding, due partly to the effects of global warming and partly to rapid urban development.



As mentioned in Chapter 1, Bangkok also suffers from the effects of land subsidence, caused by overpumping of groundwater and by the nature of the thick, soft clay on which the city is built. The maximum subsidence is now occurring in outlying areas of Bangkok in the south-eastern and southwestern industrial zones, where the phenomenon is taking place at the alarming rate of 30 mm per year. Land subsidence not only causes damage directly, but it also intensifies the impacts of flooding while threatening human life and property. In the Chao Phraya River delta, the risk factors are greater than in most other coastal cities due to land subsidence.

The main flood barriers for Bangkok are dykes and walls built along the Chao Phraya River. However, land subsidence negates the efficiency of the city's flood defences because the high-point of the dykes gradually sinks as the ground beneath these defences subsides. Land subsidence also dramatically affects the efficiency of the sewer system and underground pipes built to rapidly eliminate rainwater, a situation which tends to aggravate the flooding of urban areas during the monsoon season and periods of very high tides. Further, it makes more difficult the process of draining the low lying areas of the city that are sinking, leading to the formation of stagnant water after flooding.

### **Causes of flooding in Bangkok**

The various causes of the flooding in Bangkok are as follows:

- Heavy rainfall makes it impossible to drain water quickly from the flooded areas, as enormous quantities of rainwater fall during intense monsoon showers;
- Excessive run off from northern Thailand and the Chao Phraya River basin flowing through Bangkok towards the sea cause overflowing and flooding in the area;
- Land subsidence due to the pumping of large amounts of underground water, which results in the surface of the ground sinking to a point lower than the mean sea level, makes the draining of excess water and rainfall difficult.

### **Measures for flood prevention**

Since Bangkok is a flat and lowland area, the city uses a polder system for flood protection and drainage measures, including:

- Preventing the inflow of water from outside the polder by constructing flood barriers, such as dykes; earthen, road and railway embankments; and many types of building;
- Discharging water out of the polders, using pumping stations, water gates, tunnels and sewers, and improving drainage canals by constructing dykes and dredging canals;
- Retaining rainwater temporarily in holding ponds and wells and by constructing and improving such facilities to form temporary retention basins, or "monkey cheeks".



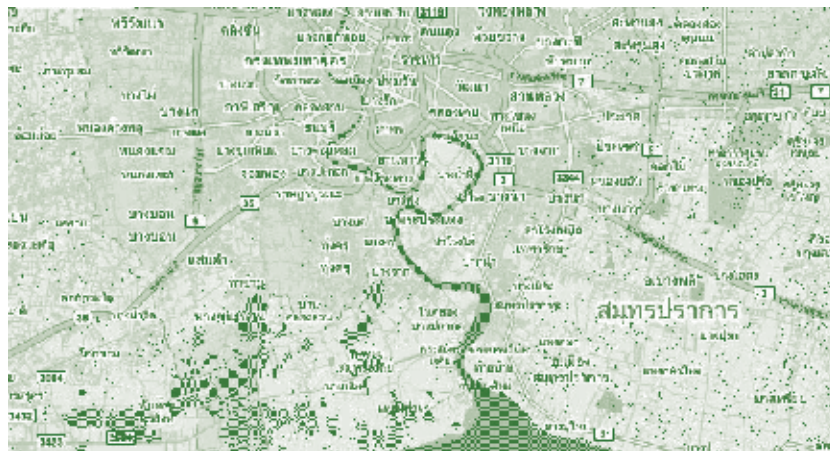
## Sea level

Besides the land subsidence that is occurring in the city, the possibility of inundation from rising sea levels also has to be taken into account. Currently, this is a relatively slow process, with the waters in the Gulf of Thailand rising at a rate of about 25 mm per year. However, if Bangkok were to be “lost” as a result of inundation, this would mean the destruction of the country’s economic engine and its status as a major hub for tourism.

A case study carried out for Bangkok provides a macro picture of projected flooding and its socio-economic impacts, using various scenarios of mean sea level rises in the twenty-first century. The simulated outcomes of the flood model used in the study shows that almost 55 per cent of Bangkok would be affected by floods if the mean sea level were to rise by 50 cm; if the mean sea level rises to twice that level (by 100 cm), 72 per cent of the city would be affected. These levels are 16 and 34 per cent higher, respectively, than the areas inundated by the severe flooding in 1995 (DUTTA, 2007).

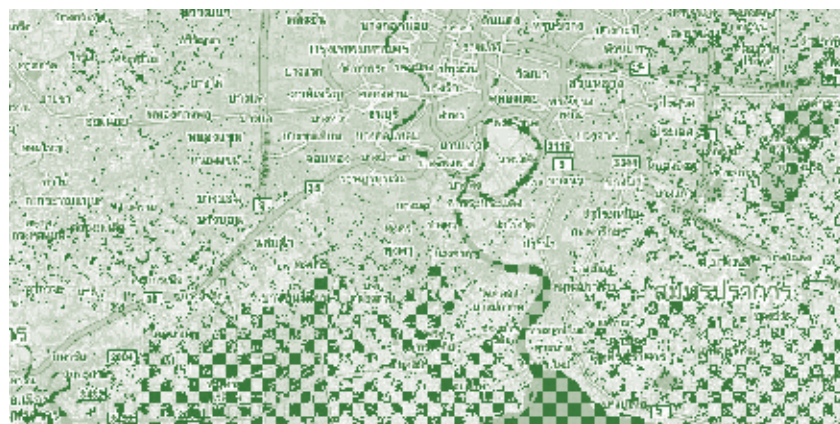
Such flooding would have adverse impacts on both the social and economic sectors of the capital. The outcomes of a recent socio-economic impacts analysis show that the number of flood-affected buildings, and the size of the population and number of roads adversely affected would rapidly increase in line with projected sea-level rises from 2025 to 2100 (Dutta, 2007). These scenarios use a website model, which may be accessed at <http://flood.firetree.net/>. Beginning with a scenario of zero flooding, the models progress, with the sea level rising by 2, 4, 6, 8 and 10 metres (see figures 4.2 to 4.7). It is clear that the impact of each model would be powerful.

Figure 4.2. Sea level rises by 0 metres above mean sea level in Bangkok and vicinity



Source: <http://flood.firetree.net>, 2008

Figure 4.3. Sea level rises by 2 metres above mean sea level in Bangkok and vicinity



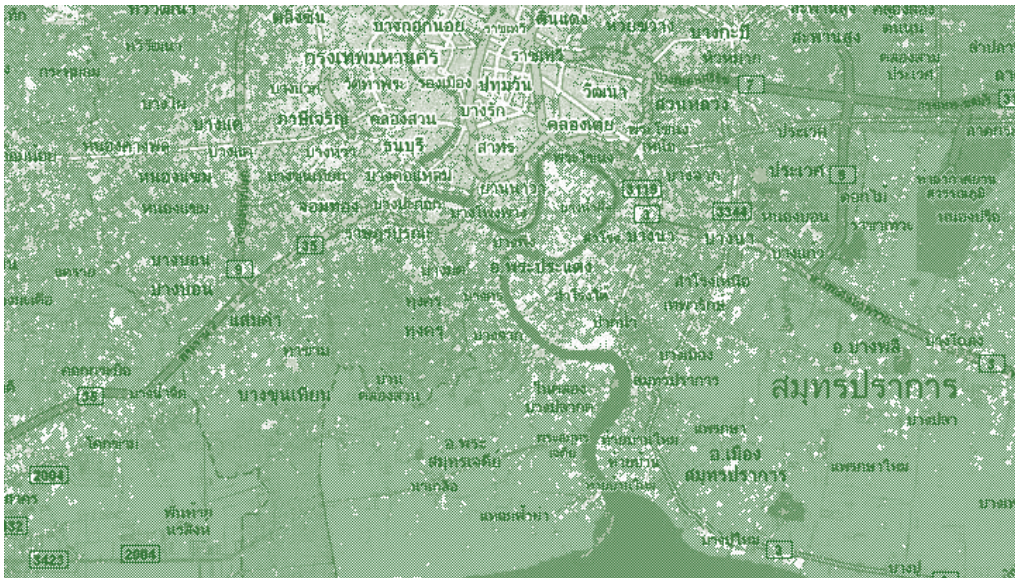
Source: <http://flood.firetree.net>, 2008

Figure 4.4. Sea level rises by 4 metres above mean sea level in Bangkok and vicinity



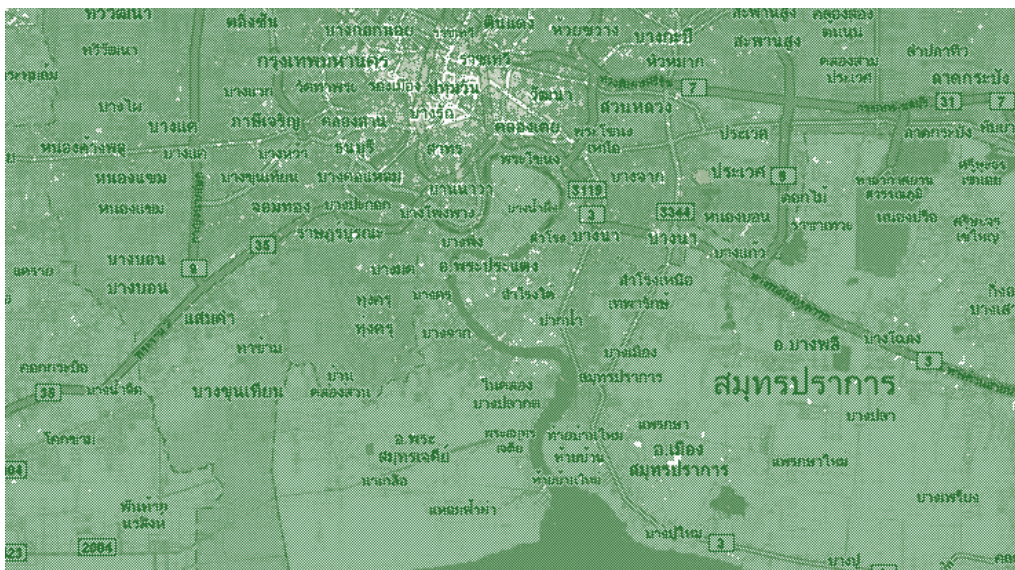
Source: <http://flood.firetree.net>, 2008

Figure 4.5. Sea level rises by 6 metres above mean sea level in Bangkok and vicinity



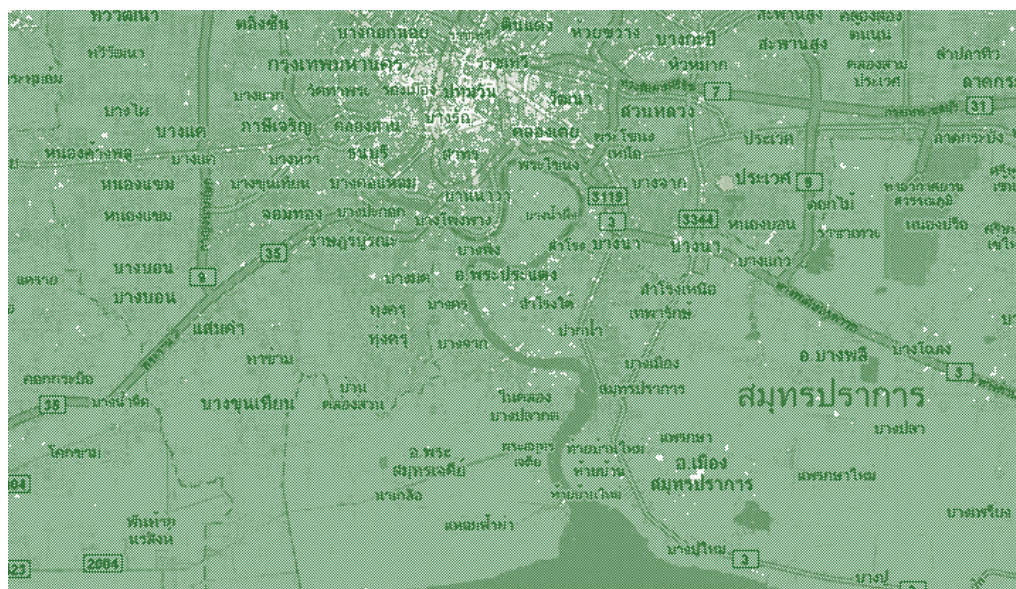
Source: <http://flood.firetree.net>, 2008

Figure 4.6. Sea level rises by 8 metres above mean sea level in Bangkok and vicinity



Source: <http://flood.firetree.net>, 2008

Figure 4.7. Sea level rises by 10 meters above mean sea level in Bangkok and vicinity



Source: <http://flood.firetree.net>, 2008

### Impact on water resources

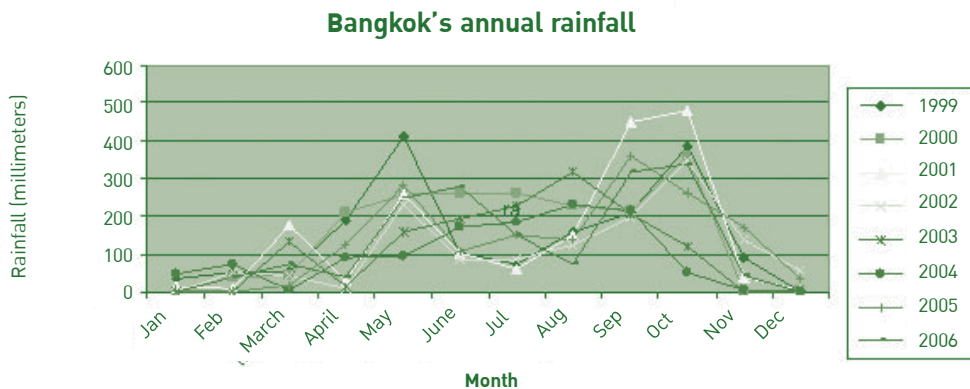
The Metropolitan Waterworks Authority (MWA) supplies about 4.65 million cubic metres (Mm<sup>3</sup>) of purified water per day to residential, industrial and commercial users in Bangkok, using surface water withdrawn from the Chao Phraya and Mae Klong rivers. This represents 91 per cent of the city’s total demand (BMA, 2006); the remaining 9 per cent (about 0.5 Mm<sup>3</sup>/day) is met by extraction of water from deep wells (Polprasert C., 2007).

The effects of global warming have caused the river flows in Thailand to be unreliable, with too high or too low flow rates during the rainy and dry seasons, respectively. The projected changes in water supply may be further exacerbated by increasing demand. Heavy pumping of ground water has resulted not only in land subsidence in most areas of Bangkok but also ground water contamination with saline intrusion, nitrates, coliform bacteria and volatile organic compounds (BMA, 2004).

Since Bangkok is expected to continue to grow over the next 10 years, the problems of water supply and contamination of both surface and ground waters will also be exacerbated. By the end of the current century, increasing temperatures are expected to boost the demand for water for agricultural purposes between 2 and 13 times in the lower and medium warming ranges, respectively, as well as the demand for water for household purposes (California Environmental Protection Agency).

Some options that could be considered if Bangkok is to achieve a sustainable supply of water might include: the harvesting of rainwater, decentralizing the wastewater management system, increasing stakeholder participation and raising awareness among consumers about water issues (Polprasert C, 2007).

Figure 4.8. Monthly rainfall variations in Bangkok



Source: Thai Meteorological Department, 2008

With average annual rainfall of 1,650 mm per year and an assumed rate of 10 per cent efficiency in rainwater harvesting, Bangkok could utilize 0.7 Mm<sup>3</sup>/day of rainwater, which is equivalent to the amount of water extracted from deep wells (BMA, 2006). Such a practice would help to mitigate the problems of land subsidence, ground water contamination and dependence on surface water sources. If more rainwater could be harvested, this would help to reduce the flooding which occurs frequently in Bangkok during the rainy season (Polprasert, 2007). The trend in monthly rainfall in Bangkok during the period 1999-2006, which is illustrated in figure 4.8, provides an indication of the potential for rainwater harvesting in the city.

## Health

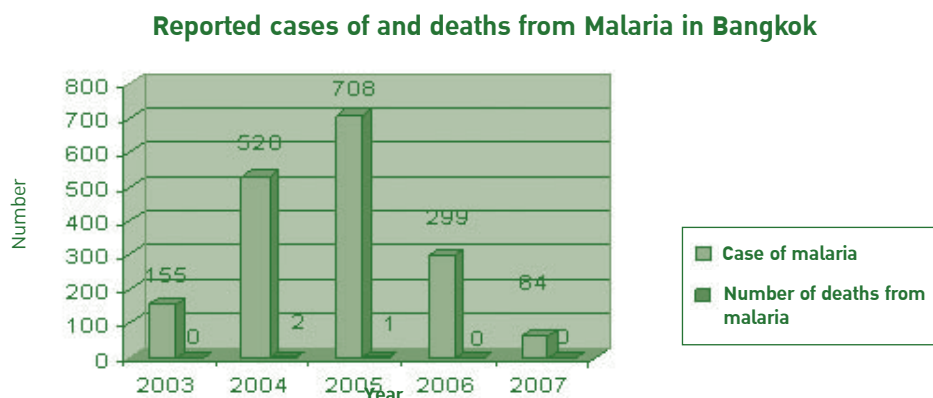
Climate change will also affect the health of Bangkok residents due to the increases in the frequency, duration and intensity of the conditions conducive to air pollution formation and oppressive heat. The primary concern is not so much the change in the average climate, but rather the projected increase in extreme conditions that are responsible for the most serious health consequences.

Climate change also has the potential to influence the incidence and spread of infectious diseases transmitted by mosquitoes, ticks, fleas, rodents and contaminated food. From time to time there have been reported cases of malaria, dengue fever, cholera and influenza, which are controlled by the Administration (see figures 4.9 to 4.11).

A recent analysis of the potential impacts of climate change on human health emphasized the risk of malaria outbreaks. Based on projected increases in the temperature for the period from 1998 to 2050 under a climate change scenario, the number of cases of malaria infection would rise substantially. Besides the tragic human toll, a preliminary estimate of the potential financial damage could be in the thousands of millions of Baht.



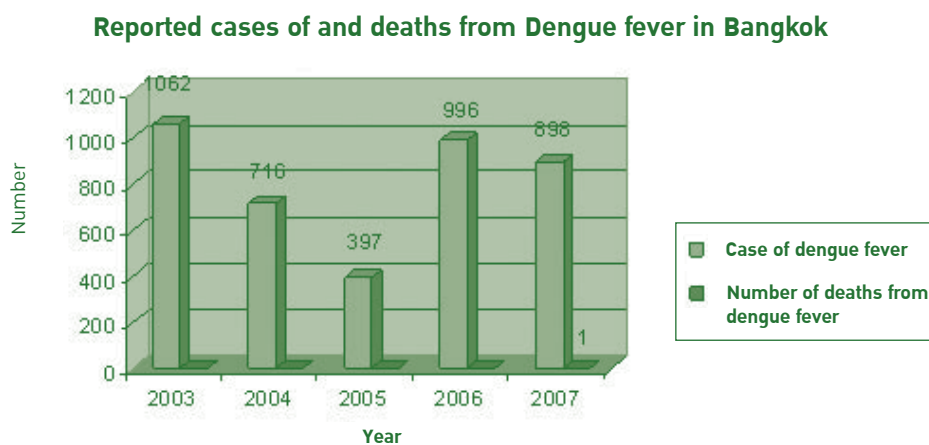
Figure 4.9. Cases of malaria in Bangkok



Source: Center for Epidemiological Information, Bureau of Epidemiology, Ministry of Public Health, 2008

Because Bangkok is situated in a low flat plain, a rise in temperature as well as the presence of still and stagnant flood waters provides a suitable breeding ground for the mosquitoes which are the vectors of malaria and dengue fever. The number of cases of, and deaths from, malaria and dengue fever are shown in figures 4.9 and 4.10.

Figure 4.10. Spread of dengue fever in Bangkok



Source: Center for Epidemiological Information, Bureau of Epidemiology, Ministry of Public Health, 2008

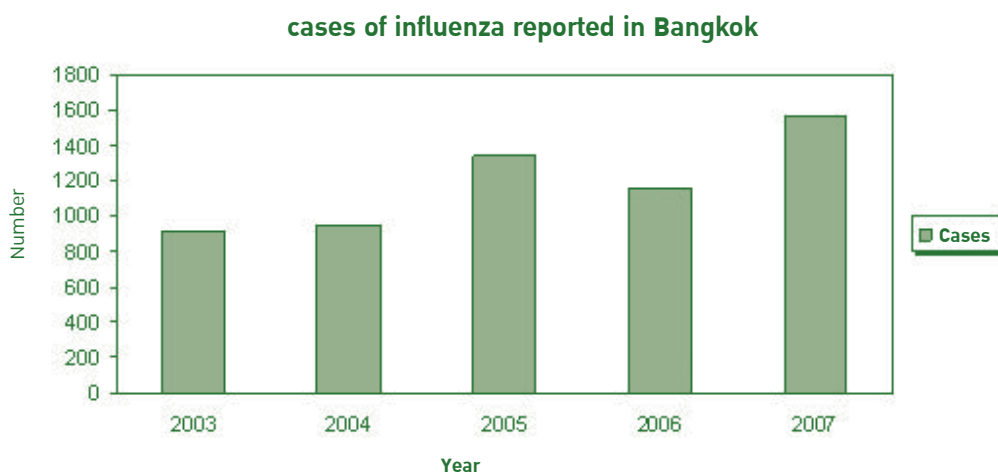
Adaptation options could be drawn from historical experience, one of which could be spraying with insecticides. However, chemical control of potential outbreaks may not be appropriate due to disease resistance and the adverse ecological effects caused in attempting to eliminate the vectors concerned. More research into and development of alternative approaches to control possible malaria outbreaks are required. Further study is also needed as research to date has focused on short-term changes in weather patterns (primarily in ambient temperature and rainfall) rather than longer-term trends.

Climate change could affect the prevalence of asthma and asthma attacks, but this is difficult to predict for several reasons. The most common asthma triggers are dust mites and moulds, the occurrence of which is higher indoors than outdoors. These triggers require a relatively humid environment for survival, responding to higher humidity with increased growth.

Many asthmatics are allergic to various plant pollens. Plants and trees typically have pollination seasons that last a few weeks in a year. To the extent that pollen-producing seasons lengthen or the release of pollens becomes more intense in response to climate change, increased exacerbation of asthma could result.

Another disease is also showing a rising trend in the number of reported cases in Bangkok, that is, influenza (see figure 4.11).

Figure 4.11. Cases of influenza in Bangkok

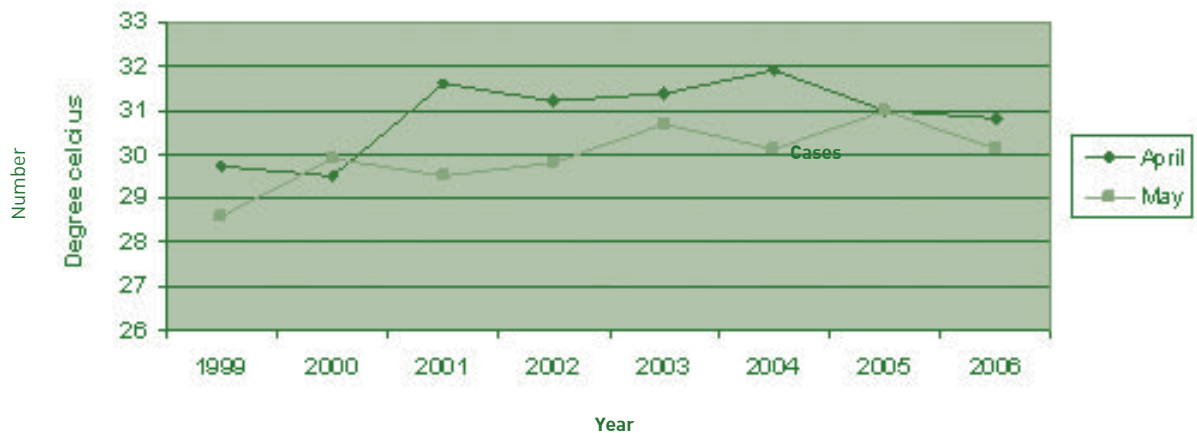


Source: Center for Epidemiological Information, Bureau of Epidemiology, Ministry of Public Health, 2008

## Temperature

Atmospheric temperature influences crop growth through its impact on photosynthesis and respiration, as well as the length of the growing season and the amount of water used. Temperature also serves as a controlling factor for plant developmental processes, such as flowering and fruit maturation, which may be threatened if lengthening of the growing season introduces asynchrony between the timing of flowering and the life cycle of important insect pollinators. In general, warming from a low to a higher temperature raises yields initially but then becomes harmful. Rising temperatures may therefore have a significant impact on the crops and other plants grown in and around Bangkok (see figure 4.12) not to mention the rest of the country, which is currently one of the world's important exporters of food.

Figure 4.12. Average temperature trends of the two hottest months in Bangkok 1999-2006



Source: Thai Meteorological Department, 2008

# Mitigation Policies and Measures

Since the Industrial Revolution, the model of national development in many countries—developed and developing alike—has been industrialization and actively growing the economy through trade and the exploitation of natural resources, among other means. Countries need such growth to generate employment and pay for improvements in the infrastructure, education and health, and all the other factors that lead to a better quality of life for their people.

However, increased industrial and economic development has led to a growing demand for energy, especially carbon-based forms of fuel, and their combustion in turn has resulted in the rising levels of greenhouse gas emissions that are being emitted into the atmosphere daily.

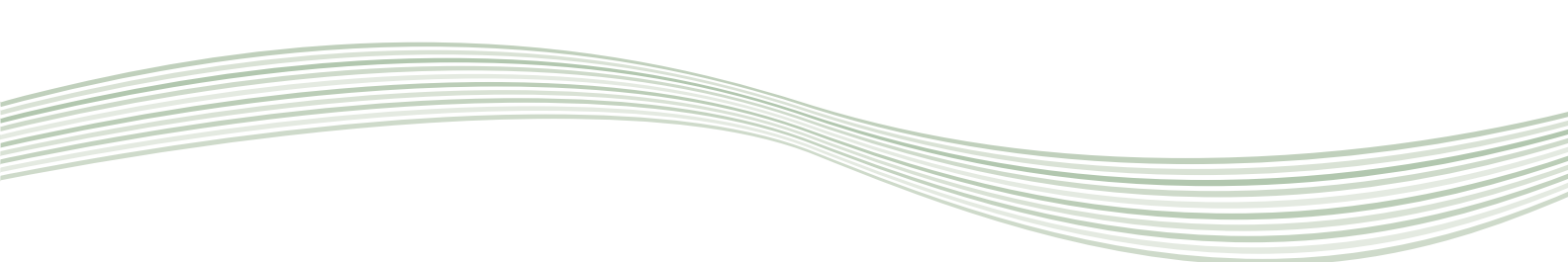
Thailand and other countries, faced with the likely impacts of climate change, have joined efforts to mitigate greenhouse gas emissions under the aegis of the United Nations. Likewise, individual countries, provinces and even large cities are taking action on their own, since their unique approaches to the challenges they face may benefit their societies, and in doing so contribute to global solutions. Thus, through the initiatives and efforts of the Bangkok Metropolitan Administration, Bangkok is currently preparing for the effects of climate change and is taking mitigation measures.

Because climate change is largely the result of human activity, it is necessary to modify that activity as well as implement effective measures, plans and policies. While each of the measures at the individual level may be small, their cumulative effect will help in reducing the emission of greenhouse gases. This chapter focuses on these aspects mostly at the level of the individual. What each person does to reduce greenhouse gas emissions can have a beneficial effect in Bangkok and beyond the borders of Thailand.

## Cooperation for Mitigating Carbon Emissions in Bangkok

The initial action of BMA in addressing the issue of long-term strategies to mitigate global warming involved hosting a meeting with organizations and agencies from both the private and public sectors to set guidelines for collaborating in this regard.

On 9 May 2007, 36 organizations jointly signed the BMA Declaration of Cooperation on Alleviating Global Warming Problems at the conclusion of their meeting in the United Nations Building in Bangkok. The declaration highlighted the following five strategies to mitigate global warming:

- 
1. Reduce energy consumption and maximize efficiencies in resource utilization in all activities to minimize their global impact;
  2. Promote support for all sectors and stakeholders to jointly reduce greenhouse gas emissions;
  3. Promote the “sufficiency economy” lifestyle to prepare for, and adapt to, global warming;
  4. Promote and support activities that lead to greenhouse gas absorption;
  5. Promote and support activities that continuously work to mitigate global warming by building public awareness and knowledge.

Since the signing of the declaration, BMA has organized events on the ninth day of each month to raise awareness among Bangkok residents of global warming concerns, and how they can take part in reducing the city’s greenhouse gas emissions. Some of these events are highlighted below:

- 9 May 2007, “Stop! Warming up Bangkok City”: a campaign to encourage the people of Bangkok along five major roads to turn off electric lights for 15 minutes from 7.00 to 7.15 pm. This single activity reduced carbon dioxide emissions by an estimated 143 tons.
- 9 June 2007, “Use Compact Fluorescent Lamps”: a campaign to encourage the people of Bangkok to change their incandescent light bulbs to energy-saving, compact fluorescent bulbs. Pilot action was organized at one of the marketplaces in Bangkok where 1,100 light bulbs were changed. BMA plans to replicate this campaign at 192 other city market places, exchanging more than 44,000 bulbs. This activity was expected to result in a reduction of 8,000 tons of carbon dioxide emissions annually.
- 9 July 2007, “Stopping Engines While Parked”: a campaign to encourage the drivers of passenger cars to turn off their engine when parked at traffic lights, or elsewhere. If 5.5 million drivers in Bangkok turned off their automobile engines for a total of 5 minutes each day, carbon dioxide emissions would be reduced by 260,975 tons annually.
- 9 and 12 August 2007, “Plant a Tree”: a campaign to encourage the residents of Bangkok to plant trees on the occasion of Her Majesty the Queen’s birthday, a national holiday. On that day, the Governor of Bangkok planted the 3,000,000<sup>th</sup> tree to mark the event in the city. When fully grown, those trees will absorb 27,000 tons of carbon dioxide annually.
- 9 September 2007, “Use Cloth Bags in Place of Plastic”: a campaign to encourage the residents of Bangkok to use reusable cloth bags when shopping, instead of accepting single-use plastic bags from vendors.
- 9 October 2007, “Reduce Garbage”: a campaign to encourage the people of Bangkok to be mindful of their consumption and the solid waste it generates, and to separate solid waste into several categories for ease of recycling. Additionally, the campaign encouraged the appropriate disposal of household hazardous waste.

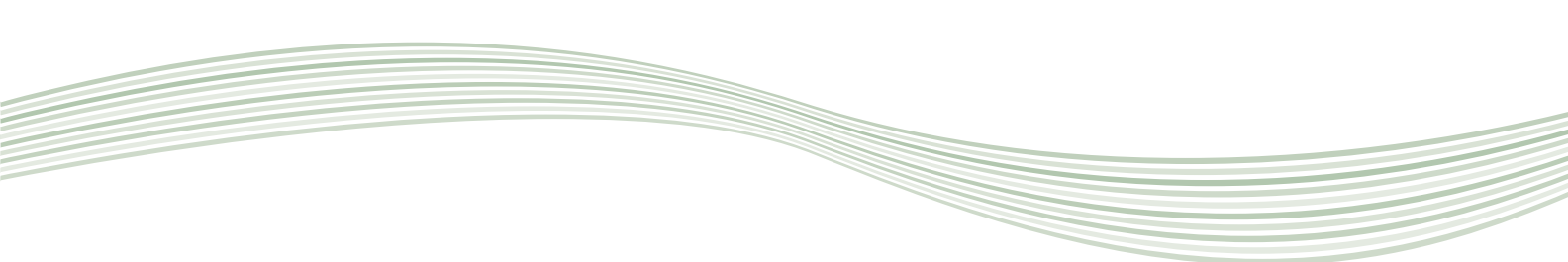
- 9 January 2008, “Renewable Energy Use”: a campaign to promote the collection of used cooking oil to produce bio-diesel fuel. This scheme involved cooperation between BMA and Bangchak Petroleum Public Co., Ltd.
- 9 February 2008, “Building Retrofit”: BMA with its environmental partner arranged a seminar on the theme of “Energy Efficiency Building Retrofit Programme” with the objective of making building owners aware of energy efficiency and energy conservation in buildings.
- 9 April 2008, “Water is Life”: a campaign to build awareness among Bangkok residents of the need to conserve water and to reduce wastewater, which is one of the sources of greenhouse gases.
- 9 May 2008, “Canal Water Quality Improvement”: with the aim of enhancing public awareness of the need to protect the city’s unique canal environment, BMA launched this campaign in cooperation with communities living along canals.

There have been other activities which demonstrate the efforts of BMA in to addressing climate change mitigation issues, such as the “car-free day” on 22 September 2007, “60 Earth Hour” on 29 March 2008 , “Launch of the Action Plan on Global Warming Mitigation 2007-2012” on 28 May 2008, “From 1 to 4 million trees” on 12 August 2008, “Formalization of Scavengers” on 22 June 2008, and “ASEAN+6 City Forum on Climate Change” on 26 and 27 June 2008 [see box 5.1].

#### Box : 5.1 ASEAN+6 City Forum on Climate Change The Greening of the ASEAN Cities, 25–27 June 2008, Bangkok, Thailand

The ASEAN+6 City Forum on Climate Change was organized during the period 26-27 June 2008 in Bangkok. The event brought together mayors or governors and delegates from Bangkok, Thailand; Jakarta, Indonesia; Kuala Lumpur, Malaysia; Albay, Phillippines; Phnom Penh, Cambodia; Vientiane and Luang Prabang, Lao People’s Democratic Republic; Beijing, China; New Delhi, India; and Fukuoka, Japan, so that they could discuss city-level planning aimed at tackling climate change and its impacts.

The forum was organized by the Bangkok Metropolitan Authority, the United Nations Environment Programme and The Nation newspaper. The purpose of the forum was to provide an opportunity for participating cities to share their ideas and experiences concerning climate change impacts and best practices in climate change mitigation and adaptation, while fostering cooperation among the cities in tackling these issues.



In addition, BMA has achieved international acceptance : the city is top of Travel & Leisure's World's Best City list following a reader's survey and 2008 World's Best Awards. Moreover, BMA has been nominated by the Ministry of Natural Resources and Environment to receive the Environmentally Sustainable Cities Award on Clean and Green Land (box 5.2). These awards enhance BMA's reputation and strengthen its effort in performing environmental management for a livable city.

The Bangkok Metropolitan Administration's Declaration of Cooperation on Alleviating Global Warming Problems has led to the establishment of the Bangkok Metropolitan Administration's Action Plan on Global Warming Mitigation 2007-2012.

### Box 5.2 BMA receives ASEAN Environmentally Sustainable Cities Award on Clean and Green Land

BMA has been selected by the Ministry of Natural Resources and Environment to receive the Environmentally Sustainable Cities Award on Clean and Green Land.

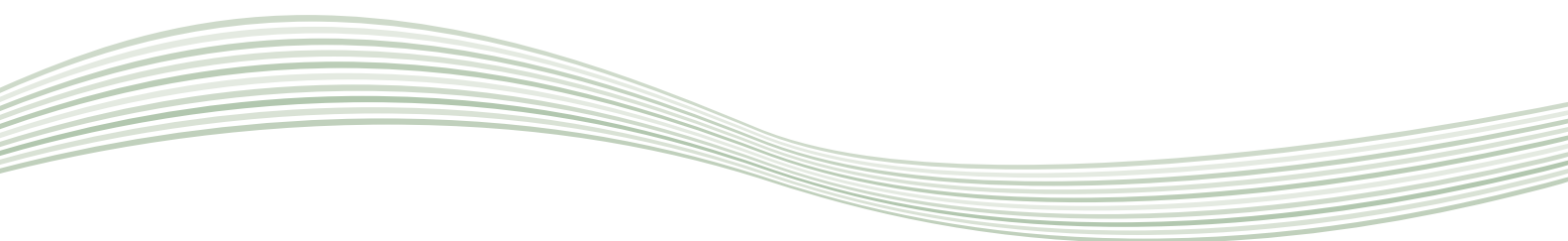
The first such award was conferred on the 10 cities in the Association of Southeast Asian Nations (ASEAN) that have undertaken exemplary measures to keep their cities clean, green and livable even as they continue to grow as centres of economic and industrial activity.

This award, which was presented on 8 October 2008, is further recognition of the efforts of BMA in improving the city's environment to ensure the well-being of Bangkok residents and visitors.

As a first step, BMA drafted an initial plan for public comment. Public opinion was sought through interviews and input to the BMA website. Academics and experts from various disciplines then used the information collected to analyse the appropriateness, feasibility and potential effectiveness of the draft plan in reducing greenhouse gas emissions. The final BMA Action Plan on Global Warming Mitigation calls for initiatives in five major areas:

- Initiative 1: Expand Mass Transit and Improve Traffic Systems
- Initiative 2: Promote the Use of Renewable Energy
- Initiative 3: Improve Electricity Consumption Efficiency
- Initiative 4: Improve Solid Waste Management and Wastewater Treatment Efficiency
- Initiative 5: Expand Park Areas

The Action Plan is aimed at bringing about a reduction in Bangkok's greenhouse gas emissions over or five-year period, that will be 15 per cent below the levels currently projected for 2012.



Greenhouse gas emissions in Bangkok will increase significantly if the current socio-economic conditions are maintained under “business as usual” assumptions. Under the BMA Action Plan it is expected that future net greenhouse gas emissions in Bangkok could grow from about 42.7 million tons of carbon dioxide per year in 2005 to more than 48.7 million tons of carbon dioxide equivalent by 2012.

As previously mentioned, the BMA target is to reduce emissions by at least 15 per cent through the implementation of the activities proposed under the five initiatives in its Action Plan. If implemented effectively, the Action Plan would yield a total net reduction in greenhouse gas emissions in 2012 of almost 39 million tons of carbon dioxide equivalent, that is, an amount that is approximately 20 per cent lower than that under the “business as usual” scenario and better than the BMA targets prior to the development of this Action Plan.

## Public Awareness

Unfortunately, the general public’s perceptions concerning climate change are much lower than that pertaining to more localized environmental issues. Not only is the nature of the impact relatively distant from the daily lives of most people, the time-scale and uncertainties of potential impacts are also more difficult to predict. Moreover, mitigation measures taken domestically or internationally in response to climate change could have possible adverse effects on the Thai economy. Thus, convincing the general public and policymakers to take serious action is a difficult task.

Continuous public awareness campaigns are needed to increase the general public’s understanding of the complex and dynamic issues involved, as well as of the potential benefits that these actions could produce, such as financial savings from improved energy efficiency.

In view of these factors, which extend beyond the confines of the nation’s capital city, Thailand is preparing to launch public awareness programmes as one of the important policies and measures related to climate change. In addition to disseminating information among different agencies through the National Climate Change Committee and the Climate Change Expert Committee, workshops and seminars are being organized on a regular basis in order to promote an exchange of views and information among scientists, public administrators, the public and private sectors, and NGOs. Also, a programme to update local people on technical and political developments will be designed to keep the general public constantly informed of climate change issues.

Despite these efforts, Thailand needs international support in the form of experts and related officials to contribute effectively to technical discussions on climate change issues and to participate actively in the process of international negotiations on these matters.





# Bangkok's Adaptation to Climate Change

It is now clear that climate change is a problem that cannot be ignored, and that all countries will feel the effects to varying degrees. However, because Thailand's capital, Bangkok, is located on a low-lying plain subject to subsidence and close to the sea, this city of 10 million is especially vulnerable to some of the impacts of climate change. Bangkok's authorities are therefore focusing on adaptation to the expected impacts to reduce the vulnerability of the city and improve the adaptive capacity and resilience of the city's inhabitants, as well as to maintain the growth of the city as a regional hub.

The purpose of this chapter is to identify and propose actions for the benefit of Bangkok that will go beyond those that are strictly tied to climate change and in particular provide net economic, social or environmental benefits no matter what degree of climate change does occur.

## General Theme of Adaptation Actions

### The process of adaptation

In the context of this report, adaptation refers to actions, measures, strategies and policies that offset or reduce the effects of climate change. They range from actions by individuals or enterprises to policies related to planning and infrastructural development. As the adaptive capacity of the country, region or community increases and the vulnerability to climate change lessens, the costs associated with its impacts will decrease accordingly. Successful adaptation will depend upon many factors including technological capability, institutional arrangements, availability of financing and exchange of information. There are a number of different types of adaptation actions which can be undertaken:

### Policy

- Undertake risk assessments for all of Bangkok and at the district level for each level of administration in order to identify the most significant areas at risk and to establish priorities for dealing with them;
- Incorporate potential climate change adaptation actions into strategic city planning, where appropriate.



## New buildings and infrastructure

- Where practicable, adopt climate-sensitive building designs that consider local coding and ventilation requirements, e.g. inclusion of natural ventilation coding, consideration of building orientation and low energy consumption;
- Design buildings to enable consideration of future climate change impacts and incorporation of future adaptation, e.g. inclusion of flood damage mitigation, appropriate low-energy consumption and water storage, and increased use of insulating materials in construction.

## Existing buildings and infrastructure

- Monitor changes in the condition of structures so that any modifications or retrofitting occur on time and prior to failure;
- Identify alternative options should there be adverse impacts on existing buildings and infrastructure in order to maintain services and connections, e.g. minimize the isolation of communities during an adverse storm event that might put the infrastructure at higher risk;
- Launch an energy-saving programme as has been done in Bangkok to retrofit buildings, including high-rise structures, as part of efforts to reduce carbon emissions by 15 per cent by 2012.
- Community health and recreation
- Establish the levels of risk communities face from climate change impacts in order to assist in prioritizing potential action;
- Control planning and activities in areas of high risk;
- Encourage the design of buildings and public spaces that provide improved levels of thermal comfort and security, e.g. protection during floods and extreme weather events.

## Natural environment

- Analyse the risks revealed by the initial risk assessment, such as the likelihood of floods, storm surges, drought and risks to the security of the water supply;
- Reduce other forms of external stress such as pollution.



## Selecting Appropriate Adaptation Responses

### Bangkok's adaptation options

Societies across the world have a long record of adapting and reducing their vulnerability to the adverse impacts of weather and climate-related events, such as floods, droughts and storms.

Bangkok has some experience in this regard, but it will require the development of additional adaptation measures at the regional and local levels in order to reduce the adverse impacts of projected climate change and variability, regardless of the scale of mitigation efforts that will be undertaken over the next two to three decades. However, adaptation alone is not expected to enable the city to cope with all the projected effects of climate change, especially not over the long term, as most of those impacts increase in magnitude. Although a wide array of adaptation options is available, more extensive adaptation than is currently occurring is required in order to reduce Bangkok's vulnerability to climate change.

The main concerns about adaptation to climate changes are that such measures take time, are costly and will be put in place over a relatively short time span of decades. Adaptation to the current climate, which has taken place over decades and centuries, has been built into virtually all designs and practices so gradually that it is scarcely recognized.

Bangkok is preparing to adapt to the climate change effects, and a number of different options exist and need to be explored.

### Risk assessment and management

Increasingly, Bangkok is advocating a risk management approach in addressing the potential consequences of climate change as a means of evaluating alternatives in the context of the various uncertainties that could occur.

Consideration is also being given to various climate change scenarios and the utilization of a risk assessment and management framework which would ensure that climate change is considered as early as possible in the decision-making process and that the appropriate actions would be taken when it is most feasible and sensible to do so, rather than being forced into action by an event caused by climate change.

### Infrastructure

The implementation of early adaptation strategies with regard to Bangkok's infrastructure would ultimately decrease the risk of asset damage and the risk of failure that would represent an economic and social cost to the city in the future.

Bangkok administrators have a role to play in encouraging the adaptation of new buildings and in fostering retrofitting actions by motivating and educating communities, setting an example and providing incentives and regulation through approval functions. Building owners and operators in Bangkok should be shown ways to reduce their power bills and help the city to cut its carbon emissions at the same time, by for example, retrofitting buildings to improve energy efficiency and reduce emissions while helping building owners save between 20 and 30 per cent on their power bills.



## Health and health care

There is evidence to suggest that humans have the capacity for coping with thermal stress, particularly in areas where the population has experienced natural acclimatization due to protracted periods of time living in a hot environment. In other words, people living in hot climates such as that of Thailand may be able to cope better than people living in colder climates when the temperature rises as a result of climate change. However, without such adaptation there is the potential for an increase in temperature-related deaths in some regions of the country, particularly in view of the increasing size of Thailand's ageing population.

Bangkok's administrators recognize that a number of climate change impacts may adversely affect the provision of health-care services. Also, taking adaptation action in such circumstances must balance the risks posed by a disease against the risk of upsetting people unnecessarily. Such action could also cause "warning fatigue", making people less likely to respond appropriately by the time that the disease does occur. Surveillance programmes, such as mosquito trapping used in the provinces, may be required to prevent outbreaks of malaria and dengue fever in the city. Thus, Bangkok may need to develop the capacity to undertake similar eradication programmes.

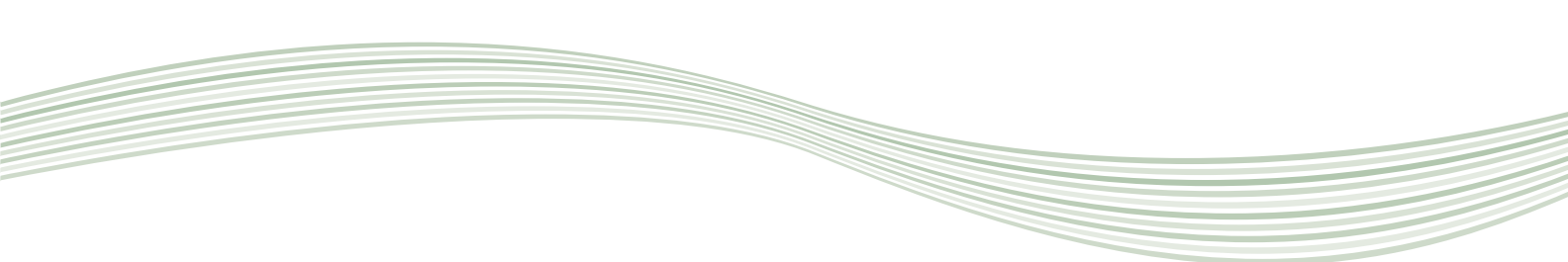
In areas currently susceptible to dengue fever, there are existing initiatives to eradicate breeding sites and to foster awareness about such actions as the need for people to stay indoors during the times of day when the vector mosquitoes are biting. These types of actions may be introduced in areas that become vulnerable to dengue and other vector-borne diseases as a result of climate change.

Any local administration adaptation actions relating to health and the risks posed by climate change should be developed by Bangkok authorities in consultation with the Ministry of Public Health and with the assistance of existing health programmes.

## General Adaptation Measures

There are a number of adaptation measures that can be applied across all levels of responsibility of the Bangkok Metropolitan Administration, as indicated below:

- Promote the establishment of communication channels to facilitate communication between city officers and scientists;
- Support capacity-building activities to raise the capability of Bangkok city officers;
- Encourage the development of climate change risk assessments at the district level in order to improve understanding of the existing climate vulnerabilities faced by specific areas of Bangkok. Also, such understanding could potentially lead to improvements in the functioning of the city;
- Raise public awareness of climate change and adaptation actions that could be implemented at home and that would produce ancillary benefits in addition to those associated with climate change, such as water and energy conservation measures;
- Strengthen the profile of climate change within communities and combine climate change actions with the national sustainability agenda in order to incorporate climate change scenarios into the policy- and decision-making processes.



Many measures that could be considered adaptation actions are already in place within some proactive programmes, such as those on green buildings, and various water and energy efficiency initiatives. While perhaps these were initially established for reasons other than addressing the risks associated with climate change, they nevertheless represent an adaptation action. For example, an adaptation action may be simply to increase the frequency or magnitude of existing programme implementation and monitoring.

Partnerships with different levels of government and or business are a useful-and sometimes essential-mechanism for increased implementation of adaptation actions. Partnerships enable the sharing of resources and existing knowledge and avoid the-reinvention of the wheel-In some cases relationships with private organizations, such as those in the building and manufacturing industries, would be needed for particular functions. Government agencies may also be able to provide guidance or assistance in this regard.

Table 6.1 provides details about the adaptation measures against various types of climate change impacts expected to be felt by different sectors and at various levels in Bangkok. Although globally the climate is changing at an unprecedented rate, time is still available for progress to be made at the local level, provided that recognition is given now to the need for adaptation to begin immediately and that it proceeds at a reasonable and affordable pace. Also, the opportunity exists to enable all key stakeholders in Bangkok to be involved in the adaptation process in a way that reduces conflict and maximizes opportunities for innovative new ideas to be applied. Some of the key adaptation areas that will have to be addressed by the city include the following:

- Water and energy conservation measures;
- Pragmatic and future-oriented reviews of standards, codes, regulations and other practices. The concept of “best practices” may offer a fruitful model;
- Emergency preparedness and response programmes;
- Improving the local public health infrastructure;
- Creating early warning system for severe weather and pollution;
- Implementing stricter zoning and building codes to minimize storm damage;
- Improving disease surveillance and prevention programmes;
- Educating local health professionals and the public about health risks associated with climate change;
- Changing both water infrastructure and management to prevent contamination of potable supplies;
- Undertaking steps to protect citizens from high temperatures both day and night. This may include emergency shelters for the most vulnerable citizens during times of extreme heat;
- Remaining alert for new and better information about the impact of global warming on the communities within BMA’s sphere, and translating that knowledge into local policies and practices than protect health.



Table 6.1. Adaptation measures for Bangkok

Climate change impact	Adaptation measures			
	Community infrastructure, operations	Business and commercial	Residential health and general population	
General long-term rising temperatures of 3-5°C	<ul style="list-style-type: none"> <li>Urban design</li> <li>Tree planting</li> <li>Water conservation</li> <li>Insect and pest controls</li> </ul>	<ul style="list-style-type: none"> <li>Actions to reduce a “heat island” effect, such as building design and green space</li> <li>Agricultural techniques</li> </ul>	<ul style="list-style-type: none"> <li>Better insulation</li> <li>Design for efficient cooling</li> <li>Pest, insect controls</li> <li>Water conservation</li> </ul>	
Ground and surface water quantity and quality	<ul style="list-style-type: none"> <li>Water use restrictions, such as the imposition of fines during periods of water shortage</li> <li>Optimize reservoir releases (based on historical data and drought anticipation)</li> <li>Expand storage capacity</li> <li>More realistic water pricing or greater regulation of withdrawals of surface and ground water</li> </ul>	<ul style="list-style-type: none"> <li>Water efficiency and conservation programmes</li> <li>Water pricing (marginal cost pricing to replace average cost pricing, use of water metering)</li> <li>Irrigation practices</li> <li>Revise shipping and tourism regulations</li> </ul>	<ul style="list-style-type: none"> <li>Water efficiency and conservation programmes, such as reducing volume of toilet flush, installing residential water conservation technologies</li> <li>Irrigation practices</li> </ul>	
Sea level rise, especially in Bang Khuntien District of Bangkok	<ul style="list-style-type: none"> <li>Land use planning</li> <li>Construction or improvement of levees, dykes</li> <li>Water reservoirs, waste discharge designs</li> </ul>	<ul style="list-style-type: none"> <li>Coastal protection phased retreat</li> <li>Harbour/port operation and engineering</li> </ul>	<ul style="list-style-type: none"> <li>Land use planning</li> <li>Ecosystem protection</li> </ul>	
Extreme weather-related events (wind storms, prolonged rain, river flooding, drought)	<ul style="list-style-type: none"> <li>Emergency preparedness plans</li> <li>Construction or improvement of levees, dykes</li> </ul>	<ul style="list-style-type: none"> <li>Emergency preparedness plans</li> <li>Flood proof buildings</li> </ul>	<ul style="list-style-type: none"> <li>Emergency preparedness plans</li> </ul>	

<p>Increased frequency and intensity of short-duration heavy rains</p>	<ul style="list-style-type: none"> <li>• Elevate buildings</li> <li>• Land use planning (e.g. consider adequacy of flood plain zones)</li> <li>• Diversify power supply</li> <li>• Upgrade transmission lines</li> <li>• Implement tree-trimming policy</li> <li>• Strengthen emergency communications</li> </ul>	<ul style="list-style-type: none"> <li>• Elevate buildings</li> <li>• Reschedule production and marketing</li> <li>• Business resumption and restoration planning</li> </ul>	<ul style="list-style-type: none"> <li>• Flood-proof homes, build elevated basements, move power-supply boxes upstairs</li> <li>• Publicly sponsored flood insurance (for areas outside of flood plains)</li> <li>• Advocate 72 hours of self-sufficiency (such as having emergency supplies on hand, canned food, water, medical, back-up power supplies, generator, fuel, radio with batteries)</li> </ul>
<p>Increased frequency and intensity of heat waves, droughts and smog episodes</p>	<ul style="list-style-type: none"> <li>• Increase the size of storm drains, culverts, bridge openings etc.</li> <li>• Increase water-absorbing capacity of urban landscape</li> </ul>	<ul style="list-style-type: none"> <li>• Increase water-absorbing capacity of large paved areas</li> </ul>	<ul style="list-style-type: none"> <li>• Ensure that storm sewers are clear of debris</li> <li>• Launch storm-sewer protection programmes</li> <li>• Increase attention paid to landscape design for reducing rapid run-off</li> </ul>
	<ul style="list-style-type: none"> <li>• Heat contingency plans</li> <li>• Use of air conditioners</li> <li>• Water and energy conservation measures</li> <li>• Air pollution abatement</li> <li>• Reduction of urban traffic</li> <li>• Planting more trees</li> </ul>	<ul style="list-style-type: none"> <li>• Use of air conditioners</li> <li>• Rescheduling of production in some cases</li> <li>• Elevate buildings</li> <li>• Reducing energy and water consumption and air emissions</li> </ul>	<ul style="list-style-type: none"> <li>• Hospital emergency preparedness</li> <li>• Education on what to do in the event of a heat wave (reduce exercise, consume liquids, stay in-doors etc.)</li> <li>• Use of residential air conditioners</li> </ul>



These broad adaptation areas have been expanded to include the following additional considerations that might be applied in certain circumstances:

- Implementing land use restrictions, especially for flood plains, coastal shorelines, areas prone to landslides and other areas considered to be at risk;
- Revising flood plain mapping and codes for loading and return frequencies, and adjusting to new realities, such as “100-year” floods becoming “50-year” floods;
- Formulating safety and fire codes for buildings and other structures that could affect public safety;
- Adopting a system for emergency management, including education and training and public outreach;
- Making public prevention and mitigation infrastructural adjustments, such as dams and weirs, flood channels, dykes, land stabilization works, transmission towers, communication devices and channels;
- Establishing effective programmes for post-disaster recovery and support at the district level;
- Providing the people with public health, agricultural and environmental programmes that would ensure their survival and the effective functioning of critical public services;
- Modifying and improving disaster response protocols, including:
  - The identification of new responsibilities for emergency services and other essential agencies to deal with the expected increase in disastrous events;
  - Those related to public expectations and the need for individual and family self-sufficiency for significant periods of time in the early stages of disasters;
  - The modification of emergency services structures.
- Recognizing that the recovery phase may need new strategies for ensuring the continuation of government and business operations;
- Getting community life back to “normal” should be a priority concern and needs to be planned in some detail before an adverse event occurs.





# Options for Action

Bangkok has been driving Thailand's strong economic performance for the past several decades, accounting for a major share of the country's gross national product. However, it has now become evident that this growth has come at a cost to the environment and to the climate. Remedial and preventive action must therefore be taken to refocus priorities and ease the strains that have become apparent at all levels. For their part, the administrators of Bangkok as one of the world's mega-cities, the Bangkok Metropolitan Administration (BMA) recognize that the capital must pursue sustainability goals for its economic and social well-being.

Energy is a core issue in this regard. At a time when the price of oil has become volatile, the city administrators must take action to encourage residents to become better informed about energy-related matters and to be prepared for fluctuating energy prices and the multiple environmental, economic and health impacts of climate change that are likely to become more stressful in the near future as a result of the combustion of oil and other fossil fuels.

## Achieving Goals

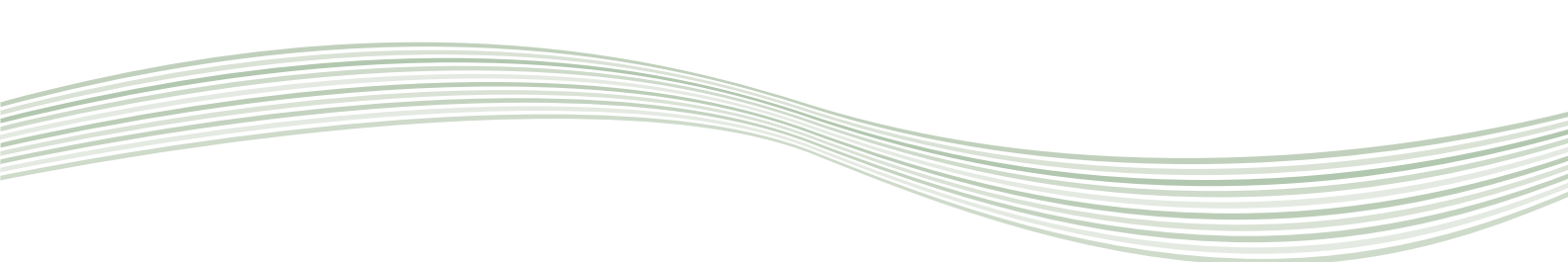
### Energy efficiency and emissions reduction

The city administrators are collaborating with the Ministry of Energy and various non-profit organizations to support local businesses, using audits to establish energy efficiency standards and building codes, and they are encouraging stakeholder involvement in appropriate aspects of the Bangkok City Action Plan to build community support for these efforts.

Bangkok is advancing long-term initiatives through the development of educational programmes and materials to promote energy efficiency and climate protection. The two most important mitigation responses that BMA can be taken to reduce its greenhouse gas emissions are

1. Adopt and encourage energy efficiency and conservation in the community;
2. Increase the use of renewable energy resources, in terms of both passive design and power generation, in individual homes and buildings and on the local grid.

Reducing the amount of emissions produced by BMA's own vehicle fleets has the potential to make a significant contribution to the city's greenhouse gas reduction targets. Such reductions are a particularly visible area for improvement in view of the highly publicized nature of petrol prices. Another practical and highly visible method of fostering the use of hybrid vehicles in Bangkok is to ensure that influential leaders such as the city's Governor are known to be using hybrid vehicles. The BMA and other leading organizations and sectors should also be encouraged to use such vehicles. This would provide leadership by example and make a strong statement that reducing emissions and air pollution and contributing to climate protection are important priorities for residents of Bangkok at all levels.



The principle behind the reduction of vehicle emissions can also be applied to the city's transit system, waste-removal trucks, school buses, street sweepers and other vehicles in the city's fleet. Although the initial cost of implementing the options for emission reduction is often higher than continuing to use conventional vehicles, in the long term fuel-efficient vehicles and alternative fuel options will save money and eventually pay for themselves many times over. The reduction of emissions from the city's vehicle fleet can be effected through the use of hybrid and other highly efficient vehicles, the introduction of alternative fuels and continuing awareness campaigns, some of which are described below.

### **Alternative sources of energy**

Alternative fuels and sources of energy include gasohol, natural gas, biodiesel, solar energy and electricity. Using these alternatives in vehicles and buildings would generally reduce harmful pollutants and exhaust emissions. Moreover, most of these fuels are produced domestically and are derived from renewable sources, although they must be produced Sustainably. In 2007 and 2008, BMA and the Ministry of Energy jointly carried out feasibility studies on an anaerobic digestion system for the production of biogas from organic waste at schools and marketplaces. At the same time, BMA and PTT, the national petroleum company, formed an innovative public-private partnership to develop, build, test and operate new natural gas stations in the Bangkok area, providing this clean-burning alternative fuel for vehicles.

### **Electricity**

Electricity can be used as a "fuel" for transportation, powering electric battery and plug-in hybrid vehicles. Providing plug-in facilities in the Bangkok area will encourage residents to switch from the use of conventionally powered cars and trucks to electric vehicles and this will contribute to the reduction of greenhouse gas emissions.

In January 2008, BMA and the Electricity Generating Authority of Thailand jointly signed a Memorandum of Understanding to replace existing T8 Fluorescent lamp with the energy-saving T5 lamp in 9 Bangkok hospitals. There are a total of 98,952 T8 fluorescent lamp in those hospitals, the target is to replace all less efficient lamps which could cut the energy consumption of the hospitals by over 30 per cent.

### **Biodiesel**

Biodiesel is a domestically produced, renewable fuel that can be manufactured from vegetable oils, animal fats, or recycled restaurant oil and grease. Biodiesel is safe and biodegradable, although it can have environmental impacts. Compared with petrol, its use in vehicles reduces the level of serious air pollutants, such as particulates, carbon monoxide and hydrocarbons, among others.

Blends of 20 per cent biodiesel and 80 per cent petroleum diesel, called "B20", can generally be used in unmodified diesel engines. Biodiesel can also be used in its pure form, "B100", but engines using such fuel may require modifications to prevent maintenance and performance problems, and this type of biodiesel may not be suitable for use during very cool weather. B100 reduces carbon dioxide emissions by more than 75 per cent compared with that produced by petroleum diesel; the use of B20 reduces carbon dioxide emissions by 15 per cent. In 2007, BMA, the Ministry of Energy, the Ministry of Natural Resources and Environment, and PTT jointly conducted experiments and tested biodiesel production and use.

## Ethanol

Ethyl alcohol, or “ethanol”, can be used as an input to alternative fuels for vehicles. Produced by fermenting starch crops that have been converted into simple sugars and distilling the resulting liquid, the feedstocks for this fuel additive include cassava, sugarcane and molasses, all produced in large quantities in Thailand.

Ethanol is most commonly used to increase the octane level in petrol and improve its emissions quality; the mixture of ethanol and petrol is called “gasohol”. BMA plans to increase the use of gasohol in the city’s vehicle fleet over the next five years, which will significantly reduce carbon dioxide emissions. BMA will also encourage public participation in efforts to reduce carbon dioxide emissions through a media partnership programme promoting the use of gasohol and biodiesel in private vehicles.

## Idle reduction campaign

“Idle reduction” is the term used to describe practices that reduce the amount of time cars idle their engines. Reducing idle time saves fuel, engine wear and money; more importantly in the context of climate change, it also reduces emissions as well as noise pollution. Launching campaigns like the one in July 2007 to encourage people to stop idling their engines while waiting to pick up children at school, at petrol stations, at marketplaces and other public places, for example, would directly reduce greenhouse gas emissions as well as air pollution while also reducing dependence on imported oil.

## Alternative fuels for waste haulers

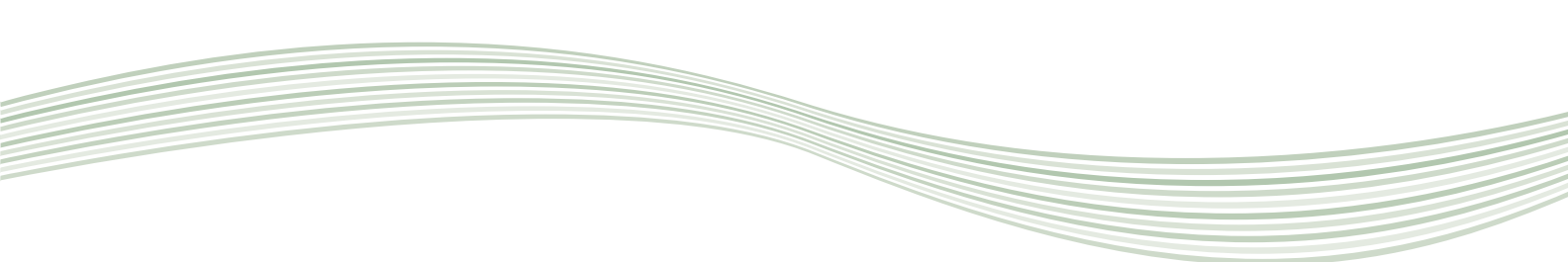
Waste haulers, or rubbish trucks, are the most inefficient vehicles plying Bangkok’s streets. They burn approximately 1 litre of fuel per kilometre, and they travel approximately 30,000 km annually, which means that each truck consumes an average of 30,000 litres of diesel a year. Furthermore, each of these trucks emits 81 tons of carbon dioxide a year.

As alternative fuel sources become more available and economically viable, it is possible to use them for these vehicles. In recent years, new natural gas fleets have come into operation in France, Spain, Belgium and the United States of America. Other clean fuels and advanced technologies are starting to be used in refuse vehicles, such as the previously described biodiesel. Hydraulic hybrid technology and the use of bio-methane fuel captured from landfills can also supply clean, renewable sources of energy for such trucks. Overall, refuse trucks that use alternative fuels would contribute to major reductions in diesel use, produce much less air pollution, save on fuel costs and reduce carbon dioxide emissions.

## Sustainable agriculture

Agriculture contributes an estimated 20 per cent of the greenhouse gases that are responsible for climate change, and it is responsible for about 50 per cent of nitrous oxide emissions (International Food Policy Research Institute, 2001).

Agriculture is an issue for city administrators: Bangkok is so large in size that it encompasses huge areas of land devoted to agriculture and livestock production. The city could therefore significantly reduce its contribution of greenhouse gases to Thailand’s total by supporting local agriculture. Locally produced fruits, vegetables, dairy and other agricultural products require transport over much shorter distances to market than similar products from other parts of the country. Such items could also be produced in ways that substantially reduce the emission of greenhouse gases. Encouraging Bangkok residents to buy and consume local agricultural products would result in cost savings and reductions in greenhouse gas emissions and other kinds of waste.



Organic farms are 20-56 per cent more energy efficient than conventional farms (Mader et.al., 2002). Increased energy efficiency comes in part from decreased use of fertilizers and pesticides and, if the farms are located near urban areas, distances to transport agricultural inputs from external sources are reduced, as is the distance to market

Bangkok could implement programmes to encourage local food production, increase the use of organic produce and foster the preservation of farmland. Some of these programmes could be designed to strengthen local economies, save costs in order to make funds available for improving people's health and preserving a traditional way of life as well. People who eat locally grown food support local farmers and the local economy, while reducing the greenhouse gases that would have been emitted by transporting food from long distances.

## Education

Education is one of the most important long-term initiatives that Bangkok administrators could use to address the issue of the city's greenhouse gas emissions. Through education, the municipality could elicit greater understanding, engagement and support from the community in the process of reducing carbon emissions. At the same time, education fosters critical thinking and nurtures the development of environmental leaders and experts needed for the city's future development.

Bangkok can create, mass produce and distribute educational media and materials to promote energy efficiency, resource efficiency, climate change preparedness and adaptation in schools, and disseminate such material through educational networks.

## Actions for Bangkok

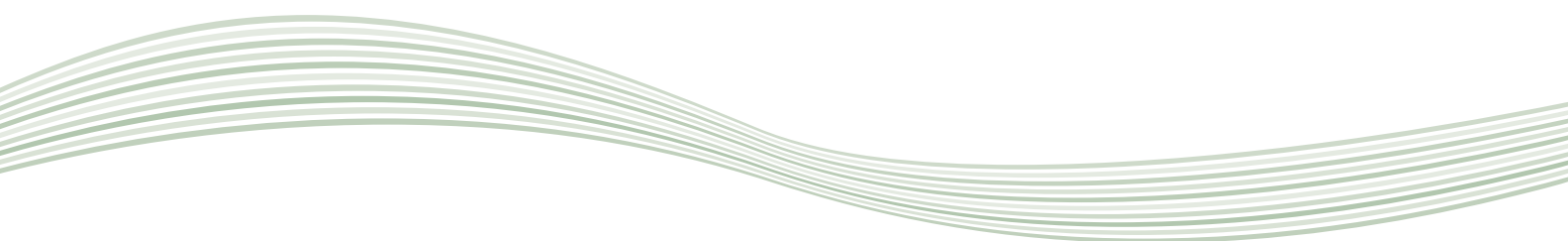
The policy of BMA is to implement policies and programmes that will help residents to understand and adapt to climate change, enabling them to make the adjustments required to cope with the various adverse impacts that climate change is expected to generate.

## Programmes

To achieve reductions in greenhouse gas emissions, city staff will be implementing several initiatives aimed at saving energy, educating the general public and working with the community. They will measure the impact of such programmes and will make any necessary adjustments as the programmes unfold.

As staff members may know little about climate change, global warming or the science behind these issues, an internal education programme will be launched to educate staff on these matters, with the support of local non-profit organizations. Through this they will gain the necessary knowledge to successfully implement the Climate Action Plan by means of educational materials, manuals, training courses and encouraging attendance at conferences and workshops.

The willingness of members of the public to participate actively in achieving reductions in greenhouse gas emissions is vital. It is also necessary to help the community to understand the significant disruption that will come about if global warming continues unabated through education and involvement because an educated citizen is one of the best assets that any community can have.



Reducing the amount of energy used in buildings will also contribute significantly to the city's greenhouse gas reduction targets. Energy efficient retrofits can be performed on any existing building, including city offices, libraries and any other structure owned by the city that uses electricity or other forms of energy. In 2007, BMA offices and structures used a significant 219.5 GWh of electricity. Retrofitting city buildings could lead to a reduction of 10 per cent of this electricity use, or a total of 22 GWh less electricity, resulting in a reduction in carbon dioxide emissions of 1,540 tons.

Bangkok's "purchasing green" programme, launched in early 2008, can make a substantial impact on the overall environmental efforts of BMA. The programme gives support to local vendors and often helps recycling programmes by creating markets for the collected materials, which are then processed and used to manufacture new products. This in turn creates new jobs and helps to strengthen the economy. Such efforts conserve natural resources, save energy and reduce solid waste, air and water pollutants and the greenhouse gases that contribute to global warming.

Organizing training workshops on disaster preparedness and recovery for the community is another important step both in terms of preparing for and adapting to climate change. Increasing the number of trained community volunteers is a measure of preparedness. BMA will make this a high priority in order to ensure that communities are well informed and ready to cope with the problems that may arise.

### **In addition to the above:**

In addition to the above, BMA will undertake the following with relevant partners:

- Create partnerships with various stakeholders to create momentum, continuity, longevity and success for the various programmes upon which it embarks;
- With regard to municipal buildings, retrofit city buildings with energy efficient lighting and appliances, collaborate with the Ministry of Energy in establishing energy efficient standards for new municipal construction and major renovations, and perform energy audits for existing buildings;
- Work with the Ministry of Transport to install light-emitting diode (LED) traffic signals and traffic flow management systems, update street lighting to a high-efficiency level, increase wastewater utilities and establish landfill-gas energy projects;
- Reduce the emissions of its vehicle fleets, using hybrids, alternative fuel vehicles and idle engine reduction policies and campaigns, as well as establishing programmes to reduce driving on duty by city employees. The municipality will also modify school buses, waste haulers and ambulances to use compressed natural gas (CNG) and biofuels;
- Establish purchasing programmes to procure energy-efficient appliances, and purchase materials that require less energy and reduce the amount of waste that such appliances and materials produce;
- Continue working with the Thai Industrial Standards Institute to create efficiency standards for office equipment, adopt recycled salvaged product use policies and develop local purchasing programmes;

- Support public and private transport by making the city pedestrian- and bicycle-friendly, providing better access to public transport, creating more park-and-ride facilities, providing incentives for hybrid or low-emission vehicle use and installing plug-in facilities for electric hybrid vehicles.
- Increase the renewable energy harvest by collecting the methane gas emitted from landfills, municipal waste transit points and marketplaces. BMA will encourage communities to take the steps necessary to collect methane. This will produce immediate benefits for public health by improving air quality, lowering energy bills and reducing greenhouse gas emissions.
- Create and maintain natural areas and engage in “urban forestry” to reduce the so-called urban heat island effect.

## Conclusion and Recommendations

It is clear from all the available evidence that the climate is changing and has been changing for some time. Despite of the mitigation measures taken under global, national and local initiatives such as the Kyoto Protocol and the BMA Action Plan on Global Warming Mitigation 2007-2012, it is expected that carbon dioxide concentrations will double by the second half of the next century. In the meantime, changes in the global climate will continue to occur and the impacts will be felt gradually but perceptibly everywhere, including in Bangkok.

Bangkok can expect the average temperature to increase over time by 3-5°C. The major impacts of that increase will be an augmented energy demand for cooling, increased heat-related illnesses and diseases, proliferation of insects and pests, and changes affecting agricultural crops and green areas. The rising sea level caused by melting glaciers and arctic ice will significantly affect the city and particularly the “sensitive” coastline of Bang Khuntien District. Greater Bangkok will also be affected by water supply changes as ground and subsurface water levels fall.

More persistent El Niño conditions, punctuated by a strong La Niña, will result in more prolonged droughts (El Niño) interspersed with very wet years (La Niña) affecting Bangkok and the rest of Thailand. There will be more frequent and more extreme weather-related events, including short-duration, very high intensity rainfall, extended heat waves and severe thunderstorms and storm surges. The likely increase in natural disaster frequency will create perhaps the most serious and possibly the most costly of the challenges the city will have to face.

To address the likely changes in the climate and their impacts on Bangkok’s economy and inhabitants, it is necessary to initiate a coordinated approach from all sectors at the local level as a matter of urgency. Those requiring timely intervention are energy, transport, alternative energy sources for transport and household uses, sustainable agriculture to reduce dependence on the long-haul transport of agricultural products, changes in consumption patterns and behaviour, and education and awareness programmes to increase the understanding of and knowledge about the ongoing and expected climate change impacts.

Existing and new technologies and initiatives yet to be developed will enhance the ability of Bangkok and other societies to reduce their emission of greenhouse gases, and adapt to climate change. These investments and efforts should yield a triple dividend, for the economy, for the environment and for society, primarily for the people of Bangkok but also of Thailand and the planet as a whole, as well as contributing to mitigating climate change.

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# Annexes

## Annex I

### Tools and Approaches for Climate Change Assessing

Vulnerability and adaptation assessments have been identified as vital tools for developing countries to evaluate and implement responses to climate change. A major problem in all regions has been the limited capacity at the regional and national levels due to deficiencies in data collection and the lack of technical expertise. It was highlighted as important to make the models, tools and methodologies that are appropriate for assessments in developing countries more widely available. Exchanging information on tools used for vulnerability and adaptation assessments, together with the outcomes of these assessments, helps countries improve capacity in this area. This can be done through workshops and symposia, regional science journals, websites to facilitate information exchange and by making better use of existing channels of information (IPCC 2007):

Researchers have developed numerous tools and approaches for assessing adaptation options. In the past, impact assessments used climate scenarios as the starting point for determining potential impacts and adaptive responses. Today, experts prefer a new approach for adaptation policy development: the vulnerability approach. The vulnerability approach is an interactive process involving five steps (IPCC 2007):

- Engage stakeholders
- Assess current vulnerability
- Estimate future conditions
- Estimate future vulnerability
- Assess and implement options

Whereas the starting point for an impact assessment is average climate conditions as determined by climate scenarios, the starting point for a vulnerability assessment is the system (e.g., community, region or sector). The vulnerability approach builds a strong foundation of knowledge regarding an area and its vulnerability before laying future climate scenarios over that matrix, and in this way the high degree of uncertainty associated with the old approach is reduced. Another advantage relates to the issue of scale. Climate scenarios often provide information on a global or large regional scale, while vulnerability assessments can be done on a much smaller scale.

The vulnerability approach is based on the concept of vulnerability, which is defined by the Intergovernmental Panel on Climate Change (IPCC) as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes". In other words, the vulnerability approach takes into consideration not only the impacts predicted by climate scenarios and socio-economic scenarios, but also a system's capacity for coping with those impacts (IPCC 2007):

## Methods

The IPCC has developed a seven-step methodology for conducting a climate change impact assessment (IPCC 2007):

1. Evaluate evidence that recently observed changes in climate have already affected a variety of physical and biological systems.
2. Make a detailed study of the vulnerabilities of human populations to future climate change, including associated sea-level rise and changes in the frequency and intensity of climate extremes, such as floods, droughts, heat waves and windstorms, and take into account potential impacts on water resources, agriculture and food security, human health, coastal and other types of settlements, and economic activities.
3. Assess the potential responses of natural environments and the wildlife that inhabits those encroachments to future climate change and identify environments at particular risk.
4. Consider how adaptation to climate change might lessen adverse impacts or enhance beneficial impacts.
5. Provide an overview of the vulnerabilities and adaptation possibilities by major regions of the world.
6. Contrast the different vulnerabilities of the developed and developing parts of the world and explore the implications for sustainable development and equity concerns.
7. Evaluate adaptation strategies

## Integrated assessment (IPCC 2001,2007)

Integrated assessment is an interdisciplinary process that combines, interprets, and communicates knowledge from diverse scientific disciplines from the natural and social sciences to investigate and understand causal relationships within and between complicated systems.

Methodological approaches employed in such assessments include computer aided modelling, scenario analyses, simulation gaming and participatory integrated assessment, and qualitative assessments that are based on existing experience and expertise. Since the SAR, significant progress has been made in developing and applying such approaches to integrated assessment, globally and regionally.

However, progress to date, particularly with regard to integrated modeling, has focused largely on mitigation issues at the global or regional scale and only secondarily on issues of impacts, vulnerability and adaptation. Greater emphasis on the development of methods for assessing vulnerability is required, especially at national and sub national scales where impacts of climate change are felt and responses are implemented. Methods designed to include adaptation and adaptive capacity explicitly in specific applications must be developed.

## Vulnerability and adaptation studies

A high quality and comprehensive vulnerability study would provide important support for the analysis and evaluation of adaptation options. Climate change involves long term analysis, and it is politically very difficult to pursue policies such as adaptation options that involve long term planning and research. Experiences with vulnerability and adaptation studies in Thailand suggest the need to refine vulnerability analysis to the greatest extent possible. The high level of uncertainty in vulnerability studies hinders the advancement of adaptation analysis that can lead to more meaningful policy recommendations. Besides the need to improve and refine the existing vulnerability and adaptation research, there are other areas where vulnerability and adaptation studies should be undertaken, including:

- Energy
- Biodiversity and timber and non timber products
- Tourism
- Permanent crops and livestock
- Coastal resources, such as beach, coastal ecology, coral reef and land use change
- Direct and indirect health effects, such as heat-related death and illness, physical and psychological trauma due to disasters, vector-borne and non-vector-borne diseases. Vulnerability and adaptation studies are not necessarily limited to the national level. Such research also should be undertaken at the subregional and regional levels as appropriate.

## Annex II

### Glossary

### Adaptation

Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and autonomous and planned. Examples are raising river or coastal dikes, the substitution of more temperature-shock resistant plants for sensitive ones.

## Annex I countries

The group of countries included in Annex I (as amended in 1998) to the United Nations Framework Convention on Climate Change (UNFCCC), including all the OECD countries in the year 1990 and countries with economies in transition. Under Articles 4.2 (a) and 4.2 (b) of the Convention, Annex I countries committed themselves specifically to the aim of returning individually or jointly to their 1990 levels of greenhouse gas emissions by the year 2000. By default, the other countries are referred to as Non Annex I countries. For a list of Annex I countries, see <http://unfccc.int>.

## Atmosphere

The gaseous envelope surrounding the Earth. The dry atmosphere consists almost entirely of nitrogen (78.1% volume mixing ratio) and oxygen (20.9% volume mixing ratio), together with a number of trace gases, such as argon (0.93% volume mixing ratio), helium and radiatively active greenhouse gases such as carbon dioxide (0.035% volume mixing ratio) and ozone. In addition, the atmosphere contains the greenhouse gas water vapour, whose amounts are highly variable but typically around 1% volume mixing ratio. The atmosphere also contains clouds and aerosols.

## Carbon dioxide (CO<sub>2</sub>)

A naturally occurring gas, also a by-product of burning fossil fuels from fossil carbon deposits, such as oil, gas and coal, of burning biomass and of land use changes and other industrial processes. It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore has a Global Warming Potential of 1.

## Climate

Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. In various parts of this report different averaging periods, such as a period of 20 years, are also used.

## Climate model

A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity, that is, for any one component or combination of components a spectrum or hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the level at which empirical parameters are involved. Coupled Atmosphere-Ocean General Circulation Models (AOGCMs) provide a representation of the climate system that is near the most comprehensive end of the spectrum currently available. There is an evolution towards more complex models with interactive chemistry and biology. Climate models are applied as a research tool to study and simulate the climate, and for operational purposes, including monthly, seasonal and interannual climate predictions.

## Climate change

Climate change refers to a change in the state of the climate that can be identified (such as by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in

the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

## Coral

The term coral has several meanings, but is usually the common name for the Order Scleractinia, all members of which have hard limestone skeletons, and which are divided into reef-building and non-reef-building, or cold- and warm-water corals.

## Deforestation

Conversion of forest to non-forest. For a discussion of the term forest and related terms such as afforestation, reforestation, and deforestation see the IPCC Report on Land Use, Land Use Change and

## Demand-side management (DSM)

Policies and programmes for influencing the demand for goods and/or services. In the energy sector, DSM aims at reducing the demand for electricity and energy sources.

## Drought

In general terms, drought is a 'prolonged absence or marked deficiency of precipitation', a 'deficiency that results in water shortage for some activity or for some group', or a 'period of abnormally dry weather sufficiently prolonged for the lack of precipitation to cause a serious hydrological imbalance'. Drought has been defined in a number of ways. Agricultural drought relates to moisture deficits in the topmost 1 metre or so of soil (the root zone) that affect crops, meteorological drought is mainly a prolonged deficit of precipitation, and hydrologic drought is related to below-normal streamflow, lake and groundwater levels. A megadrought is a longdrawn out and pervasive drought, lasting much longer than normal, usually a decade or more.

## El Niño Southern Oscillation (ENSO)

The term El Niño was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Perú, disrupting the local fishery. It has since become identified with a basinwide warming of the tropical Pacific east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere ocean phenomenon, with preferred time scales of two to about seven years, is collectively known as El Niño Southern Oscillation, or ENSO. It is often measured by the surface pressure anomaly difference between Darwin and Tahiti and the sea surface temperatures in the central and eastern equatorial Pacific. During an ENSO event, the prevailing trade winds weaken, reducing upwelling and altering ocean currents such that the sea surface temperatures warm, further weakening the trade winds. This event has a great impact on the wind, sea surface temperature and precipitation patterns in the tropical Pacific. It has climatic effects throughout the Pacific region and in many other parts of the world, through global teleconnections. The cold phase of ENSO is called La Niña.

## Energy

The amount of work or heat delivered. Energy is classified in a variety of types and becomes useful to human ends when it flows from one place to another or is converted from one type into another. Primary energy (also referred to as energy sources) is the energy embodied in natural resources (for example, coal, crude oil, natural gas, uranium) that has not undergone any anthropogenic conversion. This primary energy needs to be converted and transported to become usable energy (such as light). Renewable energy is obtained from the continuing or repetitive currents of energy occurring in the natural environment, and includes non carbon technologies such as solar energy, hydropower, wind, tide and waves, and geothermal heat, as well as carbon neutral technologies such as biomass. Embodied energy is the energy used to produce a material substance (such as processed metals, or building materials), taking into account energy used at the manufacturing facility (zero order), energy used in producing the materials that are used in the manufacturing facility (first order), and so on.

## Energy efficiency

Ratio of useful energy output of a system, conversion process or activity, to its energy input.

## Erosion

The process of removal and transport of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, winds, and underground water.

## Extreme weather event

An event that is rare at a particular place and time of year. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability density function. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. Single extreme events cannot be simply and directly attributed to anthropogenic climate change, as there is always a finite chance the event in question might have occurred naturally. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (such as drought or heavy rainfall over a season).

## Global surface temperature

The global surface temperature is an estimate of the global mean surface air temperature. However, for changes over time, only anomalies, as departures from a climatology, are used, most commonly based on the areaweighted global average of the sea surface temperature anomaly and land surface air temperature anomaly.

## Greenhouse effect

Greenhouse gases effectively absorb thermal infrared radiation, emitted by the Earth's surface, by the atmosphere itself due to the same gases, and by clouds. Atmospheric radiation is emitted to all sides, including downward to the Earth's surface. Thus greenhouse gases trap heat within the surface troposphere system. This is called the greenhouse effect. Thermal infrared radiation in the troposphere is strongly coupled to the temperature of the atmosphere at the altitude at which it is emitted. In the troposphere, the temperature generally decreases with height. Effectively, infrared radiation emitted to space originates from an altitude with a temperature of, on average,  $-19^{\circ}\text{C}$ , in balance with the net incoming solar radiation, whereas the Earth's surface is kept at a much higher temperature of, on average  $+14^{\circ}\text{C}$ . An increase in the concentration of greenhouse gases leads to an increased infrared opacity of the atmosphere, and therefore to an effective radiation into space from a higher altitude at a lower temperature. This causes a radiative forcing that leads to an enhancement of the greenhouse effect, the so called enhanced greenhouse effect.

## Greenhouse gas (GHG)

Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour ( $\text{H}_2\text{O}$ ), carbon dioxide ( $\text{CO}_2$ ), nitrous oxide ( $\text{N}_2\text{O}$ ), methane ( $\text{CH}_4$ ) and ozone ( $\text{O}_3$ ) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine and bromine containing substances, dealt with under the Montreal Protocol. Beside  $\text{CO}_2$ ,  $\text{N}_2\text{O}$  and  $\text{CH}_4$ , the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride ( $\text{SF}_6$ ), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

## (Climate change) Impact assessment

The practice of identifying and evaluating, in monetary and/or non-monetary terms, the effects of climate change on natural and human systems.

## (Climate change) Impacts

The effects of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts:

- Potential impacts: all impacts that may occur given a projected
- Change in climate, without considering adaptation.
- Residual impacts: the impacts of climate change that would occur after adaptation.

## Infectious disease

Any disease caused by microbial agents that can be transmitted from one person to another or from animals to people. This may occur by direct physical contact, by handling of an object that has picked up infective organisms, through a disease carrier, via contaminated water, or by spread of infected droplets coughed or exhaled into the air.

## Infrastructure

The basic equipment, utilities, productive enterprises, installations, and services essential for the development, operation, and growth of an organization, city, or nation.

## Kyoto Protocol

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1997 in Kyoto, Japan, at the Third Session of the Conference of the Parties (COP) to the UNFCCC. It contains legally binding commitments, in addition to those included in the UNFCCC.

## Land use and Land-use change

Land use refers to the total of arrangements, activities and inputs undertaken in a certain land cover type (a set of human actions). The term land use is also used in the sense of the social and economic purposes for which land is managed (e.g., grazing, timber extraction, and conservation). Land use change refers to a change in the use or management of land by humans, which may lead to a change in land cover. Land cover and land use change may have an impact on the surface albedo, evapotranspiration, sources and sinks of greenhouse gases, or other properties of the climate system and may thus have a radiative forcing and/or other impacts on climate, locally or globally.

## Malaria

Endemic or epidemic parasitic disease caused by species of the genus *Plasmodium* (Protozoa) and transmitted to humans by mosquitoes of the genus *Anopheles*; produces bouts of high fever and systemic disorders, affects about 300 million and kills approximately 2 million people worldwide every year.

## Methane ( $\text{CH}_4$ )

Methane is one of the six greenhouse gases to be mitigated under the Kyoto Protocol and is the major component of natural gas and associated with all hydrocarbon fuels, animal husbandry and agriculture. Coal-bed methane is the gas found in coal seams. Variety of biological sources in soil and water, particularly microbial action in wet tropical forests.

## Metric

A consistent measurement of a characteristic of an object or activity that is otherwise difficult to quantify.

## Mitigation

Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to Climate Change, mitigation means implementing policies to reduce greenhouse gas emissions and enhance sinks.

## Monsoon

A monsoon is a tropical and subtropical seasonal reversal in both the surface winds and associated precipitation, caused by differential heating between a continental-scale land mass and the adjacent ocean. Monsoon rains occur mainly over land in summer.

## Nitrous oxide ( $\text{N}_2\text{O}$ )

One of the six types of greenhouse gases to be curbed under the Kyoto Protocol. The main anthropogenic source of nitrous oxide is agriculture (soil and animal manure management), but important contributions also come from sewage treatment, combustion of fossil fuel, and chemical industrial processes. Nitrous oxide is also produced naturally from a wide

## Non Annex I

### All Parties must report on the

steps they are taking or envisage undertaking to implement the Convention (Articles 4.1 and 12). In accordance with the principle of "common but differentiated responsibilities" enshrined in the Convention, the required contents of these national communications and the timetable for their submission is different for Annex I and non-Annex I Parties. Each non-Annex I Party shall submit its initial communication within three years of the entry into force of the Convention for that Party, or of the availability of financial resources (except for the least developed countries, who may do so at their discretion).

## Non-governmental Organisation (NGO)

A non-profit group or association organised outside of institutionalized political structures to realise particular social and/or environmental objectives or serve particular constituencies.

## Ocean acidification

A decrease in the pH of sea water due to the uptake of anthropogenic carbon dioxide.

## Ozone (O<sub>3</sub>)

Ozone, the tri-atomic form of oxygen, is a gaseous atmospheric constituent. In the troposphere, ozone is created both naturally and by photochemical reactions involving gases resulting from human activities (smog). Troposphere ozone acts as a greenhouse gas. In the stratosphere, ozone is created by the interaction between solar ultraviolet radiation and molecular oxygen (O<sub>2</sub>). Stratospheric ozone plays a dominant role in the stratospheric radiative balance. Its concentration is highest in the ozone layer.

## Paleoclimate

Climate during periods prior to the development of measuring instruments, including historic and geologic time, for which only proxy climate records are available. Climate during periods prior to the development of measuring instruments, including historic and geologic time, for which only proxy climate records are available.

## Patterns of climate variability

Natural variability of the climate system, in particular on seasonal and longer time scales, predominantly occurs with preferred spatial patterns and time scales, through the dynamical characteristics of the atmospheric circulation and through interactions with the land and ocean surfaces. Such patterns are often called regimes, modes or teleconnections. Examples are the North Atlantic Oscillation (NAO), the Pacific-North American pattern (PNA), the El Niño-Southern Oscillation (ENSO), the Northern Annular Mode (NAM; previously called Arctic Oscillation, AO) and the Southern Annular Mode (SAM; previously called the Antarctic Oscillation, AAO).

## Perfluorocarbons (PFCs)

Among the six greenhouse gases to be abated under the Kyoto Protocol. These are by-products of aluminium smelting and uranium enrichment. They also replace chlorofluorocarbons in manufacturing semiconductors.

## Permafrost

Ground (soil or rock and included ice and organic material) that remains at or below 0°C for at least two consecutive years (Van Everdingen 1998).

## pH

pH is a dimensionless measure of the acidity of water (or any solution). Pure water has a pH=7. Acid solutions have a pH smaller than 7 and basic solutions have a pH larger than 7. pH is measured on a logarithmic scale. Thus, a pH decrease of 1 unit corresponds to a 10-fold increase in the acidity.

## Runoff

That part of precipitation that does not evaporate and is not transpired, but flows over the ground surface and returns to bodies of water. See Hydrological cycle projections, but are often based on additional information from other sources, sometimes combined with a narrative storyline.

## Radiative forcing

Radiative forcing is the change in the net, downward minus upward, irradiance (expressed in Watts per square metre, W/m<sup>2</sup>) at the tropopause due to a change in an external driver of climate change, such as, for example, a change in the concentration of carbon dioxide or the output of the Sun. Radiative forcing is computed with all tropospheric properties held fixed at their unperturbed values, and after allowing for stratospheric temperatures, if perturbed, to readjust to radiative-dynamical equilibrium. Radiative forcing is called instantaneous if no change in stratospheric temperature is accounted for. For the purposes of this report, radiative forcing is further defined as the change relative to the year 1750 and, unless otherwise noted, refers to a global and annual average value.

## Reforestation

Planting of forests on lands that have previously contained forests but that have been converted to some other use. For a discussion of the term forest and related terms such as afforestation, reforestation and deforestation, see the IPCC Report on Land Use, Land Use Change and Forestry (IPCC 2000).

## Retrofitting

Retrofitting means to install new or modified parts or equipment, or undertake structural modifications, to existing infrastructure that were either not available or not considered necessary at the time of construction. The purpose of retrofitting in the context of climate change is generally to ensure that existing infrastructure meets new design specifications that may be required under altered climate conditions.

## Scenario

A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from

## Sea ice

Any form of ice found at sea that has originated from the freezing of sea water. Sea ice may be discontinuous pieces (ice floes) moved on the ocean surface by wind and currents (pack ice), or a motionless sheet attached to the coast (land-fast ice). Sea ice less than one year old is called first-year ice. Multi-year ice is sea ice that has survived at least one summer melt season.

## United Nations Framework Convention on Climate Change (UNFCCC)

The Convention was adopted on 9 May 1992 in New York and signed at the 1992 Earth Summit in Rio de Janeiro by more than 150 countries and the European Community. Its ultimate objective is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". It contains commitments for all Parties. Convention entered in force in March 1994.

## Voluntary action

Informal programmes, self commitments and declarations, where the parties (individual companies or groups of companies) entering into the action set their own targets and often do their own monitoring and reporting.

## Vulnerability

Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

## Water consumption

Amount of extracted water irretrievably lost during its use (by evaporation and goods production). Water consumption is equal to water withdrawal minus return flow.

## Water stress

A country is water stressed if the available freshwater supply relative to water withdrawals acts as an important constraint on development. In global-scale assessments, basins with water stress are often defined as having a per capita water availability below 1,000 m<sup>3</sup>/yr (based on long-term average runoff). Withdrawals exceeding 20% of renewable water supply have also been used as an indicator of water stress. A crop is water stressed if soil available water, and thus actual evapotranspiration, is less than potential evapotranspiration demands.

## Annex III

### Acronyms, chemical symbols, scientific units

BMA	Bangkok Metropolitan Administration
BAU	business as usual
CDIAC	Carbon Dioxide Information Analysis Center
CH <sub>4</sub>	Methane
CFC	Chlorofluorocarbon
CO <sub>2</sub>	Carbon dioxide
DDS	Department of Drainage and Sewerage
DO	Dissolved Oxygen
ENSO	El Niño-Southern Oscillation
GDP	gross domestic product
GHG	Green House Gas
HCFC	Hydro chlorofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
MSL	mean sea level
NOAA	National Oceanic and Atmospheric Administration
N <sub>2</sub> O, NO <sub>x</sub>	Nitrous oxide
UNFCCC	United Nations Framework Convention on Climate Change

## Scientific units

### SI (System International) units

Physical quantity	Name of unit	Symbol
Length	Metre	M
Mass	Kilogramme / ton	Kg / ton
Volume	Cubic Metre	m <sup>3</sup>

### Non-SI units, quantities and related abbreviations

°C	degrees celsius (0°C = 273 kelvin approximately); temperature differences are also given in °C (=K) rather than the more correct form of "Celsius degrees"
ppm	mixing ratio (as concentration measure of GHGs): parts per million (10 <sup>6</sup> ) by volume
ppb	mixing ratio (as concentration measure of GHGs): parts per billion (10 <sup>9</sup> ) by volume
ppt	mixing ratio (as concentration measure of GHGs): parts per trillion (10 <sup>12</sup> ) by volume
Watt	power or radiant flux; 1 watt = 1 Joule / second = 1 kg m <sup>2</sup> / s <sup>3</sup>
yr	year
Ky	thousands of years
CO <sub>2</sub> -eq	carbon dioxide-equivalent, used as measure for the emission (generally in GtCO <sub>2</sub> - eq) or concentration (generally in ppm CO <sub>2</sub> -eq) of GHGs





