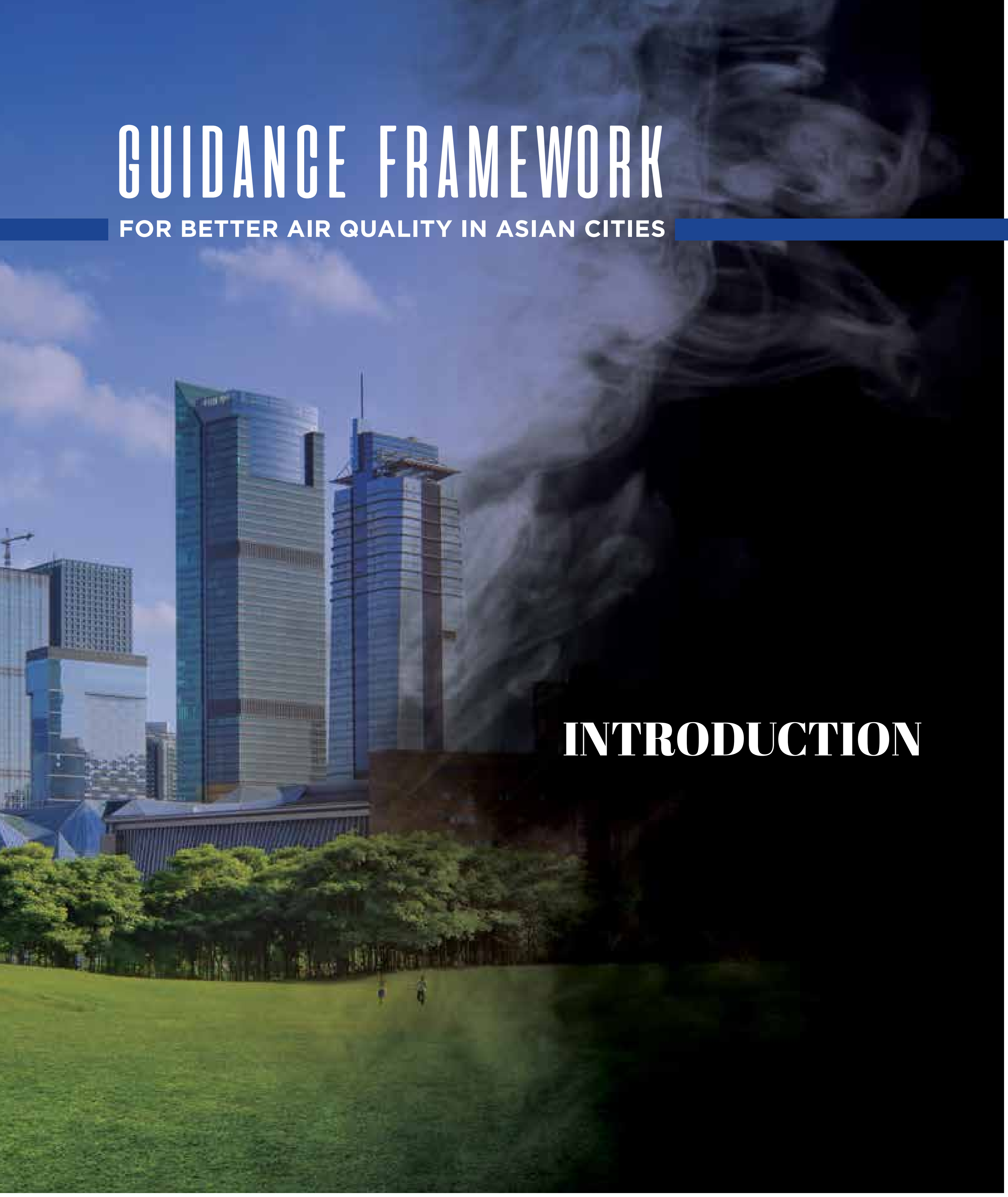
GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES



INTRODUCTION

Integrated Programme for Better Air Quality in Asia

UNEP

CLEAN AIR ASIA

GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES

Introduction

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ABOUT THE GUIDANCE FRAMEWORK FOR BETTER AIR QUALITY IN ASIAN CITIES

The Guidance Framework is a voluntary and non-binding guidance document developed as an outcome of the biennial Governmental Meetings on Urban Air Quality in Asia, co-organized by Clean Air Asia and United Nations Environment Programme Regional Office for Asia Pacific (UNEP ROAP). It is an outcome of an extensive development process, which began in 2006 when the Long Term Vision for Urban Air Quality in Asia (LTV) was envisioned by representatives of environment ministries in the region. The LTV describes the desired state of urban air quality in Asian cities by 2030; the Guidance Framework serves as a guide for cities and countries to achieve this vision. In 2016, the Guidance Framework was launched as a pioneering approach to resolve air pollution challenges at the local- and national-levels. Centered on identified priority areas of concern in air quality management in the region, the Guidance Framework provides cities and countries with development capacity indicators and recommended steps and actions to improve air quality.

The Guidance Framework serves as a cornerstone document of Clean Air Asia's Integrated Programme for Better Air Quality in Asia (IBAQ Programme), which supports countries and cities in implementing the Guidance Framework through a range of targeted interventions, including knowledge-sharing platforms to strengthen regional collaboration, capacity building activities such as trainings, study tours and city twinning, and technical assistance at both the national and subnational levels.

ABOUT CLEAN AIR ASIA

www.cleanairasia.org

Clean Air Asia is an international NGO established in 2001 as the premier air quality network for Asia by the Asian Development Bank, World Bank and USAID. Its mission is to promote better air quality and livable cities by translating knowledge to policies and actions that reduce air pollution and greenhouse gas emissions from transport, energy and other sectors.

Clean Air Asia became a UN-recognized partnership in 2007, its network spanning 261 organizations in 31 countries in Asia and worldwide, with nine country networks: China, India, Indonesia, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, and Vietnam. It is headquartered in Manila and has offices in Beijing and Delhi. Clean Air Asia leads efforts to enable Asia's more than 1000 cities to reduce both air pollution and CO_2 emissions, and thereby contribute to more livable and healthy cities with blue skies and a low carbon footprint. Clean Air Asia helps to reduce emissions, through policies, plans, programs, and concrete measures that cover air quality, transport and industrial emissions and energy use.

The Better Air Quality (BAQ) Conference is a flagship event of Clean Air Asia covering the key sectors of transport, energy and industry, with a particular emphasis on government policies and measures. Policymakers, practitioners and industry leaders meet at BAQ to network, innovate, learn, and share experiences. The biennial event was first held in 2002 and attracts close to a thousand participants from Asia and the rest of the world.

ABOUT UNEP

www.unep.org

The United Nations Environment Programme (UNEP) is the leading global environmental authority that sets the global environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and serves as an authoritative advocate for the global environment. UNEP work encompasses assessing global, regional and national environmental conditions and trends; developing international and national environmental instruments; and strengthening institutions for the wise management of the environment. UNEP's mission includes to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

CONTENTS

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ABBREVIATIONS

AAQS	Ambient Air Quality Standards
ADB	Asian Development Bank
APCAP	Asia Pacific Clean Air Partnership
AQM	Air Quality Management
BC	Black Carbon
CAAP	Clean Air Action Plan
CH_4	Methane
CO_2	Carbon dioxide
EI	Emissions Inventory
GHG	Greenhouse Gas
IEA	International Energy Agency
LTV	Long-Term Vision for Urban Air Quality in Asia
O_3	Ozone
PM	Particulate Matter
PM_{10}	Particulate Matter (≤ 10 micrometers in diameter)
$PM_{2.5}$	Particulate Matter (≤ 2.5 micrometers in diameter)
QA	Quality Assurance
QC	Quality Control
SA	Source Apportionment
SDGs	Sustainable Development Goals
SLCPs	Short-lived Climate Pollutants
SOP	Standard Operating Procedure
UN	United Nations
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
UNEP ROAP	United Nations Environment Programme Regional Office for Asia Pacific
USEPA	United States Environmental Protection Agency
WHA	World Health Assembly
WHO	World Health Organization

FOREWORD

Bjarne Pedersen
Executive Director, Clean Air Asia

One of the greatest environmental challenges we face today is air pollution. It is a priority issue for Asian cities, with the health impacts alone a cause for great concern and suffering. In 2012 there were 2.6 million deaths in the Western Pacific and South-East Asia regions attributable to ambient air pollution. And in 2015, a Clean Air Asia survey of more than 400 cities found that seven out of 10 cities in developing Asian countries had unhealthy air quality based on average annual PM_{10} levels.

In response to this situation, Clean Air Asia and the United Nations Environment Programme Regional Office for Asia Pacific were encouraged by environment ministries during Governmental Meetings on Urban Air Quality in Asia to develop a Long-Term Vision for Urban Air Quality in Asia.

The result is this Guidance Framework for Better Air Quality in Asian Cities, which provides cities with concrete and realistic roadmaps to help them fully develop their air quality management capacity, and which Clean Air Asia is committed to supporting cities and countries in implementing.

Clean Air Asia encourages both cities and national governments, as well as stakeholders and the public, to use the Guidance Framework to bolster their understanding of local needs and challenges for the implementation of effective clean air strategies.

We extend our appreciation to the environment ministries and the UNEP ROAP for their support in this endeavor, and to the regional and international experts from various organizations who contributed to the development of the Guidance Framework.

We trust that the Guidance Framework will be a valuable resource for the region in moving towards better air quality.

EXECUTIVE SUMMARY

Air pollution is now considered the world's largest environmental health risk. The World Health Organization attributed seven million global premature deaths in 2012 to the joint effects of household (indoor) and ambient (outdoor) air pollution. People living in Asia are most at risk of ambient air pollution, which now ranks among the top five or six risks in the continent's developing countries. More than 2.6 million premature deaths attributed to ambient air pollution were reported in the Western Pacific and South East Asian regions.

Ambient air pollution primarily concerns urban populations, which now comprise more than 50 percent of the world's population. The continuing trend of rapid urbanization – compounded by Asian Development Bank's projections that by 2025, 21 of the world's 37 megacities will be in Asia – places the region at great risk. Much of the burden of air pollution comes from a rise in the demand for energy and mobility. This puts additional pressure on the existing limited supplies of energy, particularly from emerging Asian economies. If the trend continues, or if more sustainable measures are not implemented, air pollution impacts could negate some of the region's economic gains. However, with the appropriate frameworks and policies, air pollution control measures can capture synergies and minimize trade-offs in addressing climate change. The application of the co-benefits approach of addressing air and climate pollutants helps identify and implement win-win strategies that help meet the economic and social development needs of developing Asian countries.

There have been a number of global efforts calling for air pollution actions in recent years. In 2014, the first United Nations Environment Assembly (UNEA) adopted a resolution calling on governments to "formulate action plans and establish and implement nationally determined ambient air quality standards" and "to establish emissions standards for their significant sources of air pollution". Air pollution was also prominently discussed at the 68th World Health Assembly (WHA) in May 2015, which passed the landmark resolution on "Health and the Environment: Addressing the health impact of air pollution". These global calls for action on air pollution strengthen regional and national initiatives, and highlight the need to prioritize addressing this issue via a collaborative and integrated approach.

In the Asia Pacific region, a large number of regional processes and air pollution abatement initiatives have been operational for a number of years. Recent episodes of "airpocalypse" serve as a wake-up call for Asia and the world, and serves as motivation to advance air quality action by national and city governments to a fully developed stage of air quality management (AQM).

The Guidance Framework for Better Air Quality in Asian Cities (Guidance Framework) – which is meant to be a "living document" that will evolve with its users – offers guidance for policymakers and decision makers in key AQM components to help them progress through the development stages of AQM. The development of the Guidance Framework is a result of discussions at the biennial Governmental Meetings on Urban Air Quality in Asia organized by the United Nations Environment Programme Regional Office for Asia Pacific (UNEP ROAP) and Clean Air Asia to harmonize approaches in tackling urban air pollution and other related areas among Asian countries. The Guidance Framework intends to provide recognized guidance for implementing the Long Term Vision for Urban Air Quality in Asia (LTV), which describes the desired state of urban air quality in Asian cities by 2030.

The vision and indicator of the LTV are as follows:

Vision: Healthy people in healthy cities, which puts emphasis on the prevention of air pollution, and which implements effective strategies for the abatement of air pollution.

Indicator: Asian cities have made significant progress towards achieving WHO air quality guideline values through the implementation of comprehensive air quality management strategies.

The primary target audience of the Guidance Framework are policymakers and decision makers at the national and local levels who are responsible for improving urban air quality. The Guidance Framework also provides information and recommendations to other relevant stakeholders who can support initiatives to improve air quality in cities:

Development organizations, the private sector, non-governmental organizations and other civil society groups, the media and academia.

The Guidance Framework complements and operates within a framework of strategic AQM. The document is organized around identified priority areas of concern in the region, which were then translated into six guidance areas. Each guidance area provides key indicators of development stages of AQM which aid cities in identifying additional and appropriate action necessary to effectively progress towards better air quality. Recommended steps to follow to implement distinct roadmaps for each guidance area are also provided.

Guidance Area 1: Ambient air quality standards and monitoring

Establishing/strengthening ambient air quality standards (AAQS) and sustainable national and local air quality monitoring systems is important to understand the status of air quality and air quality standards for public health and environment protection. The roadmap presents key action points – informed by international and regional experiences – to guide the development of AAQS. It is recommended to undertake a periodic review of AAQS as well as strengthen a sustainable air quality monitoring system to support AAQS development and enforcement. Compliance with these standards should then be linked with the development of Clean Air Action Plans (CAAPs) and other sector/development plans. Sustainable air quality monitoring systems provide data for modeling evaluation and contribute to health impact studies to appropriately inform populations-at-risk of the impacts of air pollution, with air quality standards as reference.

Guidance Area 2: Emissions inventories and modeling

It is necessary to develop an accurate and reliable emissions inventory (EI) and apply dispersion and receptor modeling techniques to have a better understanding of air pollution sources and their characterization to guide the development of CAAPs and related environmental and developmental plan and policies. The roadmap identifies steps to strengthen capacity to quantify pollutants, determine source contributions and evaluate existing and future emissions to help design CAAPs. It highlights the importance of enhancing the accuracy and reliability of EI and improving receptor-based modeling capacity while enriching technical knowledge for actual measurement and calculations. The development of localized dispersion models is essential to adapt and evaluate dispersion models for local conditions, starting with simple models and moving towards the application of more sophisticated techniques to enhance evidence base for AQM policies.

Guidance Area 3: Health and other impacts

Air pollution contributes to significant health and other impacts. Improved understanding of the impacts of air pollution informs CAAP development and helps engage stakeholders in this issue. Multi-stakeholder approaches contribute to effective co-management of air pollution as well as greenhouse gas (GHG) emissions, leading to significant co-benefits with regards to public health. The roadmap lays out the direction towards strengthening the capacity for health and other impact assessments. It is recommended to increase the accessibility of information and ensure the availability of health surveillance systems and air quality databases for exposure modeling. The roadmap is accompanied by a step-by-step guide on developing a health impact assessment.

Guidance Area 4: Air quality communication

This guidance area entails the development of an effective communication strategy to inform, educate, and strengthen stakeholder participation in all aspects of AQM. The roadmap for air quality communication presents measures that ensure the availability and accessibility of air quality monitoring data, the use of appropriate communication channels, the conducting of public warnings and forecasts, and the dissemination of comprehensive and non-technical information on the status of AQM to relevant stakeholders. The roadmap also provides guidance on communicating the co-benefits of air quality and climate change, highlighting how the inclusion of air quality benefits, specifically economic costs, in the design of climate strategies can be used to convince stakeholders to take action, and vice versa. An eight-step guide to develop an effective air quality communication plan is provided for stakeholders.

Guidance Area 5: Clean air action plans

A CAAP needs to be developed by cities and countries to include and/or legally strengthen AQM in relevant policies and

legislations, with the ultimate goal of improving air quality. The roadmap for CAAP details steps that enable governments and other stakeholders to identify appropriate policies and regulations, building on an understanding of the sources of air pollution and the status of air quality. Recommended components of a CAAP and case studies on the different developmental stages of CAAP development and implementation are provided.

Guidance Area 6: Governance

The environment and stakeholders can benefit from good air quality governance approaches in cities and countries in Asia. Effective governance aims to facilitate effective policy development and enforcement. Effective governance also educates and strengthens stakeholder participation in all aspects of AQM to prevent and reduce the impacts of air pollution. A roadmap for improving air quality governance presents the key steps needed to ensure clear, implementable and enforceable environmental policies and measures. Achieving an enabling environment for the implementation of measures with a clear institutional mandate and effective institutional arrangements is the key to reducing air pollution.

LOOKING FORWARD: Guidance Framework Implementation

Clean Air Asia is keen to support countries and cities in implementing the Guidance Framework as part of the IBAQ Programme. The range of activities include knowledge-sharing platforms to strengthen regional collaboration, capacity building activities (such as training, study tours, city twinning), and technical assistance at national and subnational levels to improve air quality using the Guidance Framework.

CHAPTER 1

INTRODUCTION

> There is a growing recognition of the opportunity to save lives with cleaner air. Nowhere is this opportunity greater than in Asia.

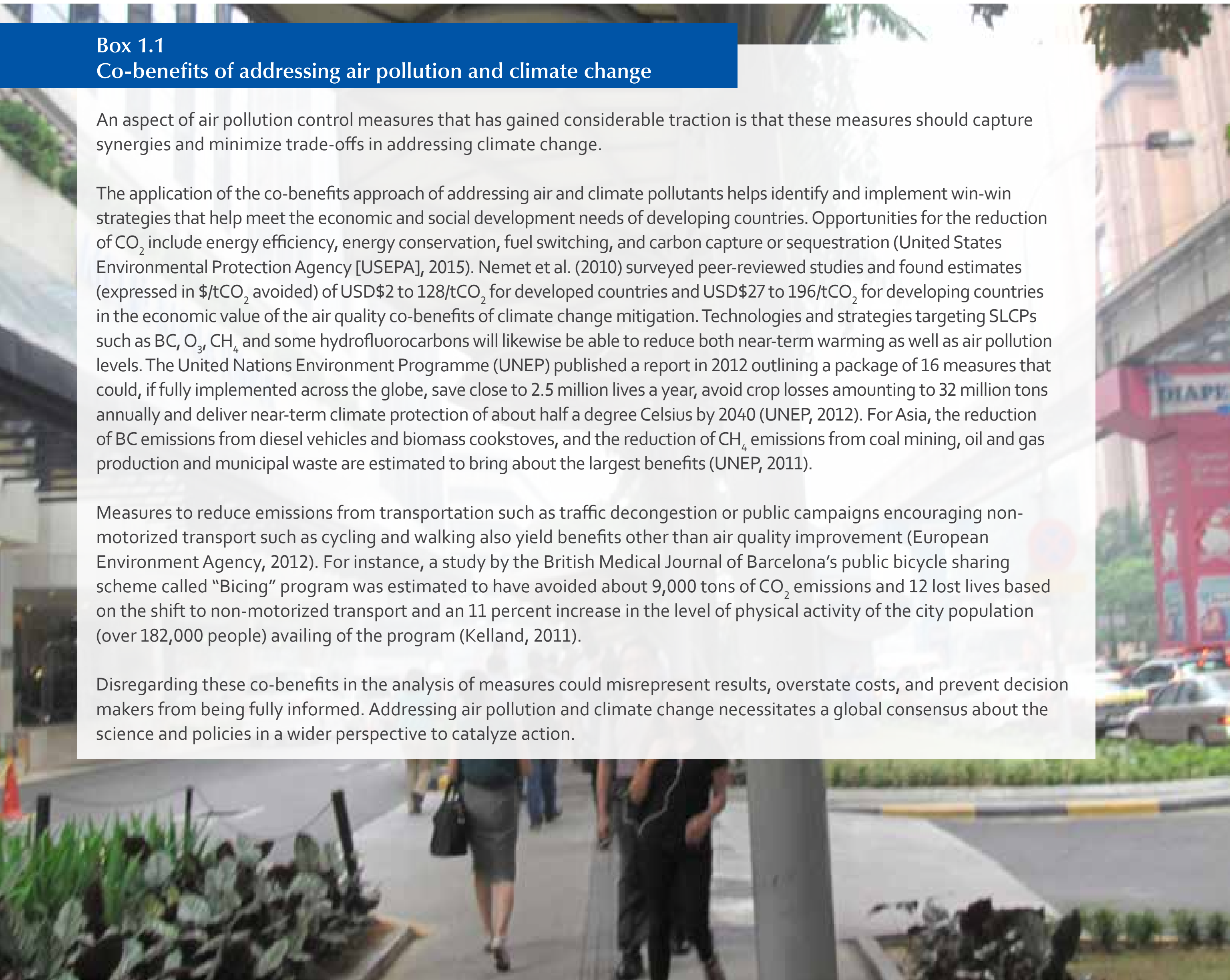
Air pollution is now considered the world's largest environmental health risk. Seven million global deaths in 2012 can be attributed to the joint effects of household (indoor) and ambient (outdoor) air pollution, according to World Health Organization's (WHO) latest estimates (WHO, 2014a).

Ambient or outdoor air pollution primarily concerns urban populations, which now comprise more than 50 percent of the world's population (United Nations [UN], 2014a). According to the World Urbanization Prospects of the United Nations, as of 2014, 16 of the world's 28 megacities (cities with more than 10 million citizens) were located in Asia. This trend of rapid urbanization in Asia is expected to continue. The Asian Development Bank (ADB) forecasts that by 2025, 21 of the world's 37 megacities will be in Asia as economic growth continues in the region (ADB, 2010).

People living in Asia are most at risk of ambient air pollution, which now ranks among the top five or six risks in the continent's developing countries (Lim et al., 2012). More than 2.6 million deaths attributed to ambient air pollution were reported in the Western Pacific and South-East Asia regions (WHO, 2014b). A 2014 survey by Clean Air Asia found seven out of 10 cities in developing Asian countries had unhealthy air pollution levels based on annual average PM_{10} levels (updated from ADB & Clean Air Asia, 2014).

The Asian Development Outlook (ADB, 2014) projects steady economic growth for developing Asia as a whole, with GDP forecasts of 6.1 percent in 2012 to 6.4 percent in 2015. With rapid urbanization - *vis a vis* continuing economic growth - comes a rise in the demand for road transport in urban areas, increased pollution from the surge in motor vehicle kilometers, and additional pressure on the existing limited supply of energy, predominantly fossil fuels such as oil and coal. Emerging Asian economies, notably China, India and, to a certain extent, South-East Asian countries - will account for more than 90 percent of net energy demand growth to 2035 (International Energy Agency [IEA], 2013a).

Fossil fuels, which currently account for about 80 percent of the world's energy supply, are a significant source of emissions. Worldwide, carbon dioxide (CO_2) emissions are expected to increase by 57 percent between 2005 and 2030, with China and India accounting for half of the growth (IEA, 2013b). Cities, in particular, are responsible for about 70 percent of global greenhouse gases (GHGs) (UN Habitat, 2011): CO_2, the most abundant GHG emitted through anthropogenic activities, has warming influences on the climate in the long-term; while short-lived climate pollutants (SLCPs) such as black carbon (BC) (a primary component of particulate matter (PM)), methane (CH_4) and ozone (O_3) have warming influences on the climate in the near-term (Climate and Clean Air Coalition, 2014; UN Habitat, 2011; UNEP 2014a). If the trend continues or if more sustainable measures, such as shift to renewable sources of energy, are not implemented, air pollution impacts could potentially negate some of the region's economic gains. However, win-win strategies are possible with the right frameworks and policies, particularly those recognizing the co-benefits of addressing air pollution and climate change (Box 1.1).



Box 1.1
Co-benefits of addressing air pollution and climate change

An aspect of air pollution control measures that has gained considerable traction is that these measures should capture synergies and minimize trade-offs in addressing climate change.

The application of the co-benefits approach of addressing air and climate pollutants helps identify and implement win-win strategies that help meet the economic and social development needs of developing countries. Opportunities for the reduction of CO_2 include energy efficiency, energy conservation, fuel switching, and carbon capture or sequestration (United States Environmental Protection Agency [USEPA], 2015). Nemet et al. (2010) surveyed peer-reviewed studies and found estimates (expressed in \$/tCO_2 avoided) of USD\$2 to 128/tCO_2 for developed countries and USD\$27 to 196/tCO_2 for developing countries in the economic value of the air quality co-benefits of climate change mitigation. Technologies and strategies targeting SLCPs such as BC, O_3, CH_4 and some hydrofluorocarbons will likewise be able to reduce both near-term warming as well as air pollution levels. The United Nations Environment Programme (UNEP) published a report in 2012 outlining a package of 16 measures that could, if fully implemented across the globe, save close to 2.5 million lives a year, avoid crop losses amounting to 32 million tons annually and deliver near-term climate protection of about half a degree Celsius by 2040 (UNEP, 2012). For Asia, the reduction of BC emissions from diesel vehicles and biomass cookstoves, and the reduction of CH_4 emissions from coal mining, oil and gas production and municipal waste are estimated to bring about the largest benefits (UNEP, 2011).

Measures to reduce emissions from transportation such as traffic decongestion or public campaigns encouraging non-motorized transport such as cycling and walking also yield benefits other than air quality improvement (European Environment Agency, 2012). For instance, a study by the British Medical Journal of Barcelona's public bicycle sharing scheme called "Bicing" program was estimated to have avoided about 9,000 tons of CO_2 emissions and 12 lost lives based on the shift to non-motorized transport and an 11 percent increase in the level of physical activity of the city population (over 182,000 people) availing of the program (Kelland, 2011).

Disregarding these co-benefits in the analysis of measures could misrepresent results, overstate costs, and prevent decision makers from being fully informed. Addressing air pollution and climate change necessitates a global consensus about the science and policies in a wider perspective to catalyze action.

The Guidance Framework for Better Air Quality in Asian Cities – meant to be a **"living document"** that will evolve with its users – **offers guidance** for policymakers and decision makers to **help them progress** through the development stages of air quality management.

There have been a number of global efforts calling for air pollution actions in recent years. In 2014, the first United Nations Environment Assembly (UNEA) adopted a resolution calling on governments to "formulate action plans and establish and implement nationally determined ambient air quality standards" and "to establish emissions standards for their significant sources of air pollution" (UNEP, 2014c). At the United Nations Climate Summit in New York City in September 2014, world leaders agreed that climate action needed to be undertaken within the context of poverty eradication and the promotion of sustainable development. A significant reduction in emissions was recognized as the critical first step towards meaningful climate action (UN, 2014b). The Sustainable Development Goals (SDGs) provide opportunities to scale up policies and action on air pollution and mitigating its impacts on health, climate, and the environment. Air pollution was also prominently discussed at the 68th World Health Assembly in May 2015, which passed a landmark resolution on "Health and the Environment: Addressing the health impact of air pollution". The resolution recognized 13 measures for member states to implement in order to reinforce the capacity of member states and cities to reduce air pollution and benefit health and climate in the near term. These measures come with cross-cutting actions including enabling health systems to lead awareness-raising among all stakeholders about the impacts of air pollution on health, developing guidelines for reducing or preventing exposure, and fostering inter-sectoral collaboration for action (WHO, 2015).

The global calls for action on air pollution bolster regional and national initiatives and highlight the need to prioritize addressing this issue via a collaborative and integrated approach, particularly in areas where the burden of air pollution is high. In the Asia Pacific region, a large number of regional processes and air pollution abatement initiatives have been operational for a number of years. The need to synergize these processes and initiatives was identified during the Combined Meeting of Consultation Meeting for the Joint Forum for Clean Air in Asia and the Pacific and the Fifth Governmental Meeting on Urban Air Quality in Asia – organized by UNEP ROAP and Clean Air Asia – in November 2014 in Colombo, Sri Lanka. As a response to the call by countries for immediate and coordinated action to deal with air pollution and its impacts – as well as to follow up on countries' actions in implementing the UNEA and WHA resolutions – the Joint Forum of the Asia Pacific Clean Air Partnership (APCAP Joint Forum) was set up by UNEP ROAP.

The demand for cleaner air is gaining momentum, particularly with recent episodes of "airpocalypse" serving as a wake-up call for Asia and the world. Nowhere is this opportunity greater than in Asia. With suitable policies in place and proven technologies available, rapidly growing Asian economies have the opportunity to advance cost-effective improvement measures in air quality to a level that it took several decades to attain in developed countries. This document aims to guide and help policymakers and other stakeholders concerned about air quality for Asia's current and future generations.

The Guidance Framework for Better Air Quality in Asian Cities – meant to be a "living document" that will evolve with its users – offers guidance for policymakers and decision makers in key AQM components to help them progress through the development stages of AQM.

LONG TERM VISION FOR URBAN AIR QUALITY IN ASIA

Vision: Healthy people in healthy cities, which puts emphasis on the **prevention of air pollution**, and which implements **effective strategies** for the abatement of air pollution.

Indicator: Asian cities have made **significant progress** towards achieving WHO **air quality** guideline values through the implementation of **comprehensive AQM strategies.**

1.1 Guidance Framework for Better Air Quality in Asian Cities

The Guidance Framework for Better Air Quality in Asian Cities (Guidance Framework) intends to provide recognized guidance in implementing the Long Term Vision for Urban Air Quality in Asia (LTV), which describes the desired state of urban air quality in Asian cities by 2030 (UNEP & Clean Air Asia, 2008). The vision and indicator of the LTV as agreed upon by the country representatives are as follows:

Vision: "Healthy people in healthy cities, which puts emphasis on the prevention of air pollution, and which implements effective strategies for the abatement of air pollution."

Indicator: "Asian cities have made significant progress towards achieving WHO air quality guideline values through the implementation of comprehensive AQM strategies."

The Guidance Framework also supports the realization of the United Nations' Sustainable Development Goals, notably Goal 11: Make cities inclusive, safe, resilient, and sustainable; Goal 13: Take urgent action to combat climate change and its impacts; and Goal 3: Ensure healthy lives and promote well-being for all at all ages (Target: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination).

1.1.1 Target audience

The primary target audience of the Guidance Framework are policymakers and decision makers at the national and local levels who are responsible for improving urban air quality. The Guidance Framework also provides information and recommendations to other relevant stakeholders who can support initiatives to improve air quality in cities: Development organizations, the private sector, non-governmental organizations and other civil society groups, the media, and academia.

1.1.2 Development process

The development of the Guidance Framework is a result of discussions at the biennial Governmental Meetings on Urban Air Quality in Asia organized by UNEP ROAP and Clean Air Asia to harmonize approaches in tackling urban air pollution and other related areas among Asian countries. Countries that have participated in the Governmental Meetings include Afghanistan, Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Iran, Japan, Korea, Lao PDR, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, and Vietnam. Table 1.1 provides an overview of the past Governmental Meetings.

The Fourth Governmental Meeting identified priority areas of concern for Asia, which were then translated into the six guidance areas (Table 1.2). The current state of AQM in Asian cities varies widely. In general, AQM in Asia has not developed rapidly enough to respond to the changing urban landscape and evolving air pollution challenges. The Guidance Framework provides direction to address these challenges. The recommendations specified in each chapter outline corresponding points for action.

1.2 Air quality management framework

The Guidance Framework complements and operates within a framework of strategic AQM (Figure 1.1). This enables government authorities to set objectives to achieve and maintain good air quality and minimize impacts on human health and the environment. The key AQM components necessary for setting objectives to achieve and maintain clean air include (Stockholm Environment Institute, 2004):

(1) Air quality monitoring – results feed into a continuous process of improving air quality and having more stringent standards, the establishment of quality assurance/quality control (QA/QC processes), communicating air quality and co-benefits; and evaluating the effectiveness of policies and measures.
(2) Emissions – involve an understanding of emission sources and their contribution as relevant input in developing short-term, medium-term and long-term strategies, and the conducting of an emissions inventory.
(3) Air quality modeling – allows for better baseline data to provide more accurate air quality forecasts; allows pollutant concentration interpolation and extrapolation; and allows analysis of the efficacy of emission control strategies.
(4) Health, environmental, and economic risk assessments – strengthening and adoption of national and local programs that allow for better baseline estimates and inform better strategies to address these risks.
(5) Communication – involves developing communication and awareness-raising campaigns to mobilize political and public support for AQM;
(6) Policies – promote a participatory approach to policy

making and include AQM as an objective for sustainable development.

(7) Financing of AQM – acknowledgement of AQM as urgent and necessary to allow for funds to be earmarked for the conducting of AQM activities.

(8) Governance – includes policy instruments, institutional set-up and mechanisms, resources, periodic review, compliance monitoring and enforcement programs, capacity building and training.

Table 1.1 Overview of Governmental Meetings and their outcome

Governmental Meeting	Date and Location	Outcome
First Governmental Meeting	13-14 December 2006 in Yogyakarta, Indonesia	The meeting recommended the development of the LTV to help inspire Asian cities and countries in the establishment of their AQM policies and programs. Clean Air Asia and UNEP ROAP were encouraged to develop a vision document on AQM in Asian cities.
Second Governmental Meeting	12-13 November 2008 in Bangkok, Thailand	Representatives from 15 environmental ministries attended the meeting. Clean Air Asia and UNEP ROAP drafted the LTV. The draft document was circulated to all participating countries and its contents discussed during the meeting.
Third Governmental Meeting	8 November 2010 in Singapore	Seventeen senior officials from national environment ministries deliberated on the way forward in achieving Asia's LTV. Priority areas for the LTV were identified: • Conduct more health impact studies as a basis for policy development • Develop a roadmap for improving ambient air quality and emission standards in Asia • Optimize resources by sharing and aligning databases on air quality • Develop a mechanism for regional AQM (air basins) • Promote the co-benefits approach for policies and programs • Prepare an overview of regional forums, networks, and organizations at the national levels to facilitate cooperation at the regional level
Fourth Governmental Meeting	6 November 2013 in Bangkok, Thailand	The meeting, composed of thirty senior officials from national environment ministries, agreed on developing a Guidance Framework which will provide a recognized guidance in implementing the LTV.

Governmental Meeting	Date and Location	Outcome
Fifth Governmental Meeting	17-18 November 2014 in Colombo, Sri Lanka	The first draft of the Guidance Framework was presented. The meeting agreed that the Guidance Framework was useful for Asian cities and was comprehensive in terms of scope. The meeting also provided feedback on how to improve the draft document. The review and finalization process for the Guidance Framework was discussed. The final draft of the Guidance Framework was shared at the First APCAP Joint Forum and updates on implementation will be reported at the Sixth Governmental Meeting on Urban Air Quality in Asia.

Table 1.2 Overview of Guidance Areas

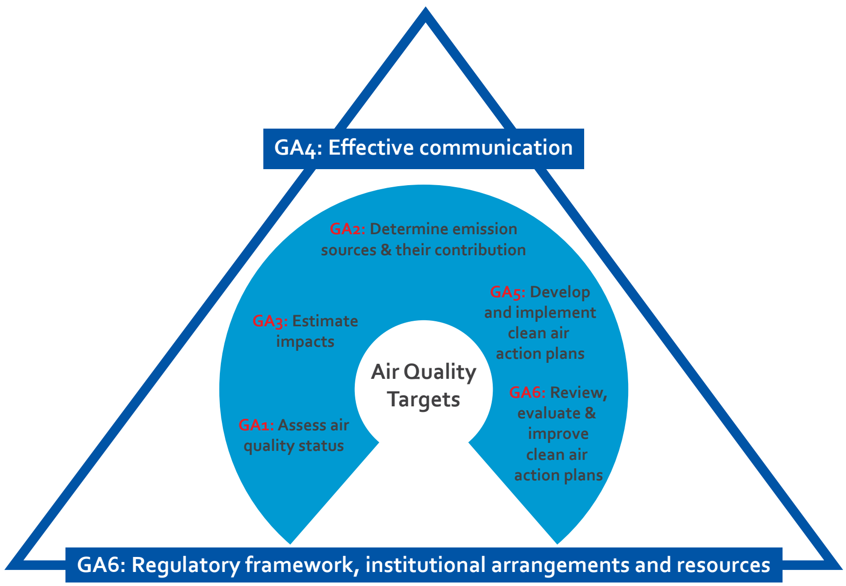
Priority areas of concern	Six Guidance Areas
Setting and strengthening national ambient air quality standards and improving air quality monitoring systems	Guidance Area 1: Ambient air quality standards and monitoring
Developing and updating emissions inventories, source apportionment, air quality modeling	Guidance Area 2: Emissions inventories and modeling
Linking air quality levels and emissions data with health impacts and their social and economic cost (including the link with climate change)	Guidance Area 3: Health and other impacts
Communicating air quality, health, and co-benefits information to government, other organizations and the public through Clean Air Reports, air quality indexes, mobile and web applications and other means.	Guidance Area 4: Air quality communication
Developing, implementing, and evaluating the effectiveness of clean air action plans, policies and measures (including co-benefits of climate change)	Guidance Area 5: Clean air action plans
Governance, covering compliance and enforcement, budgeting and financing, and institutional frameworks	Guidance Area 6: Governance

1.3 Structure of the Guidance Framework

The report is primarily organized around the six guidance areas within the AQM framework (Figure 1.1). Each chapter is provided as individual documents with a common Information Sourcebook, which is a compilation of resources to support the implementation of the Guidance Framework roadmaps. Each chapter includes: i) The objective of the guidance area and an overview of key concepts, ii) A definition of development stages that cities go through at different levels of AQM capacities, iii) An account of issues and challenges, and iv) A roadmap with recommended steps to follow in order to progress through the different development stages.

1.3.1 Development stages of air quality management

Cities can be classified according to their AQM capabilities. They could fall into any of these capability or development stages (Table 1.3): Underdeveloped, developing, emerging, maturing, or fully developed. These AQM development stages provide cities with the means with which to assess where they are on this continuum and attain the fully developed stage. The characteristics of each stage of AQM development are elaborated through indicators on data, capacity, public awareness and participation, regulatory structure and framework (**Annex VII of the Information Sourcebook).**



Note: GA = Guidance Area

Figure 1.1 Air Quality Management Framework

Table 1.3 Stages of air quality management

Stages	Indicators
Underdeveloped	There is generally little/no capacity, policies, information on, and mechanisms for AQM. The city's air quality is deteriorating due to the lack of control systems and mechanisms in place.
Developing	There is some capacity, policies, information on, and mechanisms for AQM in place but this is insufficient. Consequently, while air pollution levels at this stage remain high with associated serious health and environmental impacts, these are stabilizing and the trajectory can be reversed.
Emerging	Air quality management activities, policies, and communications are starting to be put in place and are starting to be implemented more regularly and systematically. There is some data available and used and there is demonstrated capacity at the operational level of staff, stakeholders, and institutions/ structures that support implementation.
Maturing	Air quality management activities, policies, and systems are regularly implemented, with review and monitoring systems in place to ensure quality control and the accuracy of information. These are supported by policies and governance processes that are more inclusive and varied to suit the different contexts at the national and subnational levels. There is a certain level of transparency such that information is communicated to a wider audience using different communication channels. The improvement of air quality is being achieved with the implementation of effective policies to reduce emissions.
Fully Developed	Where AQM activities, policies, and processes are in place, the focus is on ensuring the sustainability of the measures undertaken, the quality of data and research studies generated, and continuous improvement to existing measures through the upgrading of review and monitoring processes, leading to further improvements in air quality. Public participation is strengthened and supported by transparency in governance processes, regulations, and frameworks.

> In order to **achieve the Long-Term Vision**, the Guidance Framework provides **interrelated roadmaps with recommended steps** or action points for cities to progress from the stage they are currently at to the next stage of air quality management.

1.3.2 Guidance Framework roadmaps

The LTV encourages Asian cities to actively consider long-term strategies and integrate them into development planning to achieve improved air quality (UNEP & Clean Air Asia, 2008). In order to achieve the LTV, the Guidance Framework provides interrelated roadmaps with recommended steps or action points for cities to progress from the stage they are currently at to the next stage of AQM. The Guidance Framework Roadmap (Table 1.5) consists of steps categorized into:

- **Management processes** - pertain to management capacities, resources, and institutional arrangements (regulations, policies) that aid in decision-making;
- **Technical processes** – involve scientific knowledge and technical skills, tools, and equipment that are relevant to the implementation of identified measures; and
- **General considerations** – identify factors (such as needed finance and human resources, stakeholder involvement, and others) that facilitate and may potentially hinder the attainment of goals and/or effective implementation

Case studies are provided along with the recommended steps to illustrate the specific actions and successful efforts undertaken by cities or countries to improve aspects of AQM relevant to each guidance area. Each guidance area is provided as a separate chapter and are developed in such a way that they can be used separately to discuss and address a specific area or as a section of the document to tackle AQM issues in a holistic and more strategic manner.

1.4 Guidance Framework implementation

Cities need support to implement the Guidance Framework. Clean Air Asia is keen to support countries and cities in implementing the Guidance Framework as part of the IBAQ Programme. The range of activities include knowledge sharing platforms to strengthen regional collaboration, capacity building activities (i.e., training, study tours, city twinning), and technical assistance at national and subnational levels to improve air quality using the Guidance Framework. Capacity building will also be provided through training courses for cities in implementing the Guidance Framework.

Cities need **support** to implement the **Guidance Framework.**

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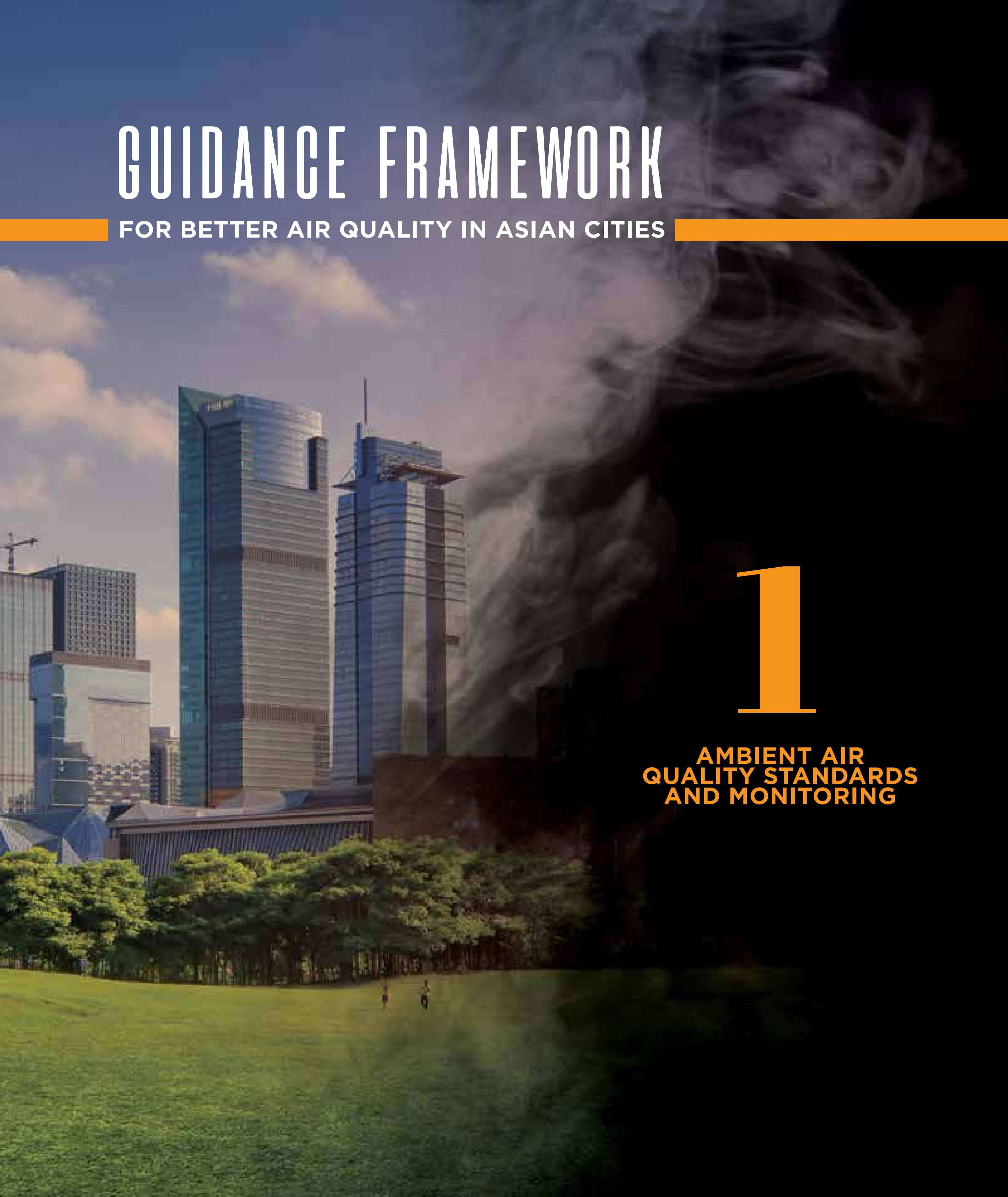
GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES



1

AMBIENT AIR QUALITY STANDARDS AND MONITORING

Integrated Programme for Better Air Quality in Asia

UNEP

CLEAN AIR ASIA

GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES

Guidance Area 1: Ambient Air Quality Standards and Monitoring

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ABOUT THE GUIDANCE FRAMEWORK FOR BETTER AIR QUALITY IN ASIAN CITIES

The Guidance Framework is a voluntary and non-binding guidance document developed as an outcome of the biennial Governmental Meetings on Urban Air Quality in Asia, co-organized by Clean Air Asia and United Nations Environment Programme Regional Office for Asia Pacific (UNEP ROAP). It is an outcome of an extensive development process, which began in 2006 when the Long Term Vision for Urban Air Quality in Asia (LTV) was envisioned by representatives of environment ministries in the region. The LTV describes the desired state of urban air quality in Asian cities by 2030; the Guidance Framework serves as a guide for cities and countries to achieve this vision. In 2016, the Guidance Framework was launched as a pioneering approach to resolve air pollution challenges at the local- and national-levels. Centered on identified priority areas of concern in air quality management in the region, the Guidance Framework provides cities and countries with development capacity indicators and recommended steps and actions to improve air quality.

The Guidance Framework serves as a cornerstone document of Clean Air Asia's Integrated Programme for Better Air Quality in Asia (IBAQ Programme), which supports countries and cities in implementing the Guidance Framework through a range of targeted interventions, including knowledge-sharing platforms to strengthen regional collaboration, capacity building activities such as trainings, study tours and city twinning, and technical assistance at both the national and subnational levels.

ABOUT CLEAN AIR ASIA
www.cleanairasia.org

Clean Air Asia is an international NGO established in 2001 as the premier air quality network for Asia by the Asian Development Bank, World Bank and USAID. Its mission is to promote better air quality and livable cities by translating knowledge to policies and actions that reduce air pollution and greenhouse gas emissions from transport, energy and other sectors.

Clean Air Asia became a UN-recognized partnership in 2007, its network spanning 261 organizations in 31 countries in Asia and worldwide, with nine country networks: China, India, Indonesia, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, and Vietnam. It is headquartered in Manila and has offices in Beijing and Delhi. Clean Air Asia leads efforts to enable Asia's more than 1000 cities to reduce both air pollution and CO_2 emissions, and thereby contribute to more livable and healthy cities with blue skies and a low carbon footprint. Clean Air Asia helps to reduce emissions, through policies, plans, programs, and concrete measures that cover air quality, transport and industrial emissions and energy use.

The Better Air Quality (BAQ) Conference is a flagship event of Clean Air Asia covering the key sectors of transport, energy and industry, with a particular emphasis on government policies and measures. Policymakers, practitioners and industry leaders meet at BAQ to network, innovate, learn, and share experiences. The biennial event was first held in 2002 and attracts close to a thousand participants from Asia and the rest of the world.

ABOUT UNEP
www.unep.org

The United Nations Environment Programme (UNEP) is the leading global environmental authority that sets the global environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and serves as an authoritative advocate for the global environment. UNEP work encompasses assessing global, regional and national environmental conditions and trends; developing international and national environmental instruments; and strengthening institutions for the wise management of the environment. UNEP's mission includes to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

CONTENTS

PREFACE

Air pollution is now considered the world's largest environmental health risk. There have been a number of global efforts calling for air pollution actions in recent years. These global calls for action on air pollution strengthen regional and national initiatives and highlight the need to prioritize addressing this issue through a collaborative and integrated approach.

In 2006, the First Governmental Meeting on Urban Air Quality in Asia[1] recognized the need for guidance in implementing a Long Term Vision for Urban Air Quality in Asia, which describes the desired state of urban air quality management in Asian cities. During the Third Governmental Meeting, environment ministries from the region identified key challenges they are facing to improve urban air quality.

To set the way forward in achieving the vision for cleaner air, Clean Air Asia led the development of the Guidance Framework for Better Air Quality in Asian Cities (Guidance Framework) to address the needs and challenges in the region. It aims to provide a recognized guidance on improving urban air quality and is organized around priority areas of concern in the region, which were translated into key guidance areas with roadmaps on how to progress in a step by step manner.

This voluntary, non-binding document consists of seven individually published chapters covering each of the Guidance Areas. Policy and decision makers in Asia, as well as other relevant stakeholders, can use one or a combination of the Guidance Framework chapters to develop local roadmaps or action plans depending on their priority areas of concern.

The Guidance Framework consists of seven main books with these titles:

- Introduction
- Guidance Area 1 - Ambient air quality standards and monitoring
- Guidance Area 2 - Emissions inventories and modeling
- Guidance Area 3 - Health and other impacts
- Guidance Area 4 - Air quality communication
- Guidance Area 5 - Clean air action plans
- Guidance Area 6 - Governance

These guidance areas come with an Information Sourcebook, which is a compilation of resources to support the implementation of Guidance Framework roadmaps. There is also an accompanying training course on Guidance Framework implementation, which is available online in the Clean Air Asia website and Integrated Programme for Better Air Quality (IBAQ Programme) website: www.cleanairasia.org/ibaq

The Guidance Framework was developed together with a team of international and regional experts and practitioners and has undergone an extensive review process through the Governmental Meetings and the involvement of external reviewers. The draft document was also shared in a number of international events, including the Asia Pacific Clean Air Partnership (APCAP) Joint Forum organized by UNEP ROAP in November 2015. The Guidance Framework was welcomed by participants from 24 countries in Asia and the Pacific, involving environment ministries, intergovernmental organizations, non-governmental organizations, and experts.

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1 Governmental Meetings on Urban Air Quality in Asia are biennial meetings organized by the United Nations Environment Programme Regional Office of Asia and the Pacific (UNEP ROAP) and Clean Air Asia that convene environment ministries with the aim to harmonize approaches across the region in tackling air pollution and related fields.

ABBREVIATIONS

AAQC	Ambient Air Quality Criteria
AAQD	Ambient Air Quality Directive
AAQG	Ambient Air Quality Guidelines
AAQGV	Ambient Air Quality Guideline Values
AAQS	Ambient Air Quality Standards
ADB	Asian Development Bank
APMA	Air Pollution and Megacities in Asia
ARB	Air Resources Board – State of California
AQ	Air Quality
AQG	Air Quality Guidelines
AQM	Air Quality Management
AQO	Air Quality Objectives
AQS	Air Quality Standards
CAA	Clean Air Act
CASAC	Clean Air Scientific Advisory Committee
CEMS	Continuous Emission Monitoring System
CO	Carbon monoxide
CO_2	Carbon dioxide
DEFRA (UK)	Department for Environment, Food, and Rural Affairs
EC	European Commission
EU	European Union
GAPF	Global Atmospheric Pollution Forum
GHG	Greenhouse Gas
ISA	Integrated Science Assessment
NAAQS	National Ambient Air Quality Standards
NO_x	Nitrogen oxides
NO_2	Nitrogen dioxide
NZIER	New Zealand Institute of Economic Research
OMB	United States Office of Management and Budget
O_3	Ozone
PA	Policy Assurance
Pb	Lead
PM	Particulate Matter
PM_{10}	Particulate Matter (≤ 10 micrometers in diameter)
$PM_{2.5}$	Particulate Matter (≤ 2.5 micrometers in diameter)
QA	Quality Assurance
QC	Quality Control
REA	Risk/Exposure Assessment
SEI	Stockholm Environment Institute
SIP	State Implementation Plan
SO_2	Sulfur dioxide
SOP	Standard Operating Procedure
TSP	Total Suspended Particulates
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WHO	World Health Organization

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CHAPTER 2

GUIDANCE AREA 1: AMBIENT AIR QUALITY STANDARDS AND MONITORING

2.1 Introduction

The establishment of standards is an important environmental management tool that will help protect public health and the natural environment. In the case of air pollution, air quality standards (AQS) prescribe the acceptable level of air quality (AQ) adopted by a regulatory authority as enforceable (Schwela et al., 2006). Air quality standards are differentiated according to: exposure – i.e. ambient (outdoor) or household (indoor); and what they intend to protect – primary standards for human health protection, and secondary standards for protection of animals, crops, vegetation, and buildings.

Air quality standards are established by taking into account various factors: prevailing exposure levels, technical feasibility, source control measures, abatement strategies, and social, economic and cultural conditions. These factors depend on a country's level of development and capability for air quality management (AQM) (World Health Organization [WHO], 2000 and WHO, 2005). Air quality standards necessitate the setting up of a reliable AQ monitoring system that evaluates trends of air pollution and compliance with these standards. Degrees of sophistication and sustainability of AQ monitoring networks and systems are often also linked with the country's economic conditions and commitment to environmental protection.

This guidance area will focus on management approaches surrounding ambient air quality standards (AAQS) and its AQ monitoring network.

To **establish and/or strengthen** air quality standards that would protect **public health and the environment**, and sustainable national and local **air quality monitoring** programs that would **enrich understanding** of air quality status.

2.1.1 Objective

To establish and/or strengthen air quality standards that would protect public health and the environment, and sustainable national and local air quality monitoring programs that would enrich understanding of air quality status.

2.1.2 Air quality standards

Various definitions surround the term AQS and related terms such as objectives, guideline values, criteria, and directives (Table 2.1). A review of the definitions of AQS shows that the term may have one or all of the following key components:

- Purpose – usually for protection of general public health or of sensitive groups, protection of environment;
- Pollutant type levels, average, time, and form – maximum allowable concentration, maximum number of exceedances from standards;
- Timescale – averaging period for concentration, target date for compliance/attainment;
- Regulatory/Voluntary – defines whether or not the standards are regulatory limits or recommendations/guides for resource management strategies; and
- Geopolitical boundary – city/province/country, special zones, and/or protected areas

Table 2.1 Summary of definitions of ambient air quality standards and related terms from different regulatory organizations

Terms related to air quality standards and their definitions		Organization/ Country	Key components
National Ambient Air Quality Standards (NAAQS)	Ambient air quality standard means a numerical expression of a specified concentration level for a particular air contaminant and the time averaging interval over which that concentration level is measured. It is a goal to be achieved in a stated time through the application of appropriate preventive and/or control measures. Primary standards set limits to protect public health, including the health of at-risk populations. Secondary standards set limits to protect public welfare, including protection against visibility impairment, damage to animals, crops, vegetation, and buildings.	United States Environmental Protection Agency (USEPA)	Indicator (e.g. PM_{10} [2], $PM_{2.5}$ [3], O_3 [4], etc.) Levels (e.g. 0.075 ppm for O_3, 12 µg/m^3 for $PM_{2.5}$, etc.) Averaging time (e.g. 1 hour, 24 hours, annual) Form (e.g. one exceedance per year)
Ambient Air Quality Standards (AAQS)	Ambient air quality standards define clean air, and are established to protect even the most sensitive individuals of the community. An air quality standard defines the maximum amount of a pollutant that can be present in outdoor air without harm to the public's health.	California Air Resources Board (ARB)	Same as U.S. NAAQS with lower concentration levels and more stringent requirements

2 Particulate matter with a diameter less than 10µm
3 Particulate matter with a diameter less than 2.5µm
4 Ground-level ozone

Terms related to air quality standards and their definitions		Organization/ Country	Key components
Air Quality Objectives (AQO)	These are policy targets generally expressed as a maximum ambient concentration to be achieved, either without exception or with a permitted number of exceedances, within a specified timescale.	Department for Environment, Food and Rural Affairs (DEFRA), UK	Timescale, maximum concentration and permitted exceedance
Air Quality Objectives (AQO)	These are limits on the acceptable presence of contaminants in the atmosphere, established by government agencies to protect human health and the environment. Generally expressed in terms of a concentration measured over a specific period of time. These are non-statutory limits used to assess air quality and to guide air management decisions – e.g., issuance of authorizations and advisories, and development of airshed management plans.	Ministry of Environment, British Columbia	Acceptable presence of contaminants Specific period of time
Ambient Air Quality Guideline Values (AAQGV)	These are the minimum requirements that outdoor air quality should meet in order to protect human health and the environment. Where air pollution levels breach guideline values, emissions reduction strategies should be implemented to improve air quality. Where levels do not breach the values, efforts should be made to maintain air quality and, if possible, reduce emissions. Guideline values should not be used as limits. If pollution approaches the guideline value, then air quality is comparatively poor and has been degraded from its background state.	Ministry for the Environment, New Zealand	Minimum air quality levels, averaging period, and guide resource management strategies
Ambient Air Quality Guidelines (AAQG)	These provide a basis for protecting public health from adverse effects of air pollutants to eliminate or reduce exposure to hazardous air pollutants and to guide national and local authorities in their risk management decisions. The WHO AAQGs are neither standards nor legally binding criteria and developed based on evaluation of most recent scientific evidence to offer guidance in reducing health impacts of air pollution.	WHO	Threshold levels Health risks Averaging period

Terms related to air quality standards and their definitions		Organization/ Country	Key components
Ambient Air Quality Criteria (AAQC)	It is a desirable concentration of a contaminant in air, based on protection against adverse effects on health or the environment. The term "ambient" is used to reflect general air quality independent of location or source of a contaminant. These are set with different averaging times appropriate for the effect that they are intended to protect against. Effects considered may be health, odor, vegetation, soiling, visibility, corrosion or other effects. Ambient air quality criteria may be changed from time to time based on new science.	Ontario Ministry of Environment, Canada	Desirable concentration guide Health and other effects
Ambient Air Quality Directives (AAQD)	The European Union (EU) ambient air quality directives set limits and targets for concentrations of various pollutants in outdoor air for the protection of health and ecosystems. It includes controls over fine particulate matter (PM).	EU	Health and ecosystems

Source: ARB, 2014; DEFRA, 2014; WHO, 2000a; Ministry for Environment New Zealand, 2002; Ontario Ministry of Environment, 2012; European Commission, 2008; Province of British Columbia, 2011; USEPA Region 4, 2014

For the benefit of this framework document, various terms (standards, criteria, objectives, and guidelines) will not be classified separately. This framework will also not make any distinction between a legally binding standard and a voluntary standard, but collectively call them AAQS. Lastly, this framework adopts WHO's definition: "A standard is the level of an air pollutant, such as a concentration or a deposition level, that is adopted by a regulatory authority as enforceable". Ambient air quality standards differ from country to country and may be above or below the respective WHO guideline value (WHO, 2000a).

2.1.3 Role of air quality standards in air quality management

Regardless of the manner of definition and establishment, the concept of AAQS is clearly an essential part of AQM or air pollution control.

In fact, the establishment of the NAAQS for the US, following the revisions of the Clean Air Act (CAA) Amendment in 1970, has been a main driver of the AQM system (Figure 2.1) (Bachmann, 2007; Chow et al., 2012).

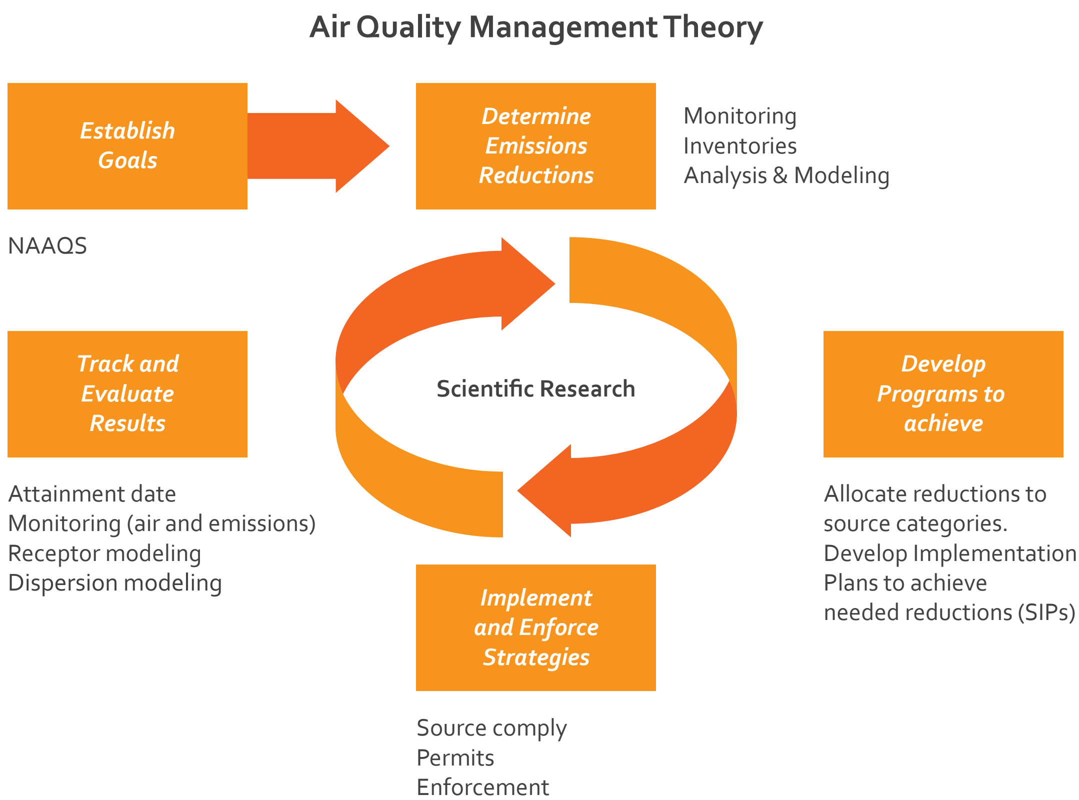

Figure 2.1 Conceptual Air Quality Management Framework
Source: Bachmann, 2007

Policies, including standards, should be set to maximize social benefits. Also, the cost of setting and enforcing AAQS should ideally be considered in order to assess their economic efficiency (Anderson and Ostro, 1982). Implementing AAQS translates into reduction in social cost of poor AQ – mortality and lost years of healthy life – as well as reduction in economic cost – hospital admissions and emergency department visits, outpatient visits, and workdays lost. Losses may include loss of output from mortality and from incapacitation due to health conditions, and may be temporary or permanent (New Zealand Institute of Economic Research, 2009).

There are uncertainties involved in measuring the economic benefits from AAQS; nevertheless, various assessments have shown that the benefits from enforcing AAQS far outweigh the costs of implementing control measures. A sample estimate of cost-benefit analysis of USEPA's 2006 NAAQS for PM alone has estimated benefits at a range of $4 billion-$40 billion per year and with estimated costs of $3 billion per year. Benefits are quantified despite some uncertainties in reducing premature deaths associated with lower PM and in monetary value of reducing mortality risk (United States Office of Management and Budget, 2013). The full attainment of the 2012 PM NAAQS by 2020 can gain as high as $2.9 billion (USEPA, 2012). The Thematic Strategy on Air Pollution that the European Commission (EC) adopted in 2005 – to achieve ambition levels for reducing the impacts of O_3 and $PM_{2.5}$ on health, acidification, and eutrophication on ecosystems – is projected to achieve a total of annual health and non-health benefits in the range of €42-€136 billion for the year 2020 (depending on what values are used for reduced mortality due to particulate matter). The health benefits (estimated at average annual costs of €94-€301) exceed costs (average annual costs of €15) for every EU citizen, by between six and 19 times (Holland, et al., 2005).

2.1.4 Establishing ambient air quality standards

Japan and Germany were two early adopters of AAQS. Japan promulgated a PM standard as early as 1932 and sulfur dioxide (SO_2) standards in 1969 (Wilkening, 2004). West Germany established AAQS for SO_2, PM, dust, nitrogen dioxide (NO_2), and carbon monoxide (CO) in 1964 (Bruckmann et al., 2014). Meanwhile, an early study also cited that the Union of Soviet Socialist Republics, Poland, Canada and Romania (for SO_2 only), as well as the western US state of California, were early adopters of AAQS in the 1960s (Stern, 1964). California's first statewide AAQS dating back to 1959 were set by the California Air Resources Board (ARB) for total suspended particulates (TSP), photochemical oxidants, SO_2, NO_2 and CO (ARB, 2014).

The WHO proposed its first air quality guidelines (AQGs) in 1972 followed by releases and updates in 1987, 2000 and 2005 (WHO, 1972; 1987; 2000a; 2000b; 2005; 2006). The AQG of 1972, 2000b, 2005 and 2006 are globally applicable, while those of 1987 and 2000a were for Europe only. These AQGs intended to provide the basis for protecting public health and the environment from the adverse effects of environmental pollutants and to guide national or local authorities in their risk assessment and risk management decisions (WHO, 2000a). These guidelines were developed and revised based on the growing body of knowledge on air pollution epidemiology and toxicology, as well as developments in risk assessment methods.

In earlier versions of the WHO guidelines, only one guideline was set for each pollutant at specific averaging periods. In the most recent update, however, the concept of interim targets was introduced to encourage countries with high pollution levels to shift to lower pollution levels and achieve significant reductions in health risks (Table 2.2).

Table 2.2 Summary of WHO ambient air quality guidelines (µg/m³)

Guideline/IT	PM_{10}		$PM_{2.5}$		O_3	NO_2		SO_2	
	Annual	24hr	Annual	24hr	Daily max 8hr mean	Annual	24hr	24hr	10min
WHO IT-1	70	150	35	75	160			125	
WHO IT-2	50	100	25	50				50	
WHO IT-3	30	75	15	37.5					
WHO AQG	20	50	10	25	100	40	200	20	500

Notes: AQG –air quality guideline; IT –interim target

Source: WHO, 2005

While the WHO AQGs are intended for worldwide use to achieve a safe AQ for public health, WHO recognizes that governments should consider their own local circumstances before directly adopting these guidelines as their own AQS. WHO further recognizes that countries differ in their level of development and AQM capability, their approach to balancing health risks, and their socioeconomic and political conditions.

When establishing AAQS, governments generally need to consider a number of scientific, social, technical and economic factors (Haq & Schwela, 2008) (Box 2.1).

Additional factors such as AQ monitoring data, existing AAQS in other countries, environmental epidemiology studies, and the WHO AQGs are considered most often in establishing or revising AAQS (Vahlsing & Smith, 2012). Air quality standards in Asia have mostly referred to the US NAAQS or WHO AQGs during their establishment; hence, this guidance area refers to the WHO process in developing and USEPA process in reviewing AAQS.

The US established its first set of NAAQS in 1971, shortly following the 1970 CAA Amendment and almost at the same time WHO released its first guidelines in 1972. As interpreted by the courts, the United States' CAA prohibits considering compliance costs in setting and reviewing AAQS, forcing USEPA to exclusively focus on protecting public health as the main driving factor (Anderson & Ostro, 1982). The US NAAQS, however, are of two types: primary standards that provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly; and secondary standards that provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings (USEPA, 2014) (Table 2.3). The NAAQS are required to be reviewed every five years and, if necessary, revised.

> While the **WHO air quality guideline values** are intended for worldwide use **to achieve a safe air quality** for public health, WHO recognizes that **governments** should consider their own **local circumstances** before directly adopting these **guidelines** as their own **air quality standards**.

Box 2.1
Factors considered in setting air quality standards

- **Sensitive receptors –** members of the human population more vulnerable to air pollution than the general population such as children, elderly, and disabled persons; components of the environment or a specific stage in biological organisms' development more sensitive than that of others
- **Pollutant behavior in the atmosphere –** the reactions the pollutant undergoes and its residence time in the atmosphere
- **Pollutant behavior in the environment** – the ability of a substance to bioaccumulate or biodegrade after entering the environment
- **Natural levels and fluctuations –** concentration levels and fluctuations of pollutants that occur naturally or enter the atmosphere from uncontrollable sources (e.g., volcanoes, deserts, forest fires)
- **Technological feasibility –** the cost and availability of technology to control or avoid emissions
- **Availability of resources for AQ monitoring–** suitable monitoring equipment and committed skillful labor to conduct the required monitoring activities should be ensured
- **Available resources for monitoring of AAQS enforcement and compliance–** may include setting compliance schedule for non-attainment areas, public disclosure of AQ information, and establishment of multisectoral panel to monitor enforcement of control measures (*vis a vis* emission standards), among others

Source: Adapted from Haq & Schwela, 2008

Table 2.3 Summary of US national ambient air quality standards

Pollutant	Primary/ Secondary	Averaging Time	Level	Form
CO	primary	8 hr	9 ppm	not to be exceeded more than once per year
		1 hr	35 ppm	
Pb	primary and secondary	rolling 3-month average	0.15 $\mu g/m^3$	not to be exceeded
NO_2	primary	1 hr	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3years
	primary and secondary	Annual	53 ppb	annual mean
O_3	primary and secondary	8 hr	0.075 ppm	annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
$PM_{2.5}$	primary	Annual	12 $\mu g/m^3$	annual mean, averaged over 3 years
	secondary	Annual	15 $\mu g/m^3$	
	primary and secondary	24 hr	35 $\mu g/m^3$	98th percentile, averaged over 3 years
PM_{10}	primary and secondary	24 hr	150 $\mu g/m^3$	not to be exceeded more than once per year on average over 3 years
SO_2	primary	1 hr	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	secondary	3 hr	0.5 ppm	not to be exceeded more than once per year

Source: USEPA, 2014

2.1.5 Reviewing the national ambient air quality standards

Considering the process of review of NAAQS in the US is worthwhile, given its long history. As required by the CAA, the standards are reviewed every five years and, if needed, revised. The review process follows five major phases and involves rigorous scientific reviews where all documents and drafts are reviewed by a Clean Air Scientific Advisory Committee (CASAC). Public hearings are held on the proposed decisions as part of the review process (Table 2.4).

An AAQS review process such as the one described can be expensive, and hence cannot be readily performed in less and least developed countries of Asia. In these cases, it is recommended that standard setting and review in those countries be based on the outcomes of the processes in WHO, USEPA and/or other developed countries. Since the WHO AQGs and their interim values were established using a rigorous evidence-based decision-making process, these can be readily chosen as a starting point for setting standards.

Table 2.4 Summary of national ambient air quality standards review process in the US

Phase	Description/Activities
Planning	A science policy workshop is organized to gather inputs from the scientific community and the public regarding policy-relevant issues and questions that will frame the review. The USEPA then prepares an Integrated Review Plan that presents the schedule for the entire review, the process for conducting the review, and the key policy-relevant science issues that will guide the review.
Integrated Science Assessment (ISA)	This assessment is a comprehensive review, synthesis, and evaluation of the most policy-relevant science, including key science judgments that are important to inform the development of the risk and exposure assessments.
Risk/Exposure Assessment (REA)	Following inputs from the ISA, REA develops quantitative characterizations of exposures and associated risks to human health or the environment associated with recent air quality conditions and with air quality estimated to just meet the current or alternative standard(s) under consideration. Risk exposure assessment includes characterization of the uncertainties associated with such estimates.
Policy Assessment (PA)	Policy Assessment provides a transparent staff analysis of the scientific basis for alternative policy options for consideration by senior USEPA management to help "bridge the gap" between the Agency's scientific assessments, presented in the ISA and REA(s), and the judgments required of the USEPA Administrator. In doing so, the PA is also intended to facilitate the CASAC's advice to the Agency and recommendations to the Administrator, as provided for in the CAA, on the adequacy of the existing standards or revisions that may be appropriate to consider. The PA focuses on evaluating the basic elements of the NAAQS: indicator, averaging time, form, and level.
Rulemaking	Taking into consideration the ISA, REA(s), and PA as well as the advice of CASAC, USEPA develops and publishes a notice of proposed rulemaking that communicates the Administrator's proposed decisions regarding the review of the NAAQS. A public comment period, during which public hearings are generally held, is taken into account before USEPA issues a final rule.

Source: USEPA, 2014

Regulatory authorities need to undertake **specific obligations** to ensure that the **standards** are implemented and met, taking into account the **cost of control strategies**.

2.1.6 Implementing national ambient air quality standards

The process does not end with issuing new or revised AAQS. Regulatory authorities need to undertake specific obligations to ensure that the standards are implemented and met, taking into account the cost of control strategies. The process takes years or even decades, especially for pollutants where the level of standards are not easily attainable. In the case of the US, within two years after the NAAQS promulgation, the USEPA must identify and designate attainment areas (meeting standards) and nonattainment areas (not-meeting standards) based on the most recent set of air monitoring data. Two types of State Implementation Plans (SIP) are then developed — an attainment-maintenance SIP if the area is designated as attainment, and an attainment-demonstration SIP if designated as nonattainment. A similar system is implemented in the EU where zones with a likelihood of an exceedance must be monitored more closely. Air quality management plans or programs are also developed to describe how those zones will come into attainment in the future. Another example of a process employed for either continual compliance determinations or determination of exceedances of AAQS is a Continuous Emission Monitoring System (CEMS) (USEPA, 2016) (See **Annex I of the Information Sourcebook**).

Another important area in AQM is multi-pollutant control. Understanding the complex interactions of pollutants with each other as well as their impacts is also critical in achieving better air quality and avoiding adverse impacts (Scheffe et al., 2009; Chow et al., 2012; Cao et al., 2013).

Many pollutants can be co-controlled. For example, reducing SO_2, nitrogen oxides (NO_x), and CO emissions may result in the reduction of CO_2, O_3 and PM. This approach would be more cost-effective than the implementation of single pollutant AQS.

Figure 2.2 shows simplified relationships and the interactions among various emissions sources, their primary pollutants, the transforming product (Intermediates) in the atmosphere, and the effects by most dominant pollutants. It should be noted that the residence time of each pollutant varies – e.g., from minutes to hours for ultrafine PM to over 100 years for carbon dioxide (CO_2) and some greenhouse gases (GHGs). The exposed concentration level, lag times and duration dictate the extent of adverse effects. Challenges for $PM_{2.5}$ -focused AQM will involve its interaction with these different pollutants and effects.

Moreover, secondary pollutants (i.e. ground-level O_3 from NO_x and VOCs) formed through diverse mechanisms in the atmosphere add to complex pollutant interactions.

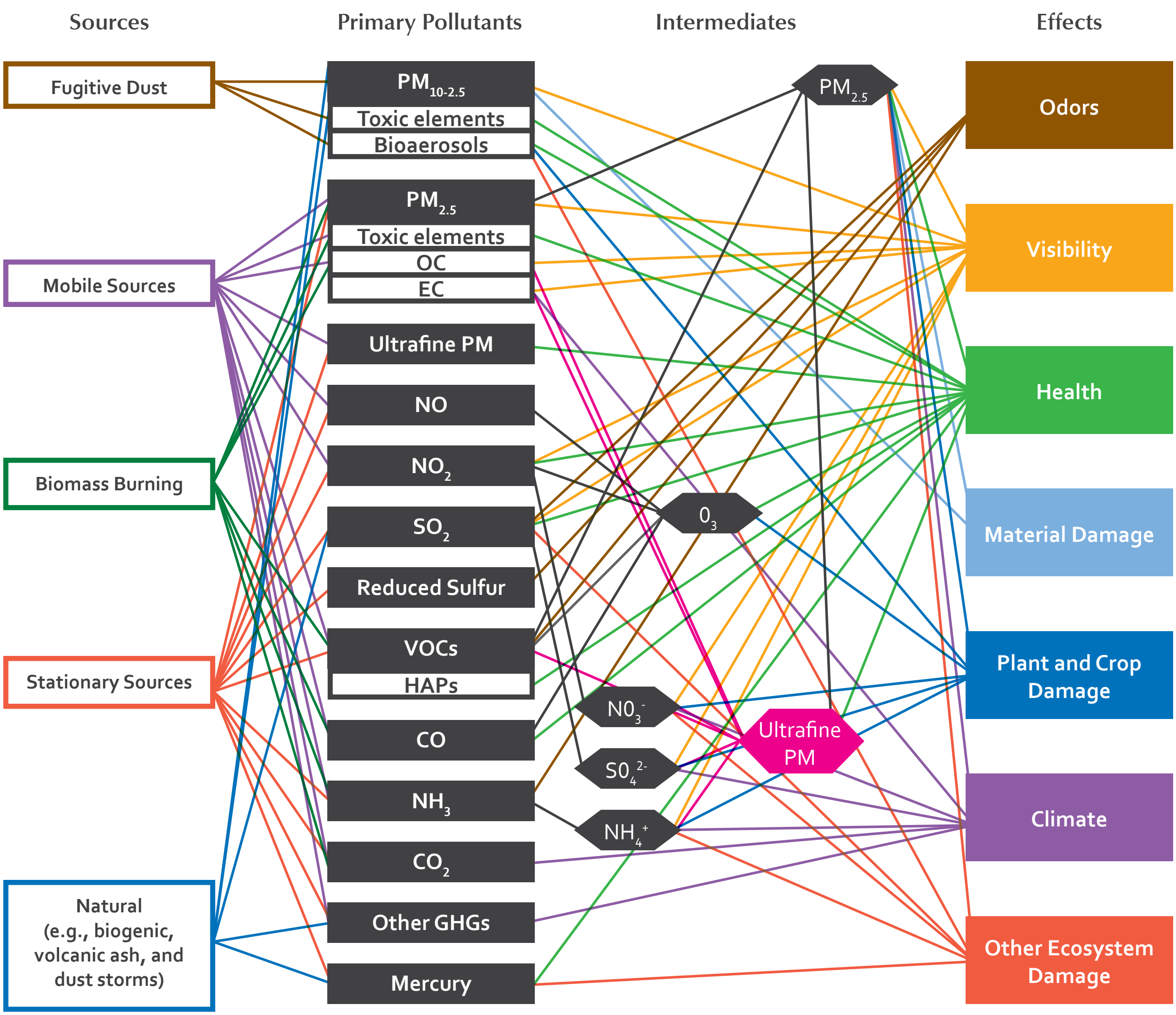

Figure 2.2 Multiple pollutants and their multiple adverse effects

Source: Cao et al., 2013

2.1.7 Air quality monitoring

Another key component of effective AQM is a sustainable and efficient AQ monitoring system. Routine monitoring of AQ provides data that allows monitoring of compliance with AAQS, assesses trends in air pollution levels and exposures, and evaluates progress and effectiveness of AQ policies and measures. Robust and credible AQ data contribute to effective decision-making in AQM and this can be achieved only through an effective monitoring system (Box 2.2). Monitoring systems/programs also need to be cost-effective; have stable financial, operational, and personnel resources; and adjusted to local needs and conditions (WHO, 1999).

The design of an AQ monitoring program is primarily defined by its purpose or objectives. The design will then determine: size and sophistication of the monitoring network (including equipment); location and number of sampling stations; duration and frequency of sampling; and, most importantly, the financial and manpower resources needed to operate and sustain the network. Air quality monitoring activities can be grouped according to three broad types of objectives: timely public reporting, compliance, and research (Table 2.5). **Index I of the Information Sourcebook** provides a case study of the phased development of Beijing's air quality monitoring system.

Table 2.5 Common objectives for conducting air quality monitoring

Basic Objectives	Specific Objectives
Timely public reporting	Assess short-term pollution levels
	Develop an air quality index (or other tools for data communication)
	Generate data to evaluate forecasted pollution concentrations by modeling
Compliance	Determine compliance and levels of exceedances with respect to standards
	Observe pollution trends
	Formulate pollution control strategies
	Examine the extent and causes of elevated concentrations
	Enhance understanding of chemical and physical properties of atmospheric pollution and pollution sources
	Evaluate the effectiveness of pollution control strategies
	Support national and international agreements and initiatives
Research	Identify pollutant generation and behavioral characteristics
	Assess impacts to different groups of populations
	Assess impacts to visibility impairment, climate change and ecosystems
	Validate models
	Discover new contaminants

Source: Adapted from USEPA, 2013 cited in ADB & Clean Air Asia, 2014

Box 2.2
Essential characteristics of an effective monitoring system

1. Well-planned and established monitoring network according to the monitoring objectives and is representative of actual air quality conditions
2. Proper implementation of quality assurance (QA) and quality control (QC) procedures
3. Sustainable operation of the air quality monitoring network
4. Effective communication of air quality information to the public
5. Effective communication of air quality information to policymaker
6. Strong commitment from authorities in terms of financial and human resource support

Source: ADB & Clean Air Asia, 2014

Routine monitoring of air quality provides data that allows monitoring of **compliance with ambient air quality standards**, assesses trends in **air pollution levels** and exposures, and **evaluates progress** and **effectiveness** of air quality policies and measures.

Air pollution – and its drivers – is **complex in nature**; it requires an **air quality monitoring** program that is **dynamic** — one that needs to be **periodically reviewed** and **improved** to ensure that it is **responsive** to these factors.

There are various technical guidelines for designing and operating an AQ monitoring program/network, including those from WHO, USEPA, and the EU (Table 2.6). Air pollution – and its drivers – is complex in nature; it requires an AQ monitoring program that is dynamic — one that needs to be periodically reviewed and improved to ensure that it is responsive to these factors (ADB & Clean Air Asia, 2014). These guidelines present differences in prescribed specifications for the number of sampling points/stations and the probe height, among others.

Table 2.6 List of internationally accepted technical guidelines for air quality monitoring networks/programs

Organization	Title/Link to Guidelines
WHO	Monitoring Ambient Air Quality for Health Impacts Assessment http://www.euro.who.int/__data/assets/pdf_file/0010/119674/E67902.pdf
USEPA	Air Planning and Standards http://www.epa.gov/airquality/montring.html Guidance for Network Design and Optimum Site Exposure for $PM_{2.5}$ And PM_{10} http://www.epa.gov/ttn/amtic/files/ambient/pm25/network/r-99-022.pdf Guidance for Using Continuous Monitors in $PM_{2.5}$ Monitoring Networks http://www.epa.gov/ttn/amtic/files/ambient/pm25/r-98-012.pdf
EU	Directives for Monitoring Atmospheric Pollution (Directive 2008/50/EC) http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0050&from=EN
Stockholm Environment Institute (SEI)	Global Atmospheric Pollution Forum (GAPF) Air Pollution Monitoring Manual http://www.sei-international.org/rapidc/gapforum/html/projects.php
Environment Canada	National Air Pollution Surveillance Program http://www.ec.gc.ca/rnspa-naps/

Source: Updated from ADB & Clean Air Asia, 2014

Established QA/QC protocols and procedures covering various elements is another essential characteristic of an effective AQ monitoring system (Table 2.7 and 2.8). Quality assurance is defined as the external system that verifies the precision, accuracy and validity of AQ measurements. Quality control is defined as the internal system for estimating and maintaining the precision, accuracy and validity of AQ measurements (Chow et al., 2012).

Table 2.7 Key elements in quality assurance and quality control

Quality Assurance	Quality Control
• System audits to assure that procedures are being followed or modified to reflect current practice • Performance audits to evaluate outputs for external standards • Inter-laboratory comparisons and co-located sampling • Interference evaluation with reference materials	• Standard Operating Procedures (SOPs), revised periodically • Periodic instrument calibrations with transfer standards • Periodic zeros and spans with performance standards • Replicate analyses • Cross-instrument comparisons • Internal consistency tests

Source: Chow et al., 2012

Table 2.8 Essential components of a quality assurance/quality control process

Activities in a quality assurance/ quality control process	Elements covered
Develop specifications for operating a monitoring network	Data quality objectives
	Measurement methodology (reference methods)
	Equipment selection and operation
	Site selection (site classification, distribution and location)
	Sampling system (shelter requirements and probe siting)
Assess compliance to the developed guidelines (standard operating procedures and calibration)	Station and analyzer operation (station visits, ensuring that operation procedures are followed, and preventive maintenance)
	Calibration (primary and secondary calibration standards, calibration frequency, calibration procedures, and zero and span verifications)
Implementing corrective actions to ensure compliance to the developed guidelines	System audits and station performance (includes independent verifications)
	Data validation
	Documentation (log books and operation manuals)
	Personnel training and technical support

Source: USEPA, 2013 and Watson et al., 2013

2.2 Stages of ambient air quality standards and air quality monitoring

In line with enabling cities to establish and strengthen AAQS to protect public health and the environment with sustainable national AQ monitoring programs that enrich understanding of air quality status, Tables 2.9 and 2.10 present indicators to aid cities or countries in identifying their current state of development in terms of AQS and monitoring.

The following are the key indicators for consideration:

- Development of AAQS and alignment with other targets
- Setting up an adequate AQ monitoring system
- Monitoring compliance
- AAQS review process
- Sustainability of AQ monitoring system

Table 2.9 Stages for ambient air quality standards to protect public health and environment

Stages	Indicators
Underdeveloped	Absence of AAQS.
Developing	Ambient air quality standards for selected criteria pollutants are available. Ad hoc AQ monitoring systems monitor compliance to AAQS. There is no review process for AAQS in place.
Emerging	Ambient air quality standards for all criteria pollutants are available. A phased approach to achieve more stringent AAQS is used. Compliance to AAQS is routinely monitored, and attainment and non-attainment assessed. Links to other sector/development plans are envisaged. There is an ad hoc review process for AAQS.
Maturing	Ambient air quality standards for criteria pollutants are in line with WHO ambient AQGs and interim targets; compliance to AAQS monitored and reported regularly to the public. Attainment and non-attainment areas are regularly assessed. Ambient air quality standards are reviewed regularly and linked with other sector/development plans. Standards for pollutants other than criteria pollutants are being considered.
Fully developed	Ambient air quality standards for criteria pollutants and other toxic pollutants are mandatory, and in line with WHO AQGs and/or interim target values; compliance to AAQS is monitored and reported regularly to the public. Ambient air quality standards are reviewed regularly (at least every five years) to improve and protect vulnerable population groups and areas. Review takes into account multiple pollutant control approaches. Attainment and non-attainment areas are designated and regularly assessed. Non-attainment areas are closely monitored and pollution strategies are evaluated in line with achieving the AAQS. Compliance and non-compliance to AAQS are linked with development/sector plans and policies (e.g., airport expansion, vehicle emissions standards, and others).

Table 2.10 Stages for strengthening air quality monitoring

Stages	Indicators
Underdeveloped	Absence of ambient AQ monitoring system.
Developing	Monitoring activities are only project-based or on an ad hoc basis and provides data to a limited range of stakeholders. Existing monitoring data is used to check compliance to AAQS but not sufficient to designate attainment and non-attainment areas. Human resources, technical capacity and financial resources are available for project-based or ad hoc monitoring only.
Emerging	Air quality monitoring system covers selected pollutants of concern and hotspots. There are QA/QC procedures as part of the AQ monitoring that have potential to be strictly implemented. Human resources, technical capacity, and financial resources are sufficient to support AQ monitoring for selected pollutants and hotspots.
Maturing	Air quality monitoring system covers all criteria pollutants and includes continuous monitoring stations, with a mix of different station types: background, roadside, industrial and residential. Quality assurance/quality control procedures are strictly followed. Air quality monitoring data are appropriately shared with different stakeholders. Human resources, technical expertise, and financial resources are sufficient to sustain AQ monitoring systems for all criteria pollutants, which has a mix of different types of monitoring stations. There are initiatives to secure funding support from other sources (aside from government) to support AQ monitoring systems.
Fully developed	Air quality monitoring system covers all criteria pollutants and other pollutants – volatile organic compounds (VOCs), toxics, among others. Adequate size and scope of AQ monitoring system is based on population, size and characteristics of the area. Different station types are present and may cover sensitive receptor sites, as necessary. Sufficient resources, including human and financial resources, are available for sustaining operation of AQ monitoring systems. Quality assurance and quality control procedures are strictly followed. A process for review of AQ monitoring system exists. Proper mechanism for communication of AQ information to target stakeholders – public, government, media, academe, private sector, civil society, development banks and foundations – are in place. Strategies are in place to assess a wide mix of financing sources to sustain AQ monitoring systems.

2.3 Issues and challenges

Despite the availability of technical guidance and assistance from international donors and organizations, issues and challenges surrounding AAQS and AQ monitoring in Asia remain. The issues and challenges on AAQS and AQ monitoring listed below are primarily based on inputs from previous Governmental Meetings on Urban Air Quality in Asia, previous and recent Clean Air Asia project findings, consultations with AQM stakeholders, and online research (SEI et al., 2004 and ADB & Clean Air Asia, 2014).

Air Quality Standards

Of the 22 Asian countries and territories surveyed by Clean Air Asia, only two have not adopted AAQS. Although some of these standards have been in place for years and even decades, challenges in ensuring that these translate into safe AQ levels that protect the health of the public and that of susceptible populations persist. Table 2.11 summarizes the standards available for some selected pollutants. However, various countries may also have standards for many other pollutants.

Table 2.11 Overview of ambient air quality standards (selected pollutants) in selected Asian countries [μg/m^3, unless otherwise stated]

Countries	$PM_{2.5}$		PM_{10}		TSP		SO_2			NO_2			O_3		CO ('000)	
	24 hr	Annual	24 hr	Annual	24 hr	Annual	1 hr	24 hr	Annual	1 hr	24 hr	Annual	1 hr	8 hr	1 hr	8 hr
Afghanistan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bangladesh	65	15	150	50	-	-	-	365	80	-	-	100	235	157	40	10
Bhutan (Mixed)	-	-	100	60	200	140	-	80	60	-	80	60	-	-	4	2
Brunei Darussalam	-	15	150	40	-	-	-	-	-	-	-	-	-	-	-	-
Cambodia	-	-	-	-	330	100	500	300	100	300	100	-	200	-	40	22.9
PR China: Grade I[1]	35	15	50	40	120	80	150	50	20	200	80	40	160	100	10	-
PR China: Grade II[1]	75	35	150	70	300	200	500	150	60	200	80	40	200	160	10	-
Fiji			50				350		200				150	150		10
India[2]	60	40	100	60	-	-	-	80	50	-	80	40	180	100	4	2
India[3]	60	40	100	60	-	-	-	80	20	-	80	30	180	100	4	2
Indonesia	65	15	150	-	230	90	900	365	60	400	150	100	235	-	30	-
Iran	25	10	50	20				96.94	18.34			39.48		100	40.075	10.575
Japan	35	15	100*	-	-	-	261.6	104.64	-	-	75-113	-	117.72	-	-	23
Lao PDR	-	-	120	50	330	100	780	300	100	320	-	-	200	-	30	10.26
Malaysia[4]	-	35	150	50	260	90	350	105	-	320	75	-	200	120	35	10
Mongolia	50	25	100	50	150	100	-	20	10	85	40	30	-	100	30	10
Myanmar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nepal	40	-	120	-	230	-	-	70	50	-	80	40	-	157	-	10
Pakistan	35	15	150	120	500	360	-	120	80	-	80	40	130	-	10	5
Philippines	75	35	150	35	230	90	-	180	80	-	150	-	140	60	35	10
Philippines[5]	50	25	150	60	230	90	-	180	80	-	150	-	140	60	35	10
Republic of Korea	50	25	100	50	-	-	392	131	52	188	113	56	196	118	29	10
Singapore[6]	37.5	12	50	20	-	-	-	50	15	200	-	40	-	100	30	10
Singapore[7]	25	10	50	20	-	-	-	20	-	200	-	40	-	100	30	10
Sri Lanka	50	25	100	50	-	-	200	80	-	250	100	-	200	-	30	10
Thailand	50	25	120	50	330	100	780 (0.3 ppm	300 (0.12 ppm)	100 (0.04 ppm)	320 (0.17 ppm)	-	57 (0.03 ppm)	200 (0.10 ppm)	140 (0.07 ppm)	34.2 (30 ppm)	10.26 (9 ppm)
Vietnam	50	25	150	50	200	140	350	125	50	200	-	40	200	120	30	10

Note: Units are in μg/m^3, unless otherwise stated

PDR = People's Democratic Republic; Pb = lead; PM_{10} = Particles with aerodynamic particle diameters of 10 μm or less; $PM_{2.5}$ = Particles with aerodynamic particle diameters of 2.5 μm or less; China: Grade I = Special protection areas, nature reserves and scenic areas; Grade II = applies to residential areas, mixed commercial/residential areas, cultural, industrial, and rural areas; [1]= GB3095-2012 | National implementation in 2016; [2] = NAAQS for Industrial, Residential, Rural, and Other Areas; [3] = NAAQS for Ecologically Sensitive Areas (notified by Central Government); [4] = Interim target for 2015; [5] = DAO 2013-13 | $PM_{2.5}$ strengthened in 2016; [6] = Singapore targets by 2020; [7] = long term targets.

*Defined as airborne particles that pass through a size-selective inlet with a 100 percent efficiency cut-off at 10 μm aerodynamic diameter.

Ozone (O_3) Conversion factor for ppb to μg/m^3: 1.962
Carbon monoxide (CO) Conversion factor for ppb to μg/m^3: 1.145

Sulfur dioxide (SO_2) Conversion factor for ppb to μg/m^3: 2.616
Nitrogen dioxide (NO_2) Conversion factor for ppb to μg/m^3: 1.880

Source: Updated from Clean Air Asia, 2014 [collected from various sources]

Institutional

There is no global target/roadmap/framework on air pollution (similar to the Kyoto Protocol or United Nations Framework Convention on Climate Change [UNFCCC]) for climate change or Montreal Protocol for ozone depleting substances), thus there is a lack in alignment of AQS with global guidelines or standards (i.e. WHO guidelines and interim targets).

Alignment between AQS and other sectoral standards (e.g. vehicle and fuel quality standards) at the country or city level is also missing. There are a few local governments (cities or provinces) in Asia with far more advanced fuel and vehicle quality or emissions criteria than those for the rest of the country. This is usually because of the national government's policy to implement stricter standards in key cities prior to implementation at the country level. One of these cities is Jakarta, where SO_2 (24 hr), NO_2 (24 hr and annual), and O_3 (annual) standards are more stringent than those for the rest of Indonesia (Clean Air Asia, 2010).

Management and technical

Air pollution competes with other environment and development issues. Other competing urban environment issues include municipal solid waste, storm water/flood management, access to clean water, etc.

Environmental enforcement and implementation of standards is also generally weak. As a consequence, there are technical capacity deficiencies in assessing compliance with the standards and a wide participation of stakeholders in the implementation of AAQS and policies is lacking.

Alignment of AQM policies with other sector policies and plans are limited. Economic goals to promote certain industries (e.g. automobile) or industrial expansion can counter any air pollution reduction goals.

Some Asian countries have not updated/revised their standards for more than five years. In some cases, countries have kept their AAQS much higher than WHO guidelines even when the actual concentration levels have been met for a long time. This can unintentionally create an allowance to pollute instead of aiming towards AQ improvement.

Financial

The financial constraints for AQS is not so much on the establishment of the standards but more on the implementation of the standards, especially in the lack of funds for AQ monitoring systems to check compliance with the standards. There is also limited funding for local research and studies on exposure risks, policy reviews and relevant pollutant control strategies which are necessary inputs to the establishment or review of AQS.

Air Quality Monitoring

While there are now more AQ data available in the region as compared with a decade ago, several issues on AQ monitoring remain.

Institutional

Awareness of AQ monitoring data and results in all levels of government, stakeholder, and general public is lacking. This is linked with air pollution not always being a priority agenda for governments and in turn translates to lacking wide stakeholder participation and investment for AQ monitoring.

Collaboration with other relevant stakeholders is weak. There is weak or no coordination among different monitoring agencies, no SOPs, and harmonization of monitoring networks and devices. There is lack of participation in regional monitoring network activities and lacking active participation and investment from private sector and academe.

Management and technical

There is often a lack of staff dedicated to AQ monitoring in Asian cities. Staff often have to simultaneously cover other environmental monitoring and reporting work. Air quality monitoring involves the use of sophisticated equipment and good technical understanding of air quality science. When personnel are trained specifically for AQ monitoring jobs, they often move on to other roles faster than they are replaced and knowledge and skills are often lost in the organization.

There is limited training for new staff and skills upgrade for existing staff which then translate to a wide array of technical issues in AQ monitoring – i.e. calibration, QA/QC, data management, etc.

Technical capability relevant for AQ monitoring is lacking or missing – including meteorological monitoring, data management skills, AQ monitoring equipment repair and troubleshooting.

Financial

Funding for AQ monitoring is often inadequate and not sustainable. Almost all countries in Asia benefited from foreign grants or technical assistance to fund the establishment of their AQ monitoring system. Several of these networks' operations ended as soon as project funds were depleted. Countries and cities also started to make significant investments from local funds but the monitoring activities were also not maintained due to lack of sustainability plans. There is lack of strong commitment from authorities to continue monitoring efforts.

2.4 Roadmap for ambient air quality standards and air quality monitoring

To move up the development stages for AAQS and AQ monitoring, there are measures that cities or countries can implement to overcome issues and challenges (Table 2.12 for AAQS and Table 2.13 for AQ monitoring).

Table 2.12 Recommended steps to implement roadmap for better ambient air quality standards to protect public health and environment

Developmental stages	Steps to follow

Underdeveloped	**Management Process**
	• Create advocacy and awareness campaigns to bring air pollution into the public agenda and push for a political decision to establish and adopt AAQS [See *Guidance Area 4 Air quality communication*]
	• Conduct stakeholder meetings and public input workshops so that the process of establishing AAQS recognizes and involves major stakeholders – AQ experts, epidemiologists, toxicologists, medical professionals, ecologists, environmental economists, industries, government line ministries, and non-governmental organizations representing the public. The consultative approach and collective wisdom may provide wider acceptability of the standards and its rationale, and ensure effective implementation through stakeholders' participation
	• Identify thought leaders, decision makers and influencers to ensure linkages of AAQS with other sector policies
	• Establish Technical Team from different government and non-government stakeholder groups who will be responsible for the oversight of the process to develop AAQS for criteria pollutants. The team would be a small working group of select government staff, with the possible addition of consultants or university experts
	
	Technical Process
	• Determine selection of pollutants and averaging periods, basis for which may include:
	  o Whether or not substances or mixtures pose widespread problem in terms of sources and potential for exposure is large
	  o Availability of significant information on health effects (e.g., WHO guidelines, USEPA criteria documents, other air pollution epidemiological studies)
	  o Past trends in ambient air levels (e.g., rising $PM_{2.5}$ levels due to urbanization and motorization)
	  o Guidance from international standards and established standards from neighboring Asian countries with similar socioeconomic and environment conditions

Developmental stages	Steps to follow
Developing	**Management Process** • Continue awareness campaigns to sustain public interest on air pollution and demand for more stringent AAQS for all criteria pollutants • Strengthen implementation of AAQS through development of clean air action plans and reporting of progress [See *Guidance Area 5 on Clean air action plans*] • Strengthen coordination and integration of AQM policies with other sector policies and plans (e.g., transport, energy, industry, among others) **Technical Process** • Develop at the national level standard/uniform methodologies for AQ monitoring to guide cities • Build capacity for AQ monitoring system to cover selected pollutants of concern and hotspots, monitor compliance to AAQS, and ensure that major cities have at least one monitoring station per area to designate and assess attainment and non-attainment areas • Build capacity for ad hoc review of AAQS
Emerging	**Management Process** • Strengthen implementation of AAQS • Consider AAQS in the development of other sector plans **Technical Process** • Establish attainment and non-attainment for cities or regions • Cluster cities or zones according to AQ levels, compliance, and attainment; assess for possibility of more stringent standards in "cleaner" cities • Conduct assessment and review on phasing-in more stringent standards for criteria and other pollutants • Build capacity for regular review of AAQS
Maturing	**Management Process** • Establish a robust health statistics database based on health surveillance [See *Guidance Area 3 on Health and other impacts*] **Technical Process** • Regularly assess attainment and non-attainment areas • Conduct a comprehensive review of most policy-relevant science and literature on risks and exposures that are globally and locally available • Cooperate with academe and technical agencies to conduct risks/exposure assessments • Review AAQS regularly (at least every five years) and routinely monitor compliance • Gather inputs from the academic and scientific communities, and the private and public sectors to prepare policy-relevant issues that will frame the review

Developmental stages	Steps to follow
Fully developed	**Management Process** • Adopt international targets on air pollution • Align AAQS for criteria pollutants and other toxic pollutants with WHO AQGs and/or interim targets • Communicate costs and benefits of implementing AAQS in line with climate and other sector policies to the public **Technical Process** • Prepare cost-benefit analysis on the implementation of AAQS [See *Guidance Area 3 on Health and other impacts*] • Review AAQS regularly (at least every five years) or when important WHO AQGs are updated • Review linkages of AAQS with sector plans

Table 2.13 Steps to follow to implement roadmap for strengthening air quality monitoring

Developmental stages	Steps to follow
Underdeveloped	**Management Process** • Adopt AAQS (if there is none yet), to mandate routine AQ monitoring • Conduct AQ monitoring to support standards development • Define AQ monitoring objectives and data quality objectives • Identify capacities, skills and training needs for staff • Consider partnering with local university or research institute to support AQ monitoring activities **Technical Process** • Choose AQ monitoring equipment within available budget and manpower resources. Consider phased expansion (in terms of scope and complexity) of air quality monitoring systems especially for cities with limited resources (e.g. start with less complex, more cost-effective passive sampling) • Develop capacity for simple monitoring (e.g., manual samplers) and prioritize pollution hotspots • Build capacity for at least one station for air pollution monitoring of key pollutants
Developing	**Management Process** • Create project opportunities with other sectors (e.g., health, transport) to link AQ monitoring activities • Refine AQ monitoring objectives and data quality objectives • Identify capacities and skills and training to strengthen staff resources • Start reporting AQ data to the public [See *Guidance Area 4 on Air quality communication*] • Collaborate with local or international academic organizations for AQ monitoring studies • Identify funding sources for AQ monitoring activities • Prepare AQ monitoring plans and guidelines • Provide sustainable training to address staff movements and technological developments **Technical Process** • Expand AQ monitoring network by adding more stations or pollutants monitored or improving frequency according to monitoring objectives and to support compliance monitoring to AAQS • Develop QA/QC plan, SOPs, and guidelines at the national level for AQ monitoring to guide cities

Developmental stages	Steps to follow
Developing	• Develop QA/QC measures • Improve data management and AQ monitoring data use for health assessments • Build capacities for use of monitoring in AQ modeling – e.g. dispersion modeling [See *Guidance Area 2 on Emissions inventories and modeling*] and health assessments [See *Guidance Area 3 on Health and other impacts*]
Emerging	**Management Process** • Prepare plans to sustain AQ monitoring network, starting with financing of maintenance, equipment upgrade and human resource • Enhance reporting mechanisms of AQ data to the public to increase public awareness [See *Guidance Area 4 on Air quality communication*] • Collaborate with other countries' AQ monitoring activities • Ensure initiatives are in place to secure funding support from external sources; optimize use of AQ data to generate interest and mobilize resources **Technical Process** • Cooperate with meteorological agencies for sharing of expertise in AQ data interpretation and modeling • Enhance capacities for AQ modeling work [See *Guidance Area 2 on Emissions inventories and modeling*] • Make use of AQ data for health assessments [See *Guidance Area 3 on Health and other impacts*] • Make use of AQ data for assessing effectiveness of AQ and other related sector policies [See *Guidance Area 5 on Clean air action plans*] • Expand AQ monitoring network system to include more pollutants relevant for compliance and health assessments • Implement continuous skills training on AQ monitoring • Share technical expertise and knowledge with other Asian countries • Implement QA/QC procedures for AQ monitoring system
Maturing	**Management Process** • Sustain AQ monitoring network systems with proper planning and management • Develop strategies to access diverse financing sources to sustain operations • Network with neighboring countries and share data and technical knowledge through study visits **Technical Process** • Strengthen capacity for AQ modeling, including forecasting and health assessments • Review of AQ monitoring network system, including assessment of relevance of location/siting • Ensure adequate size and scope of monitoring system
Fully developed	**Management Process** • Collaborate with other countries to establish regional centers for AQ monitoring **Technical Process** • Pending availability of funds and capacity, explore or invest in studies using sophisticated or alternative AQ monitoring methods – e.g. monitoring supersites and remote sensors – for improved understanding of secondary PM mechanisms and regional transport of air pollution • Participate in studies and regional harmonization/cooperation work

Ambient air quality standards and AQ monitoring systems are two important AQM components that are closely interlinked. A simplified step-wise process to improve AAQS and AQ monitoring systems is discussed in **Annex I of the Information Sourcebook** and accompanied by case studies to better illustrate the recommended steps.

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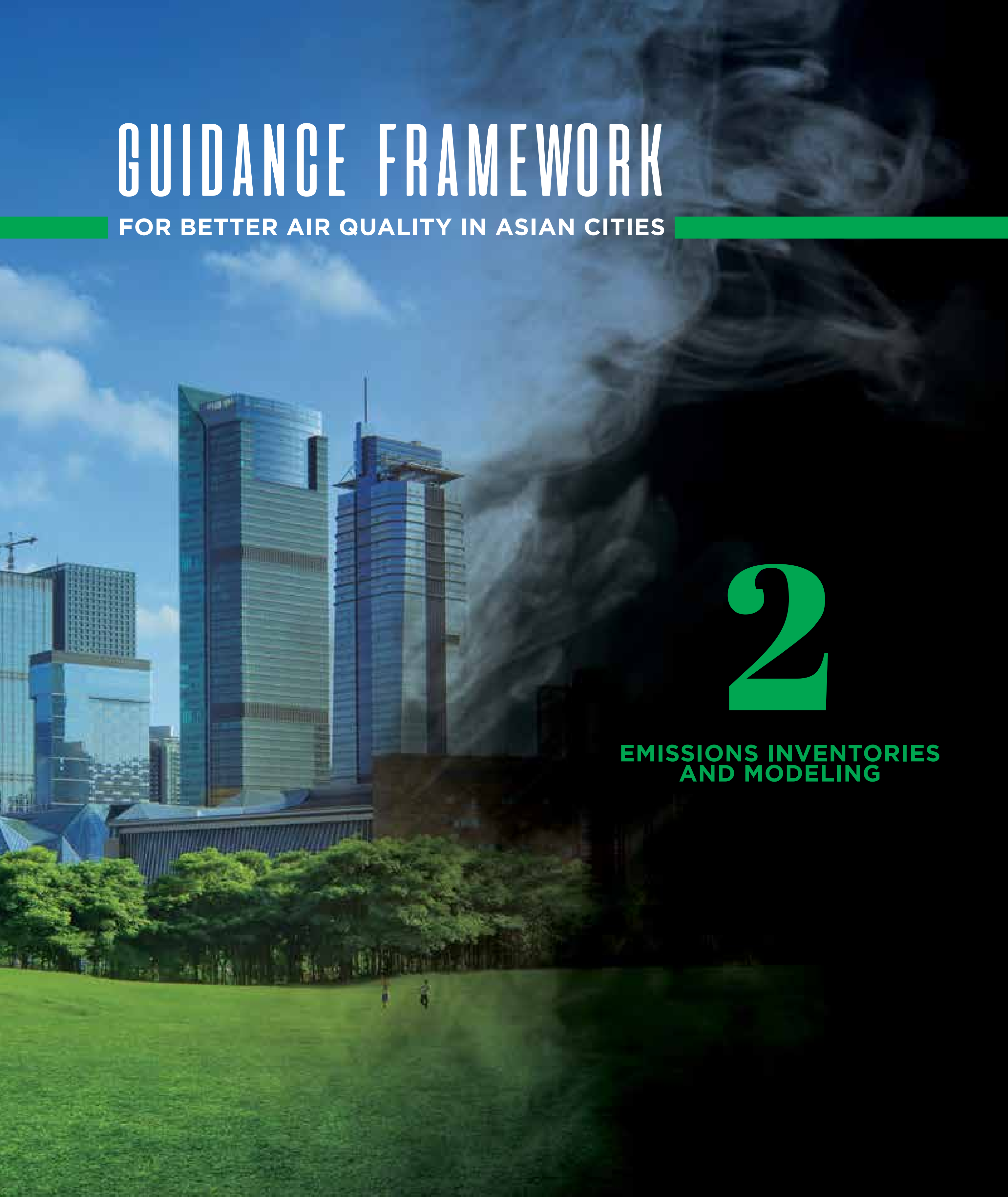
GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES



2

EMISSIONS INVENTORIES AND MODELING

Integrated Programme for Better Air Quality in Asia

UNEP

CLEAN AIR ASIA

GUIDANCE FRAMEWORK
FOR BETTER AIR QUALITY IN ASIAN CITIES
Guidance Area 2: Emissions Inventories and Modeling

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ABOUT THE GUIDANCE FRAMEWORK FOR BETTER AIR QUALITY IN ASIAN CITIES

The Guidance Framework is a voluntary and non-binding guidance document developed as an outcome of the biennial Governmental Meetings on Urban Air Quality in Asia, co-organized by Clean Air Asia and United Nations Environment Programme Regional Office for Asia Pacific (UNEP ROAP). It is an outcome of an extensive development process, which began in 2006 when the Long Term Vision for Urban Air Quality in Asia (LTV) was envisioned by representatives of environment ministries in the region. The LTV describes the desired state of urban air quality in Asian cities by 2030; the Guidance Framework serves as a guide for cities and countries to achieve this vision. In 2016, the Guidance Framework was launched as a pioneering approach to resolve air pollution challenges at the local- and national-levels. Centered on identified priority areas of concern in air quality management in the region, the Guidance Framework provides cities and countries with development capacity indicators and recommended steps and actions to improve air quality.

The Guidance Framework serves as a cornerstone document of Clean Air Asia's Integrated Programme for Better Air Quality in Asia (IBAQ Programme), which supports countries and cities in implementing the Guidance Framework through a range of targeted interventions, including knowledge-sharing platforms to strengthen regional collaboration, capacity building activities such as trainings, study tours and city twinning, and technical assistance at both the national and subnational levels.

ABOUT CLEAN AIR ASIA

www.cleanairasia.org

Clean Air Asia is an international NGO established in 2001 as the premier air quality network for Asia by the Asian Development Bank, World Bank and USAID. Its mission is to promote better air quality and livable cities by translating knowledge to policies and actions that reduce air pollution and greenhouse gas emissions from transport, energy and other sectors.

Clean Air Asia became a UN-recognized partnership in 2007, its network spanning 261 organizations in 31 countries in Asia and worldwide, with nine country networks: China, India, Indonesia, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, and Vietnam. It is headquartered in Manila and has offices in Beijing and Delhi. Clean Air Asia leads efforts to enable Asia's more than 1000 cities to reduce both air pollution and CO_2 emissions, and thereby contribute to more livable and healthy cities with blue skies and a low carbon footprint. Clean Air Asia helps to reduce emissions, through policies, plans, programs, and concrete measures that cover air quality, transport and industrial emissions and energy use.

The Better Air Quality (BAQ) Conference is a flagship event of Clean Air Asia covering the key sectors of transport, energy and industry, with a particular emphasis on government policies and measures. Policymakers, practitioners and industry leaders meet at BAQ to network, innovate, learn, and share experiences. The biennial event was first held in 2002 and attracts close to a thousand participants from Asia and the rest of the world.

ABOUT UNEP
www.unep.org

The United Nations Environment Programme (UNEP) is the leading global environmental authority that sets the global environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and serves as an authoritative advocate for the global environment. UNEP work encompasses assessing global, regional and national environmental conditions and trends; developing international and national environmental instruments; and strengthening institutions for the wise management of the environment. UNEP's mission includes to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

CONTENTS

PREFACE

Air pollution is now considered the world's largest environmental health risk. There have been a number of global efforts calling for air pollution actions in recent years. These global calls for action on air pollution strengthen regional and national initiatives and highlight the need to prioritize addressing this issue through a collaborative and integrated approach.

In 2006, the First Governmental Meeting on Urban Air Quality in Asia[1] recognized the need for guidance in implementing a Long Term Vision for Urban Air Quality in Asia, which describes the desired state of urban air quality management in Asian cities. During the Third Governmental Meeting, environment ministries from the region identified key challenges they are facing to improve urban air quality.

To set the way forward in achieving the vision for cleaner air, Clean Air Asia led the development of the Guidance Framework for Better Air Quality in Asian Cities (Guidance Framework) to address the needs and challenges in the region. It aims to provide a recognized guidance on improving urban air quality and is organized around priority areas of concern in the region, which were translated into key guidance areas with roadmaps on how to progress in a step by step manner.

This voluntary, non-binding document consists of seven individually published chapters covering each of the Guidance Areas. Policy and decision makers in Asia, as well as other relevant stakeholders, can use one or a combination of the Guidance Framework chapters to develop local roadmaps or action plans depending on their priority areas of concern.

The Guidance Framework consists of seven main books with these titles:

- Introduction
- Guidance Area 1 - Ambient air quality standards and monitoring
- Guidance Area 2 - Emissions inventories and modeling
- Guidance Area 3 - Health and other impacts
- Guidance Area 4 - Air quality communication
- Guidance Area 5 - Clean air action plans
- Guidance Area 6 - Governance

These guidance areas come with an Information Sourcebook, which is a compilation of resources to support the implementation of Guidance Framework roadmaps. There is also an accompanying training course on Guidance Framework implementation, which is available online in the Clean Air Asia website and Integrated Programme for Better Air Quality (IBAQ Programme) website: www.cleanairasia.org/ibaq

The Guidance Framework was developed together with a team of international and regional experts and practitioners and has undergone an extensive review process through the Governmental Meetings and the involvement of external reviewers. The draft document was also shared in a number of international events, including the Asia Pacific Clean Air Partnership (APCAP) Joint Forum organized by UNEP ROAP in November 2015. The Guidance Framework was welcomed by participants from 24 countries in Asia and the Pacific, involving environment ministries, intergovernmental organizations, non-governmental organizations, and experts.

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1 Governmental Meetings on Urban Air Quality in Asia are biennial meetings organized by the United Nations Environment Programme Regional Office of Asia and the Pacific (UNEP ROAP) and Clean Air Asia that convene environment ministries with the aim to harmonize approaches across the region in tackling air pollution and related fields.

ABBREVIATIONS

ACAP	Asia Center for Air Pollution Research
AQM	Air Quality Management
AQSM	Air Quality Simulation Model
BC	Black Carbon
CAAP	Clean Air Action Plan
CAM	Crustal + Alluvial + Marine Constituents
CAMx	Comprehensive Air Quality Model with Extensions
CH_4	Methane
CMAQ	Community Multi-Scale Air Quality
CMB	Chemical Mass Balance
CPCB	Central Pollution Control Board
CO	Carbon monoxide
CUACE	Chinese Unified Atmospheric Chemistry Environment
DEFRA (UK)	Department for Environment, Food, and Rural Affairs
EAGrid	East Asian Air Pollutant Emission Grid Database
EC	Elemental Carbon
EEA	European Environment Agency
EF	Emission Factor
EI	Emissions Inventory
EPD (Hong Kong)	Environmental Protection Division
GAPF	Global Atmospheric Pollution Forum
GHG	Greenhouse Gas
HC	Hydrocarbons
HDV	Heavy Duty Vehicles
HFCs	Hydrofluorocarbons
HTSVE	High-Temporal Spatial Resolutions Vehicle Emissions Inventory
IPCC	Intergovernmental Panel on Climate Change
JTOP	Japan Auto-Oil Program
LDV	Light Duty Vehicles
MM5	Mesoscale Meteorological Model
MOE (New Zealand)	Ministry of Environment
MOEJ	Ministry of the Environment of Japan
NAQPMS	Nested Air Quality Prediction Model System
NO_x	Nitrogen oxides
NO_2	Nitrogen dioxide
N_2O	Nitrous oxide
NMVOCs	Non-Methane Volatile Organic Compounds
OC	Organic Carbon
OECD	Organization for Economic Co-operation and Development
PATH	Pollutants in the Atmosphere and their Transport over Hong Kong
PM	Particulate Matter
PM_{10}	Particulate Matter (≤ 10 micrometers in diameter)
$PM_{2.5}$	Particulate Matter (≤ 2.5 micrometers in diameter)
PFCs	Perfluorinated Compounds
PMF	Positive Matrix Factorization
PRD	Pearl River Delta
QA	Quality Assurance
QC	Quality Control
REAS	Regional Emissions Inventory in Asia
RIAS	Rapid Inventory Assessment Technique
SA	Source Apportionment
SF_6	Sulfur hexafluoride
SEI	Stockholm Environment Institute
SIA	Secondary Inorganic Aerosols
SMOKE	Sparse Matrix Operator Kernel Emissions Processing System
SOP	Standard Operating Procedure
SO_2	Sulfur dioxide
TC	Total Carbon
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
VKT	Vehicle Kilometers Travelled
WRF	Weather Research and Forecast Model


VIỆT NAM

To develop **emissions inventory** and apply source apportionment and dispersion modeling techniques to **guide clean air action plans** and related environmental policies; **strengthening** air quality management and the **basis** for subsequent evaluation of the **effectiveness** of measures to protect **human health** and the **environment**.

CHAPTER 3

GUIDANCE AREA 2: EMISSIONS INVENTORIES AND MODELING

3.1 Introduction

This guidance area addresses the issues of developing an accurate and reliable emissions inventory (EI) which can be used as input to dispersion models in order to estimate exposure of human populations and the environment. Information from EIs are also important for understanding air pollution sources to draw up control measures to mitigate industrial, transport, and residential emissions and achieve compliance with emission standards. Source apportionment (SA) is a science-based approach to assess the contribution of emissions of specific source types to air pollutant concentrations at receptor sites. The guidance area also discusses the issues and challenges in Asian cities and regions and develops a roadmap and recommendations on how to implement effective approaches to resolve the challenges.

3.1.1 Objective

To develop EI and apply SA and dispersion modeling techniques to guide clean air action plans (CAAPs) and related environmental policies; strengthen air quality management (AQM) and the basis for subsequent evaluation of the effectiveness of measures to protect human health and the environment.

This **guidance area** is **important** in air quality management since only a quantitative **knowledge** of the emissions from **air pollution sources** allows mitigating **air pollutant concentrations** and, correspondingly, **avoiding health and environmental impacts** by reducing emissions via appropriate **control measures**.

3.1.2 Role of emissions inventories, source apportionment and modeling in air quality management framework

3.1.2.1 Emissions inventories and source apportionment

This guidance area is important in AQM since only a quantitative knowledge of the emissions from air pollution sources allows mitigating air pollutant concentrations, and, correspondingly, avoiding health and environmental impacts by reducing emissions via appropriate control measures. Holistically, an effective AQM requires a process of continual improvement in knowing where pollution is coming from and how much each of the sources is contributing to the ambient air pollution. For this reason, in an area of concern (i.e. area of non-attainment of air quality standards), it has to be assessed which sources are the most relevant ones for which the reduction of emissions will lead to a significant decrease of pollutant concentrations. Two approaches used to resolve this task are EI and SA.

An EI is a listing, by source, of the amounts of air pollutants – including criteria pollutants, greenhouse gases (GHGs), volatile organic compounds (VOCs), among others – actually or potentially discharged into the atmosphere of a community during a given time period (Organisation for Economic Co-operation and Development [OECD]), 2001; European Environment Agency [EEA], 2013; Stockholm Environment Institute [SEI], 2008). The EEA considers EI as a valuable tool to help define priorities and set specific objectives for AQM policies and guidance mechanisms, to help assess the potential health and environmental impacts and consequently, to estimate the costs of control and benefits of avoided health and environmental impacts [See *Guidance Area 3 on Health and other impacts*] (EEA, 2013). Emissions inventories facilitate assessment and prioritization of long-term reduction measures for estimated future emissions as well as target emission sources. The compilation of EIs can be accomplished at the national level, or it can be a composite of emissions obtained at smaller geographical scales such as a municipality or city (SEI, 2008).

Information from EIs can be used to establish emission trends (if EIs are routinely compiled) and determine hotspots and exposure areas by simulating air pollutant concentrations via dispersion models (United States Environmental Protection Agency [USEPA], 2014a). Air pollutant concentration maps, along with data on population density and baseline information on health outcomes, could guide policymakers to design and implement regulations and CAAPs [See *Guidance Area 5 on Clean air action plans*].

There are two approaches in establishing EI: top-down and bottom-up approaches. The top-down EI approach uses national- or regional-level emission estimates allocated to a city, area, or grid according to surrogate parameters (i.e. population, employment, energy consumption, resource use, vehicle number, etc.), typically used when local data are not available and resources are limited (SEI, 2008). Activity rate is derived from international, national, regional, or local level statistical information on source and process characteristics. Temporal change is estimated using allocation of the total amount of emissions according to hours of activity and operation of each source. An example of a top-down EI approach is presented in **Annex II-A of the Information Sourcebook.**

The bottom-up EI approach, on the other hand, gathers information from individual sources, processes, activity rates and their levels, and subsequently estimates emission factors (EFs). Emission factors are the average rate of emission of a pollutant per unit of activity for a given source. The process requires more financial resources to implement, but results to more accurate estimates than the top-down approach (SEI, 2008). Available information sources for EFs are tabulated in **Annex II-A of the Information Sourcebook.**

There are significant challenges in EI approaches that have to be taken into account in order to assess an EI's reliability (See Section 3.3). Once a reliable EI has been achieved, dispersion modeling is then used to estimate ambient air pollutant concentrations at receptor sites. The dispersion modeling tool – depending on the model systems used – can provide information on contributions of emission sources to ambient air pollutants measured at a site. Owing to the complexity brought about by physical and chemical properties of air pollutants, coupled with meteorological and geographical characteristics of sampling domains, certain levels of uncertainty of modeling results would be expected.

Emissions inventories provide information on emission loads of primary air pollutants that are directly released from different source categories (shares of pollution loads) in an inventory area. It does not provide information on sources located from outside the domain of emissions nor information on secondary pollutants that are formed in the atmosphere. Emissions inventories could not directly provide information related to contributions from each source category to ambient air pollution at a receptor site.

Source apportionment by receptor modeling, can provide contributions of different source categories to ambient levels of some pollutants. This information is necessary for the development of sector-specific CAAPs [See *Guidance Area 5 on Clean air action plans*]. It involves ambient sampling and measurement of atmospheric particles and/or VOCs, semi-VOCs, followed by laboratory analyses to characterize the chemical composition. Such information could help in the validation and improvement of the available EI data (Environment Canada, 2013). Chemical speciation helps to understand the properties of the pollutants at receptor site(s) and to identify the source types of pollution, including sources that are not readily identified in preliminary EIs.

Three SA approaches or techniques are in use: (1) source emission shares of pollution load in an area based on EI, (2) SA based on dispersion modeling, and (3) SA based on receptor modeling. Source apportionment based on EI provides information on contribution of different source categories (e.g., power plants, vehicles) and sub-categories (e.g., diesel-powered vehicles, two-wheelers, passenger cars within vehicle category) to total emission loads of identified pollutant(s). On the other hand, dispersion models are used to estimate source contribution to ambient air concentration of identified pollutant(s). While dispersion models use emissions data, meteorological data, and chemical transformation to estimate pollutant concentrations, receptor models use chemically-speciated ambient pollutant concentration

data and source profiles to estimate source contribution to ambient levels measured in receptor sites. Receptor models are normally used for SA of pollutants found as mixtures in ambient air with contributions from different sources (i.e. PM, VOCs, or semi-VOCs). In the process, the portion of secondary air pollutants attributed to regional and long-range pollution transport may also be apportioned.

The three approaches mentioned above have their own limitations and challenges, and should therefore be used complementarily. An overview of the properties of the methods is presented in **Annex II-A of the Information Sourcebook.** Each approach can mutually validate outputs and lead to more robust results. As an example, measurements conducted close to the sources can validate EFs while compiling source profiles. Results from SA by receptor modeling can be used to identify the missing sources in an EI.

Figure 3.1 illustrates the links between EI and SA methods. Ambient monitoring data can, in turn, help validate dispersion models by comparing simulated concentrations with measured ones. A combination of these models can therefore facilitate a strong pollution control strategy (Guttikunda, 2011).

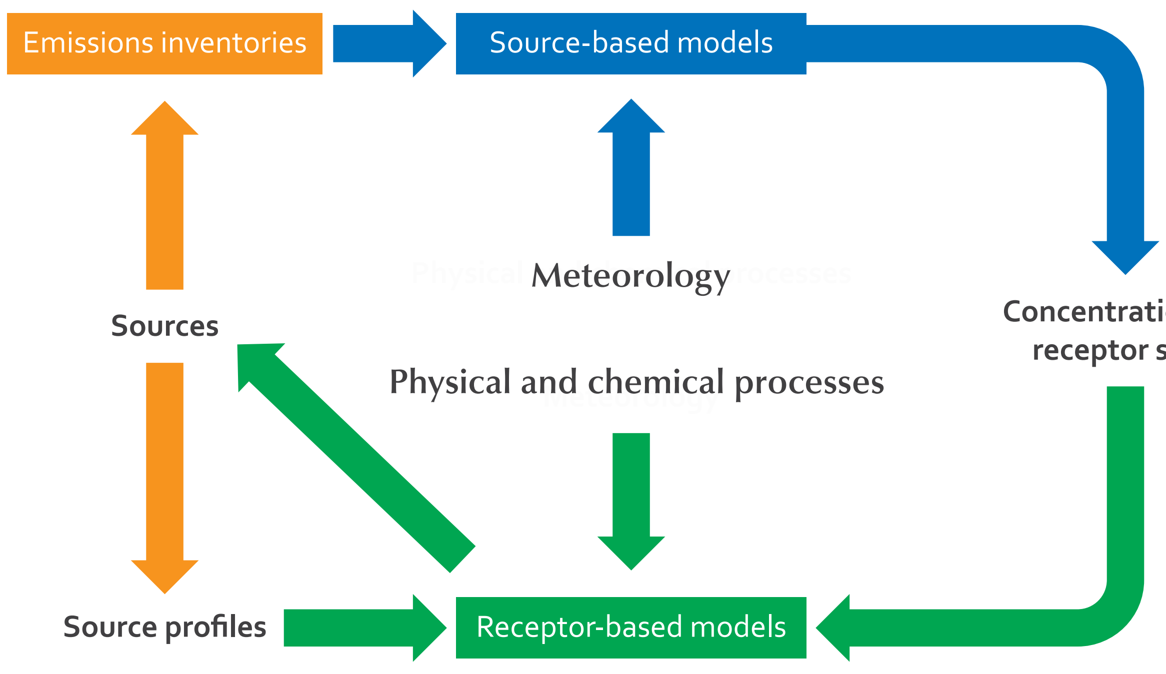


Figure 3.1 Schematic representation of how top-down and bottom-up SA approaches are linked

Adapted from European Commission, 2014

Both emissions inventories and source apportionment **have their own limitations** and challenges, and should therefore be **used complementarily**.

3.1.2.2 Receptor-based and source-based modeling

As Figure 3.1 demonstrates, the linkage between EI results and pollution concentration at receptor sites is provided by source-based (dispersion) models on the one hand and receptor-based models on the other. Prediction of air pollutant concentrations by EI and dispersion modeling are verified by air quality monitoring results [See *Guidance Area 1 on Ambient air quality standards and monitoring*]. Monitoring also comes in when a receptor-based model identifies the types of sources leading to SA. Predicted concentrations also allow the estimation of health and environmental impacts [See *Guidance Area 3 on Health and other impacts*]. The same applies for measuring exposures (concentrations) at receptor sites. Emissions inventories and SA are important ingredients of CAAPs [See *Guidance Area 5 on Clean air action plans*] and their scope must be regulated by legislation. Control measures based on a reliable EI must be implemented by means of appropriate governance [See *Guidance Area 6 on Governance*].

Receptor-based modeling

Receptor-based approaches have been termed "receptor models" (USEPA, 2013a). They are mathematical or statistical procedures that use source profiles as well as physical and chemical characteristics of pollutant gases and particles at sources and receptor sites in a given area to estimate the presence and fraction of source contributions at receptor locations. Unlike dispersion models, receptor-based models do not require pollutant emissions, meteorological data, chemical transformation, and deposition mechanisms to estimate contribution of sources to receptor concentrations (USEPA, 2013a). Receptor-based models cannot identify the contribution of individual sources if several sources of the same type and emission characteristics (e.g. two or more power plants, two or more cement plants) are located in the area considered. Receptor-based models complement dispersion models instead by apportioning concentrations at receptor sites to distinct source types. An overview of receptor-based model types is described in **Annex II-B of the Information Sourcebook.**

Dispersion or source-based modeling

The dispersion model, also known as air quality simulation model (AQSM) or source-based model, is a numerical technique or methodology for estimating air pollutant concentrations in space and time. Data inputs to dispersion models consist mainly of emissions, meteorological, and topographical data. The parameters that constitute a dispersion model include (SEI, 2008): a) emissions sources, including their locations and emissions rates; b) receptor locations; c) meteorological specifications; d) deposition rates, if these will be considered; and e) output specifications or what kind of values are required (e.g., average concentrations).

Dispersion models can provide valuable estimates such as the concentrations of pollutants that are too difficult or expensive to measure, influence of geophysical factors on dispersion, among others. With the wealth of technical estimates they can provide, dispersion models can contribute in designing ambient air monitoring networks [See *Guidance Area 1 on Ambient air quality standards and monitoring*]. They can also be useful in evaluating the impact and efficiency of policy and mitigation strategies [See *Guidance Area 5 on Clean air action plans*]. Lastly, dispersion models can contribute in forecasting air pollution episodes and assessing the risks of and tracking originating sources of accidental hazardous substance releases (New Zealand Ministry of Environment [MoE], 2004). The major objective of dispersion models is to simulate air pollutant concentrations at receptor sites, starting from reliable emission estimates and using monitored or modeled meteorological data. This can be performed at costs much lower than those for air quality monitoring. Figure 3.2 illustrates that dispersion modeling complements air quality monitoring and can even replace monitoring activities provided an accurate and reliable EI exists. A comparison of air quality monitoring and modeling capabilities are provided in **Annex II-A of the Information Sourcebook.**

With the wealth of **technical estimates** they can provide, dispersion models can **contribute** in designing ambient **air monitoring networks**. They can also be **useful** in evaluating the **impact and efficiency** of policy and mitigation strategies.

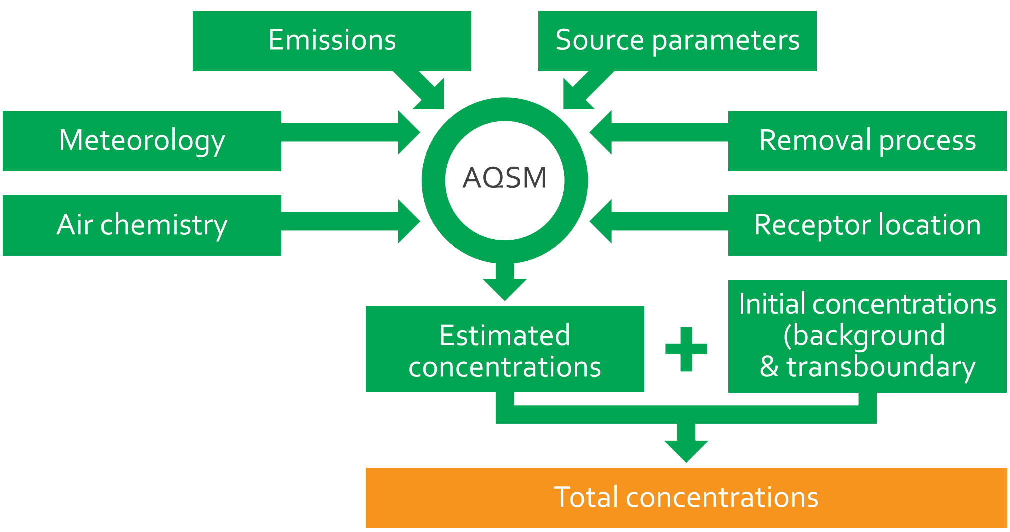


Figure 3.2 Basic components of dispersion modeling

Source: SEI, 2008

3.2 Stages of emissions inventory, source apportionment, receptor and dispersion modeling development

Strengthening the capacity for quantification of pollutants, determination of source contributions, and evaluation of existing and future emissions help shape and define policies for improving air quality. Such capacity also helps in the assessment of compliance with national and international targets, and evaluation of the effectiveness of measures to protect human health and the environment. As a starting point, Table 3.1 presents indicators that would aid cities in identifying their current state of AQM development for EI, SA, and air quality modeling.

The key indicators that should be considered in progressing from underdeveloped to fully developed stage include:

- Capacity for conducting EI (i.e. frequency, scope, and approach)
- Capacity for conducting SA (i.e. availability of source profiles and scope)
- Verifying accuracy and reliability of EI and SA
- Capacity for applying elementary and/or sophisticated dispersion models

"**Strengthening** the capacity for **quantification** of pollutants, determination of **source contributions**, and **evaluation** of existing and future **emissions** help shape and **define policies** for **improving** air quality."

Table 3.1 Stages of emissions inventory, source apportionment, receptor and dispersion modeling

Stages	Indicators
Underdeveloped	No EI has ever been compiled There is no ambient air quality monitoring system. Particulate matter (PM) source profile data are not collected and receptor-based SA is not conducted Pollution dispersion has not been modeled/mapped
Developing	An initial EI or a rapid EI is available for criteria and/or other air pollutants covering major sources (e.g. those using the Global Air Pollution Forum (GAPF) EI Methodology or the WHO Rapid Inventory Assessment (RIAS) approach) An ad hoc EI may have been compiled using a top-down EI approach with default EFs and surrogate activity data EI results are not reviewed nor validated. Quality assurance/quality control (QA/QC) manuals for EI are developed PM source profile data are not collected and receptor-based SA is not conducted Dispersion modeling is not conducted but capacity is being developed for dispersion model applications[2] Ambient air quality monitoring and meteorological monitoring systems are being developed and are being considered for emission-exposure-impacts modeling

2 Applications include exposure estimates and selection of appropriate AQ monitoring sites

Stages	Indicators
Emerging	EI for criteria pollutants covering major sources as well as sources with increasing importance are regularly compiled based on a mixed top-down and bottom-up approach Default EFs and EFs obtained from local academic research are used There are initial plans to use more sophisticated or higher tier EI approaches, such as those by USEPA and EEA EI review process and results are considered and or utilized in AQM policy development, implementation, and evaluation Rapid EIs for toxic pollutants are being planned Initial attempts to validate EIs are made Receptor-based SA for PM and VOCs/semi-VOCs is conducted on an ad hoc basis by research/academic institutions PM source profile from external and local literature/studies are used to describe source profiles for major local sources. Attempts are made to validate receptor-based SA QA/QC procedures for EI and SA are regularly implemented Simple steady-state dispersion models are used to estimate pollutant concentrations using meteorological measurement inputs Non-steady state dispersion models are beginning to be explored/initiated SA and dispersion modeling results sometimes align EI, SA, and dispersion modeling results are used in identifying air quality policies or measures

Stages	Indicators
Maturing	EI for air pollutants are systematically and routinely compiled (with an initial inclusion of toxic pollutants) using a bottom-up approach, local EFs and some actual emissions measurements. All relevant sources (major and emerging) are covered. EI methodologies that are more sophisticated than those of GAPF and WHO RIAS are being applied. EIs make use of higher tier activity data EIs are reviewed and validated regularly. QA/QC procedures are routinely implemented EI results are used as important inputs in air quality policy development, implementation, and evaluation Receptor-based SA for PM and VOCs/semi-VOCs is conducted using different approaches by academe and government agencies/research institutions Receptor-based SA for key toxic pollutants is initiated PM source profile data needed for Chemical Mass Balance (CMB) are collected mostly from local information sources and assumed to describe source profiles for the majority of local sources. Air quality is monitored at several receptor sites during all seasons and receptor-based SA is conducted using CMB, UNMIX and Positive Matrix Factorization (PMF) models, covering both general and episodic conditions. An integrated database on (i) sources in the area, (ii) source profiles, and (iii) ambient receptor site measurements is developed SA is conducted on both general conditions and pollution episodes. Results from receptor-based SA and dispersion model are increasingly aligned[3] Initial attempts to validate SA are made More advanced steady state dispersion models or even non-steady state models are used for exposure estimation using local data[4] Dispersion models incorporate local land use and emissions profile data. Local AQ monitoring and other measured data are used for model verification and performance evaluation The role of EI and SA in air quality management is understood and appreciated by policymakers and the public in general EI, SA, and dispersion modeling results are also used to review or assess progress or achievements of AQ policies or measures Capacity to forecast future emissions and dispersion is being developed

3 If results from both models do not align, cities would go one stage back. This also applies to Maturing and Fully developed stages.
4 Such as land use, topographical data, and meteorological data

Stages	Indicators
Fully developed	EIs for criteria, toxics, and other air pollutants are compiled with a bottom-up approach at predefined intervals (e.g., annually or every two years), covering all types of relevant sources. Emissions are measured cost-effectively and as regularly as possible QA/QC procedures are routinely implemented and regularly reviewed and updated EI validation is performed as a routine procedure without exception EI results are used as important inputs in air quality policy development, implementation, and evaluation Receptor-based SA studies for PM and VOCs/semi-VOCs are routinely performed by academe and government/research institutions Receptor-based SA for key toxic pollutants is routinely performed PM data for SA studies are collected primarily from local information sources to represent more accurately the majority of local pollution source profile Air quality is monitored at several receptor sites during all seasons to cover both general and episodic conditions. Receptor-based SA is conducted using CMB, UNMIX and PMF models. An integrated database on sources in the area, source profiles, and ambient receptor site measurements is in place and updated routinely SA model validation and performance evaluation use local data Results from receptor and dispersion models are run in parallel. Reasons for any divergent results are identified All models (steady state, non-steady state, photochemical) are routinely applied and validated to estimate exposure, using routinely updated meteorological data and local data Dispersion models are developed and used with incorporation of local land use and emissions profile data. Local measurement data is used for model verification and performance evaluation. New dispersion models more appropriate for the local situation are developed if needed. Localized air quality models or locally-developed models when available are updated as regularly as possible EI, SA, and dispersion models are used in an integrated manner Capacity to forecast future emissions and dispersion is well established Dispersion modeling results are used for studies that measure impacts of air pollution on public health and the environment

> "One major **institutional problem** in developing emissions inventories, source apportionment and air quality modeling is the **lack of an integrated action plan** and strategy, especially the **poor linkage** among source inventory, emission, air quality monitoring, meteorological situation and receptor-based modeling."

3.3 Issues and challenges

Asian cities are faced with a number of institutional, management and technical, and financial issues and challenges, which differ for each stage of development. As the stage advances from underdeveloped to fully developed, fewer issues and lesser challenges are noted.

Institutional

An institutional framework with specific focus on the development and application of EI and SA techniques is not available. Emissions inventories and SA are used mostly for academic purposes; there is no mechanism to make use of these techniques or available information for policy inputs.

One major institutional problem in developing EI, SA, and air quality modeling is the **lack of an integrated action plan and strategy**, especially the poor linkage among source inventory, emission, air quality monitoring, meteorological situation, and receptor-based modeling. As a result, there is a lack of coordination among different agencies, and data in their custody are not easily available. There is also limited transboundary collaboration to address air pollution dispersed over neighboring municipalities/provinces. Lastly, there is very limited stakeholder capability and participation in development of EI, SA, and air quality modeling. Local stakeholders and the public may not be fully aware of the usefulness of these techniques and often do not show adequate interest in participating in the necessary activities.

Management and Technical

- **Policy and decision making processes are limited** and constrained by lack of reliable EI and sufficient information for SA to guide CAAPs development.

- **Only a limited number of reliable EI and SA studies are extant**. There is also a particular scarcity of studies comparing the results of different receptor-based models.

- **Studies concerning the linkage of air pollution EI to climate change are limited.**

- **Poor data/information availability and transparency on EI and SA**. Input data uncertainty is a problem both for EI and SA. Outliers and anomalous values contribute to input data uncertainty if they are not identified (Karagulian & Belis, 2012). The same is true if there are no established criteria on how to treat values of concentrations below the detection limit in SA. Estimation of values below the detection limit has a high impact on the quality of results since the uncertainty of estimated values is higher than that of measured ones.

- **Difficulty in acquiring reliable local data, especially for source activities**. In bottom-up inventories, it may be difficult to acquire reliable local data due to multiplicity and complexity of emission sources and limited technical resources. Available secondary data also may not be up-to-date. Default EFs are often used, without much analysis on applicability or uncertainty. These practices may not provide reliable estimates.

- **Lack of quality assured data for developing and updating EI**. In most areas, secondary data, particularly on source emission measurements, may not be of acceptable quality, and ascertaining the quality is difficult due to lack of transparency. At point sources, emission measurement are often performed at the bottom of a stack and may not be representative of the emissions at the top of the stack.

- **Some EIs do not include future projections or, if they do, projections are inaccurate** due to lack of understanding of dynamic changes of economy and the development process in a certain area.

- **Complexity of more sophisticated EI calculations** which require technical knowledge of emission sources and processes.

- **Uncertainties in EI and SA and difficulties in their estimation**. Currently, a high-resolution regional emission inventory takes years to develop, which leads to air quality modeling outputs that are based on outdated emission information. Significant uncertainties would henceforth be associated with the simulation results and the derived AQM plans. Factors leading to uncertainties in EI are outlined in **Annex II-A of the Information Sourcebook**. Precision in air quality dataset measured by sample-specific uncertainties are used in various multi-linear receptor models but the expense involved with repetitive field measurements and laboratory analysis for air quality monitoring renders this approach practically infeasible (Hopke, 2003).

- **Model performance uncertainty**. Receptor-based models rely on the mass conservation principle between source and receptor (Karagulian & Belis, 2012). All receptor models make the same assumptions, e.g., on unvaried compositions of source emissions, non-reactivity of chemical species, and other characteristics (Watson et al., 2002).

- **Analytical uncertainty.** Sources of analytical uncertainty in SA modeling include the usual uncertainties of chemical analysis of samples (Eurachem/CITAC, 2012).

- **Lack of local source profiles**. Significant differences in fuel composition and control technology exists, hence, the source profile in Asia has a potentially large difference from those in North America and Europe.

- **Necessity of model validation**. The predicted results from a dispersion model must be validated against monitoring data (U.K. Department for Environment, Food and Rural Affairs [DEFRA], 2009). The predicted results from a dispersion model may differ from measured concentrations for a large number of reasons.

Financial

The development of EI and SA is resource-intensive. Choosing the methodology for the development and implementation of EIs depends on the availability of data, time, manpower, and financial capabilities (British Columbia Ministry of Environment Air Quality, 2013). While the application of air quality models is a relatively cheap option as some of these models have been developed by and tested in some countries in transition such as China and India, they still need reliable EI as well as meteorological data to guide CAAPs and policy measures. With many other pressing demands in developing countries and cities, obtaining adequate financial resources for AQM in general is a major issue. City-level initiatives often need to be aligned with the national development agenda to gain full financial support from the national government.

3.4 Roadmap for emissions inventory, source apportionment, receptor and dispersion modeling

To progress towards a fully developed system of EI, SA and dispersion modeling within an integrated and rational AQM approach, there are a number of management and technical steps at each stage that the city – and if applicable, provincial or national authorities – should follow. These are compiled for each stage in Table 3.2.

Table 3.2 Steps to follow to implement a roadmap for emissions inventory, source apportionment and dispersion modeling

Developmental stages	Steps to follow
Underdeveloped	**Management Process** • Identify potential stakeholders from different levels of government and from other non-government, academe, and private sectors • Ensure buy-in of decision makers from the identified stakeholders through seminars, workshops, and policy papers that encourage awareness on importance of EI and SA studies on AQM • Establish a working group of technical experts and an advisory group of policymakers and decision-makers • Assess existing technical capacity of working group and identify training or resource needs • Research around the region for case studies and approaches that may be adapted for local implementation of EI or SA • Secure funding from internal (in-country) and external (international) sources **Technical Process** • Identify and secure activity data needed using rapid assessment procedures (GAPF, 2012; WHO, 1993) • Determine the objective, design and scope, extent of details and pollutants for EI development and implementation work plans. Refer to basic considerations in Box 3.1 • Build the technical capacity of compiling EI for criteria pollutants for main source categories by top-down approach with statistical information, default EFs, and surrogate activity data • Participate in regional EI networks (i.e. Acid Deposition Monitoring Network in East Asia [EANET]) and assess methods that may be adapted for local EI • Build capacity for dispersion model applications for local air quality simulation using the top-down EI • Develop quality assurance/quality control (QA/QC) guidance manual for EI

Developmental stages	Steps to follow
Developing	**Management Process** • Involve more stakeholders • Establish a cooperation framework by the local or national government among the working group (i.e. technical team, data providers), advisory group, and experts to set up a stable EI system • Develop a sustainable data collection plan with relevant organizations producing data inputs for EI • Develop a review process involving experts and stakeholders for continual improvement in EI for use in AQM policies • Enhance technical capacity for EI through sustainable training **Technical Process** • Build the capacity for compiling mixed top-down and bottom-up EI for criteria and other pollutants • Evaluate the applicability of default EFs and EFs obtained from academic and/or other countries' research • Assess capacity to use more sophisticated EI approaches (i.e. USEPA, EEA) • Adapt applicable methods used in regional EI networks and disseminate results • Develop a review process and conduct regular validation of EI to ensure good data quality • Prepare and implement monitoring plan (sampling locations, schedule, among others) for collection of ambient samples, and arrange for necessary monitoring and analytical instruments. Refer to available literature (e.g., CPCB, 2006; 2007a) • Identify laboratories within the region capable of doing analysis for major PM components, e.g. ions, elements, organic carbon (OC) and elemental carbon • Collect ambient sample(s) and send for analysis for key chemical constituents to laboratories (in-country or abroad) with the appropriate technical capacity • Build capacity for initial SA for PM and VOCs/semi-VOCs on an ad hoc basis or by research/academic institutions • Evaluate applicability of any PM source profiles available (external or from local studies) for major local sources • Initialize characterization of local source profiles and apply in CMB runs • Use CMB model to determine SA, and compare results with similar reported studies • Develop QA/QC procedures for SA • Secure appropriate receptor model software (Box 3.2) and source profiles (e.g., SPECIATE [USEPA, 2014b], CPCB, 2010) • Initialize use of dispersion models for exposure (concentration) simulation • Analyze the correlation of SA results from dispersion and receptor-based models, and provide recommendations to improve their alignment • Develop and propose control measures on the basis of findings from EI, SA and dispersion modeling

Developmental stages	Steps to follow
Emerging	**Management Process** • Set-up a framework for review and continual improvement of the EI and SA estimates, and organize long-term resources for the same • Engage and ensure buy-in of all relevant stakeholders in implementing sustainable data collection plan • Enhance technical capacity through sustainable training • Identify and prioritize resource, equipment and infrastructure investments necessary to establish local capacity for chemical speciation analysis **Technical Process** • Enhance capacity for routine compilation of EI for criteria pollutants (with initial inclusion of toxics and GHGs) • Enhance capacity for bottom-up EI approach using available local EFs and/or utilize actual measurements for several main emission sources • Use EI results as basis for development of AQM policies, implementation and evaluation • Plan for use of rapid EIs for toxic pollutants • Build capacity to contribute to regional EI studies • Continually improve review processes and QA/QC procedures for EI and SA • Enhance capacity for SA using more sophisticated approaches • Conduct SA by at least two receptor models, e.g. CMB and PMF • Conduct SA using available local profiles needed by CMB; use international profiles for other sources • Identify a few key sources and develop local source profiles • Plan for conducting SA for toxic pollutants (i.e. PAHs, dioxins) • Conduct sensitivity analysis using different sets of source profiles available internationally • Conduct PM speciation measurement and analysis in a regular manner • Evaluate model outputs by statistical tools • Develop an integrated database on source and ambient pollution characteristics • Build capacity to use more advanced steady-state models and if possible, non-steady state models for exposure estimation using local data • Incorporate local land use and emission profile data • Validate modeling results by local measurement data • Evaluate alignment of results from receptor-based SA and dispersion models • Ensure use of EI, SA, and dispersion modeling findings to review or assess progress or achievements of air quality policies and measures

Developmental stages	Steps to follow
Maturing	**Management Process** • Set up a comprehensive framework for development of local, regional, and national-level EI and SA using local source profiles, and necessary infrastructure (e.g., laboratory, GIS-based database system) • Set up for review and continual improvement of EI and SA estimates • Make long-term provisions for required resources (i.e. human, financial, infrastructure) • Establish a mechanism for use of EI and SA for policy decisions • Continually enhance technical capacity through sustainable trainings and participation in knowledge sharing platforms **Technical Process** • Build the operations and management system of compiled bottom-up EI for pollutants and GHGs at pre-defined intervals (i.e. annually or every two years) using more refined EI approaches • Ensure capacity to participate in regional EI studies using refined EI approaches • Ensure regular update and review of standard operating procedures (SOPs) and QA/QC procedures for EI and SA • Enhance technical capacity for SA studies; collaborate with academe and other research institutions and explore more advanced methods • Complete local source profiles for majority of sources and maintain database for the same • Conduct receptor-based SA using a variety of models (i.e. CMB, UNMIX, PMF) • Collect PM speciation data covering spatial, seasonal variations and business as usual; as well as episodic scenarios • Use multiple SA techniques, conduct sensitivity analysis and disseminate peer reviewed results • Conduct regular audits of laboratory facilities and data quality checks for ensuring good SA estimates • Develop and continually update an integrated database of speciated data, source profiles, and ambient receptor site measurements • Conduct continuous PM speciation measurement and analysis, and update SA every year • Develop localized dispersion models and apply for SA at least one month per season • With factors leading to diverged results identified and resolved, ensure alignment of SA results from dispersion and receptor models for most of the time • Apply and validate all models (steady state, non-steady state, photochemical) routinely to estimate exposure • Improve local land use and emissions profile data for incorporation into dispersion models • Use EI, SA, and dispersion models in an integrated manner for AQM policymaking or evaluating policies • Build capacity to forecast future emissions and dispersion

Developmental stages	Steps to follow
Fully developed	**Management Process** • Set up an institutional framework for continual improvement of infrastructure including state-of-the-art laboratory facilities, techniques, documentation, and database management systems for EI and SA • Sustain use of EI and SA for policy decisions and feedback for improving EI and SA and specific scientific inputs • Ensure allocation of adequate and sustainable technical and financial resources • Ensure that all stakeholders are regularly involved **Technical Process** • Continually enhance the operations and management system of compiled EI for pollutants, toxics, and GHGs annually or every two years • Build and sustain the capacity for EI of toxic pollutants • Participate in studies that conduct regional EI • Explore capacity building opportunities for more sophisticated SA methods • Conduct SA for selected criteria and toxic pollutants regularly • Collect PM speciation data regularly covering trace and molecular marker species • Upgrade source profiles in CMB applications • Establish and continually assess data quality by EI validation and SA verification • Conduct SA using multiple SA techniques with comprehensive scientific analysis of the data and results • Organize international peer review and dissemination of results • Sustain enforcement of control measures • Sustain capability to apply steady-state, non-steady state and photochemical modeling • Enhance capacity for forecasting emissions and dispersion • Sustain an AQM system using inputs from EI, SA, and dispersion modeling to AQ policymaking and evaluation of effectiveness or impacts of AQ policies and measures

Box 3.1
Basic considerations in emissions inventory development

General planning considerations. The most important step in initiating an EI is determining the objectives from which major planning considerations need to be taken into account. Factors that need to be considered include:

- ultimate use of, background and basis for the inventory;
- identification of point, areas, and mobile source categories;
- responsibility for the inventory;
- staff and budget requirements/constraints;
- geographical coverage;
- selection of base year;
- variation of source emissions: daily, seasonal, annual;
- rule effectiveness;
- minimal source size;
- data collection methods;
- emission estimate approach, including selection of sources for EFs;
- status of existing EIs;
- inventory data handling system;
- QA/QC measures, including naming a QA coordinator; and
- use of the inventory for modeling purposes (e.g., as input to a photochemical dispersion model).

Source: SEI, 2008

Box 3.2
List of reference manuals for emissions inventory

The relevant manuals and guidebooks for EI, some of which provide EFs, are listed in the table below.

Manual/Guidebook	Website
Assessment of sources of air, water, and land pollution – A guide to rapid source inventory techniques and their use in formulating environmental control strategies. Part One: Rapid Inventory techniques in environmental pollution. By Alexander Economopoulos (WHO, 1993).	http://whqlibdoc.who.int/hq/1993/WHO_PEP_GETNET_93.1-A.pdf
Asia Center for Air Pollution Research. Guidelines for Developing Emission Inventory in East Asia (ACAP, 2011).	http://www.acap.asia/publication/pdf/em_inventory/em_guideline.pdf
Global Atmospheric Pollution Forum. Global Air Pollution Forum Emission Manual (GAPF, 2012).	http://sei-international.org/rapidc/gapforum/html/emissions-manual.php
Intergovernmental Panel on Climate Change. IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).	http://www.ipcc-nggip.iges.or.jp/public/2006gl/
New Zealand, Ministry of Environment. Good Practice Guide for Atmospheric Dispersion Modeling (MoE, 2004).	http://www.mfe.govt.nz/publications/air/good-practice-guide-atmospheric-dispersion-modelling
Stockholm Environment Institute. Foundation Course on Air Quality Management in in Asia: Emission, G Haq and D Schwela (eds.) (SEI, 2008).	http://www.sei-international.org/publications?pid=1087
Stockholm Environment Institute. The Forum air pollutant emissions inventory preparation manual. Version 5, November 2012 (SEI, 2012).	http://www.sei-international.org/gapforum/tools.php
United States Environmental Protection Agency. A complication of Air Pollutant Emission Factors (AP-42) (USEPA, 1995).	http://www.epa.gov/ttn/chief/ap42/index.html
India, Central Pollution Control Board. Air quality monitoring, emission inventory and source apportionment study for Indian cities – National Summary Report (CPCB, 2011).	http://cpcb.nic.in/FinalNationalSummary.pdf
India, Central Pollution Control Board. Conceptual Guidelines and Common Methodology for Air Quality Monitoring, Emission Inventory & Source Apportionment Studies for Indian Cities (CPCB, 2007b).	http://cpcb.nic.in/sourceapportionmentstudies.pdf

Detailed guidelines "Establishing emissions inventory, source apportionment and modeling for Asian cities" focused on management and technical processes are elaborated in **Annex II-B of the Information Sourcebook**. Case studies that demonstrate different stages of development of cities (Boxes 3.3 to 3.5) are also provided. Initiatives in Japan on general survey of emissions and EI for non-criteria pollutants (e.g. VOCs and GHGs) are described in Box 3.6, while regional EI databases and frameworks are described in Boxes 3.7 and 3.8. A case study on SA conducted by the CPCB in six Indian cities is described in Box 3.9. A comparison of receptor-based models (CMB, UNMIX and PMF for VOCs) in Beijing is described in Box 3.10. The complementary nature of EI and SA techniques, wherein SA results were used to validate EI in Hong Kong and the Pearl River Delta (PRD) Region is shown in Box 3.11.

Box 3.3
Road traffic emissions inventory in Hanoi

Objective: To evaluate an inventory for vehicle emissions in Hanoi for the year 2010 and to predict road traffic emissions from 2010 to 2040.

Methods: Emissions of the vehicle fleet of Hanoi are estimated as a function of vehicle age-dependent EFs and vehicle kilometers travelled (VKT). Vehicle age-dependent and vehicle type-dependent EFs are taken from a publication of the Department of Transport, UK. VKT/year are taken from a previous publication of the Research Centre for Environmental Monitoring and Modeling at the Hanoi University of Science. Motorcycles, heavy duty vehicles (HDVs), and light duty vehicles (LDVs) are classified according to vehicle lifetimes in three, six, five groups, respectively. Prediction of carbon monoxide (CO) and nitrogen oxides (NO_x) emissions for 2010 to 2040 are made through two scenarios for new and in-use vehicles: (1) Euro 3 standard for motorcycles and Euro 4 standard for LDV and HDV in 2012, Euro 5 standard for LDV and HDV in 2015; (2) Euro 3 standard for motorcycles and Euro 4 standard for LDV and HDV in 2014, Euro 5 standard for LDV and HDV in 2017.

Results: Motorcycles are the major source of CO, hydrocarbons (HC), NO_x, PM and CO_2 emissions in Hanoi in 2010 (see Table below):

Pollutant	Motorcycles		HDVs		LDVs	
	Emission [tonnes]	Proportion [%]	Emission [tonnes]	Proportion [%]	Emission [tonnes]	Proportion [%]
CO	160,378	98	418	0.26	2680	1.6
HC	12,495	98	100	0.8	155	1.2
NO_x	7,275	75	2,087	22	297	3.1
PM	227	81	51	18	3	1.2
CO_2	1,603,407	76	232,720	11	281,812	13. 3

The results of the two scenarios do not differ significantly – by 2020, CO total emissions will be reduced by 13 percent and NO_x total emissions will decrease by 15 percent. For 2040, the corresponding emission reductions are predicted to amount to 36 percent for CO and 23 percent for NO_x. While emissions from LDVs and HDVs are predicted to be increasing, the major contribution to total emissions in 2040 will be from motorcycles both from CO and NO_x.

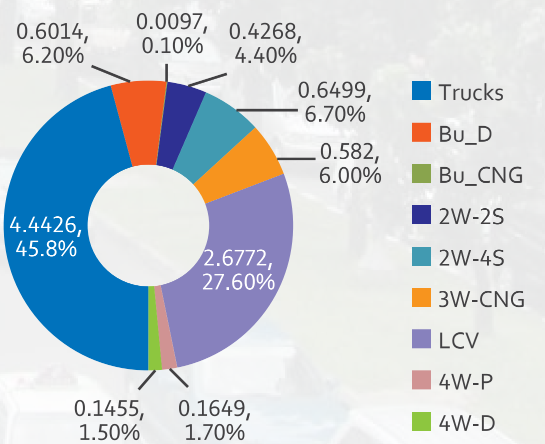
Source: Manh et al., 2011

Box 3.4
Emissions inventory for major cities in India

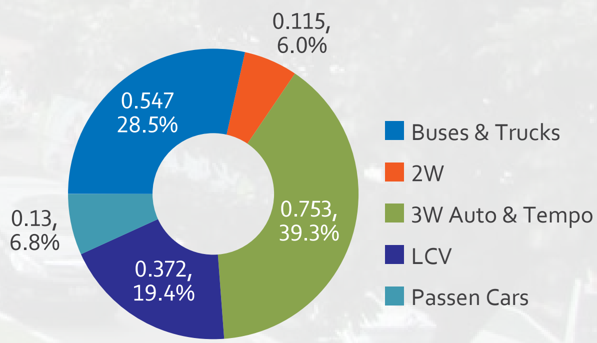
Emissions inventory for six cities were developed in 2007 for sulfur dioxide (SO_2), PM, NO_x, CO, and HC, with future projections for the years 2012 and 2017. It involved estimation of emissions from various activities (vehicular, industrial, residential, commercial, etc.). A combination of top-down and bottom-up approaches was used for identification of all major emission sources, reliable estimates, and adequate representation of various factors influencing emissions (land use, socio-economic structure, and spatial and temporal distribution of source activities vis-à-vis pollutants). In addition to data obtained from secondary sources of information, activity rates were collected through primary surveys including questionnaire surveys, personal interviews, house-to-house surveys, actual traffic counts, among others. While this approach provides reasonable quality of data on emission estimates, resolutions with respect to time and space are limited in view of resources and available timeframe. Important features of methodology are summarized below:

- Detailed in-situ primary surveys within 2x2-km zone of influence around each monitoring location to identify all significant pollution sources (e.g., construction activities, industries fuel use, domestic fuel combustions, size and activities of diesel generator sets, etc.) and also to collect activity rate through personal interviews.
- Diurnal traffic count surveys on different categories of roads along with personal interviews at parking lots/petrol pumps with vehicle owners for obtaining data on age, fuel use, VKT per day, etc.
- Use of local EF for vehicular exhaust emissions and selection of appropriate EF for stationary sources (i.e. roadside dust, domestic fuel combustions, industries, construction activities, etc.);
- Extrapolation of city level EI based on detailed inventories prepared in 2x2-km grids, and city land use plans.
- Future projections of emission scenarios considering developmental plans, changes in the land-use and activities and/or activity levels, (with or without implementation of given pollution control plans), etc.

Results:



Mobile Source - EI: PM_{10}-Delhi



Mobile Source - EI: PM_{10}-Kanpur

Bu_D: Bus (Diesel); Bu_CNG: Bus (compressed natural gas); 2W-2S: Two-wheeler (two stroke); 2W-4S: Two-wheeler (four-stroke): 3W-CNG: Three-wheeler (compressed natural gas); LCV: light commercial vehicle; 4W-P: Four-wheeler (petrol); 4W-D: Four-wheeler (diesel)

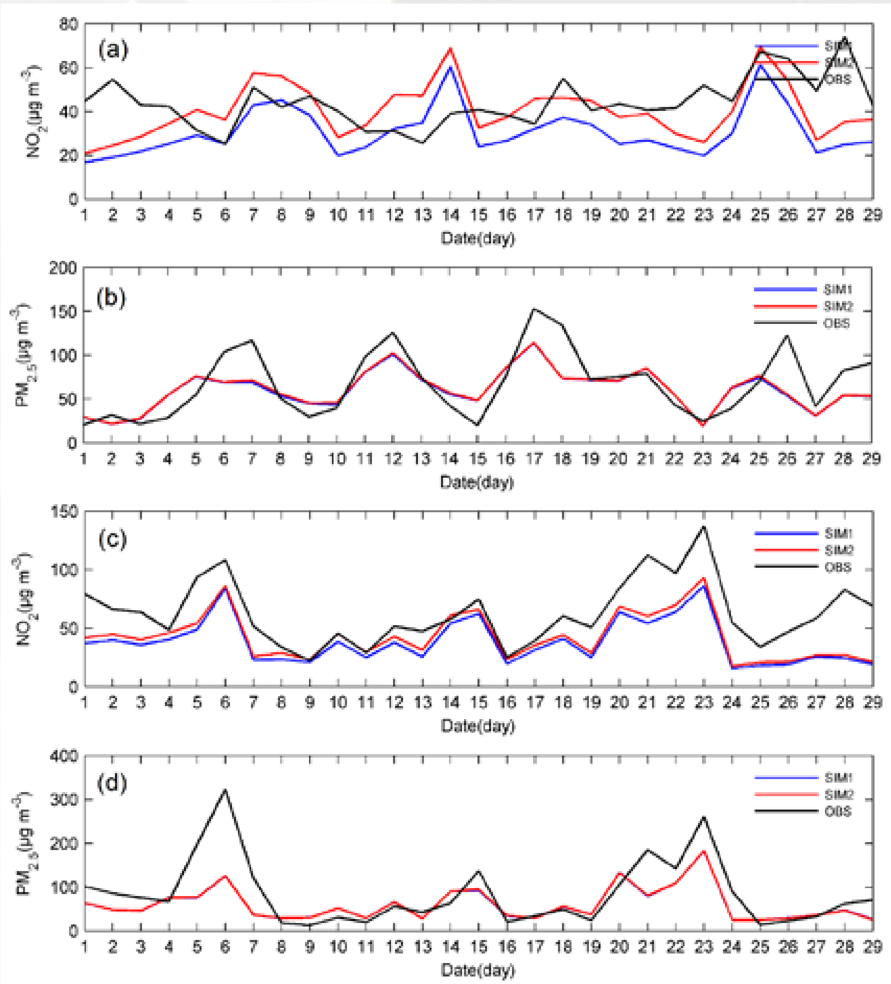
Source: CPCB, 2011

Box 3.5
Impact of vehicle emissions on urban air quality in Beijing

Objective: To estimate the contribution of vehicle emissions to the air pollution exposure in Beijing's main urban areas in July and December 2013.

Methods: Use of a high temporal-spatial resolution vehicle emissions inventory (HTSVE) in the Chinese Unified Atmospheric Chemistry Environment (CUACE) model was used to estimate the wind field and other meteorological parameters. Simulation of nitrogen dioxide (NO_2) and $PM_{2.5}$ (PM ≤ 2.5 micrometers in diameter) was performed with (a) default emissions of CUACE ('SIM1') and (b) the improved emissions of Beijing's HTSVE ('SIM2').

Results: SIM2 estimated concentrations are higher than SIM1 estimates. The mean vehicle emission contribution to outdoor air NO_2 is 55 percent in July 2013 and 49 percent in December; the corresponding percentages for $PM_{2.5}$ are 5.4 percent and 10.5 percent, respectively. The observed concentrations of NO_2 and $PM_{2.5}$ in July 2013 (figures a, b) and December 2013 (figures c, d) are compared with the simulated concentrations in the figures below.



The comparison of site average NO_2 and $PM_{2.5}$ concentrations between SIM1, SIM2, and observation in July (a,b) and December (c,d) 2013.

Source: He et al,. 2015

Box 3.6
Status and recent initiatives in emissions inventory in Japan

General Survey of the Emissions of Air Pollutants

This survey, carried out every three years by Ministry of the Environment of Japan (MOEJ), is conducted to grasp the state of sulfur oxides (SO_x) emissions, NO_x emissions, and soot and dust emissions from business establishments subject under the Air Pollution Control Law. This questionnaire survey requires hourly emission, yearly operation hours, soot and dust concentration, and amount of fuel usage. In the investigation, the amount of emissions of prefecture air pollution became clear via facility and by soot and smoke emissions from factory. The results of the survey can be accessed at http://www.env.go.jp/air/osen/kotei/index.html (in Japanese).

Studies to develop the national emissions inventory for volatile organic compounds

In order to assess the progress of measures to suppress VOCs emission from stationary sources in Japan, the emissions of VOCs from stationary sources have been estimated and compiled into the national "Emissions Inventory for VOC" every year by MOEJ.

The study targeted around 200 kinds of VOCs. Emissions are estimated mainly through (i) multiplying the shipping volume of VOC-containing products (e.g., paints) by emission rates, or (ii) summing up the VOC emissions reported in the voluntary plans related to VOC reduction that are implemented by industry organizations. This survey can be accessed at http://www.env.go.jp/air/osen/voc/inventory.html (in Japanese).

National Greenhouse Gas Inventory

Under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, parties included in Annex I (developed countries and countries with economy in transition) are required to submit an annual national GHG inventory to the secretariat of UNFCCC. A GHGs inventory by the MOEJ is an accounting of the amount of anthropogenic GHGs (CO_2, CH_4, N_2O, and HFCs, PFCs, and SF_6) emissions by sources and removals by sinks in a year. For GHG inventories, the emissions estimates for each gas are conducted by each sector and source category, based on statistics instead of actual measurement data. The inventory can be accessed at http://www-gio.nies.go.jp/index.html.

Japan Auto-Oil Program

Under the Japan Auto-Oil Program (JATOP) conducted by the Japan Petroleum Energy Center, the inventory for the emissions from vehicle and stationary sources are compiled using the top-down approach. The inventory for vehicle emissions estimates the emissions from each operation process. The evaporation fuel and tire wear for FY2000, FY2005, and FY2010 are estimated by the JATOP Emission Inventory Vehicle Emission Estimation Model. The inventory for stationary sources estimates NO_x, SO_x, CO, NMVOC, PM, and NH_3 from combustion sources, as well as NMVOC, and NH_3 from other sources. The inventory of stationary sources will be disclosed as part of the JATOP Emission Inventory-Data Base. Information for this program can be accessed at http://www.pecj.or.jp/english/jcap/index_e.asp.

CO_2 = carbon dioxide; CH_4 = methane, N_2O = nitrous oxide,
HFCs = hydrofluorocarbons; PFCs = perfluorinated compounds; SF_6 = sulfur hexafluoride;
NMVOC = non-methane volatile organic compounds; PM = particulate matter; NH_3 = ammonia

Box 3.7
Overview of East Asian Air Pollutant Emission Grid Database (EAGrid)

The purpose of this original project was to enter emissions data into a long-range atmospheric transport model that incorporated an atmospheric chemical reaction process meant to elucidate the mechanisms by which sulfates and nitrates are formed, transported, and removed. The original East Asian Air Pollutant Emissions Grid Database (EAGrid1995) contained estimates of emissions per grid cell of air pollutants such as SO_2, NO_x, NMVOCs, and NH_3 for China, Taiwan, Japan, the Republic of Korea, the Democratic People's Republic of Korea, and Mongolia. EAGrid2000 includes CO, PM_{10}, and mercury in addition to those that were already included in EAGrid1995.

In order to clarify local domestic contributions to air pollution in simulations of trans-boundary air pollution arriving in Japan from other East Asian countries, EAGrid 2000-Japan is the inventory refined by nesting a sub grid covering Japan. Emission for FY2005 and FY2010 are newly estimated in order to update EAGrid-Japan 2000.

Source: Center for Global Environmental Research, 2007

Box 3.8
Regional Emission Inventory in Asia (REAS)

For the analysis of long-term trends of the Asian atmospheric environment, the first inventory of historical and future projected emissions in Asia, Regional Emission inventory in ASia (REAS) 1.11, has been developed and made available for download since 2007. Recently, the REAS inventory was updated and re-opened as version 2.1. The major role of the REAS is to provide emission input data for atmospheric chemistry models. Data from REAS has the following scope:

- Species: SO_2, NO_x, CO, NMVOC, PM_{10}, $PM_{2.5}$, BC, OC, NH_3, CH_4, N_2O, CO_2
- Years: 2000–2008
- Areas: East, Southeast, South, and Central Asia, Asian part of Russia
- Emission Sources: Fuel combustion in power plants, industry, transport and domestic sectors, agricultural activities, and others
- Spatial Resolution: 0.25 degree by 0.25 degree
- Temporal Resolution: Monthly

BC – Black Carbon; OC – organic carbon

Source: Kurokowa, et al., 2013

Box 3.9
Source apportionment studies in Indian Cities

Objective: Ambient air quality monitoring data generated in Indian cities over the last decade reveal that PM concentrations are exceeding the air PM standards at many locations. Air pollution problem becomes complex due to multiplicity and complexity of air polluting sources (e.g. industries, automobiles, generator sets, domestic fuel burning, road side dusts, construction activities, etc.). The CPCB considers a cost-effective approach for improving air quality in polluted areas to involve (i) identification of emission sources; (ii) assessment of extent of contribution of these sources on ambient environment; (iii) prioritizing the sources that need to be tackled; (iv) evaluation of various options for controlling the sources based on feasibility and economic viability; and (v) formulation and implementation of most appropriate action plans. Source apportionment studies help in identifying the sources & extent of their contribution.

Methods: Accordingly, SA studies have been initiated in six major cities viz. (i) Bangalore; (ii) Chennai; (iii) Delhi; (iv) Kanpur; (v) Mumbai; and (vi) Pune. The studies focus on apportionment of PM_{10}, one of the most critical pollutants. Conceptual guidelines for a common methodology and SOPs for sampling and analysis were developed to guide the investigators for each city. In addition, separate projects on the development of EFs for vehicles and emission profiles for vehicular as well as non-vehicular sources have been performed, which would provide necessary inputs to the SA studies.

The scope for SA studies includes the concentrations for various constituents of PM_{10}, such as elemental carbon (EC), organic carbon (OC), total carbon (TC), the sum of ions of sulfate (SO_4^{2-}), nitrate (NO_3^-), and ammonium (NH_4^+) or secondary inorganic aerosols (SIA), and the sum of elements aluminum, calcium, silicon, iron, sodium, paladium, and ions calcium (Ca^{++}), sodium (Na^+), chlorine (Cl^-), representative of Crustal + Alluvial + Marine constituents (CAM) at selected locations (7 – 10 locations covering different land use viz. residential, industrial, and kerbside) and application of receptor (CMB8) and receptor-based models to assess the contribution from various sources, future projections and evaluation of various control options to develop cost-effective action plans.

Results: Results obtained in these studies are numerous. The most relevant are those for PM_{10}, EC, OC, TC, SIA, and CAM concentrations and source apportionment, see table 1-3 below (explanation of acronyms in the text). Industrial and kerbside carbon contents are major contributors to PM_{10}.

Table1: Major components [μg/m³] of PM_{10}, EC, OC, TC, SIA and CAM at residential sites in six Indian cities

City	PM_{10}*	EC	OC	TC	SIA	CAM
Bangalore	98	5.6	14.0	19.6	15.5	26.8
Chennai	123	4.7	14.4	19.1	10.7	17.5
Delhi	419	18.5	100.4	118.8	21.2	27.2
Kanpur	213	19.4	53.7	73.1	29.9	16.1
Mumbai	207	9.2	41.1	50.3	9.8	28.2
Pune	132	4.4	29.6	34.0	14.1	40.6

Table2: Major components [μg/m³] of PM_{10}, EC, OC, TC, SIA and CAM at industrial sites in six Indian cities

City	PM_{10}*	EC	OC	TC	SIA	CAM
Bangalore	137	8.1	21.4	29.5	9.5	23.6
Chennai	142	8.3	27.8	36.1	15.5	14.6
Delhi	519	13.7	73.3	87.1	18.7	33.5
Kanpur	385	38.0	105.3	143.4	30.2	15.2
Mumbai	196	9.1	36.5	45.6	11.4	24.5
Pune	136	4.0	27.8	31.9	9.4	32.6

Table3: Major components of PM_{10}, EC, OC, TC, SIA and CAM at kerbside sites in six Indian cities

City	PM_{10}*	EC	OC	TC	SIA	CAM
Bangalore	164	14.3	34.3	48.6	10.9	25.6
Chennai	170	10.9	27.1	38.0	12.9	10.9
Delhi	576	13.7	64.2	77.9	13.5	25.0
Kanpur	275	24.3	61.6	85.5	27.6	18.3
Mumbai	205	10.3	41.6	51.9	8.9	27.1
Pune	195	10.4	37.1	47.5	8.9	33.9

* Average of 20-day monitoring in each of the seasons (winter, summer, post-monsoon)

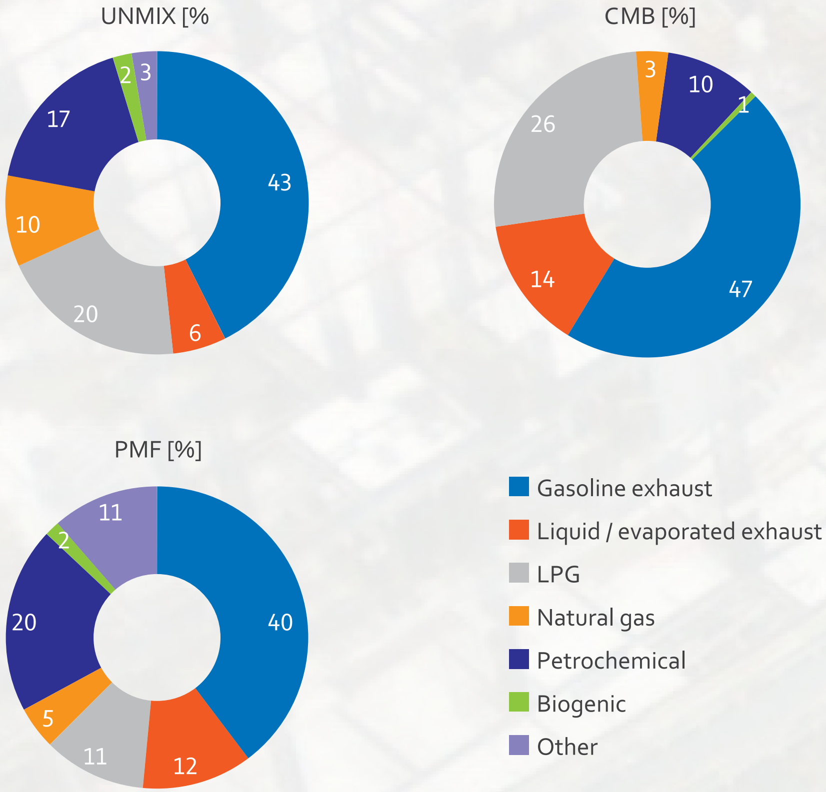
Source: Gargava & Rajagopalan, 2015

Box 3.10
Comparisons of receptor-based models for source apportionment of VOCs in Beijing

Objective: To apply the UNMIX and CMB models to VOC source apportionment based on a data set investigated previously with the PMF model by Song et al. (2008) and compare results.

Methods: Samples were collected on the roof of a five-story building on the campus of Peking University surrounded by heavy traffic intersections. In August 2005, VOC concentrations were quantified by a custom-built Gas Chromatography – Flame Ionization Detector/Mass Spectrograph system, which separated 31 carbon species from 1019 samples. Analysis of samples with the CMB and UNMIX models, and comparison with PMF model results were made.

Results: All three models showed that gasoline-related emissions contributed between 49 percent and 61 percent to VOCs. Petrochemical emissions contributed between 10 percent and 20 percent and liquefied petroleum gas (LPG) between 11 percent and 26 percent, depending on the model. The figures below illustrate the findings.



Source: Song et al., 2008

Box 3.11
Emissions inventory and source apportionment in Hong Kong and the Pearl River Delta of China

The Hong Kong Environmental Protection Department (EPD) is the environmental authority responsible for AQM in Hong Kong. Through more than 20 years of capacity building, Hong Kong has progressed into the fully developed stage in terms of EI and SA. The successful experience in Hong Kong also sheds light on the AQM practice in the nearby Pearl River Delta (PRD), which has progressed into the maturing stage and is envisioned to achieve fully developed stage within three years.

The EI in Hong Kong covers six major air pollutants, namely SO_2, NO_x, respirable suspended particulates (or PM_{10}), fine suspended particulates (or $PM_{2.5}$), VOCs and CO, from six emission categories, namely public electricity generation, road transport, navigation, civil aviation, other fuel combustion and non-combustion sources. Starting from 1997, the EI is updated annually by using the latest compilation methodology and new activity rate and EF and by revising the errors identified in the estimates. Major updates in the recent years include revised emission estimates from marine vessels with new local vessel activity rate and emission compilation methodologies, revised emission estimates from on-road vehicles by means of remote sensing equipment and advanced portable emission measurement systems, and revised VOC emission estimates from regulated VOC-containing products by sales report data submitted by importers (EPD, 2015).

The first Regional Air Pollutant EI in the PRD region was developed in 2006 under the framework of Guangdong/Hong Kong Cooperation. An EI Handbook for Air Pollutants in the PRD Region was compiled to provide the basis for the quantitative evaluations of effectiveness of emission reduction measures. It also provided unified development procedures of EI and the quality assurance system in Hong Kong and Guangdong (Zheng et al., 2009). In 2010, the PRD Regional Atmospheric Environmental Research Center was established with one of the responsibilities of development and update of dynamic air pollutant emission inventory and database systems in the PRD (Zheng et al., 2013). The PRD regional emission inventory is updated once every two to three years by using the latest compilation methodology and new activity rate and EF wherever available.

The EPD has initiated PM_{10} and $PM_{2.5}$ speciations with the aims of understanding the chemical compositions of PM and identifying major contributing sources by SA techniques. With the continuous financial support from the Hong Kong Government, the once-every-six-day PM_{10} sampling has been continuing since 1998 from a network of ten monitoring stations representing different environmental backgrounds. As of February 2015, PM_{10} measurement has been continued for over seventeen years. $PM_{2.5}$ sampling was initiated in 2000 with a 1-year sampling campaign conducted once every four years (2000/2001, 2004/2005, and 2008/2009). Starting from 2011, $PM_{2.5}$ measurement has changed to be in line with the sampling frequency of PM_{10} at six monitoring sites across the territory, which include four collocated sites. As of February 2015, $PM_{2.5}$ measurement has continued for over four years. Collocated measurement is important for QA/QC of results and estimation of measurement uncertainties to be used in receptor modeling analysis (Hyslop & White, 2008).

PM_{10} and $PM_{2.5}$ masses are measured for identifying areas that meet or do not meet the Air Quality Objective and supporting designation of an area as attainment or non-attainment. Apart from mass, major chemical elements, water-soluble ions, OC/EC/total carbon, and non-polar organic compounds in all PM samples are characterized by a set of advanced instruments. Organic carbon, EC, and individual peaks for OC, EC, and pyrolyzed carbon are measured using Thermal Optical Transmittance and Thermal Optical Reflectance by both National Institute for Occupational Safety and Health (NIOSH) and Interagency Monitoring of PROtected Visual Environments (IMPROVE) protocols. The speciation data are analyzed to characterize the composition and temporal and spatial variations of PM concentrations.

The rich PM_{10} and $PM_{2.5}$ speciation dataset has served significantly the identification of major sources and quantification of their contributions by receptor models. The SA analysis is updated bi-annually with the addition of measurement in the recent two years. In the previous stages of analysis, at least three receptor models were conducted, including Principal Component Analysis, PMF, and UNMIX for source identification. Through years of detailed examination and inter-comparisons of the receptor modeling results, it has been concluded that PMF model is the most suitable model for PM source identification and quantification in Hong Kong.

Annual, seasonal, monthly and weekly trends of different sources are discovered by SA. This sheds light on potential contributing sources during different meteorological conditions and pollution episodes. Results have clearly shown the effectiveness of local control on emissions from motor vehicles. Their contributions to both PM_{10} and $PM_{2.5}$ have decreased more than 60 percent during the past decade. However, the successful local control is offset by the increasing regional contribution from Mainland China, mostly in the form of secondary sulfate and biomass burning associated with northerly wind in winter and spring. As a result, the PM pollution level has remained steady in the past five years, however, with a distinct compositional pattern. Regional contribution to PM_{10} in Hong Kong was around 40 to 50 percent in year 2000 and has increased to around 70 percent in 2010 (Yuan et al., 2013).

Hong Kong has established its own AQ modeling system called 'Pollutants in the Atmosphere and their Transport over Hong Kong (PATH). The PATH modeling system is an integrated numerical modeling system with Sparse Matrix Operator Kernel Emissions Processing System (SMOKE) version 2.4 as the emission module, Weather Research and Forecast model (WRF) version 3.6 as the meteorological module, and Community Multi-scale Air Quality (CMAQ) version 4.6 as the chemical transport module. Both emission and chemical transport modules support CB05 and SAPRC chemical mechanisms. The PATH modeling system is setup in a four-nested domain with the coarsest grid size of 27 km cover most part of East Asia down to the finest grid size of 1 km covering Hong Kong and its surrounding cities. Results from PATH are compared with the Comprehensive Air Quality Model with Extensions (CAMx) and the Nested Air Quality Prediction Model System (NAQPMS) to improve the reliability of the simulation results. Currently, CAMx is used for SA in Hong Kong. Hong Kong is considering the development of an SA module in the PATH system.

The SA results were used to validate EI, e.g., for on-road emissions of PM (Yuan et al., 2013). The SA results also contributed directly to the formulation of a series of pollution control measures implemented locally and regionally. For example, the sharp increase of residual oil contribution has resulted in the mandatory switch to low sulfur fuel for ocean going vessels when berthing in Hong Kong waters. Increasing regional contributions from Mainland China also triggered regional collaboration in combating regional pollution between Hong Kong and Guangdong governments under the "one country, two systems" principle. The Hong Kong experience is also utilized in the development of Guangdong-Hong Kong-Macau $PM_{2.5}$ joint speciation network which covers 12 stations and starts operation in December 2014. The Guangdong-Hong Kong-Macau $PM_{2.5}$ joint speciation monitoring network would help improve the scientific understanding of $PM_{2.5}$ emission sources and formation processed in Southern China, and contribute significantly to the policy-making on effectively controlling PM pollution.

Source: EPD, 2015

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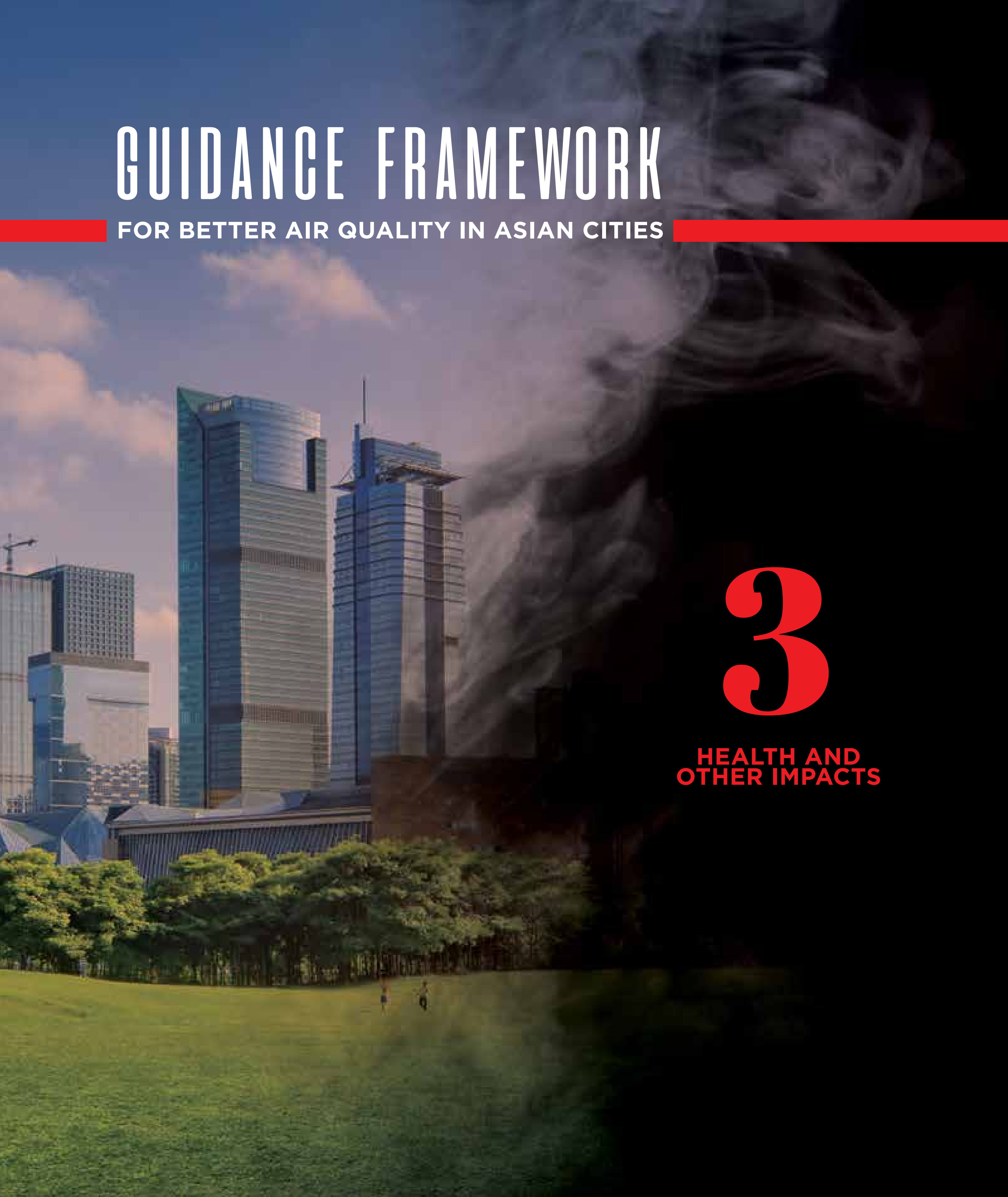

GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES

3

HEALTH AND OTHER IMPACTS

IBAQ
Integrated Programme for Better Air Quality in Asia

UNEP

CLEAN AIR ASIA

GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES

Guidance Area 3: Health and other impacts

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ABOUT THE GUIDANCE FRAMEWORK FOR BETTER AIR QUALITY IN ASIAN CITIES

The Guidance Framework is a voluntary and non-binding guidance document developed as an outcome of the biennial Governmental Meetings on Urban Air Quality in Asia, co-organized by Clean Air Asia and United Nations Environment Programme Regional Office for Asia Pacific (UNEP ROAP). It is an outcome of an extensive development process, which began in 2006 when the Long Term Vision for Urban Air Quality in Asia (LTV) was envisioned by representatives of environment ministries in the region. The LTV describes the desired state of urban air quality in Asian cities by 2030; the Guidance Framework serves as a guide for cities and countries to achieve this vision. In 2016, the Guidance Framework was launched as a pioneering approach to resolve air pollution challenges at the local- and national-levels. Centered on identified priority areas of concern in air quality management in the region, the Guidance Framework provides cities and countries with development capacity indicators and recommended steps and actions to improve air quality.

The Guidance Framework serves as a cornerstone document of Clean Air Asia's Integrated Programme for Better Air Quality in Asia (IBAQ Programme), which supports countries and cities in implementing the Guidance Framework through a range of targeted interventions, including knowledge-sharing platforms to strengthen regional collaboration, capacity building activities such as trainings, study tours and city twinning, and technical assistance at both the national and subnational levels.

ABOUT CLEAN AIR ASIA
www.cleanairasia.org

Clean Air Asia is an international NGO established in 2001 as the premier air quality network for Asia by the Asian Development Bank, World Bank and USAID. Its mission is to promote better air quality and livable cities by translating knowledge to policies and actions that reduce air pollution and greenhouse gas emissions from transport, energy and other sectors.

Clean Air Asia became a UN-recognized partnership in 2007, its network spanning 261 organizations in 31 countries in Asia and worldwide, with nine country networks: China, India, Indonesia, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, and Vietnam. It is headquartered in Manila and has offices in Beijing and Delhi. Clean Air Asia leads efforts to enable Asia's more than 1000 cities to reduce both air pollution and CO_2 emissions, and thereby contribute to more livable and healthy cities with blue skies and a low carbon footprint. Clean Air Asia helps to reduce emissions, through policies, plans, programs, and concrete measures that cover air quality, transport and industrial emissions and energy use.

The Better Air Quality (BAQ) Conference is a flagship event of Clean Air Asia covering the key sectors of transport, energy and industry, with a particular emphasis on government policies and measures. Policymakers, practitioners and industry leaders meet at BAQ to network, innovate, learn, and share experiences. The biennial event was first held in 2002 and attracts close to a thousand participants from Asia and the rest of the world.

ABOUT UNEP
www.unep.org

The United Nations Environment Programme (UNEP) is the leading global environmental authority that sets the global environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and serves as an authoritative advocate for the global environment. UNEP work encompasses assessing global, regional and national environmental conditions and trends; developing international and national environmental instruments; and strengthening institutions for the wise management of the environment. UNEP's mission includes to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

CONTENTS

PREFACE

Air pollution is now considered the world's largest environmental health risk. There have been a number of global efforts calling for air pollution actions in recent years. These global calls for action on air pollution strengthen regional and national initiatives and highlight the need to prioritize addressing this issue through a collaborative and integrated approach.

In 2006, the First Governmental Meeting on Urban Air Quality in Asia[1] recognized the need for guidance in implementing a Long Term Vision for Urban Air Quality in Asia, which describes the desired state of urban air quality management in Asian cities. During the Third Governmental Meeting, environment ministries from the region identified key challenges they are facing to improve urban air quality.

To set the way forward in achieving the vision for cleaner air, Clean Air Asia led the development of the Guidance Framework for Better Air Quality in Asian Cities (Guidance Framework) in 2014 to address the needs and challenges in the region. It aims to provide a recognized guidance on improving urban air quality and is organized around priority areas of concern in the region, which were translated into key guidance areas with roadmaps on how to progress in a step by step manner.

This voluntary, non-binding document consists of seven individually published chapters covering each of the Guidance Areas. Policy and decision makers in Asia, as well as other relevant stakeholders, can use one or a combination of the Guidance Framework chapters to develop local roadmaps or action plans depending on their priority areas of concern.

The Guidance Framework consists of seven main books with these titles:

- Introduction
- Guidance Area 1 - Ambient air quality standards and monitoring
- Guidance Area 2 - Emissions inventories and modeling
- Guidance Area 3 - Health and other impacts
- Guidance Area 4 - Air quality communication
- Guidance Area 5 - Clean air action plans
- Guidance Area 6 - Governance

These guidance areas come with an Information Sourcebook, which is a compilation of resources to support the implementation of Guidance Framework roadmaps. There is also an accompanying training course on Guidance Framework implementation, which is available online in the Clean Air Asia website and Integrated Programme for Better Air Quality (IBAQ Programme) website: www.cleanairasia.org/ibaq

The Guidance Framework was developed together with a team of international and regional experts and practitioners and has undergone an extensive review process through the Governmental Meetings and the involvement of external reviewers. The draft document was also shared in a number of international events, including the Asia Pacific Clean Air Partnership (APCAP) Joint Forum organized by UNEP ROAP in November 2015. The Guidance Framework was welcomed by participants from 24 countries in Asia and the Pacific, involving environment ministries, intergovernmental organizations, non-governmental organizations, and experts.

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1 Governmental Meetings on Urban Air Quality in Asia are biennial meetings organized by the United Nations Environment Programme Regional Office of Asia and the Pacific (UNEP ROAP) and Clean Air Asia that convene environment ministries with the aim to harmonize approaches across the region in tackling air pollution and related fields.

ABBREVIATIONS

ABCs	Atmospheric Brown Clouds
AQM	Air Quality Management
BC	Black Carbon
CAAP	Clean Air Action Plan
CAHA	Climate and Health Alliance
CPCB	Central Pollution Control Board
CFCs	Chlorofluorocarbons
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
DPSEEA	Driving Force-Pressure-State-Exposure-Effect-Action
ECHP	European Centre for Health Policy
EPD (Hong Kong)	Environmental Protection Department
GAPF	Global Atmospheric Pollution Forum
GBD	Global Burden of Disease
GCEC	Global Commission on the Economy and Climate
GHG	Greenhouse Gas
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HFE	Fluorinated ethers
HIA	Health Impact Assessment
IARC	International Agency for Research on Cancer
IPCC	International Panel on Climate Change
MOEF (India)	Ministry of Environment, Forest, and Climate Change
NAAQS	National Ambient Air Quality Standards
NAMP	National Air Quality and Monitoring Program
NGO	Non-Governmental Organization
NH_3	Ammonia
NO_x	Nitrogen oxides
NO_2	Nitrogen dioxide
OECD	Organisation for Economic Co-operation and Development
O_3	Ozone
PFC	Perfluorinated Compounds
PM	Particulate Matter
PM_{10}	Particulate Matter (≤ 10 micrometers in diameter)
$PM_{2.5}$	Particulate Matter (≤ 2.5 micrometers in diameter)
SEI	Stockholm Environment Institute
SLCPs	Short-Lived Climate Pollutants
SO_2	Sulfur dioxide
UK	United Kingdom
UNEP	United Nations Environment Programme
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
WMO	World Meteorological Organization

The **exposure to ambient air pollution, particularly fine particulate matter** is estimated by WHO to have **caused 3.7 million premature deaths** worldwide in 2012.

CHAPTER 4

GUIDANCE AREA 3: HEALTH AND OTHER IMPACTS

4.1 Introduction

Ambient air pollution is a much more significant public health risk than previously assumed. This is one of the findings of two recent estimates on the global impact of air pollution on health —from the World Health Organization (WHO) in 2012 (WHO, 2014a) and from the Global Burden of Disease (GBD) project in 2010 (Lim et al., 2012).

The exposure to ambient air pollution, particularly fine particle or particulate matter ($PM_{2.5}$) is estimated by WHO to have caused 3.7 million[2] premature deaths worldwide in 2012. Most of the burden of air pollution is borne by the middle- and low-income countries in the WHO Western Pacific (WHO, 2014b) and South-East Asia regions – an estimated 1.6 million and 0.94 million deaths, respectively.

Over 76 million years of healthy life are lost due to air pollution according to the GBD's 2010 findings (Lim et al., 2012). The GBD ranks air pollution as the third most important risk of premature death in the world, after dietary risks and high blood pressure.

2 WHO's estimates' range is 3.188-4.291 million.

To **establish and/or strengthen** national and local programs that **monitor the health, environmental and economic impact** of air pollution consistently.

The GBD study shows that Asia gets the largest share of the ambient $PM_{2.5}$ -related deaths worldwide with an estimated 2.15 million deaths in 2010. Approximately 57 percent of these cases are in China and about 29 percent in India. This is also the case with premature deaths worldwide due to ground-level ozone (O_3) exposure, with Asia accounting for 83 percent of such deaths or 126,508 cases in 2010 (Figure 4.1).

More recently, in 2013, a group of experts working on behalf of WHO's International Agency for Research on Cancer (IARC) classified ambient air pollution in general and $PM_{2.5}$ in particular as carcinogenic (IARC Group 1) to humans (WHO/IARC, 2013a, b, c). This classification is based on sufficient evidence of carcinogenicity in humans and experimental animals, and strong evidence on the mechanisms (Brauer et al., 2012; Loomis et al., 2013; 2014). As a carcinogen, particulate matter (PM) has no threshold for the onset of effects.

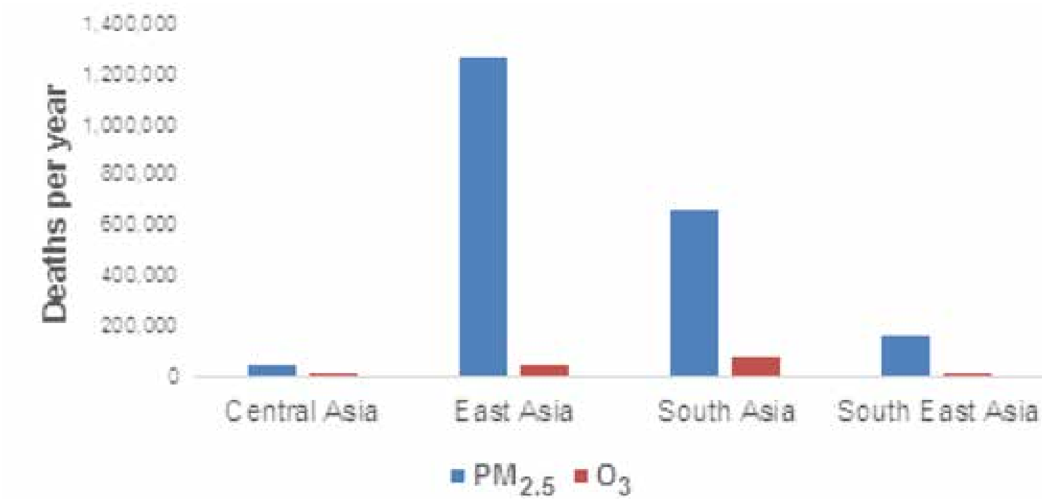

Figure 4.1 Regional distribution of premature deaths per year due to $PM_{2.5}$ and O_3

Source: Lim et al., 2012

4.1.1 Objective

To establish and/or strengthen national and local programs that monitor the health, environmental, and economic impact of air pollution consistently.

4.1.2 Importance of considering health and environmental impacts

Ambient and household air pollution has many significant impacts on human health and the environment. Many air pollutants have been classified as carcinogenic, in addition to causing a variety of respiratory and cardiovascular diseases. Impacts of air pollution on the environment include acidification of soil and freshwater systems, eutrophication of lakes and rivers, ozone layer depletion, and global climate change.

Understanding and estimating the impacts of air pollution as well as its economic costs to society are integral in the overall air quality management (AQM) framework. Any AQM framework is based on the Driving Force-Pressure-State-Exposure-Effect-Action (DPSEEA) framework depicted in Figure 4.2.

Analyzing the cost of air pollutant control measures *vis a vis* the benefits of avoided health and environmental impacts as a result of these measures is critical in improving the effectiveness of AQM. Without estimates on pollution damage costs, it is impossible to determine the cost effectiveness of air pollution prevention, mitigation, and control strategies. Identifying efficient and effective technologies and policy tools, needed for target setting and management strategy, also becomes unworkable.

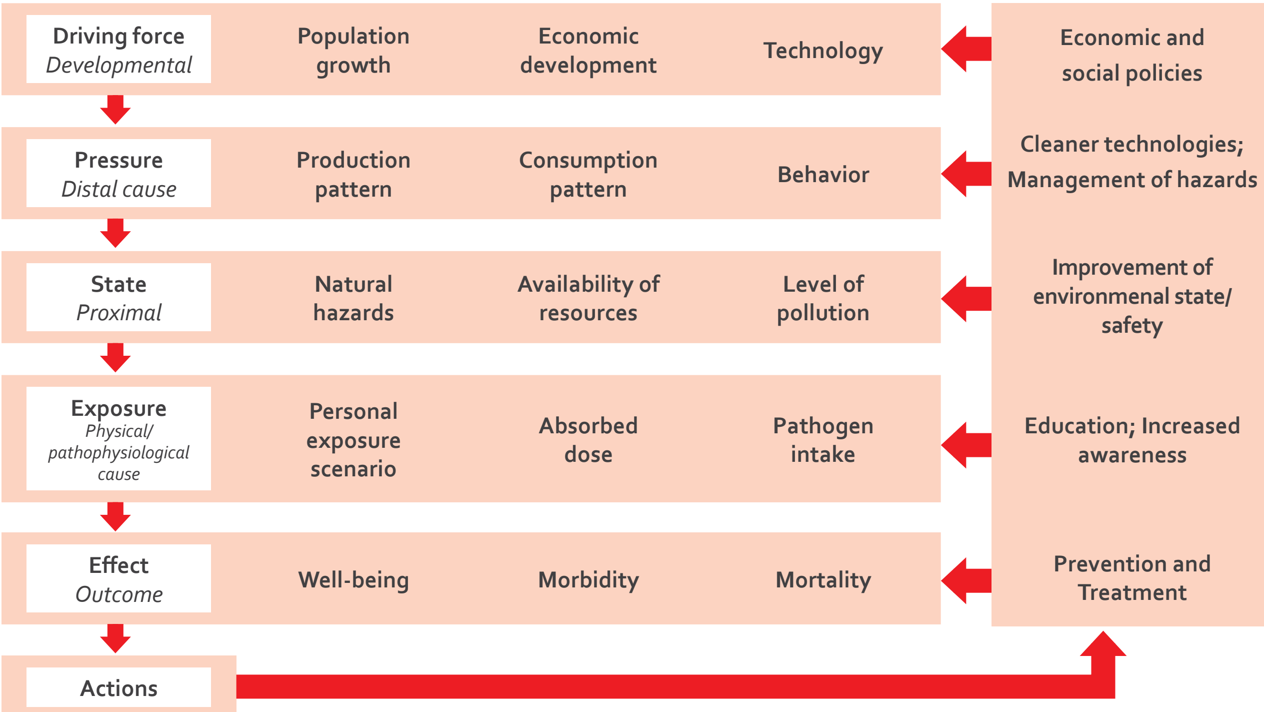

Figure 4.2 The DPSEEA framework[3,4]

Source: Adapted from WHO, 1995a

Understanding and estimating the impacts of **air pollution** as well as its **economic costs** to society are integral in the **overall air quality management** framework.

3 Absorbed dose: The amount of air pollutant absorbed, and therefore available to undergo metabolism, transport, storage, or elimination in the human body (WHO, 2000b).

4 Pathogen intake: The taking in of substances which can cause harm or disease (WHO, 2000a; Cyclopedic Medical Dictionary, 1997).

4.1.2.1 Health impacts of air pollution

The greatest impacts on human health tend to be focused on the effects of these common pollutants – $PM_{2.5}$, O_3, nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) – as well as toxic air pollutants and heavy metals.

Particulate matter

Evidence suggests that there is a close correlation between exposure to high concentrations of small particles and increased mortality or morbidity, both in the short- and long-term (Hirota & Martin, 2013; United States Environmental Protection Agency [USEPA], 2009; Hogg et al., 2004; WHO, 2013a,b; Brook et al., 2010; Chuang et al., 2007; Rückerl et al., 2006). Fine particulate matter, after it is inhaled, penetrates deep into the lung and the air sacs. The particles damage cells in the airways and affect the lung; this is associated with the exacerbation of asthma and chronic obstructive pulmonary disease (Riva et al., 2011; USEPA, 2009; Risom et al., 2005). The fine particulates cause further damage as they impact the heart and circulatory system.

$PM_{2.5}$-related deaths occur due to:

- cardiovascular disease, notably ischemic heart disease and stroke (WHO, 2013a,b);
- lung cancer (WHO, 2013a, b, c);
- chronic obstructive pulmonary disease (WHO, 2013a, b, c); and
- acute lower respiratory infection (WHO, 2013a, b; Roth et al., 2008; Lanata et al., 2004).

Non-fatal health impacts of exposure to $PM_{2.5}$ include non-fatal heart attacks, irregular heartbeat, aggravated asthma and decreased lung function, acute bronchitis, and increased respiratory symptoms. These can lead to absence from work and reduced school attendance, as well as increased hospital admissions and doctor's visits.

A component of $PM_{2.5}$ that should also be mentioned is black carbon (BC), which refers to elemental carbon-containing particles that are emitted from incomplete combustion of fossil fuels and biomass (Long et al., 2013). According to WHO, there is sufficient evidence for an association between daily variations in BC concentrations and short-term changes in all-cause and cardiovascular mortality, as well as cardiopulmonary hospital admissions (Janssen et al., 2012). For long-term BC exposure, cohort studies have provided sufficient evidence of relationships to all-cause and cardiopulmonary mortality. Exposure-relationships from both short- and long-term studies are much stronger for BC than for $PM_{2.5}$ and PM_{10} (Janssen et al. 2012). This statement does not mean that "any specific source, component, or size class of PM maybe excluded as a possible contributor to PM toxicity" (Hedley Index, 2013).

Given that ambient $PM_{2.5}$ -related deaths are largely concentrated in Asia, the risk of ambient PM ranks among the top health risks everywhere in Asia (Table 4.1).

Table 4.1 Risk factors ranked by attributable burden of disease, 2010

	Global	High-income Asia Pacific	East Asia	South East Asia	South Asia	Central Asia
High blood pressure	1	1	1	1	3	1
Tobacco smoking, including second-hand smoke	2	2	2	2	2	3
Alcohol use	3	3	6	6	8	2
Household air pollution from solid fuels	4	42	5	3	1	12
Diet low in fruits	5	5	3	4	5	5
High body-mass index	6	8	9	9	17	4
High fasting plasma glucose	7	7	8	5	7	7
Childhood underweight	8	39	38	13	4	25
Ambient particulate matter pollution	9	9	4	11	6	10
Physical inactivity and low physical activity	10	4	10	8	11	9

Source: Lim et al., 2012

Ground-level ozone
Ground-level ozone is less soluble in water. It is thus not scrubbed in the upper respiratory tract and reaches the lower respiratory tract where it dissolves in the fluid of the thin surface layer of lung cells. Free radicals and other oxidants in the fluid are assumed to react rapidly with the cell molecules and mediate the effects of O_3 exposure of the human lung. Ozone exposure is a major factor in asthma morbidity and mortality. Even short-term exposure can aggravate existing lung diseases and make the lungs more susceptible to infection.

Health effects of short-term exposure to O_3 include (USEPA, 2014a, 2013a; WHO 2013a, b):

- Increased all-cause mortality
- Increased cardiovascular mortality in adults younger than 75 years
- Increased hospital admission for heart diseases in adults older than 65 years
- Increased hospital admissions for respiratory diseases in adults older than 65 years
- Increased hospital admissions for chronic obstructive pulmonary disease
- Potentially increased hospital admissions for asthma
- Increased school absences

Nitrogen dioxide
Upon inhalation of NO_2, the human respiratory tract can absorb between 70-90 percent of the gas, and even greater levels when breathing from the mouth – e.g., during exercise. Nitrogen dioxide is increasingly deposited in the lower respiratory tract and can remain in the lung for prolonged periods (WHO, 2006). Short-term exposure to NO_2 is enough to cause aggravations in people with asthma and other

lung diseases. Above safe levels, NO_2 exposure can cause inflammation of the airways. Some studies have shown associations between NO_2 long-term exposure and mortality. However, present evidence is not sufficient to conclude that effects on mortality can be attributed to exposure to NO_2 itself (Institute of Occupational Medicine, 2004).

Health effects of long-term exposure to NO_2:

- Exacerbation of symptoms of bronchitis in asthmatic children (WHO, 2013b)
- Reduced lung function in children (WHO, 2013a; b)

Sulfur dioxide

The main anthropogenic source of SO_2 is the burning of sulfur-containing fossil fuels for domestic heating, power generation, and motor vehicles. Being highly soluble in water, inhaled SO_2 is readily absorbed in the human respiratory tract, in particular, while breathing from the mouth. Inhaled SO_2 can cause inflammation of the respiratory tract (WHO, 2013a).

Epidemiological studies have linked SO_2 long-term exposure to:

- Causation of changes in lung function
- Exacerbation of existing heart diseases
- Increased number of asthma attacks

WHO, in its most recent factsheet (WHO, 2014), believes that present evidence is sufficient to conclude that effects on mortality can be attributed to exposure to SO_2.

Toxic air pollutants and heavy metals

Examples of toxic air pollutants include benzene (in gasoline), benzo[a]pyrene (in tar and asphalt fumes, and diesel engine emissions), perchloroethlyene (in dry cleaning chemicals), methylene chloride (in solvents and paint strippers), asbestos, toluene, arsenic, and metals such as zinc, cadmium, mercury, chromium, nickel, and lead compounds.

People exposed to toxic air pollutants due to poisonous smog at ample concentrations and durations may have increased chances of cancer, reproductive and birth defects, immunological damages, and retarded neurological development. Some persistent toxic air pollutants accumulate in body tissues because unlike organic pollutants, toxic metals do not decay.

Toxic air pollutants such as benzene, benzo[a]pyrene, nickel and arsenic, in particular, are classified as carcinogenic; no safe level of exposure has been derived by WHO for these metals. While ammonia (NH_3) in itself is not classified as carcinogenic, it converts gaseous acids, especially sulfuric and nitric acids, to $PM_{2.5}$, which is carcinogenic (Martin, 2008). In a recent publication, Paulot & Jacob (2014) suggested that elimination of NH_3 emissions would achieve a greater health benefit than the reduction of the $PM_{2.5}$ national standard from 15 to 12 μg/m^3.

More detailed information about health impacts due to exposure to toxic air pollutants can be accessed at WHO (1995b) and USEPA (2007).

4.1.2.2 Environmental impacts of air pollution

Air pollutants are causing changes in the ecosystem and are indirectly affecting wildlife, in addition to directly affecting animal populations that are exposed to harmful air pollutants (United Kingdom Website (UK), 2014b). Extensive experimental studies to assess the potential threat from O_3 to agriculture conducted in Europe and North America have demonstrated crop losses due to O_3 impacts amounting to billions of dollars (Avnery et al., 2011a). The impact of air pollution on cultural heritage materials is also a serious concern because it can lead to loss of important parts of a county's history and culture.

Acid rain

Acid rain containing nitric and sulfuric acids, causes damage to forests and the acidification of soils and water bodies, potentially disrupting the food chain. Acid deposition may have various effects on crops, including significant yield loss in many species. Acid rain also accelerates the erosion of buildings, statues, and sculptures. Further information can be accessed from the USEPA (2012b), Phinney et al. (2004), and UK (2014a).

Eutrophication

Dry and wet deposition of airborne nutrients such as nitrates and phosphates can stimulate algal blooms. In turn, these blooms can cause fish kills and loss of plant and animal life because of oxygen depletion (United States Geological Survey, 2014).

Haze

Haze is caused by the scattering and absorption of sunlight by airborne fine PM (USEPA, 2012c). Haze degrades visual range, obscuring the clarity, color, texture, and forms of objects in cities and scenic areas. Haze has potential impacts on air quality, climate, and the hydrological cycle (Ramanathan et al., 2001).

Atmospheric brown clouds

Atmospheric brown clouds (ABCs) primarily consist of particles and pollutant gases, such as nitrogen oxides (NO_x), carbon monoxide (CO), SO_2, NH_3, and hundreds of organic gases and acids from indoor and outdoor air pollution due to biomass and fossil fuel burning (Ramanathan et al., 2008). Five ABC hotspots exist; three of them lie in East, South, and South-East Asia. The five ABC hotspots potentially have large impacts on regional and global climate, freshwater budget, agriculture, and health (Ramanathan et al., 2008; Ramanathan & Ramana, 2003).

Ozone layer depletion

Stratospheric ozone, particularly in the polar zones, is being gradually destroyed by chlorine- and bromine-containing substances referred to as ozone depleting substances. The Montreal Protocol on Substances that Deplete the Ozone Layer entered into force in 1989 to protect stratospheric ozone and, consequently, protect life from increased ultraviolet radiation at Earth's surface (United Nations Environment Programme [UNEP], 2011). These controls under the Protocol have proven effective for safeguarding public health[5]. Ultraviolet radiation can damage sensitive crops and reduce crop yields. Most ozone-depleting substances are also potent greenhouse gases (GHGs), contributing to global warming. There is strong evidence available on the effect of stratospheric ozone changes on Earth's surface climate (UNEP, 2010; USEPA, 2011a).

Crop and forest damage

Ground-level O_3 can reduce agricultural crop and commercial forest yields, diminish growth and influence survival of tree seedlings, and increase plant susceptibility to disease, pests, and other stresses. Wang & Mauzerall (2004) estimated a total US$5 billion loss per year for wheat, rice, maize, and soybean for China, South Korea, and Japan. Ghude et al. (2014) estimated India's crop loss for cotton, soybean, rice, and wheat to amount to 6 Mtons with a value of US$1.3 billion for 2005. These studies, however, may have substantially underestimated the effect O_3 has on crop productivity in Asia due to more sensitivity to O_3 of Asian-grown wheat and rice cultivars (Emberson et al., 2009).

Global climate change

The naturally occurring gases of the Earth's atmosphere trap some of the sun's heat in the troposphere. This "greenhouse effect" keeps the Earth's temperature stable. Human activities are producing too much of some of these GHGs (USEPA, 2014e). As a result, the Earth's atmosphere is trapping more of the sun's heat, causing the Earth's average temperature to rise (global warming). Global warming could have significant impacts on human health, agriculture, water resources, precipitation and draughts, forests, wildlife, and coastal areas. Table 4.2 presents some of the properties of GHGs.

5 Controls implemented under the Montreal Protocol have enabled the global community to avoid millions of cases of fatal skin cancer and tens of millions of cases of non-fatal skin cancer and eye cataracts. The U.S. estimates that, by the year 2065, more than 6.3 million skin cancer deaths will have been avoided in that country alone and that efforts to protect the ozone layer will have saved it an estimated US$4.2 trillion in healthcare costs over the period 1990–2065 (United Nations Development Programme, 2012). Moreover, in 2011, the United States Environmental Protection Agency estimated that more than 22 million Americans born between 1985 and 2100 would avoid suffering from cataracts as a result of the Montreal Protocol (UNEP, 2012).

Table 4.2 Sources and lifetimes of greenhouse gases

Compound	Sources	Lifetime [years]	Reference
CO_2	Fossil fuel and biomass burning	3–4	Gurjar, et al., 2010
CH_4	Rice paddies, livestock, natural gas leaks	12	IPCC, 2007
N_2O	Agriculture, fossil fuel combustion, wastewater management, industrial processes	114	USEPA, 2010; IPCC, 2007
CFCs	Air conditioners, refrigerators, sprays	45–1,700	IPCC, 2007
HFCs		1.4–270	
HCFCs		1.3–17.9	
PFCs		740–50,000	
HFEs		0.33–136	
Halons		16–65	

CO_2: Carbon dioxide; CFCs: Chlorofluorocarbons; HCFCs: Hydrochlorofluorocarbons ; HFCs: Hydrofluorocarbons; CH_4: Methane; PFCs: Perfluorinated compounds; HFEs: Fluorinated ethers

4.1.3 Link of air pollution and climate change; co-benefits

Many air pollutants such as PM, SO_2, NO_2, and CO have the same sources as GHGs. Major GHGs are CO_2, CH_4, and O_3. Ozone formation follows from various chemical transformations such as photochemical oxidation of organic vapors by organic peroxyl free radicals in the presence of NO_x, and CH_4 photo-oxidation via various sequences (Johnston & Kinnison, 1998). Greenhouse gases have to be reduced to mitigate climate change, while air pollutants have to be controlled to avoid direct effects on human and environmental health. Measures to mitigate climate change can reduce air pollution, and actions reducing local and regional air pollution can reduce GHG emissions. There is a need to jointly assess these interrelated policies. The co-control of air pollution and GHG emissions will be cost-effective and create co-benefits (Intergovernmental Panel on Climate Change [IPCC], 2007; Anenberg et al., 2012; Climate and Health Alliance (CAHA), 2012; HEAL, 2012; West et al., 2013; GCEC, 2014). The linkages between air pollution and climate and their relation to health and environmental impacts are depicted in Figure 4.3.

A United Nations Environment Programme/World Meteorological Organization (UNEP/WMO) report has compiled scientific studies that have shown that reductions of emissions of short-lived climate pollutants (SLCPs) can potentially prevent millions of premature deaths, prevent the loss of million tons of crops, and reduce global temperatures by 0.5°C [0.2°C–0.7°C] over the next four decades (UNEP/WMO, 2011). Several UNEP-recommended actions to reduce emissions of BC, organic carbon, $PM_{2.5}$, CO, NO_x, and CH_4 and case studies on co-benefits of linking air pollution and GHG reduction are provided in **Annex III-A and III-B of the Information Sourcebook.**

Measures to mitigate climate change **can reduce air pollution**, and **actions** reducing local and regional air pollution can reduce greenhouse gas emissions. There is **a need** to jointly assess these **interrelated policies**.

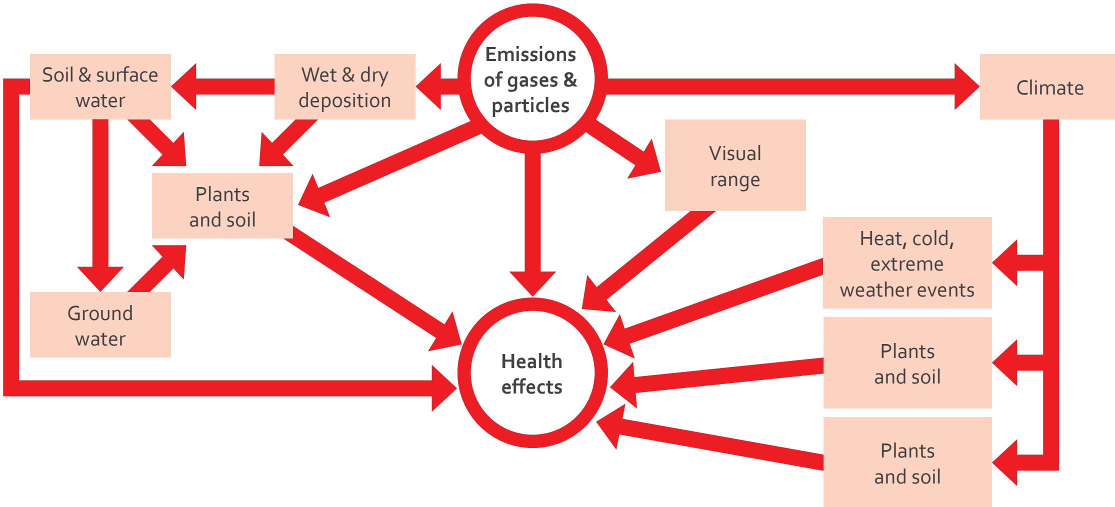

Figure 4.3 Linkages between air pollution, climate, and health impacts

Source: Stockholm Environment Institute (SEI), 2008

Health impact assessment in a clean air action plan is a means of assessing the **positive and negative health impacts** of existing **air pollution abatement** policies, strategies, plans and projects.

4.1.4 Health impact assessment in clean air action plans

A clean air action plan (CAAP) is a long-term plan intended to improve air quality and public health by identifying measures to reduce emissions from sectors such as transport, industries, waste deposits, residential burning, among others [see *Guidance Area 5 on Clean air action plans*]. Health impact assessment (HIA) in a CAAP is a means of assessing the positive and negative health impacts of existing air pollution abatement policies, strategies, plans and projects. Many definitions of HIA exist (Birley, 1995; European Centre for Health Policy [ECHP], 1999; Lock, 2000; International Association for Impact Assessment, 2006), the main definition being that of the ECHP: "A combination of procedures, methods and tools by which a policy, program or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within a population" (WHO, 2007).

Health impact assessment is a valuable tool within a CAAP to develop policies, strategies, programs and projects for cleaner air by providing information for decision makers and addressing policymaking requirements. One of the objectives of an HIA study is to assess whether or not air pollution has an effect on human health. This tool brings policies and people together and involves all stakeholders. It is a proactive process that can mitigate health impacts due to air pollution. The HIA procedure within a CAAP is shown in Figure 4.4. A stepwise process for HIA development and implementation as well as case studies are provided in **Annex III-C of the Information Sourcebook.** The case of a multicity time-series study of short-term effects of air pollution on mortality under the Public Health and Air Pollution in Asia (PAPA) project is also provided in **Annex III of the Information Sourcebook.**

PHASE	PROCESS	DESCRIPTION
Policy and programme development for prospective assessments	Screening	Quickly establishes the 'health relevance' of air polution. Is HIA required?
	Scoping	Identifies key air pollutants & public concerns, establishes Terms of Reference, sets boundaries
	Appraisal	Rapid or in-depth assessment of baseline health status, adverse health impacts of air pollution using available evidence – who will be affected, significance, projection, mitigation
Policy implementation	Recommendations	Identifies strategies and measures to manage adverse health impacts
	Reporting	Communicates to stakeholders conclusions & recommendations to mitigate adverse health impacts
	Monitoring	Action, where appropriate, to monitor actual adverse health impacts to enhance existing evidence base

Figure 4.4 The procedure for health impact assessment in clean air action plans

Source: Adapted from WHO, 2015

4.2 Stages of health and environmental impact assessment

Strengthening the capacity for health and environmental impact assessment helps shape and define policies for improving air quality. Such capacity also helps in the assessment of the effectiveness of measures to protect human health and the environment. As a starting point, Table 4.3 presents indicators that would aid cities in identifying their current state of AQM development for health and environmental impact assessment.

The following served as key considerations in progressing through the stages:

- Availability of information for estimating health and other impacts
- Processes for estimating health impacts of air pollution
- Capacity for estimating health and other impacts of air pollution
- Presentation of results of health impacts assessment for policy development purposes

Table 4.3 Stages for the assessment of health and other impacts due to air pollution

Stages	Indicators
Underdeveloped	Absence of health surveillance system Unavailability of meteorological and air quality databases for emission-exposure-impacts modeling Absence of anecdotal observations of and information on health impacts by health authorities Lack of capacity for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to HIA • exposure assessment • health and environmental impact assessment Studies on socio-economic cost of pollution and benefits of pollution control are not available Cost effectiveness/cost-benefit analysis is not conducted
Developing	A health surveillance system is being developed Meteorological and air quality databases are being developed for emission-exposure-impacts modeling Initial observations on health impacts due to air pollution exposure exist Capacity is being developed for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to HIA • exposure assessment • health and environmental impact assessment Studies on socioeconomic cost of pollution and benefits of pollution are not available Cost effectiveness/cost-benefit analysis is not conducted

Stages	Indicators
Emerging	A health surveillance system starts to provide reliable data Meteorological and air quality databases are beginning to be established for emission-exposure-impacts modeling Routine observations on health impacts due to air pollution exposure are becoming more and more common Capacity is increasing and regularly enhanced by training for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to HIA • exposure assessment • health and environmental impact assessment Limited studies on socioeconomic cost of pollution and benefits of pollution control are available, mostly performed by academic/research institutions Cost-effectiveness/cost-benefit analysis is intermittently conducted by academic/research institutions Presentation of results of HIA, studies on socioeconomic cost of pollution, and cost-effectiveness/cost-benefit analysis considers its use in AQM policy development, implementation, and evaluation
Maturing	A health surveillance system is in place and is becoming a basis of HIA due to air pollution Meteorological and air quality databases are routinely used for emission-exposure-impacts modeling Systematic epidemiological studies on health impacts due to air pollution exposure are performed including exposure and health impact assessment studies of major facilities or areas (e.g., schools, hospitals, among others) and of vulnerable populations (e.g., children and the elderly), using rapid assessment techniques Capacity and understanding of issues is increased for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to HIA • exposure assessment • health and environmental impact assessment Studies on socioeconomic cost of pollution and benefits of pollution control are becoming available, performed by both academic/research institutions and the government Cost effectiveness/cost benefit analysis is conducted by academic/research institutions and the government Presentation of results of HIA, studies on socioeconomic cost of pollution, and cost-effectiveness/cost-benefit analysis systematically considers its use in AQM policy development, implementation, and evaluation

Stages	Indicators
Fully developed	A health surveillance system makes available reliable data and is always taken as the basis of HIA due to air pollution Meteorological and air quality databases are regulated to be routinely used for emission-exposure-impacts predictions Systematic epidemiological studies on health impacts due to air pollution exposure are performed including exposure and health impact assessment studies of major facilities or areas (e.g., schools, hospitals) and of vulnerable populations (e.g., children and the elderly), using sophisticated assessment techniques Capacity is sustainably enhanced for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to HIA • exposure assessment • health and environmental impact assessment Studies on socioeconomic cost of pollution and benefits of pollution control are available, performed by academic/research institutions and the government. There is a process in place for estimating socio-economic costs adapted to local conditions Cost-effectiveness/cost-benefit analyses are routinely performed by academic/research institutions and the government following a localized system for estimating costs and benefits Presentation of results of HIA, studies on socioeconomic cost of pollution, and cost-effectiveness/cost-benefit analysis systematically considers its use in AQM policy development, implementation, and evaluation

4.3 Issues and challenges

While a number of Asian cities and countries have developed CAAPs over the last 15 years to address the challenge of air pollution, a number of considerable challenges remain to be resolved, especially in urban areas in Asia. This relates particularly to conducting HIA *vis a vis* air pollution. In addition, the valuation of the benefits of avoiding health impacts within CAAPs is often not performed.

Institutional

- **Insufficient human resources and institutional capability within governmental agencies possessing knowledge on the health and environmental impacts of air pollution,** and understanding the linkages between GHG mitigation and air pollution reduction in minimizing health and environmental impacts.
- **Limited understanding of governmental institutions of the importance of studies on health and environmental impacts caused by air pollution.** This understanding needs to get the support of all agencies and other stakeholders in providing data necessary for epidemiological studies.
- **Lack of collaboration, communication, and coordination between environmental authorities and health authorities** – preventing agencies from sharing of demographic, monitoring, mortality, and morbidity data needed for epidemiological studies.
- **Lack of understanding among government agencies of the linkage between source and emissions inventory, air quality monitoring, meteorological situation, and health and environmental impacts due to air pollutant exposure.** All these issues are important components of a CAAP, with health and environmental impacts as the most relevant as these could help bring about desired behavior change.
- **Lack of media information and awareness** on: (1) health and environmental impacts of air pollution, and of the health and economic benefits of actions to avoid or minimize the impacts due to air pollution; and (2) impacts of GHG emissions, their linkage to air pollution impacts, and the co-benefits of GHG mitigation and air pollutant emission reduction.
- **Lack of public awareness** that would enable public society groups/non-governmental organizations (NGOs) with interest in combating air pollution and pushing the government to act. These organizations can be interested to launch citizen science projects on air pollution exposure and effect assessment.

Management and Technical

- **Limited information on health impacts due to air pollution.** Policy and decision making process are limited and constrained by poor data and information on health impacts/effects, social and economic effects of the health risks. Limited connection with planning and policy development
- **Only a few Asian countries develop systematic CAAPs** to update or set emission and air quality standards based on health impacts/effects and monitor/enforce the compliance.
- **Limited health impact modeling** and/or short-term and long-term impact estimation by means of epidemiological health impact studies
- **Poor "public health surveillance programs**[6]—i.e. poor collection of mortality and morbidity information for selected health impacts, lack of cohort and time-series studies.
- **Poor early warning systems to protect the public against air pollution episodes**. These are needed in case of transboundary air pollution (haze episodes), emergency situations due to industrial malfunction, and meteorological events (such as strong inversions).
- **Lack of awareness and studies** on the following:
    - Short-term and long-term health and environmental impacts. Awareness is important to protect the public and the environment against the impacts of air pollution. Local studies are needed to assess the severity of health and environmental impacts.
    - Valuation of health and environmental impacts. Such studies are critical to get information about the benefits of avoiding health and environmental impacts as trade-offs to costs of abatement measures.
    - Linkage between air pollution health impacts and GHG mitigation measures. Awareness of the linkages is critical to understand the interrelationship between air pollution and GHGs.

6 Public health surveillance is defined as the ongoing, systematic collection, analysis and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to the appropriate individuals or institutions"(WHO, 1999)

- Risk communication and effective guidance to protect the population from the impacts of heavy pollution
- Valuation of co-benefits of air pollution health impacts and GHG mitigation measures. The co-benefits of simultaneous air pollution reduction and GHG mitigation in terms of health and environmental impacts are usually higher than those of reducing air pollutant emissions and mitigating GHG emissions separately.

Financial

In many Asian countries, lack of sufficient governmental funding prevents the development and implementation of health surveillance system and the conduct of epidemiological studies to assess relationships between exposure to air pollutants and health impacts. Funding is especially needed for studies on long-term exposure to air pollutants. Poor communities are constrained financially to introduce and apply protective and adaptation approaches.

In addition, the valuation of the benefits of avoiding health impacts as a consequence of CAAPs is often not performed. The opportunities of tapping into other sources of funding such as public-private-partnerships, grants or loans from international funding agencies, and citizen science or crowdsourcing approaches are often not known or, if known, not explored (Oxford English Dictionary, 2014)[7].

Despite these challenges, some Asian countries have assessed the local health consequences of air pollution and estimated their economic impact. Health studies in Bangkok and Hong Kong have provided some rationale to take air pollution abatement actions (Lee et al., 2013; Vichit-Vadakan & Vajanpoom, 2011; Hedley, 2009; Vassanadumrongdee & Matsuoka, 2005). The estimated premature deaths, hospital admissions, outpatient visits, and economic loss from air pollution in the Hedley Environmental Index system give such a strong incentive (Box 4.1). The USEPA has collaborated with national experts in several Asian cities to conduct systematic studies on the health and economic impacts of air pollution control policies (e.g. USEPA, 2014h).

Box 4.1
Hedley Environmental Index: measuring Hong Kong's air pollution cost

The Hedley Environmental Index (Hedley Index) closes the gap between generating scientific evidence and communicating the risks in terms of the number of deaths, the number of hospital bed-days, the number of doctor visits, the total economic loss, the loss of tangible cost – hospital admissions, outpatient visits (including travel cost), and work absence, and the loss of healthy life value (Hedley Index, 2014a). Using internationally established exposure-response relationships between air pollutants and health impacts of current levels of pollution, the Hedley Index is acting as a tool to assess the potential public health benefits for strengthened air quality standards in Hong Kong.

On the Hedley Index website (Figure 4.5), data on the five key air pollutant indicators $PM_{2.5}$, PM_{10}, NO_2, SO_2, and O_3 are reported from three roadside stations and 10 general monitoring stations run by the Hong Kong Environmental Protection Department (EPD). The data is then plotted real-time against the WHO's short- and long-term Air Quality Guidelines. To delve deeper into the issue, the historical series within a program called "Air Quality Tracker" adds a different function, allowing to review data beginning in 1998, and track the history of each pollutant (Hedley Index, 2014b).

The actual figures in the Hedley Index provide a rather conservative estimate, which does not yet account for air pollution's effects on vulnerable groups such as pregnant women and young children, the monetary losses of the long-term health burden, or the economic costs of Hong Kong's lost tourism.

7 Citizen science is also known as crowd science, crowd-sourced science, civic science, volunteer monitoring or networked science.

Figure 4.5 The Hedley Environmental Index Board

According to the Hedley Index, each year, air pollution kills more than 3,000 people in Hong Kong (Kwong, 2012). The Hedley Index is frequently cited and used as a teaching tool by policy researchers, media, and NGOs, and has become a key reference for Hong Kong EPD officials (Ng, 2012; Cheng & Luo, 2009).

The Hedley Index promoted the communication on air quality and its health impact as well as raised the awareness in Hong Kong. On December 30, 2013, Hong Kong EPD launched the Air Quality Health Index to replace the Air Pollution Index, which reports the short-term health risk of air pollution and helps the public take precautionary measures to protect health.

4.4 Roadmap for health and environmental impact assessment

Reliable information on health and environmental impacts is essential for AQM. To implement a roadmap for health and environmental impact assessment within AQM, a first step is to assess where a city is in the AQM developmental stages, then follow the recommendations to progress to the next stage. Table 4.4 gives the recommended steps to implement the roadmap and overcome the challenges outlined above.

Table 4.4 Recommended steps to implement a roadmap for health and other impacts assessment and overcome the challenges of air pollution impacts on health and the environment

Developmental stages	Steps to follow
Underdeveloped	**Management Process** • Start to conduct health and environmental impact assessment (WHO, 2004b; USEPA, 2011b) • Start to prepare an air quality monitoring system **Technical Process** • Learn from international experiences and studies on health impacts and consider the health factors in the policy, plan and strategy development process
Developing	**Management Process** • Ensure that health risk estimations are used to inform policy makers and are being considered in the policies and plan development • Prioritize identification of air pollution control plans and policies that consider impacts on health **Technical Process** Enhance capacity for: • estimating exposure (Global Atmospheric Pollution Forum (GAPF), 2011) • initial estimates of health risks and/or other impacts (WHO, 2004b) • an initial health surveillance approach (WHO, 2014d; Nsubuga et al., 2006)
Emerging	**Management Process** • Use information on health and other impacts to inform policy development • Integrate risk assessment into policies **Technical Process** Ensure: • growing capacity for simplified approaches to estimate exposure (WHO, 2004b) • improved understanding of the technical and economic feasibility of major pollution control measures (USEPA, 2011d; 2008b; Reis, 2005) Enhance capacity for estimates such as: • the health risks and/or other impacts (WHO, 2006) • the economic impacts, based on international studies (Organisation for Economic Co-operation and Development (OECD), 2014)

Developmental stages	Steps to follow
Maturing	**Management Process** • Establish a robust health statistics database based on a health surveillance system to enable and facilitate health studies • Translate study results into policy tools in a transparent manner • Develop and implement communication strategies targeted at policy makers and the public • Ensure that scenarios for future needs of AQM are developed (USEPA, 2012f) **Technical Process** Ensure that: • exposure and HIA studies of major facilities or areas (e.g., schools, hospitals) and of vulnerable populations (e.g., children and the elderly) are conducted (Makri & Stilianakis, 2008) • major studies on health impacts are systematically conducted (Rothman & Greenland, 1998) • studies on other impacts of air pollution (e.g., on buildings and agriculture) are available (Emberson et al., 2003; Rao et al., 2014) • studies on social economic cost of pollution and benefit of pollution control are available (OECD, 2014) • cost-effectiveness/cost-benefit analysis are being conducted (USEPA, 2010b; Clean Air for Europe, 2012) • emissions inventories and dispersion modeling are further developed (European Environment Agency, 2013)
Fully developed	**Management Process** • Integrate health risk assessment into policies and strategies • Develop and implement communication strategies with policy makers and the public as target audiences **Technical Process** • Conduct health and environmental impact studies regularly and systematically. Report results to influence policies. Link health and environmental impacts projections based on scenarios with policy changes in emissions-related sectors (e.g., transport). Conduct regularly and systematically exposure and HIA of major facilities or areas (e.g., schools, hospitals) and of vulnerable populations (e.g., children, elderly, and people with existing ailments and/or disabilities). Make available studies on other impacts of air pollution (e.g., on buildings and agriculture) as well as socioeconomic cost of pollution and benefit of pollution control. Conduct cost-effectiveness/cost-benefit analysis. • Develop regulatory air quality simulation models to support the policymaking process

Municipal, provincial and national governments should recognize the need to consider health and environmental impacts as an important ingredient of AQM. In fact, if there were no impacts of air pollution, there would also be no need for action. In developing Asian countries, it is important to strengthen the political will and understanding of the social and economic costs of air pollution, which often surpass the costs of control measures [See *Guidance Area 6 on Governance*]. A strong governmental response is needed to mitigate the health and environmental effects of air pollution (Box 4.2). It is also important to strengthen the linkages among source inventory, emission, air quality monitoring, meteorological situation, and health and environmental impacts due to air pollutant exposure. To better understand these linkages, it is necessary to involve all relevant stakeholders in the development of action plans for health and environmental impact assessment as an integral part of CAAPs [See *Guidance Area 5 on Clean air action plans*]. Similarly, the collaboration, communication, and coordination between environmental authorities and health authorities on the municipal, provincial and national levels should be strengthened. Enhancing the institutional capability with respect to AQM issues through sustainable education and training and provision of sufficient human resources is also significant [See *Guidance Area 6 on Governance*].

Sufficient financial resources should be allocated for the following health and environmental impact studies. If reliable emissions and meteorological data exist, models can be used to estimate exposure [See *Guidance Area 2 on Emissions inventories and modeling*] and – with the application of established exposure-response relationships – corresponding health environmental impacts. This would be the low-cost option because appropriate models can be downloaded free of charge e.g. the USEPA website. If a health surveillance system is in place, epidemiological studies can be performed but the cost of such studies can be high to very high depending on the type of study, the number of cases and the planned duration of a study.

Financial resources should be made available for:

- emission-exposure-impact studies
- a health surveillance system (if it does not exist)
- short-term and long-term health and environmental studies
- studies on the valuation of health and environmental impacts
- studies on the linkage between air pollution health impacts and GHG mitigation measures
- studies on the valuation of co-benefits of air pollution health impacts and GHG mitigation measures

Municipal, provincial and national **governments should recognize** the need to **consider health and environmental impacts** as an important ingredient of **air quality management**. In fact, if there were **no impacts of air pollution**, there would also be **no need for action**. In **developing Asian countries**, it is important to **strengthen the political will** and understanding of the social and economic costs of air pollution, which often surpass the **costs of control measures**.

Box 4.2
Responding to the health effects of air pollution in India

Outdoor air concentrations of various air pollutants in Indian cities are continuing to be a major health concern in India because of their persistent high levels. The impact of long-term exposure to urban air pollution on the respiratory and other organ systems of the body was studied in Kolkata and Delhi, two highly polluted megacities in the country (Ray & Lahiri, 2010). Moreover, the health impacts of vehicular pollution during 2007 to 2010 have been investigated (Ray & Lahiri, 2012). Compared to rural controls, the urban population had a significantly higher prevalence of upper and lower respiratory symptoms, bronchial asthma, and lung function deficits. The adverse health consequences in the urban population were positively associated with PM_{10} levels in ambient air and with personal exposures to benzene. Long-term exposures to high levels of urban air pollution in these cities are adversely affecting the physical and mental health of citizens, especially of children and the elderly. In Kolkata, long-term exposure to air pollution arises mostly from vehicular exhausts.

Another study estimated the number of premature deaths in 14 Indian cities (Nema & Goyal, 2010). Based on the PM_{10} concentration levels of 2001, among the metro cities, the highest number of mortality cases is observed in Delhi (4889), followed by Kolkata (4303), Mumbai (1959), and Chennai (1272). India has set up institutions to respond to the air pollution and its health impacts. The Ministry of Environment, Forest, and Climate Change (MoEF) is the nodal agency in the Central Government for overseeing the implementation of India's environmental policies and programs. The MoEF initiated environmental epidemiological studies in different areas of indoor and outdoor pollution to identify and develop programs that shall create a database and suggest environmental mitigation measures.

The Central Pollution Control Board (CPCB) under MoEF is responsible for planning and executing comprehensive nation-wide programs for the prevention and control of air pollution. The CPCB is executing a nationwide National Air Quality Monitoring Program (NAMP). The NAMP is covering 545 operating stations spread over covering 225 cities/towns in 26 States and five Union Territories. A system for collecting real-time online data has been established and publishes air quality data from 35 continuously monitoring stations operated by various agencies (MoEF, 2014). The CPCB has stipulated National Ambient Air Quality Standards (NAAQS) since 1982. The NAAQS are based on health criteria and follow a land use based approach. The NAAQS have been revised in November 2009 in consultation with the civil society and experts, for 12 pollutants including SO_2, NO_2, PM_{10}, $PM_{2.5}$, O_3, Pb, As, Ni, CO, NH_3, benzene, and B(a)P. These standards/limits provide a legal framework for the control of air pollution and the protection of public health.

In January 2014, a Steering Committee on health related issues on Air Pollution was formed, with a view towards framing an action plan for mitigating the adverse health impacts of indoor and outdoor air pollution.

In June 2015 the Government of India launched the air quality index in New Delhi and urged the people to change their lifestyle in order to help protect the environment (Hindustan Times, 2015).

As: Arsenic; B(a)P: Benzo(a)pyrene; NH_3: Ammonia; Ni: Nickel; Pb: Lead

Source: CPCB, 1998; MOEF, 2014

4.5 References

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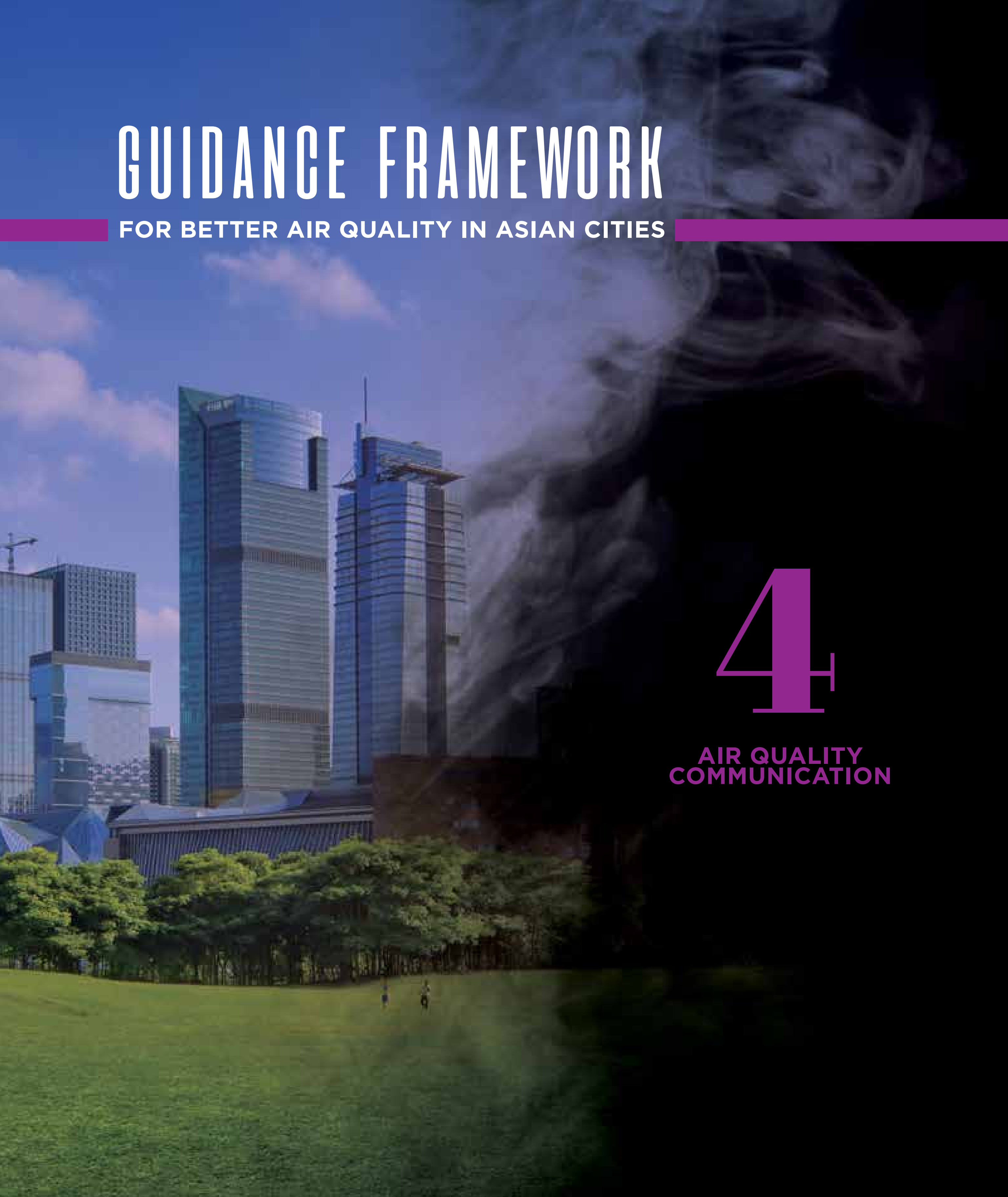
GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES



4

AIR QUALITY COMMUNICATION

IBAQ
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UNEP

CLEAN AIR ASIA

GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES

Guidance Area 4: Air Quality Communication

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Vietnam

ABOUT THE GUIDANCE FRAMEWORK FOR BETTER AIR QUALITY IN ASIAN CITIES

The Guidance Framework is a voluntary and non-binding guidance document developed as an outcome of the biennial Governmental Meetings on Urban Air Quality in Asia, co-organized by Clean Air Asia and United Nations Environment Programme Regional Office for Asia Pacific (UNEP ROAP). It is an outcome of an extensive development process, which began in 2006 when the Long Term Vision for Urban Air Quality in Asia (LTV) was envisioned by representatives of environment ministries in the region. The LTV describes the desired state of urban air quality in Asian cities by 2030; the Guidance Framework serves as a guide for cities and countries to achieve this vision. In 2016, the Guidance Framework was launched as a pioneering approach to resolve air pollution challenges at the local- and national-levels. Centered on identified priority areas of concern in air quality management in the region, the Guidance Framework provides cities and countries with development capacity indicators and recommended steps and actions to improve air quality.

The Guidance Framework serves as a cornerstone document of Clean Air Asia's Integrated Programme for Better Air Quality in Asia (IBAQ Programme), which supports countries and cities in implementing the Guidance Framework through a range of targeted interventions, including knowledge-sharing platforms to strengthen regional collaboration, capacity building activities such as trainings, study tours and city twinning, and technical assistance at both the national and subnational levels.

ABOUT CLEAN AIR ASIA
www.cleanairasia.org

Clean Air Asia is an international NGO established in 2001 as the premier air quality network for Asia by the Asian Development Bank, World Bank and USAID. Its mission is to promote better air quality and livable cities by translating knowledge to policies and actions that reduce air pollution and greenhouse gas emissions from transport, energy and other sectors.

Clean Air Asia became a UN-recognized partnership in 2007, its network spanning 261 organizations in 31 countries in Asia and worldwide, with nine country networks: China, India, Indonesia, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, and Vietnam. It is headquartered in Manila and has offices in Beijing and Delhi. Clean Air Asia leads efforts to enable Asia's more than 1000 cities to reduce both air pollution and CO_2 emissions, and thereby contribute to more livable and healthy cities with blue skies and a low carbon footprint. Clean Air Asia helps to reduce emissions, through policies, plans, programs, and concrete measures that cover air quality, transport and industrial emissions and energy use.

The Better Air Quality (BAQ) Conference is a flagship event of Clean Air Asia covering the key sectors of transport, energy and industry, with a particular emphasis on government policies and measures. Policymakers, practitioners and industry leaders meet at BAQ to network, innovate, learn, and share experiences. The biennial event was first held in 2002 and attracts close to a thousand participants from Asia and the rest of the world.

ABOUT UNEP
www.unep.org

The United Nations Environment Programme (UNEP) is the leading global environmental authority that sets the global environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and serves as an authoritative advocate for the global environment. UNEP work encompasses assessing global, regional and national environmental conditions and trends; developing international and national environmental instruments; and strengthening institutions for the wise management of the environment. UNEP's mission includes to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

CONTENTS

PREFACE

Air pollution is now considered the world's largest environmental health risk. There have been a number of global efforts calling for air pollution actions in recent years. These global calls for action on air pollution strengthen regional and national initiatives and highlight the need to prioritize addressing this issue through a collaborative and integrated approach.

In 2006, the First Governmental Meeting on Urban Air Quality in Asia[1] recognized the need for guidance in implementing a Long Term Vision for Urban Air Quality in Asia, which describes the desired state of urban air quality management in Asian cities. During the Third Governmental Meeting, environment ministries from the region identified key challenges they are facing to improve urban air quality.

To set the way forward in achieving the vision for cleaner air, Clean Air Asia led the development of the Guidance Framework for Better Air Quality in Asian Cities (Guidance Framework) to address the needs and challenges in the region. It aims to provide a recognized guidance on improving urban air quality and is organized around priority areas of concern in the region, which were translated into key guidance areas with roadmaps on how to progress in a step by step manner.

This voluntary, non-binding document consists of seven individually published chapters covering each of the Guidance Areas. Policy and decision makers in Asia, as well as other relevant stakeholders, can use one or a combination of the Guidance Framework chapters to develop local roadmaps or action plans depending on their priority areas of concern.

The Guidance Framework consists of seven main books with these titles:

- Introduction
- Guidance Area 1 - Ambient air quality standards and monitoring
- Guidance Area 2 - Emissions inventories and modeling
- Guidance Area 3 - Health and other impacts
- Guidance Area 4 - Air quality communication
- Guidance Area 5 - Clean air action plans
- Guidance Area 6 - Governance

These guidance areas come with an Information Sourcebook, which is a compilation of resources to support the implementation of Guidance Framework roadmaps. There is also an accompanying training course on Guidance Framework implementation, which is available online in the Clean Air Asia website and Integrated Programme for Better Air Quality (IBAQ Programme) website: www.cleanairasia.org/ibaq

The Guidance Framework was developed together with a team of international and regional experts and practitioners and has undergone an extensive review process through the Governmental Meetings and the involvement of external reviewers. The draft document was also shared in a number of international events, including the Asia Pacific Clean Air Partnership (APCAP) Joint Forum organized by UNEP ROAP in November 2015. The Guidance Framework was welcomed by participants from 24 countries in Asia and the Pacific, involving environment ministries, intergovernmental organizations, non-governmental organizations, and experts.

1 Governmental Meetings on Urban Air Quality in Asia are biennial meetings organized by the United Nations Environment Programme Regional Office of Asia and the Pacific (UNEP ROAP) and Clean Air Asia that convene environment ministries with the aim to harmonize approaches across the region in tackling air pollution and related fields.

ABBREVIATIONS

AB32	California State Law Assembly Bill 32
ADB	Asian Development Bank
API	Air Pollution Index
AQ	Air Quality
AQHI	Air Quality and Health Index
AQM	Air Quality Management
AQS	Air Quality Standards
BRT	Bus Rapid Transit
CSE	Centre for Science and Environment
CO	Carbon monoxide
EC	European Commission
EEA	European Environment Agency
EPD (Hong Kong)	Environmental Protection Department
GDP	Gross Domestic Product
GHG	Greenhouse Gas
MOEJ	Ministry of the Environment of Japan
NO_2	Nitrogen dioxide
O_x	Photochemical oxidants
O_3	Ozone
PBL	Planbureau voor de Leefomgeving
PCD (Thailand)	Pollution Control Department
PM	Particulate Matter
PM_{10}	Particulate Matter (≤ 10 micrometers in diameter)
$PM_{2.5}$	Particulate Matter (≤ 2.5 micrometers in diameter)
SPM	Suspended Particulate Matter
SO_2	Sulfur dioxide
UNECE	United Nations Economic Commission for Europe
USEPA	United States Environmental Protection Agency
WHO	World Health Organization


世界人民大团结

Communication is an essential part of **air quality management** because the adoption of **air pollution control measures** will only be effective if its **relevance and impact** are conveyed to policymakers and to interested parties likely to be **affected by the intervention**.

CHAPTER 5

GUIDANCE AREA 4: AIR QUALITY COMMUNICATION

5.1 Introduction

Air quality (AQ) communication involves the active use of data to inform the general public and key stakeholders about air pollution issues. It aims to raise awareness, change attitudes and foster behavior change. Communication is an essential part of air quality management (AQM) because the adoption of air pollution control measures will only be effective if its relevance and impact are conveyed to policymakers and to interested parties likely to be affected by the intervention. In communicating air pollution prevention, careful consideration should be given to the target audiences, the message that is being sent, and the communication channel used to deliver it.

5.1.1 Objective

To develop an effective communication strategy to inform, educate and strengthen stakeholders' participation in all aspects of AQM, in order to prevent and reduce air pollution impacts.

5.1.2 Why communicate air quality issues?

The communication of AQ issues, particularly to the general public, is normally required as part of national legislation that has provisions for authorities to inform and warn the public when air quality standards (AQS) are exceeded. Moreover, numerous policies adopted to reduce urban air pollution can also assist in mitigating climate change and vice versa [See *Guidance Area 6 on Governance*] (Nemet et al., 2010). Communication of these potential 'co-benefits' can encourage stakeholders to support the adoption and implementation of emissions reduction measures.

A rise in environmental awareness over the past decades means the public is now more concerned about the quality of the air they breathe. A 2011 Clean Air Asia survey on public perceptions of air pollution in Asia found that the majority of the 628 individuals surveyed felt that AQ in their city had deteriorated or had remained the same as the previous year. They perceived motor vehicles as the main source of pollution and felt that air pollution was affecting their health (Clean Air Asia, 2011a). These results were further confirmed in a 2013 Centre for Science and Environment (CSE) air pollution survey of New Delhi residents, which found that approximately 64 percent of respondents felt air pollution was worsening. Also, 74 percent of respondents said that air pollution was responsible for respiratory symptoms, the frequency of which increased during winter (CSE, 2013).

However, many individuals are not only victims of air pollution but are also contributors to the problem. Understanding public perception of, and attitudes to AQ, is important in ensuring successful citizen involvement in AQM (Saksena, 2007). A number of factors shape public attitudes and behavior. These include: knowledge (e.g., how individuals interpret information based on existing beliefs); psychological factors (e.g., values, attitudes and emotions that affect behavior and give a sense of responsibility); habits (e.g., mostly habitual and routine behavior that contributes to polluting emissions); structural conditions (e.g., infrastructure — or lack of it — that can lead to "lock-in" situations, providing an obstacle to behavioral change); and socio-demographic patterns (e.g., the influence of these factors vary with individual circumstances) (Haq et al., 2013). Communication is therefore important to raise awareness, change public attitudes, and promote environmentally friendly behaviors, such as the use of public transport and non-motorized transport.

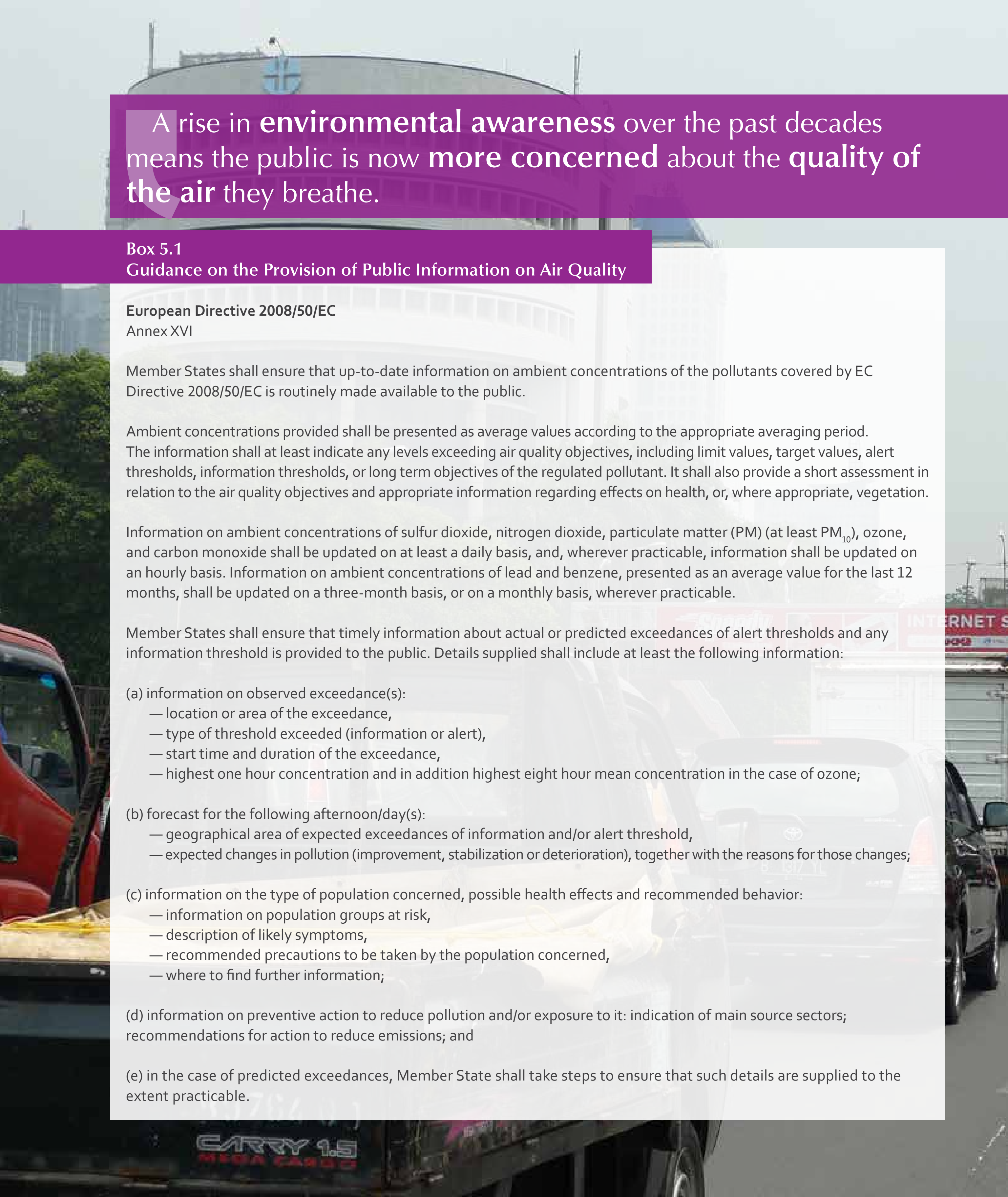
A range of organizations and groups are involved in the communication of AQ information. These include: environmental agencies that are monitoring, collating, and reporting on the state of AQ; public health agencies that are providing advice to protect health; non-governmental organizations that are raising awareness and creating political pressure; and the media, which provide the communication channels to reach different stakeholder groups.

5.1.3 Overview of guidelines on the provision of public information on air quality

The 1998 United Nations Economic Commission for Europe (UNECE) Aarhus Convention establishes the public right to have access to environment information and participate in decision-making to ensure environmental justice. Parties to the Convention are required to make the necessary provisions so that public authorities – at national, regional or local level – implement these rights in practice. Under the Convention, everyone has the right to receive environmental information that is held by public authorities, to participate in environmental decision-making, and to review procedures to challenge public decisions that have been made without respecting public rights or environmental law in general.

A number of international guidelines on the reporting and dissemination of AQ information is currently available (Box 5.1). European Directive 2008/50/EC on ambient AQ requires that the public and appropriate organizations – i.e., environmental, consumer, healthcare bodies, industry federations – should be provided with adequate ambient AQ information. This should be freely available and accessible through any media, including the internet or telecommunications. Annual reports for all pollutants stating when limit values, target values, and long-term objectives have been exceeded should also be publicly available. Section 127 of the United States Clean Air Act (1990) outlines the need to inform the public on the status of AQ.

An Asian Development Bank (ADB) and Clean Air Asia (2014) report on good practice for AQ monitoring distinguishes between information for the public and information for policymakers. Public AQ information should be translated in a form that is accessible, concise, and easy to understand; while information for policy makers should be framed in such a way that it is incorporated into a relevant issue or scenario – e.g., comparative advantages, sociopolitical trends, economic trends, and so on. In contrast, researchers/scientists require more detailed and technical AQ information – technical reports, scientific publications in peer-reviewed journals, and online databases can be used as references for their studies. Information is best shared among this group of stakeholders through conferences, seminars, and workshops.



A rise in **environmental awareness** over the past decades means the public is now **more concerned** about the **quality of the air** they breathe.

Box 5.1
Guidance on the Provision of Public Information on Air Quality

European Directive 2008/50/EC
Annex XVI

Member States shall ensure that up-to-date information on ambient concentrations of the pollutants covered by EC Directive 2008/50/EC is routinely made available to the public.

Ambient concentrations provided shall be presented as average values according to the appropriate averaging period. The information shall at least indicate any levels exceeding air quality objectives, including limit values, target values, alert thresholds, information thresholds, or long term objectives of the regulated pollutant. It shall also provide a short assessment in relation to the air quality objectives and appropriate information regarding effects on health, or, where appropriate, vegetation.

Information on ambient concentrations of sulfur dioxide, nitrogen dioxide, particulate matter (PM) (at least PM_{10}), ozone, and carbon monoxide shall be updated on at least a daily basis, and, wherever practicable, information shall be updated on an hourly basis. Information on ambient concentrations of lead and benzene, presented as an average value for the last 12 months, shall be updated on a three-month basis, or on a monthly basis, wherever practicable.

Member States shall ensure that timely information about actual or predicted exceedances of alert thresholds and any information threshold is provided to the public. Details supplied shall include at least the following information:

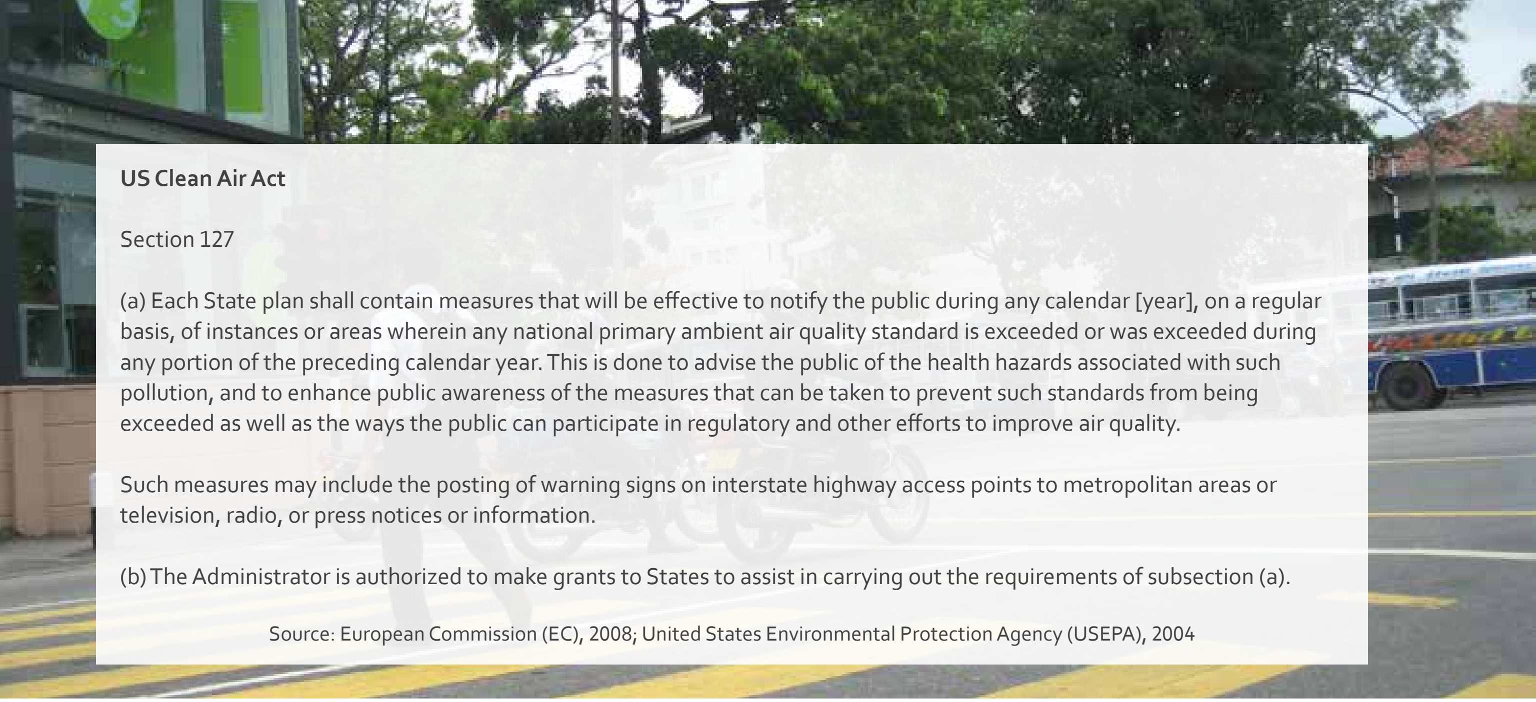
(a) information on observed exceedance(s):
- — location or area of the exceedance,
- — type of threshold exceeded (information or alert),
- — start time and duration of the exceedance,
- — highest one hour concentration and in addition highest eight hour mean concentration in the case of ozone;

(b) forecast for the following afternoon/day(s):
- — geographical area of expected exceedances of information and/or alert threshold,
- — expected changes in pollution (improvement, stabilization or deterioration), together with the reasons for those changes;

(c) information on the type of population concerned, possible health effects and recommended behavior:
- — information on population groups at risk,
- — description of likely symptoms,
- — recommended precautions to be taken by the population concerned,
- — where to find further information;

(d) information on preventive action to reduce pollution and/or exposure to it: indication of main source sectors; recommendations for action to reduce emissions; and

(e) in the case of predicted exceedances, Member State shall take steps to ensure that such details are supplied to the extent practicable.



US Clean Air Act

Section 127

(a) Each State plan shall contain measures that will be effective to notify the public during any calendar [year], on a regular basis, of instances or areas wherein any national primary ambient air quality standard is exceeded or was exceeded during any portion of the preceding calendar year. This is done to advise the public of the health hazards associated with such pollution, and to enhance public awareness of the measures that can be taken to prevent such standards from being exceeded as well as the ways the public can participate in regulatory and other efforts to improve air quality.

Such measures may include the posting of warning signs on interstate highway access points to metropolitan areas or television, radio, or press notices or information.

(b) The Administrator is authorized to make grants to States to assist in carrying out the requirements of subsection (a).

Source: European Commission (EC), 2008; United States Environmental Protection Agency (USEPA), 2004

5.1.4 Platforms for communicating air quality

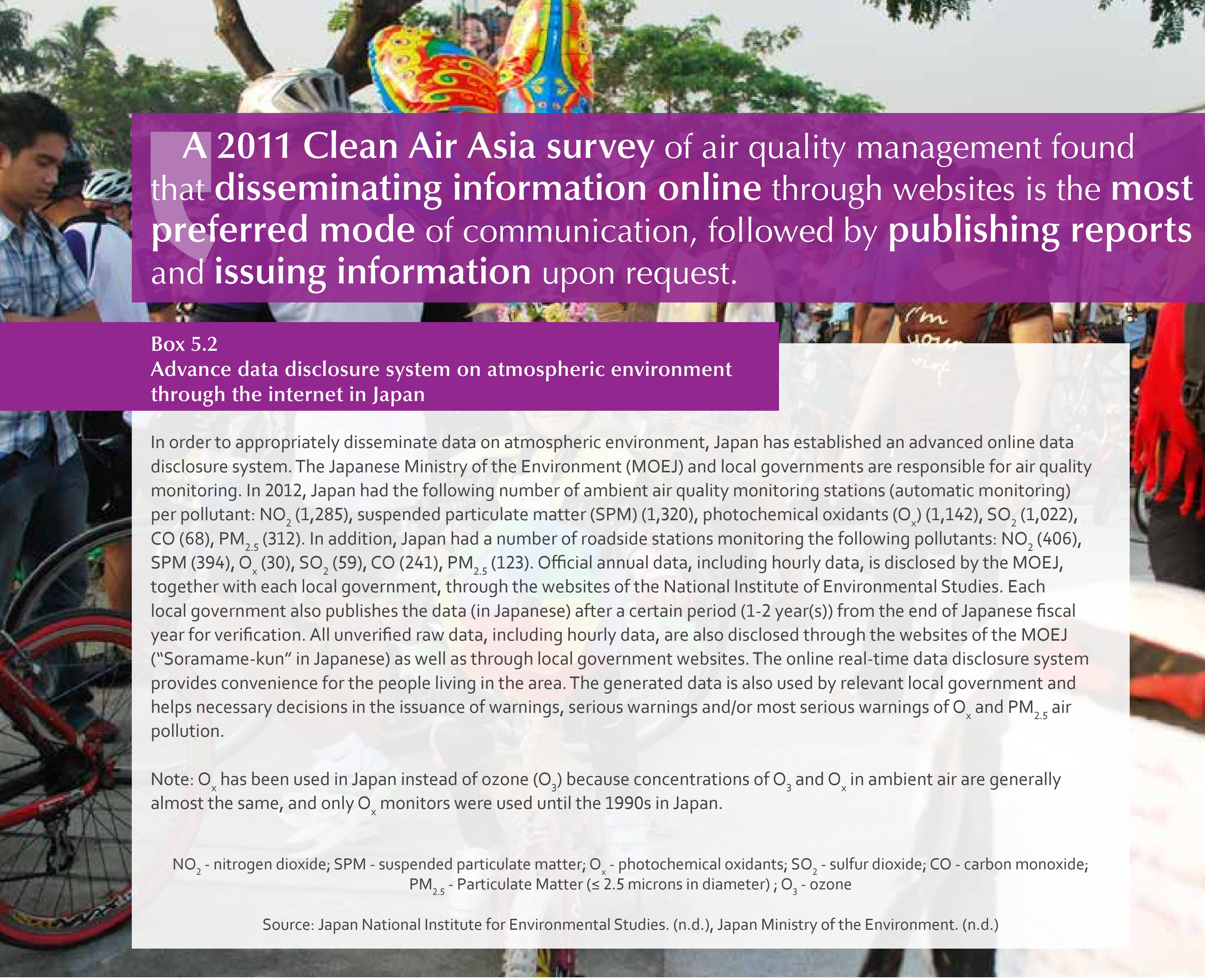
A wide range of channels, such as those listed below, is currently used to communicate the status of AQ in Asian cities to the general public and key stakeholders:

- Published (printed) reports – reports, brochures, papers
- Print media – newspapers
- Broadcast media – television and radio
- Website – online databases
- Email or mobile alerts
- Public display screens or booths/information boards
- Internal communications/requests
- Upon-request information
- Others: social networking sites, microblogs

Commonly used tools to communicate air quality information to policymakers include:

- Policy briefs
- Written reports
- Summary tables
- Visual presentations
- Interpretation of information
- Pie chart and map
- Satellite imagery

A Clean Air Asia survey of AQM (ADB & Clean Air Asia, 2014) found that disseminating information online through websites is the most preferred mode of communication, followed by publishing reports and issuing information upon request. The least used mode of information dissemination is broadcasting on television and publishing in the print media. Air quality monitoring data in Japan is disseminated through an advanced online data disclosure system to gain support of the general public in promoting upgrade and improvement of AQ monitoring systems (Box 5.2).



> A **2011 Clean Air Asia survey** of air quality management found that **disseminating information online** through websites is the **most preferred mode** of communication, followed by **publishing reports** and **issuing information** upon request.

Box 5.2
Advance data disclosure system on atmospheric environment through the internet in Japan

In order to appropriately disseminate data on atmospheric environment, Japan has established an advanced online data disclosure system. The Japanese Ministry of the Environment (MOEJ) and local governments are responsible for air quality monitoring. In 2012, Japan had the following number of ambient air quality monitoring stations (automatic monitoring) per pollutant: NO_2 (1,285), suspended particulate matter (SPM) (1,320), photochemical oxidants (O_x) (1,142), SO_2 (1,022), CO (68), $PM_{2.5}$ (312). In addition, Japan had a number of roadside stations monitoring the following pollutants: NO_2 (406), SPM (394), O_x (30), SO_2 (59), CO (241), $PM_{2.5}$ (123). Official annual data, including hourly data, is disclosed by the MOEJ, together with each local government, through the websites of the National Institute of Environmental Studies. Each local government also publishes the data (in Japanese) after a certain period (1-2 year(s)) from the end of Japanese fiscal year for verification. All unverified raw data, including hourly data, are also disclosed through the websites of the MOEJ ("Soramame-kun" in Japanese) as well as through local government websites. The online real-time data disclosure system provides convenience for the people living in the area. The generated data is also used by relevant local government and helps necessary decisions in the issuance of warnings, serious warnings and/or most serious warnings of O_x and $PM_{2.5}$ air pollution.

Note: O_x has been used in Japan instead of ozone (O_3) because concentrations of O_3 and O_x in ambient air are generally almost the same, and only O_x monitors were used until the 1990s in Japan.

NO_2 - nitrogen dioxide; SPM - suspended particulate matter; O_x - photochemical oxidants; SO_2 - sulfur dioxide; CO - carbon monoxide; $PM_{2.5}$ - Particulate Matter (≤ 2.5 microns in diameter) ; O_3 - ozone

Source: Japan National Institute for Environmental Studies. (n.d.), Japan Ministry of the Environment. (n.d.)

Factors such as cost, frequency of reporting and information format influence the type of communication channel used to disseminate AQ information. Publishing information online is considered to be significantly cheaper than the cost of using television and print media. In addition, advances in communication technology make sharing and accessing of data easier through the use of downloadable mobile applications. For example, Thailand's Pollution Control Department (PCD) has established the mobile application Air4Thai, which makes AQ information available to users in Bangkok and other areas in Thailand.

In terms of method or format of AQ information to be disseminated, several ways of presenting AQ information in Asian cities have been identified (ADB & Clean Air Asia, 2014):

- raw number – raw data is shared in numerical form
- raw graph – raw data is shared in graphical form
- conc – AQ data is expressed as concentration
- stats – AQ data has undergone statistical analyses (e.g., expressed as percentiles)
- spatial – AQ data is represented spatially
- text – data has an accompanying text that describes the AQ

5.1.5 The use of indexes in air quality communication

Air Quality Index (AQI) is often used as a tool to communicate the state of AQ to the public. Different countries have their own AQIs corresponding to different national AQS such as the Air Pollution Index (Malaysia) and the Pollutant Standard Index (Singapore).

The AQI translates raw data (e.g., pollutant concentrations) to a number on a scale that is further divided into bands that correspond to a defined pollution concentration. Depending on the AQI value, these bands could be defined as "good", "moderate", "unhealthy for sensitive groups", "unhealthy", "very unhealthy", and "hazardous", which have different meanings for different vulnerable groups of the population. The index is also color-coded to make the information more comprehensible and visually appealing. Table 5.1 presents an example of an AQI produced by the USEPA.

However, AQIs can vary from one country to another in terms of the type of pollutants monitored, the range of values, and the banding. It is important that AQIs are free from ambiguity and that uniform AQI categories are used throughout the country by different agencies (Box 5.3).

Public awareness of AQIs or alerts also varies between countries. There is limited evidence to suggest that individuals change behavior to reduce exposure, either in response to air quality data or perceptions of exposure. A US study found that while a third of 1,962 participants were aware of air quality alerts, only 10-15 percent of individuals reported changing behavior in response to predicted poor air quality. Instead, personal perceptions of poor air quality were cited as the main driver of behavior than official advice (Laumbach et al., 2015).

The AQI is not the only form of expressing AQ information. In most cases, indexes are enhanced with other data visualization tools such as the geographical information system to show the spatial variation of AQ and distribution of air pollutants. Some cities also take advantage of novel technologies and innovative approaches to convey AQ information (Box 5.4).

An ADB & Clean Air Asia (2014) survey of AQ monitoring in Asian cities found that only 55 percent of the cities mentioned use AQIs. Table 5.2 shows eight countries (Brunei Darussalam, India, Malaysia, People's Republic of China, Republic of Korea, Singapore, Thailand, and Vietnam) fully implement AQIs. A number of countries had national guidelines for indexes; however, these were only implemented in a few cities or were not implemented at all.

Table 5.1 USEPA Air Quality Index including different bands and corresponding definitions

Numerical Value	Levels of Health Concern	Meaning
0 to 50	Good	Air quality is considered satisfactory and air pollution poses little or no risk
51 to 100	Moderate	Air quality is acceptable; however, for some pollutants, there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution
101 to 150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected
151 to 200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious effects
201 to 300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected
301 to 500	Hazardous	Health alert: everyone may experience more serious health effects

Source: USEPA, 2013

Table 5.2 Overview of air quality (and similar) indexes in Asia

Countries	Status	Official Name	Reporting Frequency	Pollutants Included
Afghanistan	—	—	—	—
Bangladesh	Proposed	Air Quality Index	Daily	SO_2, NO_2, CO, O_3, $PM_{2.5}$, PM_{10}
Bhutan	—	—	—	—
Brunei Darussalam	Implemented	Pollution Standard Index	Daily	PM_{10}
Cambodia	—	—	—	—
PR China	Implemented	Air Quality Index	Hourly	SO_2, NO_2, PM_{10}, CO, O_3, $PM_{2.5}$
India	Implemented	National Air Quality Index	Hourly	SO_2, NO_2, CO, O_3, NH_3, $PM_{2.5}$, PM_{10}, Pb
Indonesia	Implemented but irregular	Indeks Standar Pencemar Udara/ Pollution Standard Index	Daily	PM_{10}, SO_2, CO, O_3, NO_2
Japan	—	—	—	—
Lao PDR	—	—	—	—
Malaysia	Implemented	Air Pollutant Index (API)	Hourly	CO, O_3, SO_2, NO_2, PM_{10}
Myanmar	—	—	—	—
Nepal	—	—	—	—
Pakistan	Implemented but irregular	Air Quality Index	Daily (Irregular)	Includes PM_{10}, $PM_{2.5}$
Philippines	Implemented in selected cities	Air Quality Index	Daily	TSP, SO_2, CO, O_3, NO_2, PM_{10}, $PM_{2.5}$
Republic of Korea	Implemented	Community Air Quality Index	Hourly	SO_2, NO_2, CO, O_3, PM_{10}
Singapore	Implemented	Pollution Standard Index	Daily, 3-hr, hourly (for $PM_{2.5}$)	$PM_{2.5}$, PM_{10}, SO_2, CO, O_3, NO_2
Sri Lanka	Established but not implemented	Sri Lanka Air Quality Index	Daily, weekly	O_3, $PM_{2.5}$, PM_{10}, CO, SO_2, NO_2
Thailand	Implemented	Air Quality Index	Hourly, daily	PM_{10}, O_3, SO_2, NO_2, CO
Vietnam	Implemented	Air Quality Index	Hourly	Not indicated

Source: Updated from ADB & Clean Air Asia (2014)

Box 5.3
Hong Kong's air pollution index

Hong Kong has developed an air pollution index (API), which includes health risk categories and provides advice to different vulnerable stakeholder groups on what action to take. Since 1995, Hong Kong has implemented an API (or AQI) system that reports an aggregated index based on the pollutant with the highest level of concentration for a given day or hour at a specific station. The index covered four pollutants with indexes based on Hong Kong's Air Quality Objectives. The main limitation of this API approach was that it ignored the joint effects of different air pollutants on the health of the exposed community.

In response to the 2005 World Health Organization (WHO) Air Quality Guidelines, the Hong Kong government commissioned university teams to review its Air Quality Objectives and consequently review its API system. After studying the different index systems implemented around the world, the team of experts recommended an approach similar to what Canada has adopted. The Air Quality and Health Index (AQHI) of Canada made use of local air pollution and health data, ensuring that the air quality reporting system is based on health outcomes observed locally.

In December 2013, Hong Kong adopted an AQHI system that utilized health risks derived from local hospital admissions data for air pollution-related illnesses. While the Canada AQHI made use of mortality data, Hong Kong revised the approach to use morbidity data instead. The AQHIs are reported on a scale of one to 10 and are grouped into five health risk categories (low, moderate, high, very high, serious) that provide health-risk information and precautionary measures for susceptible groups.

This reporting system, which informs the public of the short-term health risk of air pollution in Hong Kong, is the first of its kind in Asia.

The latest hourly AQHI and forecast is communicated using the following platforms:

(i) Environmental Protection Department (EPD) website at http://www.aqhi.gov.hk, accessible from a personal computer or a mobile device such as a smartphone;
(ii) AQHI application for mobile devices or an AQHI alert wizard for desktop computers; or
(iii) AQHI hotline (2827 8541), which gives verbal updates through an interactive voice recording system , or provides a printed update through the fax-on-demand service.

All of the above methods provide AQHI information 24 hours a day. There are also updates provided at regular intervals via the mass media, on different TV and radio channels.

The adoption of the AQHI system in Hong Kong empowers the public with the information to put pressure on the national government to prioritize air pollution response. If local air pollution and hospital data are available, other Asian cities can adopt this AQHI system using the methodology developed by Hong Kong (Wong et al., 2012.).

Source: Wong et al., 2012

Box 5.4
Innovative approaches to air quality communication

Living Light, Seoul, South Korea

Image source: http://www.livinglightseoul.net/

Living Light is a building facade of the future that displays air quality and public interest in the environment. It is a permanent outdoor pavilion in Peace Park in Seoul, Korea. It has a dynamic skin that glows and blinks in response to both data about air quality and public interest in the environment. It is unique for its capability to dynamically represent environmental air quality via a public media architecture structure. Parts of the panel roof glow when the air quality is better than last year's or when onlookers send a text message querying the data for a specific postcode.

The outer perimeter of the pavilion represents a giant map of Seoul with the 27 neighborhood boundaries redrawn based on existing air quality sensors of the Korean Ministry of Environment. Each shape in this new map encloses the air space closest to one of the sensors. The map then illuminates based on the comparison of historical and real-time sensor data, and text messaging requests from passers-by, becoming an interactive, environmental building façade (Infosthetics, 2009).

Ballon de Paris, Paris France

Image Source: https://plus.google.com/+A%C3%A9roparisBallondeParis/posts

Since 2008, the balloon, called Ballon de Paris, has been partnering with AIRPARIF (a licensed air-quality-measurement company in France). Not only does the balloon have the capacity to take air quality measurements, but changes color depending on the quality of ambient air in Paris. Every two hours the balloon shows two air quality indices: ambient air quality provided by six urban stations and air quality measured at five traffic stations in Paris.

Very Good   Good   Fair   Poor   Very Poor

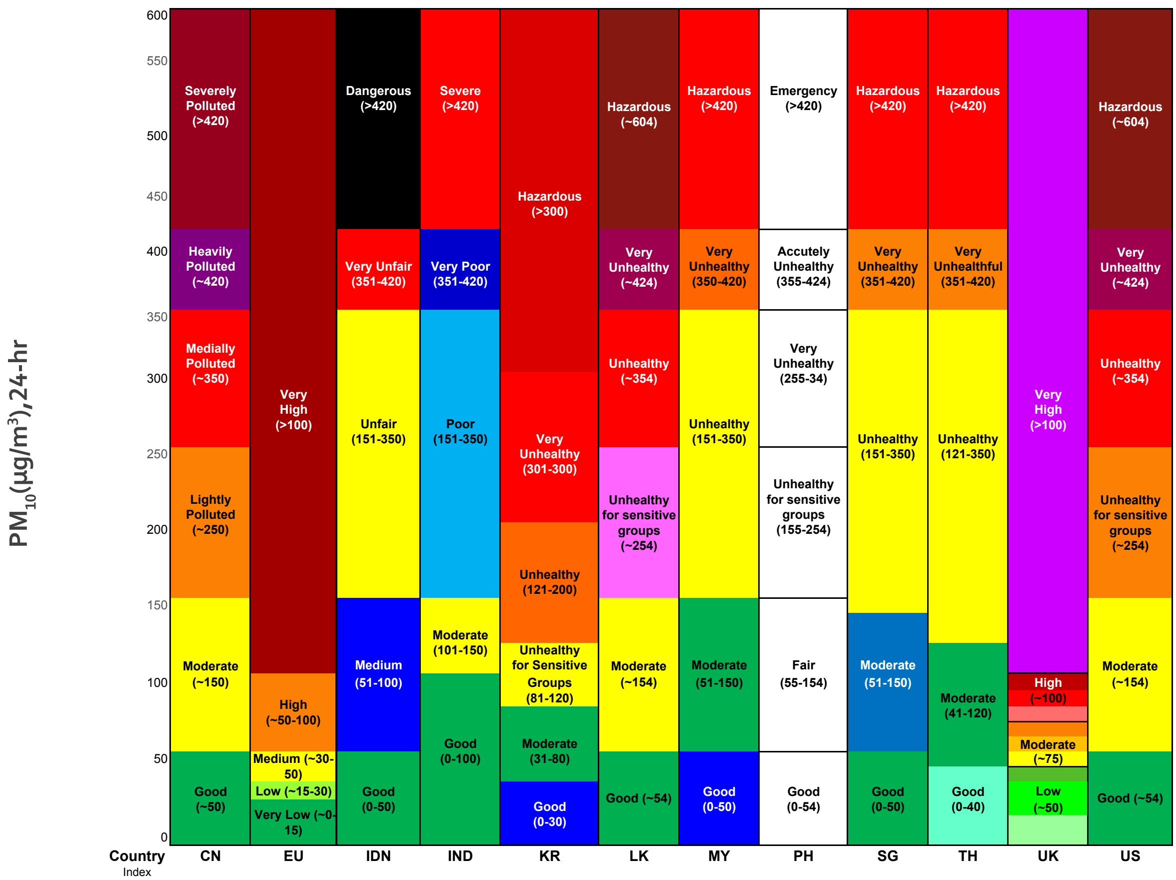
The indices illustrate in a simple and easily understandable manner the amount of the three most problematic pollutants in major European cities: NO_2, O_3 and PM. The balloon turns green for good air quality in Paris, orange for fair and red for poor. It can be seen for over 19 kilometres (12 miles) (Ballon de Paris, 2015).

Source: Infosthetics, 2009; Ballon de Paris, 2015

In Asia, AQIs may significantly vary from one country to another (Figure 5.1). Some of the key variations in different components are summarized below:

- Pollutants Covered: Most countries have indexes on PM_{10}, SO_2, NO_2, and CO. Very few consider $PM_{2.5}$.
- Bands: Bands of the pollutant concentrations vary per country, usually depending on their national ambient AQS.
- Frequency of Reporting: Most report the index daily, with China and Republic of Korea reporting hourly.
- Reporting Area: Mostly by stations but are also offered by region/district in some developed cities.
- Reporting Channels: Mostly reported through websites but there are other countries that also include reporting through smartphone apps, social networks, newspapers, radio and television.
- Text Descriptions: Some countries base description on pollution levels (low, slightly polluted, high); while others base it on health impacts (low, unhealthy for sensitive groups, unhealthy, and hazardous).

These variations may lead to public confusion in interpreting AQIs from different cities or countries. Hence, it may be useful to explore the harmonization of AQIs in Asia despite the challenges posed by various national AQ guidelines/standards used in different countries.



CN = China; EU = European Union; IDN = Indonesia; IND = India; KR = Republic of Korea; LK = Sri Lanka; MY = Malaysia; PH = Philippines; SG = Singapore; TH = Thailand; UK = United Kingdom; US = United States

Figure 5.1 Comparison of PM_{10} AQI in selected countries

Source: Clean Air Asia, 2015

In 2010, ADB & Clean Air Asia developed a Clean Air Scorecard to provide a comparative index that could be used to identify potential improvement areas for Asian cities. The Clean Air Scorecard is an Excel-based tool incorporating three indexes: (i) Air Pollution and Health, (ii) Clean Air Management Capacity, and (iii) Clean Air Policies and Actions. This work aims to address the need for a comparative index that may be used to assess AQ levels. The Air Pollution and Health Index (APHI) assesses air pollution levels of cities against WHO guideline values and interim targets (Table 5.3). A "good air" day in this index therefore relates to WHO guidelines rather than the city's ambient air quality standards (AAQS), which are generally less stringent. This index includes six pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, and CO). A city is required to have, at a minimum, monitoring data for PM with a diameter of 10 microns or less (PM_{10}). The WHO guidelines and interim targets were considered as the basis for the excellent category. Succeeding categories were based on interim targets 1 and 2 as well as annual average levels of Asian cities.[2]

The index is separately calculated for each pollutant and not as a composite index. For a city with data for different pollutants, the pollutant with the lowest score is considered the main pollutant of concern. As such, the score considered in the computation of the city's overall clean air score is based on the pollutant with the lowest score under the APHI. When comparing cities, however, it is required that the cities' APHI score is based on the same pollutant or set of pollutants. Table 5.3 presents the score banding and description for each category.

2 For example, excellent is based on the WHO guideline of 20 $\mu g/m^3$ and interim target 3 of 30$\mu g/m^3$. Good and moderate categories are based on the interim target 2 of 50 $\mu g/m^3$ and the interim target 1 of 70 $\mu g/m^3$, respectively. Poor and very poor categories are based on annual average PM_{10} of 101.23 $\mu g/m^3$ in 180 cities in Asia and the standard deviation of 50 $\mu g/m^3$.

Table 5.3 Score bands and category descriptions for the Air Pollution and Health Index

Air Pollution and Health Index		
Category	**Score Band**	**Description**
Excellent	81–100	Low levels of pollution within WHO-prescribed guidelines. Public health implications for pollutants monitored are limited and hardly noticeable.
Good	61–80	Relatively low levels of air pollution but considerable impacts to sensitive groups.
Moderate	41–60	Elevated levels of air pollution with aggravated symptoms for sensitive groups and contributing to onset of risks for exposed healthy individuals.
Poor	21–40	High levels of pollution with significant health effects to vulnerable populations and contributing to increased risks for exposed healthy individuals.
Very Poor	11–20	Extremely high levels of pollution affecting a large share of population.
Critical	1–10	Critical levels of air pollution resulting in adverse health effects to public in general.

Source: Clean Air Asia, 2011b

Since its development, the Clean Air Scorecard has been applied in 24 Asian cities in nine countries (Bac Ninh, Bangkok, Cagayan de Oro, Can Tho, Changchung, Chiang Mai, Colombo, Dalian, Foshan, Guangzhou, Hangzhou, Hanoi, Harbin, Iloilo, Jakarta, Jiangyin, Jinan, Kathmandu, Korat, Metro Manila, Quetta, Tongxiang, Visakhapatnam, Zhaoqing). The Clean Air Scorecard bandings in the APHI may be adapted to follow the same format of existing AQIs where poor AQ has low AQI values and good AQ has high AQI values.

Table 5.4 shows the characteristics of AQ status reports in selected Asian countries. Most of the reports focus on data analysis. While useful, it can overlook other aspects of AQM such as the health and socioeconomic impacts of air pollution as possible measures to mitigate the impacts. Priority action areas to improve AQ are also absent. Such deficiencies are missed opportunities in ensuring that policymakers understand the situation and that they are provided with the evidence base for formulating sound policies.

Generally, national (and sometimes regional) AQ status reports have a prescribed format, content and reporting frequency. However, AQM is primarily a local issue and city residents are interested to know the quality of the air they are breathing and the progress of the implementation of AQM measures and plans. Unfortunately, national reports have a broad scope and cannot provide detailed information per locality. Current national AQ status reports usually focus on compliance with standards and target values, and are unfortunately presented in a format that is not accessible to the public.

Table 5.4 Overview of air quality status reports in selected Asian countries

Country/City	Title	Lead Organization	Frequency	Most recent version during drafting of document (2014)
India	National Ambient Air Quality Status Report	Central Pollution Control Board	Annual	2012
Malaysia	As part of: Malaysia Environmental Quality Report	Department of Environment	Annual	2013
Philippines	National Air Quality Status Report	Environmental Management Bureau	Every two years	2010-2011
PR China	As part of: State of the Environment in China	Ministry of Environmental Protection	Annual	2012
	State of 74 Cities Air Quality	Ministry of Environmental Protection	Monthly	2014
Republic of Korea	Monthly and Annual Report of Air Quality in Korea (in Korean)	Ministry of Environment	Monthly/ Annual	Monthly (February 2015); Annual (2014)
Thailand	Thailand's Air & Noise Status and Management (in Thai)	Pollution Control Department	Annual	2012
Vietnam	As part of: National Environmental Report	VEA	Annual	2012

Contents	Status/ Remarks	Link
• Air quality monitoring system information • Air quality assessment (for one year): general and pollutant- specific (SO_2, NO_2, SPM, PM_{10}, and others) • Air quality trends • Initiatives for air pollution control	2012 version published in January 2014	http://cpcb.nic.in/divisionsofheadoffice/pams/NAAQStatus_Trend_Report_2012.pdf
• Air quality: monitoring, current status, and trends • River, ground and marine water quality • Pollution sources inventory	Regularly prepared and published	https://enviro.doe.gov.my/view.php?id=15791
• Sources of air pollution • Status of ambient air quality • Air quality management (by source and by organization) • Best practices and lessons learned • Challenges and recommendations	Report for 2012 under preparation	Most recent: http://www.emb.gov.ph/portal/Portals/23/PDF%20Files/DenrAirQualityStatReport10-11.pdf For past reports: http://emb.gov.ph/eeid/publications.htm
• Reduction of total discharge of major pollutants • Atmospheric environment: status of air quality (by pollutant), acid rain frequency and distribution, emissions estimates and measures, actions • State of water, marine, acoustic, solid waste, radiation, nature and ecology, land and rural environment, forest, grassland, climate and natural disasters • Environmental management	Regularly prepared and published (in Chinese and English)	http://english.mep.gov.cn/standards_reports/soe/
• Air quality: monthly average concentration of pollutants; pollutants and cities of concern	Regularly prepared and published online	http://www.cnemc.cn/publish/totalWebSite/news/news_40273.html
• Air quality standard • Sources of air pollution • Air quality monitoring system information • Status of ambient air quality • Air quality management • Air Quality forecast & alert system • Status on yellow sand	Prepared and published from 1998 to 2014 in Korean	http://www.airkorea.or.kr/last_amb_hour_data http://www.airkorea.or.kr/eng/real/realTime
• Air quality status and volume of emissions • Measures on prevention and control of air and noise pollution with focus chapters on key sources (industry/vehicles) • Public awareness campaigns	Regularly prepared and published but only available in Thai	http://www.pcd.go.th/download/en_air.cfm
• Economic development activities, changes in climate and other environmental pressures • State of environment – quality of soil, water and air • Special focus on solid waste and biodiversity • Impacts of environmental pollution • State of environmental management • Proposed measures	Regularly prepared and published but only available in Vietnamese (except for 2007). Each year has a different theme. 2012 focused on surface but 2013 will focus on air environment.	http://vea.gov.vn/vn/hientrangmoitruong/baocaomtquocgia/Pages/default.aspx

Source: Updated from Clean Air Asia, 2012

5.1.6 Communicating co-benefits of air quality and climate change

Many strategies to reduce greenhouse gases (GHGs) also have the added co-benefit of decreasing air pollutants (e.g. PM, NO_x, and SO_2). Measures to reduce emissions of GHGs to 50 percent of 2005 levels by 2050 can reduce the number of premature deaths from the chronic exposure to air pollution by 20 to 40 percent. The most significant of these measures is switching from fossil fuels to renewable energy (Planbureau voor de Leefomgeving [PBL], 2009).

However, there is currently no single "meta-metric" to deliver all information needed for a meaningful integration of air and climate policies (European Environmental Agency [EEA], 2013). Metrics used to communicate the Global Warming Potential/Global Temperature Change Potential or the relative contribution of GHGs to climate change – parts per billion (ppb) – of CO_2, for example, are different from the metrics for air quality – ambient concentrations micrograms per cubic meter (µg/m^3). In addition, health and ecosystem metrics are impact-focused (mortality, morbidity, crop losses, among others). There is a need for a suite of metrics with a focus on integrated policies.

The inclusion of AQ benefits in the design of climate strategies can be used to motivate stakeholders to take action as AQ benefits are local, nearer term and have health benefits (Nemet et al., 2010). This includes highlighting the economic costs of action, especially to decision-makers.

The AQ co-benefits of climate change mitigation have been estimated within the range of US$2- $196 per ton of CO_2 (t/CO_2), with an average of US$49 t/$CO_2$. The highest benefits occur in developing countries (Nemet et al., 2010). For example, if China pursued a stringent air policy to reduce the number of premature deaths from chronic exposure to outdoor air pollution by 70 percent by 2050, this policy will lower gross domestic product (GDP) by 7 percent (compared with a baseline trend without policy). However, the air quality benefits would be equivalent to 7.5 percent of GDP while greenhouse gas emissions would be 40 percent lower (PBL, 2009). Box 5.5 discusses the co-benefits achieved from the implementation of legislation to reduce GHGs in the USA.

Box 5.5
Achieving co-benefits in California

On September 27, 2006, then California Governor Arnold Schwarzenegger signed into law the California State Law Assembly Bill 32 (AB32). AB32 was the most ambitious subnational climate change legislation in the United States. The law authorized the California Air Resource Board (CARB) to develop a series of multi-sector market-driven and command-control regulations to reduce emissions of GHGs to 1990 levels by 2020.

AB32 has been phased-in with a scoping plan that was developed shortly after its passage (2008). The scoping plan helped to define a series of early actions that would take effect in 2010. It also set the stage for a series of mandatory reductions that came into force at the end of 2012. The mandatory reductions consisted of an emissions trading scheme that covered 85 percent of California's emissions sources. AB32 also included narrower provision targeting high global warming potential gases, energy efficiency, clean transportation, industry, forest and waste/recycling.

A macro-economic assessment of the overall economic impacts of AB32 was undertaken, including an analysis of energy savings and air pollution reductions. The assessment suggested that AB32 would reduce combustion-generated soot or $PM_{2.5}$ by 15 tons per day and NOx by 61 tons per day. The estimated benefits of these reductions included improvements in public health, estimated to be US$4.3 billion in 2020, 770 fewer premature deaths, and 76,000 fewer workdays lost (Climate Action Team, 2007).

> Many strategies to **reduce greenhouse gases** also have the **added co-benefit** of decreasing **health-damaging** air pollutants.

The inclusion of **air quality benefits** in the design of **climate strategies** can be used to **motivate** stakeholders **to take action** as AQ benefits are local, nearer term and **have direct health benefits**.

The transport sector is one area where co-benefits could be communicated both to key stakeholders and the general public. There are 'win-win' scenarios that benefit both air quality and climate (Figure 5.2). Box 5.6 discusses the co-benefits of introducing a bus rapid transit (BRT) system in Jakarta (Indonesia). Equally, under a 'win-lose- scenario' either climate or air quality would benefit, but not both (e.g. replacement of gasoline with biofuels which are beneficial for the climate but is detrimental to air quality due to increased particulate emissions) (EEA, 2013). Interventions to more active transport (i.e. walking and cycling), along with BRT/ public transport and improved land use, can result in reduced GHG emissions and offer immediate health co-benefits – e.g., a reduction in cardiovascular and respiratory disease from air pollution, less traffic injury and less noise-related stress. In contrast, shifting from gasoline to diesel vehicles could increase health-damaging particulate matter emissions (PM_{10}, $PM_{2.5}$).

When communicating co-benefits of air quality and climate change policies, it is important to do this in a coherent way, using a suite of metrics that connects the socioeconomic, environmental, and health information. Key messages will need to be identified to provide guidance and improve stakeholder awareness, especially at the city and regional level.

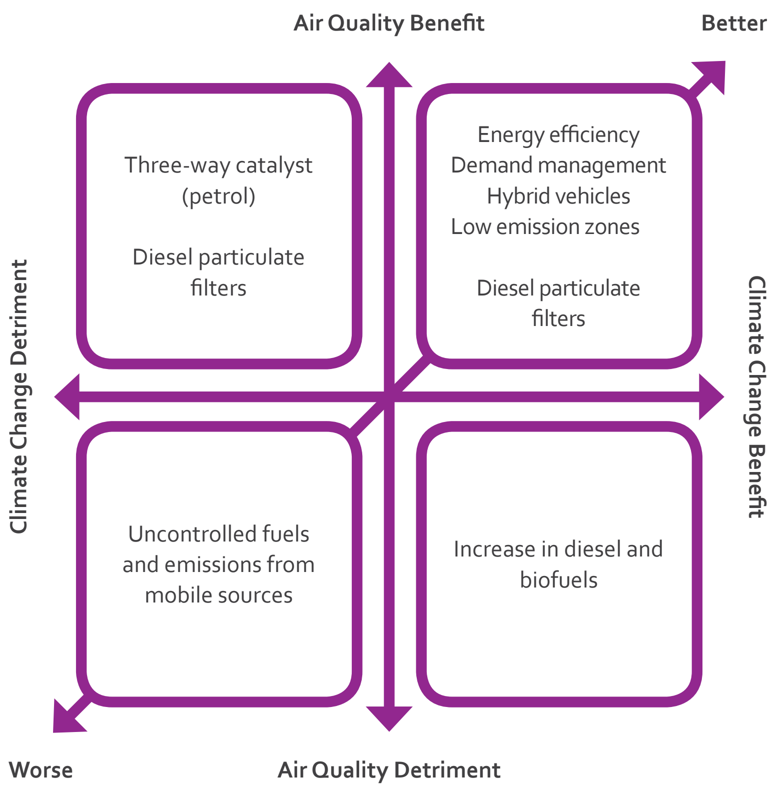
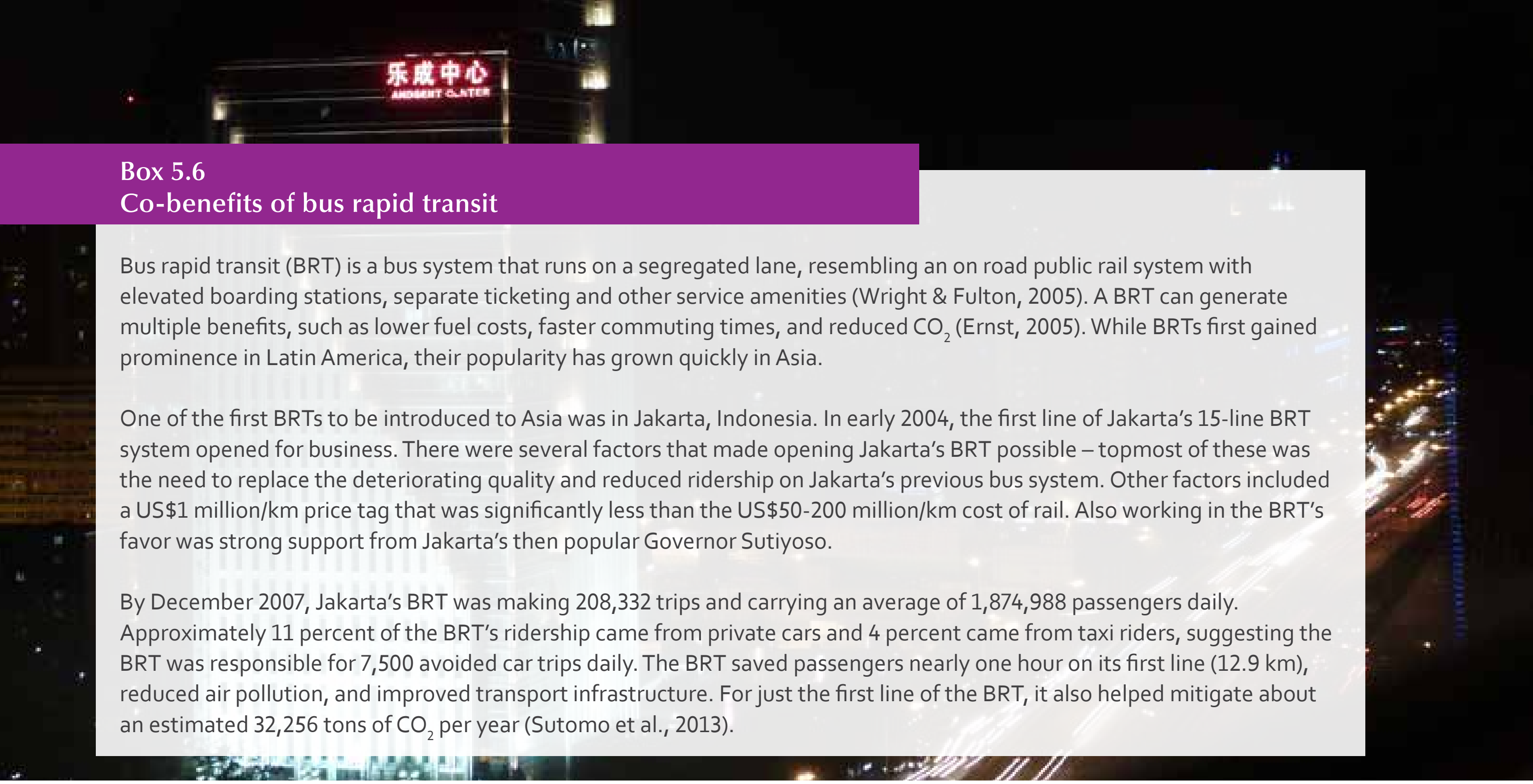


Figure 5.2: Air quality – climate change co-benefits in transport

Source: Adapted from EEA, 2013



Box 5.6
Co-benefits of bus rapid transit

Bus rapid transit (BRT) is a bus system that runs on a segregated lane, resembling an on road public rail system with elevated boarding stations, separate ticketing and other service amenities (Wright & Fulton, 2005). A BRT can generate multiple benefits, such as lower fuel costs, faster commuting times, and reduced CO_2 (Ernst, 2005). While BRTs first gained prominence in Latin America, their popularity has grown quickly in Asia.

One of the first BRTs to be introduced to Asia was in Jakarta, Indonesia. In early 2004, the first line of Jakarta's 15-line BRT system opened for business. There were several factors that made opening Jakarta's BRT possible – topmost of these was the need to replace the deteriorating quality and reduced ridership on Jakarta's previous bus system. Other factors included a US$1 million/km price tag that was significantly less than the US$50-200 million/km cost of rail. Also working in the BRT's favor was strong support from Jakarta's then popular Governor Sutiyoso.

By December 2007, Jakarta's BRT was making 208,332 trips and carrying an average of 1,874,988 passengers daily. Approximately 11 percent of the BRT's ridership came from private cars and 4 percent came from taxi riders, suggesting the BRT was responsible for 7,500 avoided car trips daily. The BRT saved passengers nearly one hour on its first line (12.9 km), reduced air pollution, and improved transport infrastructure. For just the first line of the BRT, it also helped mitigate about an estimated 32,256 tons of CO_2 per year (Sutomo et al., 2013).

> For air quality communication **to be effective**, it needs to ensure that it **raises awareness**, **changes attitudes** and **fosters low-polluting behavior**. This will not only **improve air quality** but will ensure that **vulnerable groups are protected**.

5.2 Stages of air quality communication

For AQ communication to be effective, it needs to ensure that it raises awareness, changes attitudes, and fosters low-polluting behavior. This will not only improve AQ but will ensure that vulnerable groups are protected. Table 5.5 presents the different stages involved in the effective communication of AQ information, and associated health and co-benefits in Asian cities. It highlights the main indicators for each stage of AQM development, from underdeveloped to fully developed.

The key indicators for consideration include:

- Development and implementation of communication strategies (i.e. AQ communication plan)
- Availability of and access to AQ information (i.e. air quality monitoring data, health and other impacts, policies, action plans)
- Types of AQ information communicated
- Use of communication platforms to inform stakeholders about state of air quality

5.3 Issues and challenges

Several key challenges currently exist in Asia, which prevent the effective communication of AQ information. These can be identified under three broad headings:

Institutional

- **Limited capacity in processing AQ information**. Where AQ data is available, there may not be in-house capacity to use this data and develop awareness-raising programs to target different stakeholder groups.

Table 5.5 Stages of air quality communication

Stages	Indicators
Underdeveloped	There is limited raw/unprocessed AQ monitoring data available for communication activities. AQ data or any other relevant information is not shared with the public. There is limited public awareness of the need for understanding sources and health impacts of air pollution in AQM.
Developing	Limited AQ monitoring data (processed) data from ad hoc or project-based monitoring activities are used in communication activities. Available AQ information is not updated. Communication activities for policymakers and the public are implemented on an ad hoc or project basis. AQ data is available to the public through request. There is low level of public awareness of the need for understanding sources and health impacts of air pollution.
Emerging	Processed AQ monitoring data, AQI, and general information on pollution sources are used in communication activities. Available AQ information is updated but not on a regular basis. Press releases on the state of AQ are issued on a case-to-case basis. Advisories are made during events of high air pollution but no system is in place. Communication activities for policymakers and the public are becoming more common. Public can download general information on AQ online. One or two media channels are used to communicate AQ. Public awareness of the need for understanding sources and health impacts of air pollution is starting to become routinely considered.
Maturing	Processed AQ monitoring data, AQI, information on pollution sources from emissions inventory/ source apportionment (EI/SA), local data on impacts of air pollution and AQM action plans are used in communication activities. AQ information is updated on a regular basis. Press releases on the state of AQ are regularly issued. Advisories are systematically released during events of high air pollution. Communication strategies for policymakers and the public are developed and implemented; the process is institutionalized and systematized in AQM. Public can download more AQ information online (i.e. processed AQ monitoring data, AQ trends, health impacts). A wider selection of modern communication channels is used. Public awareness of the need for understanding sources and health impacts of air pollution is becoming standard.
Fully developed	Comprehensive and non-technical information on status of AQM (i.e. processed AQ monitoring data, AQI, more detailed information from EI/SA, local health impacts of air pollution, AQM policies and action plans to control air pollution for specific areas) are communicated to stakeholders on a regular basis. AQ information is updated on a real time basis. Press releases on the state of AQ are routinely used. Advanced public warnings/forecasts are accurately issued and system is in place to advice subsequent action. Communication strategies for policymakers and the public are developed and implemented; the process is institutionalized and systematized in AQM. Public can download information on state of AQ, local impacts (health, environmental, etc.), policies and action plans for specific areas online. Multiple communication channels and innovative solutions/technologies are utilized. Public awareness of the need for understanding sources and the health impacts of air pollution is extensive.

In order **to move towards** a fully developed **air quality communication program**, air quality information needs to be **clear**, comprehensive, **accurate**, precise, **understandable** and relevant to the concerns at hand.

Management/Technical

- **Limited dissemination and coverage of AQ information**. The availability of AQ data may be limited. If data is available, its scope, type and frequency may be restricted to certain cities/countries.
- **Differences in AQIs may lead to public confusion**. Differences between AQIs used by cities/regions and countries may cause the public to misinterpret the situation and reduce the impact of initiatives to reduce air pollution.
- **Limited public guidance on air pollution episodes**. Information on what the public should do to reduce exposure and emissions in a severe air pollution event may be unavailable.
- **Limited influence of AQ communication on attitudes and behavior**. Where public information is available, it may not be developed to have an impact on influencing the attitudes and behavior of different target audiences to reduce emissions and health impacts. This could be partly due to the poor understanding of influential groups – e.g., media and civil society – of air pollution issues.

Financial

- **Limited availability of financial resources for AQ communication**. Communication may be considered less important compared to identifying air pollution sources, determining the status of air quality, and assessing its impact on human health and wellbeing. However, in order to reduce pollution and protect public health, the communication of air pollution information should be seen as a key component of effective air quality management.

5.4 Roadmap for air quality communication

Air quality communication involves understanding the status of AQ, its sources and impact on human health. It is dependent on other components of AQM such as AQS and AQ monitoring. This information can be used to raise awareness of air pollution issues and foster voluntary behavioral change among key stakeholders.

Local government's management of polluting emissions from small businesses and domestic premises in the neighborhood, together with its role in urban planning, contribute to the state of regional and local AQ. Figure 5.3 provides examples of actions local government can take to improve local AQ. In addition, citizens can be encouraged to adopt behaviors that are low-polluting and reduce their exposure to pollutants during poor AQ alerts.

In order to move towards a fully developed AQ communication program, AQ information needs to be clear, comprehensive, accurate, precise, understandable and relevant to the concerns at hand (Table 5.6). The information should also provide some indication of reliability and uncertainty. Messages need to be directed at a specific target group, given at the right time and distributed through an appropriate channel. To do this, an AQ communication plan has to be formulated (Wartenberg, 2009; CiteAir, 2007). The detailed process of developing a clean air communication plan, along with information sources and case studies, is provided in **Annex IV of the *Information Sourcebook***.

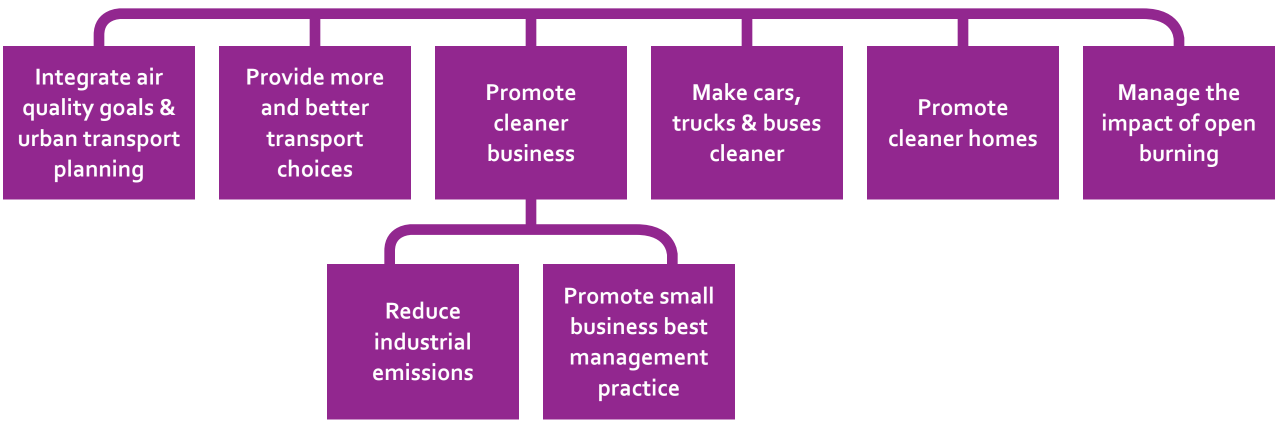


Figure 5.3 Local Government Actions on Air Pollution

Source: New South Wales Environmental Protection Agency (n.d.)

Table 5.6 Steps to follow to implement a roadmap for air quality communication

Developmental stages	Steps to follow
Underdeveloped	**Management Process** • Adopt AAQS (if none yet adopted) to mandate AQ monitoring [See *Guidance Area 1: Ambient air quality standards and monitoring*] • Build capacity for communicating AQ information to policymakers and the public **Technical Process** • Build capacity to measure, collate, and process AQ data from ad hoc or project-based monitoring activities for use in communication activities
Developing	**Management Process** • Enhance capacity to communicate AQ information to policymakers and the public in a more systematic way • Build capacity to issue ad hoc press releases on state of AQ and advisories during pollution episodes • Start building capacity for information technology to ensure online accessibility of general AQ information to the public **Technical Process** • Strengthen capacity to measure, collate, process, and update AQ monitoring data and general information on pollution sources for use in more regular communication activities • Develop capacity to use one or two media channels to communicate AQ Information • Adopt an AQI
Emerging	**Management Process** • Develop and implement communication strategies for policymakers and the public • Strengthen capacity to institutionalize and systematize AQ communication to policymakers, the public, and a wider range of stakeholders • Strengthen capacity to issue regular press releases on state of AQ and systematically release advisories during pollution episodes • Ensure that the public can access more AQ information online (i.e. processed AQ monitoring data, AQ trends, health impacts) • Ensure resources are available for AQ communication **Technical Process** • Strengthen capacity to measure, collate, process, and update processed AQ monitoring data, AQI, information on pollution sources from EI/SA, local data on air pollution health impacts, and AQM action plans for use in regular and systematic communication activities • Enhance capacity to use a wider selection of modern communication channels

Developmental stages	Steps to follow
Maturing	**Management Process** • Develop and implement communication strategies for all stakeholders • Strengthen capacity to institutionalize and systematize AQ communication to all stakeholders • Strengthen capacity to issue routine press releases on state of AQ • Systematically provide advance warnings/forecasts and public health hazards of air pollution impacts • Update AQ information online (i.e. processed AQ monitoring data, AQ trends, health impacts) and ensure accessibility to the public and all stakeholders • Ensure resources are available for AQ communication **Technical Process** • Strengthen capacity to communicate comprehensive and non-technical information on status of AQM (i.e. processed AQ monitoring data, AQI, more detailed information from EI/SA, local data on air pollution health impacts, and AQM action plans) for use in regular and systematic communication activities • Update AQ information on a real-time basis • Enhance capacity to use multiple communication channels and innovative technologies to communicate AQ Information
Fully developed	**Management Process** • Ensure proper implementation and review of communication strategies for all stakeholders; ensure feedback mechanism • Highlight co-benefits of AQ and GHG mitigation • Strengthen capacity to issue routine press releases on state of AQ • Systematically provide advance warnings/forecasts and public health hazards of air pollution impacts • Update AQ information on a real-time basis and make available online (i.e. processed AQ monitoring data, AQ trends, health impacts); ensure accessibility to the public and all stakeholders • Ensure resources are available to sustain AQ communication activities • Dedicate/assign staff position for public engagement/communication **Technical Process** • Strengthen capacity to communicate comprehensive and non-technical information on status of AQM through sustainable training (i.e. processed AQ monitoring data, AQI, more detailed information from EI/SA, local data on air pollution health impacts, and AQM action plans) • Ensure routine and systematic communication activities • Update AQ information on a real-time basis • Explore innovative solutions for AQ communication

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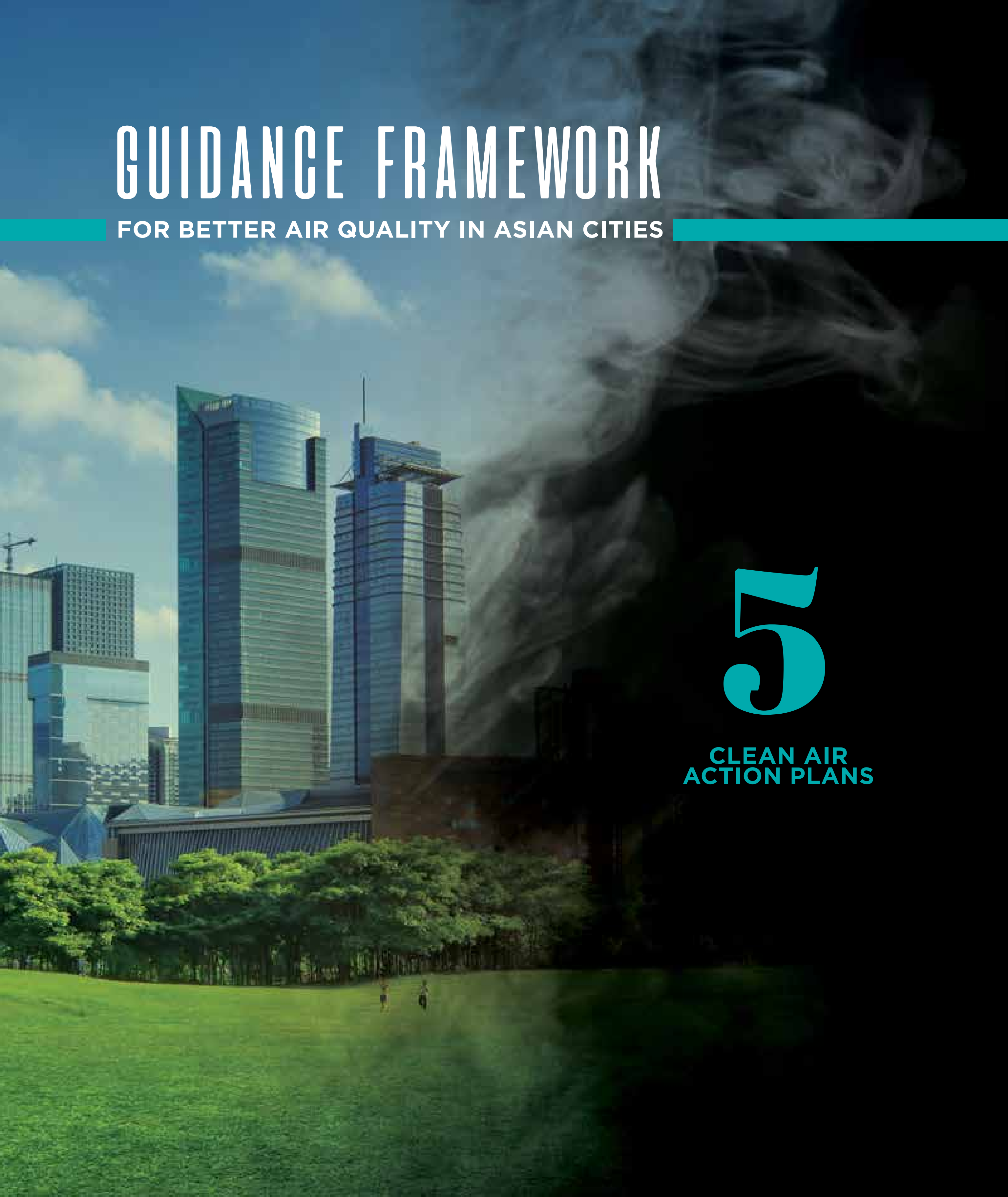

GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES

5

CLEAN AIR ACTION PLANS

IBAQ
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CLEAN AIR ASIA

GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES

Guidance Area 5: Clean Air Action Plans

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ABOUT THE GUIDANCE FRAMEWORK FOR BETTER AIR QUALITY IN ASIAN CITIES

The Guidance Framework is a voluntary and non-binding guidance document developed as an outcome of the biennial Governmental Meetings on Urban Air Quality in Asia, co-organized by Clean Air Asia and United Nations Environment Programme Regional Office for Asia Pacific (UNEP ROAP). It is an outcome of an extensive development process, which began in 2006 when the Long Term Vision for Urban Air Quality in Asia (LTV) was envisioned by representatives of environment ministries in the region. The LTV describes the desired state of urban air quality in Asian cities by 2030; the Guidance Framework serves as a guide for cities and countries to achieve this vision. In 2016, the Guidance Framework was launched as a pioneering approach to resolve air pollution challenges at the local- and national-levels. Centered on identified priority areas of concern in air quality management in the region, the Guidance Framework provides cities and countries with development capacity indicators and recommended steps and actions to improve air quality.

The Guidance Framework serves as a cornerstone document of Clean Air Asia's Integrated Programme for Better Air Quality in Asia (IBAQ Programme), which supports countries and cities in implementing the Guidance Framework through a range of targeted interventions, including knowledge-sharing platforms to strengthen regional collaboration, capacity building activities such as trainings, study tours and city twinning, and technical assistance at both the national and subnational levels.

ABOUT CLEAN AIR ASIA

www.cleanairasia.org

Clean Air Asia is an international NGO established in 2001 as the premier air quality network for Asia by the Asian Development Bank, World Bank and USAID. Its mission is to promote better air quality and livable cities by translating knowledge to policies and actions that reduce air pollution and greenhouse gas emissions from transport, energy and other sectors.

Clean Air Asia became a UN-recognized partnership in 2007, its network spanning 261 organizations in 31 countries in Asia and worldwide, with nine country networks: China, India, Indonesia, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, and Vietnam. It is headquartered in Manila and has offices in Beijing and Delhi. Clean Air Asia leads efforts to enable Asia's more than 1000 cities to reduce both air pollution and CO_2 emissions, and thereby contribute to more livable and healthy cities with blue skies and a low carbon footprint. Clean Air Asia helps to reduce emissions, through policies, plans, programs, and concrete measures that cover air quality, transport and industrial emissions and energy use.

The Better Air Quality (BAQ) Conference is a flagship event of Clean Air Asia covering the key sectors of transport, energy and industry, with a particular emphasis on government policies and measures. Policymakers, practitioners and industry leaders meet at BAQ to network, innovate, learn, and share experiences. The biennial event was first held in 2002 and attracts close to a thousand participants from Asia and the rest of the world.

ABOUT UNEP

www.unep.org

The United Nations Environment Programme (UNEP) is the leading global environmental authority that sets the global environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and serves as an authoritative advocate for the global environment. UNEP work encompasses assessing global, regional and national environmental conditions and trends; developing international and national environmental instruments; and strengthening institutions for the wise management of the environment. UNEP's mission includes to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

CONTENTS

PREFACE

Air pollution is now considered the world's largest environmental health risk. There have been a number of global efforts calling for air pollution actions in recent years. These global calls for action on air pollution strengthen regional and national initiatives and highlight the need to prioritize addressing this issue through a collaborative and integrated approach.

In 2006, the First Governmental Meeting on Urban Air Quality in Asia[1] recognized the need for guidance in implementing a Long Term Vision for Urban Air Quality in Asia, which describes the desired state of urban air quality management in Asian cities. During the Third Governmental Meeting, environment ministries from the region identified key challenges they are facing to improve urban air quality.

To set the way forward in achieving the vision for cleaner air, Clean Air Asia led the development of the Guidance Framework for Better Air Quality in Asian Cities (Guidance Framework) to address the needs and challenges in the region. It aims to provide a recognized guidance on improving urban air quality and is organized around priority areas of concern in the region, which were translated into key guidance areas with roadmaps on how to progress in a step by step manner.

This voluntary, non-binding document consists of seven individually published chapters covering each of the Guidance Areas. Policy and decision makers in Asia, as well as other relevant stakeholders, can use one or a combination of the Guidance Framework chapters to develop local roadmaps or action plans depending on their priority areas of concern.

The Guidance Framework consists of seven main books with these titles:

- Introduction
- Guidance Area 1 - Ambient air quality standards and monitoring
- Guidance Area 2 - Emissions inventories and modeling
- Guidance Area 3 - Health and other impacts
- Guidance Area 4 - Air quality communication
- Guidance Area 5 - Clean air action plans
- Guidance Area 6 - Governance

These guidance areas come with an Information Sourcebook, which is a compilation of resources to support the implementation of Guidance Framework roadmaps. There is also an accompanying training course on Guidance Framework implementation, which is available online in the Clean Air Asia website and Integrated Programme for Better Air Quality (IBAQ Programme) website: www.cleanairasia.org/ibaq

The Guidance Framework was developed together with a team of international and regional experts and practitioners and has undergone an extensive review process through the Governmental Meetings and the involvement of external reviewers. The draft document was also shared in a number of international events, including the Asia Pacific Clean Air Partnership (APCAP) Joint Forum organized by UNEP ROAP in November 2015. The Guidance Framework was welcomed by participants from 24 countries in Asia and the Pacific, involving environment ministries, intergovernmental organizations, non-governmental organizations, and experts.

1 Governmental Meetings on Urban Air Quality in Asia are biennial meetings organized by the United Nations Environment Programme Regional Office of Asia and the Pacific (UNEP ROAP) and Clean Air Asia that convene environment ministries with the aim to harmonize approaches across the region in tackling air pollution and related fields.

ABBREVIATIONS

AQI	Air Quality Index
AQM	Air Quality Management
ASEAN GIZ CASC	Association of Southeast Asian Nations—Deutsche Gesselschaft für Internationale Zussammenarbeit Clean Air for Smaller Cities
CAAP	Clean Air Action Plan
CPCB	Central Pollution Control Board
CO	Carbon monoxide
CO_2	Carbon dioxide
DPSIR	Driving Forces-Pressures-State-Impacts-Responses
EEA	European Environment Agency
EI	Emissions Inventory
GHG	Greenhouse Gas
NOx	Nitrogen oxides
PM	Particulate Matter
PM_{10}	Particulate Matter (≤ 10 micrometers in diameter)
$PM_{2.5}$	Particulate Matter (≤ 2.5 micrometers in diameter)
PRD	Pearl River Delta
SA	Source Apportionment
SEI	Stockholm Environment Institute
SO_2	Sulfur dioxide
SPM	Suspended Particulate Matter
UNEP	United Nations Environment Programme
UNEP-PCFV	United Nations Environment Program Partnership for Clean Fuels and Vehicles
USEPA	United States Environmental Protection Agency
YRD	Yangtze River Delta

The **key features** of a clean air action plan include: **instruments and strategies** to comply with **air quality** and emission standards; **adoption and implementation** of control measures; continuous improvement after compliance, and anticipation of **future trends** such as **national policies and international commitments**.

CHAPTER 6

GUIDANCE AREA 5: CLEAN AIR ACTION PLANS

6.1 Introduction

A clean air action plan (CAAP) intends to improve air quality and public health by identifying cost-effective measures to reduce emissions from sectors such as transport, industries, waste deposits and residential burning, among others. A CAAP is also a collection of regulations, policies and programs for cleaner air. The process of CAAP development is led by the government and involves stakeholders.

Clean air action plan approaches vary depending on the contexts of cities and countries, as well as their needs and capacities to develop and implement a CAAP. Nevertheless, there are good examples of CAAPs available for the different developmental stages of air quality management (AQM) that may apply to cities.

In general, the key features of CAAP include: instruments and strategies to comply with air quality and emission standards; adoption and implementation of control measures; continuous improvement after compliance, and anticipation of future trends such as national policies and international commitments.

6.1.1 Objective

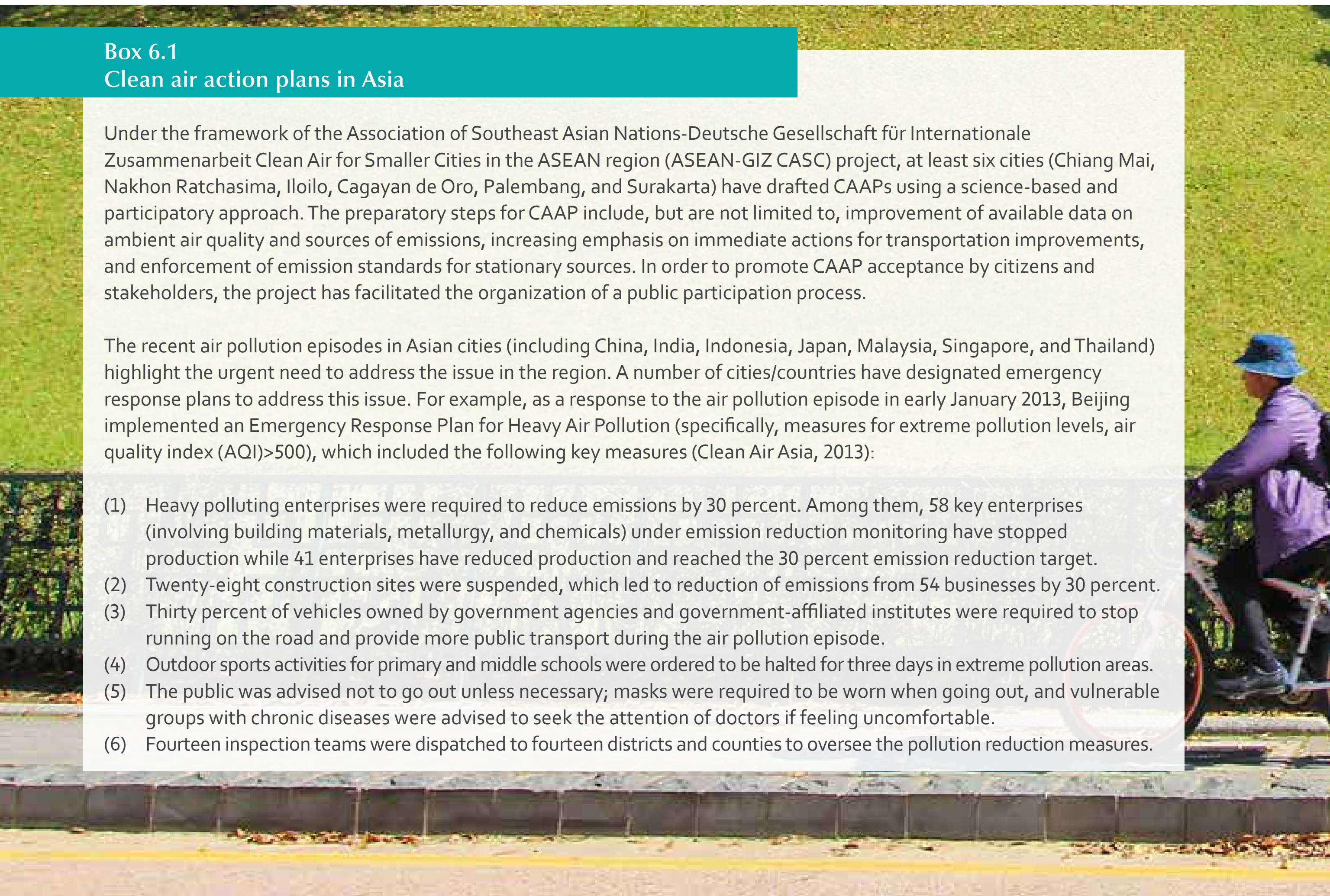
To include and/or strengthen AQM in relevant policies and legislations of cities and countries in the Asian region through CAAP development; and, ultimately, protect public health and the environment against impacts of air pollution.

6.1.2 Importance of clean air action plans

Air quality management requires concerted and incremental efforts – tailored to the goals and resources available in the area – to address the growing air pollution problems in the region.

The 2010 Global Burden of Disease estimates over 2.1 million premature deaths and 52 million years of healthy life lost due to ambient fine particle air pollution in the developing countries of Asia, where air pollution levels are the highest in the world (Lim et al., 2012). A number of cities in Asia, including several Chinese cities, have already developed CAAPs in the wake of recent air pollution episodes (Box 6.1 and Box 6.2).

To include and/or strengthen air quality management in **relevant policies and legislations** of cities and countries in the **Asian region** through clean air action plan development; and, ultimately, **protect public health** and the environment against **impacts of air pollution**.



Box 6.1
Clean air action plans in Asia

Under the framework of the Association of Southeast Asian Nations-Deutsche Gesellschaft für Internationale Zusammenarbeit Clean Air for Smaller Cities in the ASEAN region (ASEAN-GIZ CASC) project, at least six cities (Chiang Mai, Nakhon Ratchasima, Iloilo, Cagayan de Oro, Palembang, and Surakarta) have drafted CAAPs using a science-based and participatory approach. The preparatory steps for CAAP include, but are not limited to, improvement of available data on ambient air quality and sources of emissions, increasing emphasis on immediate actions for transportation improvements, and enforcement of emission standards for stationary sources. In order to promote CAAP acceptance by citizens and stakeholders, the project has facilitated the organization of a public participation process.

The recent air pollution episodes in Asian cities (including China, India, Indonesia, Japan, Malaysia, Singapore, and Thailand) highlight the urgent need to address the issue in the region. A number of cities/countries have designated emergency response plans to address this issue. For example, as a response to the air pollution episode in early January 2013, Beijing implemented an Emergency Response Plan for Heavy Air Pollution (specifically, measures for extreme pollution levels, air quality index (AQI)>500), which included the following key measures (Clean Air Asia, 2013):

(1) Heavy polluting enterprises were required to reduce emissions by 30 percent. Among them, 58 key enterprises (involving building materials, metallurgy, and chemicals) under emission reduction monitoring have stopped production while 41 enterprises have reduced production and reached the 30 percent emission reduction target.
(2) Twenty-eight construction sites were suspended, which led to reduction of emissions from 54 businesses by 30 percent.
(3) Thirty percent of vehicles owned by government agencies and government-affiliated institutes were required to stop running on the road and provide more public transport during the air pollution episode.
(4) Outdoor sports activities for primary and middle schools were ordered to be halted for three days in extreme pollution areas.
(5) The public was advised not to go out unless necessary; masks were required to be worn when going out, and vulnerable groups with chronic diseases were advised to seek the attention of doctors if feeling uncomfortable.
(6) Fourteen inspection teams were dispatched to fourteen districts and counties to oversee the pollution reduction measures.

Box 6.2
China's National Clean Air Action Plan

China has been making efforts and is building its capacity for CAAP development. The CAAP in China can be categorized by scope (national, regional, provincial, or city level), duration (five-year plan, three-year plan, and one-year plan) and focus area. China's State Council released its Action Plan for Air Pollution Prevention and Control (Action Plan) on 12 September 2013, eight months after the widely reported air pollution episode that occurred in January 2013, which covered one-sixth of China's territory. The Action Plan sets the roadmap for air pollution and control for the next five years in China with a focus on three key regions – Beijing-Tianjin-Hebei area (Jing-Jin-Ji), Yangtze River Delta (YRD) and Pearl River Delta (PRD). The Action Plan release was reported publicly by state media on the website of the China central government, Xinhua News Agency, and CCTV as a crucial step forward for air pollution prevention and control in China.

General requirements
A new air pollution prevention and control mechanism will be established in which the government takes the leading role in incorporating enterprises' initiatives, market drivers, and public participation. The new mechanism relies on regional management and stage by stage control, which promotes industrial structure optimization, science and technology innovation, and quality economic growth. The ultimate goal is to achieve environmental, economic and social benefits, and strive to build a beautiful China.

Goal
After a five-year initiative, the overall national air quality will be improved. Heavily polluted days shall be reduced dramatically. Regional air quality in Jing-Jin-Ji, YRD, and PRD will be improved. Through a follow-up initiative lasting another five years or even longer, there will be less and less heavily polluted days until they are eliminated and the national air quality is improved significantly.

Specific indicators
By 2017, the urban concentration of PM_{10} shall decrease by 10 percent compared with 2012, and annual number of days with fairly good air quality will gradually increase. Concentration of $PM_{2.5}$ in Jing-Jin-Ji, YRD and PRD region shall respectively fall by around 25 percent, 20 percent and 15 percent. Fine particulate matter annual concentration in Beijing shall be controlled below 60 $\mu g/m^3$.

Measures
In June 2013, 10 measures – called the National 10 Measures – were disclosed in a strongly worded statement by the State Council to prevent and control air pollution. The Action Plan is the detailed implementation plan of the National 10 Measures:

- Increase efforts of comprehensive control and reduce emission of multi-pollutants
- Optimize the industrial structure, promote industrial restructure
- Accelerate the technology transformation and improve the innovation capability
- Adjust the energy structure and increase the clean energy supply
- Strengthen environmental thresholds and optimize industrial layout
- Improve environmental economic policies through the market mechanism
- Improve law and regulation system; carry on supervision and management based on law
- Establish the regional coordination mechanism and the integrated regional environmental management body
- Establish monitoring, alerting, and emergency response system for air pollution episodes
- Clarify the responsibilities of the government, enterprise, and society; mobilize the public to participate in environmental protection

Mechanism Development

- Establishment of regional collaboration mechanisms in Jing-Jin-Ji and YRD with the participation of provincial governments and relevant central ministries in the region;
- Air pollution monitoring and alert system will be established together by environmental protection and meteorological agencies.

New incentives

- Central government will disclose 10 best and 10 worst air quality cities monthly;
- Targets for $PM_{2.5}$ in three key regions and PM_{10} in other key areas will be considered as compulsory targets in the social and economic development objectives for provinces and be part of the performance evaluation indicators for provincial leaders.

PM_{10} - Particulate matter ≤ 10 micrometers in diameter; $PM_{2.5}$ - Particulate matter ≤ 2.5 micrometers in diameter

Source: Ministry of Environmental Protection, 2013

> A **clean air action plan** is necessary for air quality management because it will enable the government as well as wider stakeholders to **mobilize resources** in the **most effective and efficient manner** to achieve air quality objectives.

A CAAP is necessary for AQM because it will enable the government as well as wider stakeholders to mobilize resources in the most effective and efficient manner to achieve air quality objectives. Air quality objectives are derived from the long-term vision and goals of improving air quality. An example of vision and goal statements and objectives of improving air quality in Palembang City, Indonesia is shown in Box 6.3. The Indonesian city of Palembang has recently completed its Clean Air Plan under the framework of ASEAN-GIZ CASC project (ASEAN-GIZ CASC, 2014; Clean Air Asia, 2012).

Box 6.3
Vision and goal statements and objectives of improving air quality in Palembang City, Indonesia

Vision:
Clean and healthy air in Palembang

Goal:
To improve air quality through implementation of science-based strategies for emissions reduction that contributes to public health and reduced environmental and climate change impacts

Objectives:
To achieve and maintain air quality within the ambient air quality standards for which there is an accepted risk for human beings and the environment, with the indicator of performance at a minimum of 340 days in a year compliance with the National Ambient Air Quality Standards for criteria pollutants by 2018.

Source: ASEAN-GIZ Clean Air for Smaller Cities, 2015

The experience of developed countries demonstrates that the CAAP has been an efficient instrument of air pollution control. With the CAAP, multi-year efforts to reduce emissions have been made through various control measures and clear frameworks for implementation and enforcement of the control strategies. As a result, emissions from anthropogenic sources have been substantially reduced, and most developed countries reported improvement in their nation's urban air quality (United States Environmental Protection Agency [USEPA], 2012; European Environment Agency [EEA], 2015).

On the other hand, efforts to reduce emissions are yet to be seen in most developing countries even as accelerating urban growth is likely to cause increased air pollution–generating activities. Clean air is most often a least-priority program in developing countries. It is not well-known that for developing cities and countries that do not have established procedures for AQM and have limited AQM capacity, a simplified CAAP could be developed so as not to delay addressing the air pollution problem. A simplified CAAP could include: a rapid assessment of the most important sources; monitoring results from a minimal set of air pollutant concentration monitors; comparison with air quality standards; impacts on public health and the environment; and identification of air quality objectives, control measures and key projects or sectors (Schwela & Haq, 2004; Clean Air Asia, 2011).

6.1.3 Developing a clean air action plan

In general, the process of developing a CAAP typically includes four steps (Clean Air Asia, 2011), with stakeholder participation and communication being part of the whole process:

(1) Assessment
(2) Action plan development
(3) Implementation and enforcement
(4) Review and improvement

Assessment of current and projected scenarios is a starting point for CAAP development. This includes review and analysis of the status and trends of air quality [See *Guidance Area 1 on Ambient air quality standards and monitoring*]; impacts on public health and the environment [See *Guidance Area 3 on Health and other Impacts*]; information on key pollutants and sources of pollutant emissions [See *Guidance Area 2 on Emissions inventories and modeling*]; indicators of economic growth, energy use and population growth and their projections in future years; baseline emissions inventory (EI) for targeted pollutants; and projected levels of emissions. In addition, for identified domain area and pollutants, source apportionment (SA) information may be used to prioritize the source types that need to be dealt with. For example, motorized vehicles – being ubiquitous and a ground-level source – may result in higher impact as compared to a localized large industry emitting through an elevated stack. Prioritizing emission sources based on SA using source-oriented or receptor-oriented modeling would essentially include sources that have larger contributions to ambient air pollution levels [See *Guidance Area 2 on Emissions inventories and modeling*]. A case study of India's CAAP development, which illustrates the CAAP assessment process including air quality measurements, EI, and receptor-based modeling is provided in Box 6.4.

Action plan development is a way to address the existing situation as well as future scenarios, with due consideration of projected population growth; demand and management of services (energy, transport, among others); sector-specific developmental plans (e.g., road network, housing, industries) from municipal corporations and urban and industrial development agencies; and expected technological advancements (e.g., new vehicles with better engine and emission control devices). The action plan development encompasses identification of different types of control measures, estimation of effect of the control measures on pollutant emission reduction, cost-effectiveness of the control measures, and co-benefits.

A survey on the state of clean air action planning in cities was conducted by Clean Air Asia in 2011 with the aim of understanding the current situation, fostering learning and sharing best practices, and strengthening the capacity of cities (Clean Air Asia, 2013). The key components of plans and the outlines of contents across the 16 action plans from seven Chinese cities and nine international cities were listed and summarized with the same details. The structure of the key components reflects the DPSIR (Driving Forces-Pressures-State-Impacts-Responses) framework:

- Driving forces: introduction and background
- Pressures: causal analysis of effects and attribution to individual sources
- State: current status, Air Pollutant Index, comparison to objectives/standards, EI, and key pollutants
- Impacts: impact on public health and the environment
- Responses: development and implementation of the action plan and following components

This study identified the recommended components of a CAAP which are tabulated in **Annex V-A of the Information Sourcebook**. The content of each component and the degree of detail in each step may be different, depending on the local situation and current air quality status. Baseline assessment, goal setting, and evaluation are the essential steps for either a detailed CAAP or a basic one. As cities and countries progress to different stages of CAAP development, the content and level of detail of the CAAP components could be expanded to respond to local needs and capacities.

Implementation and enforcement are key to reducing air pollutant emissions and achieving air quality objectives. A successful and implementable CAAP needs clear institutional framework and responsibilities, stakeholder coordination and communication, political support, allocation of financial resources, technical capabilities, and review and improvement (Clean Air Asia, 2012). Three factors determine the success of a city or country in providing better air quality:

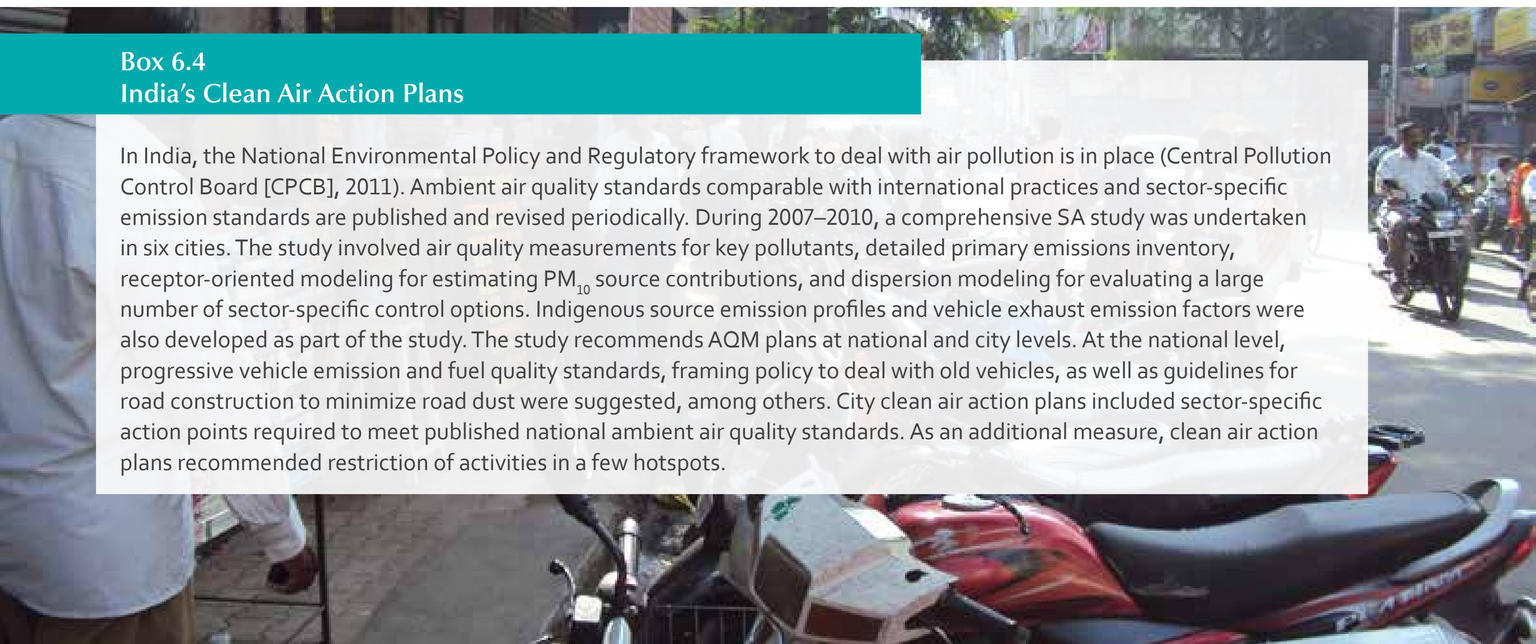
- the existence of policies and action plans, and their implementation details (mechanism, timeline, assignment of responsibility);
- provision of enough resources to implement the policies and action plans; and
- actual implementation of the policies and action plans.

Review and improvement refers to the process to track and report on implementation of measures and overall changes in emissions (comparing the plan and change in monitored air quality). It is important to identify mechanisms and responsibilities for monitoring/tracking progress to enable review of the effectiveness of available control measures; and to determine if changes are needed to achieve greater reductions, address excessive costs or amend measures, as appropriate.

While customized to the local needs, constraints, and air quality objectives, the process of CAAP development is also evolving. Several trends have emerged in CAAP development (Clean Air Asia, 2012): move from single pollutant to multiple pollutant action planning; expansion to regional AQM; involvement of multiple stakeholders in the development and implementation process; planning for long-term air quality improvement; and integration of CAAP and greenhouse gas (GHG) mitigation plan.

In summary, the CAAP is useful as cities or countries move up the stages of AQM development. A good CAAP benefits from the following good practices:

- draws inputs from the assessment of air pollution sources and emissions, ambient air pollution levels (adequately representing temporal and spatial variations), air quality goals (standards or target values) [See *Guidance Area 1 on Ambient Air Quality Standards and Monitoring*], information on SA and exposure assessment (through dispersion modeling) [See *Guidance Area 2 on Emissions inventory and modeling*], and international experiences;
- evaluates source mitigation and control options for their efficacy (based on cost-benefit or cost-effectiveness analysis), technical feasibility, and ease of implementation;
- sets targets and timelines for actions;
- is discussed with all major stakeholders, and delineates their roles and responsibilities;
- addresses implementation issues such as institutional arrangements and partnerships, infrastructure, and financial resources [See *Guidance Area 6 on Governance*];



Box 6.4
India's Clean Air Action Plans

In India, the National Environmental Policy and Regulatory framework to deal with air pollution is in place (Central Pollution Control Board [CPCB], 2011). Ambient air quality standards comparable with international practices and sector-specific emission standards are published and revised periodically. During 2007–2010, a comprehensive SA study was undertaken in six cities. The study involved air quality measurements for key pollutants, detailed primary emissions inventory, receptor-oriented modeling for estimating PM_{10} source contributions, and dispersion modeling for evaluating a large number of sector-specific control options. Indigenous source emission profiles and vehicle exhaust emission factors were also developed as part of the study. The study recommends AQM plans at national and city levels. At the national level, progressive vehicle emission and fuel quality standards, framing policy to deal with old vehicles, as well as guidelines for road construction to minimize road dust were suggested, among others. City clean air action plans included sector-specific action points required to meet published national ambient air quality standards. As an additional measure, clean air action plans recommended restriction of activities in a few hotspots.

- considers future activity growths and projected air pollution scenarios;
- is progressive and gives due consideration to technological advancements;
- defines monitoring and evaluation mechanism
- provides opportunities for mid-term corrections; and
- is periodically reviewed and upgraded

6.1.4 Policies and control measures to improve air quality

The CAAP encompasses short-term, medium-term, and long-term mitigation and control measures to reduce emissions from mobile (transport), stationary (industry), and area sources. Several different types of measures for improving air quality can be broadly identified and categorized as follows:

- Conservation: reducing the use of resources through energy conservation
- Efficiency: carrying out the same activity, but doing so more efficiently, thus reducing resource use and emissions of air pollutants
- Abatement: applying a technological approach to reduce emissions
- Fuel switching: substituting a lower emission fuel for a higher emission fuel
- Demand management: implementation of policies or measures which serve to control or influence the demand for a product or service
- Behavioral change: changing the habits of individuals or organizations in such a way as to reduce emissions – e.g. travelling by bus instead of by car

These measures can be brought about in many different ways through legislation, economic instruments, voluntary agreements, and available technologies [See *Guidance Area 6 on Governance*]. Specifically, measures to reduce air pollution from mobile and stationary sources – i.e. transport sector, industrial, and area sources – can be summarized as follows:

a) Measures to reduce emissions from transport
Emissions from motor vehicles are determined by vehicle technology, fuel type and quality, land use, and use of vehicle. Hence, controlling emissions involves addressing each one of the following measures:

(1) improved emissions standards and technologies;
(2) cleaner fuels;
(3) improved fuel efficiency;
(4) improved inspection and maintenance;
(5) improved transport planning and traffic demand management;
(6) shift to public transport, promotion of non-motorized/active transport (i.e. cycling, walking)

Some of the measures can only be taken together with other specific interventions. For example, more stringent emissions standards cannot be achieved without imposing stricter fuel quality standards. Table 6.1 presents an overview of measures to control emissions from transport.

Two case studies in Japan that introduced the CAAP multiple pollutant approach in reducing emissions from the transport sector and from factories are presented in Box 6.5 and Box 6.6. The cases also highlight rigorous monitoring and review system, demonstrating air quality improvement over time.

b) Measures to reduce air pollution from industrial sources
Measures to reduce air pollution from industrial sources may include the following key areas:

i. Land use planning and zoning
- use of planning regulations to restrict the location of new industries and to establish suitable industrial areas/zones;
- compulsory environmental impact assessment for specified new major industries to require assessment of their potential for air pollution and to recommend improvement in location, processes, fuels, industry technology and emission limits; and
- relocation of existing industries away from residential and other sensitive land uses.

ii. Promotion of cleaner production
- increase the efficiency of industrial processes;
- energy and materials saving;
- use of improved quality fuels (e.g. with lower sulfur content) or switch to cleaner fuels such as natural gas; and
- adoption of new technologies.

iii. Reduction of emissions in industry
- setting priorities by focusing on emissions from the major emission sources;
- requirements for use of cleaner fuels;
- requiring the use of – and providing an action plan for implementation of – best available technology for specific industrial processes;
- compulsory notification of accidents;
- licensing of specified polluting processes;
- compulsory emission standards required, as well as an enforcement strategy for such; and
- setting strict fines for exceeding emission standards.

Table 6.1 Overview of measures to control emissions from transport

Measure	Regulation	Economic
Emissions standards and technologies	• Maximum emission standards for conventional emissions (carbon monoxide (CO), hydrocarbons, nitrogen oxides (NO_x), particulate matter (PM) and for toxic air pollutants • Certification and assembly line testing	• Tax differentials favoring abatement technology • Vehicle taxes for emission levels • Incentives/disincentives • Fiscal incentives for scrapping old vehicles
Cleaner fuels	• Fuel quality standards for gasoline (lead, volatility, benzene, aromatics) • Fuel quality standards for diesel fuel (volatility, sulfur, aromatics, cetane number, polyaromatic hydrocarbons) • Limitations on fuel additives	• Differentiated fuel pricing favoring cleaner fuels
Fuel efficiency	• Fuel efficiency for vehicle fleets • Maximum power/weight ratios • Speed limits • Various traffic management measures to increase share of optimal anti-congestion measures, combined with measures controlling vehicle kilometers traveled	• Broad based carbon tax on fuels/emission charges • Fuel-economy based vehicle taxes • Research and Development incentives (direct funding, tax credits, emissions test exemptions)
Inspection and maintenance	• Mandatory inspection and maintenance, anti-tampering and enforcement programs • Diesel smoke control programs	
Transport planning and traffic demand management: to increase load of fleet, reduce travel demand times and reduce travel time	• Public transportation system • Parking control measures • Individual ownership limitations • Pedestrian-only zones in cities • Car use restrictions • Privileges (e.g. restricted highway lanes) for high-occupancy vehicles • Improvement of biking/walking conditions • "Park and ride" programs • Limitations and restrictions on freight transport	• Road-based carbon tax on fuel • Emission-related vehicle taxes • Road pricing or distance charges • Parking charges • Fiscal incentives for carpool programs • Insurance adjustment for distance • Land-use and physical planning instruments to reduce commuter travel and redistribute urban activities • Redistribute mechanisms for financing more efficient transport modes

Source: Adapted from Stockholm Environmental Institute (SEI), 2008

c) Measures to reduce air pollution from area sources
Burning of biomass, open burning of waste, forest fires, and dust from soil, roads and construction sites can be major area sources in a city. Measures to control these emissions may include:

- enforcement of bans on burning of materials or waste;
- promotion of alternatives to burning;
- better waste management; and
- paving roads, revegetation programs in dust control areas and use of street sweeping equipment.

Actions requiring low cost with high effectiveness and shorter implementation period are better than those having high effectiveness but high costs or long implementation period. A few promising scenarios with select combination of options may be evaluated using a source model. Model predictions should particularly focus on hotspots. Alternative plans may be discussed with stakeholders (e.g., fuel quality improvement program with petroleum oil companies, stricter norms for vehicles with automobile manufacturers) and the most appropriate one may be adopted.

Choosing between technology-based options (cost-intensive) and management-based options (less costly but may be difficult to enforce) will always be a dilemma. As a guiding principle, impact of cleaner technology options is long-lasting. For example, stricter fuel quality and emission standards such as EURO IV, V, and VI may provide better dividend, in the long run. Similarly, use of natural gas in place of coal for industrial combustion and/or efficient control systems (Electrostatic Precipitator and/or bag filter) may offer better results. However, a few technology-based interventions (e.g., improving auto fuel quality) are decided at the national level and not at the local scale (nonetheless, they can influence such decisions).

Certain measures – such as cleaner transport and energy – may require substantial financial resources, and at times, delay implementation. Necessary funds may be organized through internal or external sources. Internal funds provide a sense of ownership, which may result in more efficient implementation of CAAP. In addition to public funding, private partnership may be explored. The "polluter pays principle" may be applied and "pollution tax" may be levied for generating funds [See *Guidance Area 6 on Governance*]. External funding from international financial institutes or donor agencies may also be available. Cost-benefit analysis (also incorporating health costs) for "business as usual" and CAAP scenarios may be useful, and may result in larger commitment and efforts from stakeholders [See *Guidance Area 3 on Health and other impacts*]. Table 6.2a and Table 6.2b provide guidance in determining cost-effective strategies and actions.

Box 6.5
Basic policies and plans for area-wide emission reduction of NOx and particulate matter in designated three metropolitan areas of Japan

In Japan, development of basic policies and plans for area-wide emission reduction of NO_x and PM emitted from vehicles is mandatory in three designated highly populated metropolitan areas (Figure 6.1) under the Law Concerning Special Measures to Reduce the Total Amount of Nitrogen Oxides and Particulate Matter Emitted from Motor Vehicles in Specified Areas (Automobile NO_x and PM Law) enacted in 2001. The goal was set "to attain environmental quality standards in most monitoring stations in the designated areas by 2010".

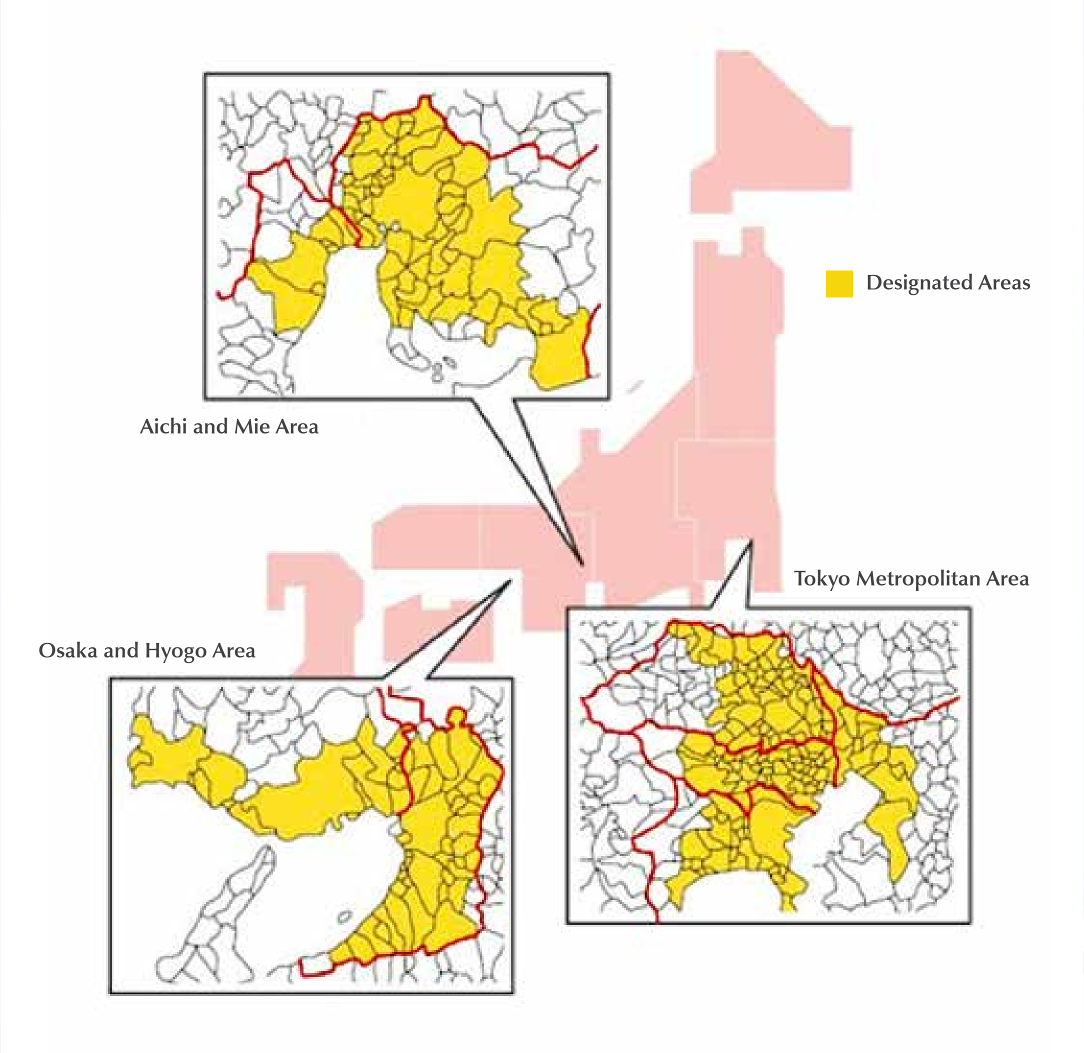


Figure 6.1 Areas Designated under the Automobile NO_x and PM Law

Source: Ministry of the Environment, Japan and Ministry of Land, Infrastructure, Transport and Tourism, (n.d.)

In addition to basic policies and plans, the following measures have been introduced in the designated areas:

- **regulation on in-use vehicles** (ban on the use of vehicles not meeting specified emission standards for trucks, buses, and diesel vehicles; this applies only to the vehicles registered in the designated areas)
- **emission reduction by business operators** (development of vehicle management plans by large business operators)
- measures to address **localized pollution** and **incoming traffic from outside the designated areas**[2]

The goal has been achieved and the annual average concentration of suspended particulate matter (SPM) in the designated areas – 294 ambient air quality monitoring stations and 165 roadside monitoring stations – has shown gradual but steady improvement as illustrated in Figure 6.2.

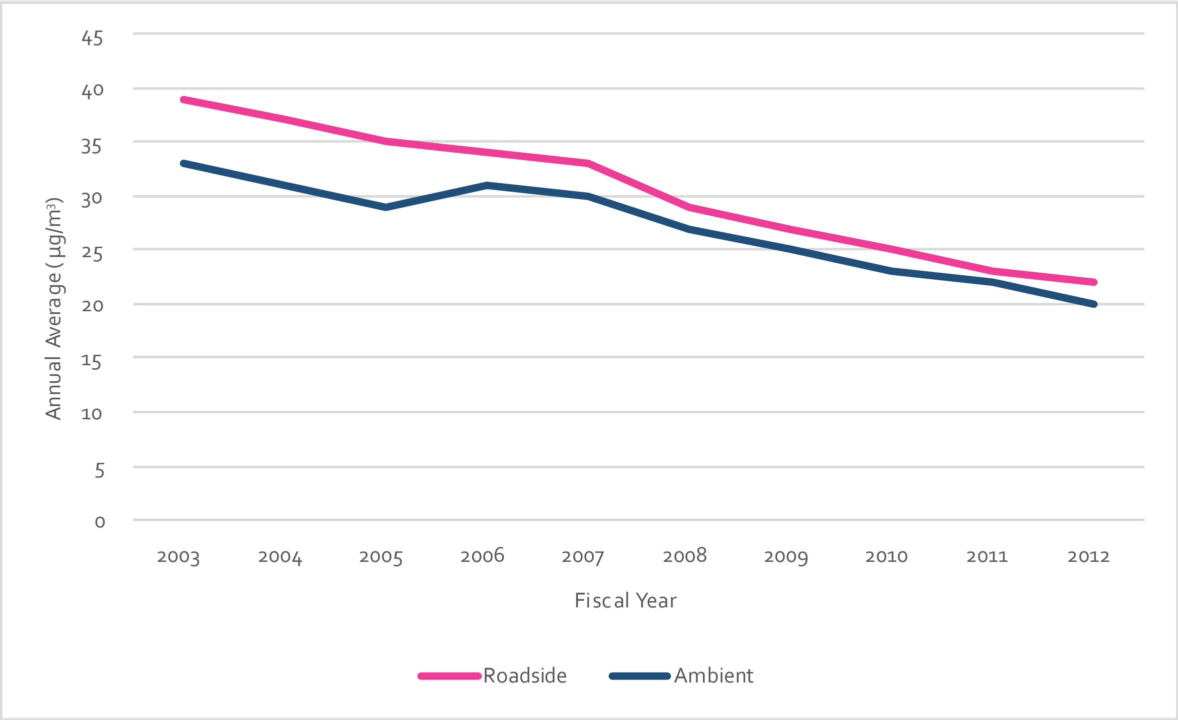


Figure 6.2 Annual Average Concentration of SPM in Designated Areas under the Automobile NO_x and PM Law

Source: Ministry of Environment Japan, 2014

2 These measures were introduced in 2008, following the partial amendment of the Automobile NO_x and PM Law in 2007.

Box 6.6
Total emission control plans by Kawasaki City, Japan

The Japanese city of Kawasaki experienced rapid industrial development during the 1950s and adverse health effects due to very serious air pollution. In response, the city has since made various efforts to control air pollution. Plans to control total emission were among the distinct features of the city's policy.

The city introduced its own **total emission control system**, known as the "Kawasaki Method", under the Pollution Prevention Ordinance in 1972. Based on the ordinance, the city sets its own environmental target values for air pollutants, which are more ambitious than national environmental quality standards. For each of these pollutants, it sets area emission limits taking into account the locations and emission status of the emission sources (such as factories). Under the total emission control system, different emission standards were set for each facility based on the simulation results of ambient concentration using an atmospheric dispersion model. The pioneering total emission control system from Kawasaki played an important role in promotion of pollution control at both the national and local levels.

In addition, as the character of environmental problems became more complex, **a comprehensive total emission control (also known as a basket regulation) to reduce SPM** was introduced under the Ordinance for Conservation of Living Environment including Pollution Prevention in 1999. The basket regulation not only addressed the primary sources of SPM (soot and dust) but also its precursors, such as SO_x, NO_x, and hydrogen chloride. Under the regulation, emission standards related to PM were established for new business facilities over a certain size. The regulation was extended to cover existing facilities in 2005.

As a result, annual emissions of soot and dust from factories have deceased over time and the ambient concentrations of SPM began to fall (Figure 6.3). The attainment status has been fairly good since 2004, with all the ambient monitoring stations meeting the environmental quality standards except in 2006 and 2010.

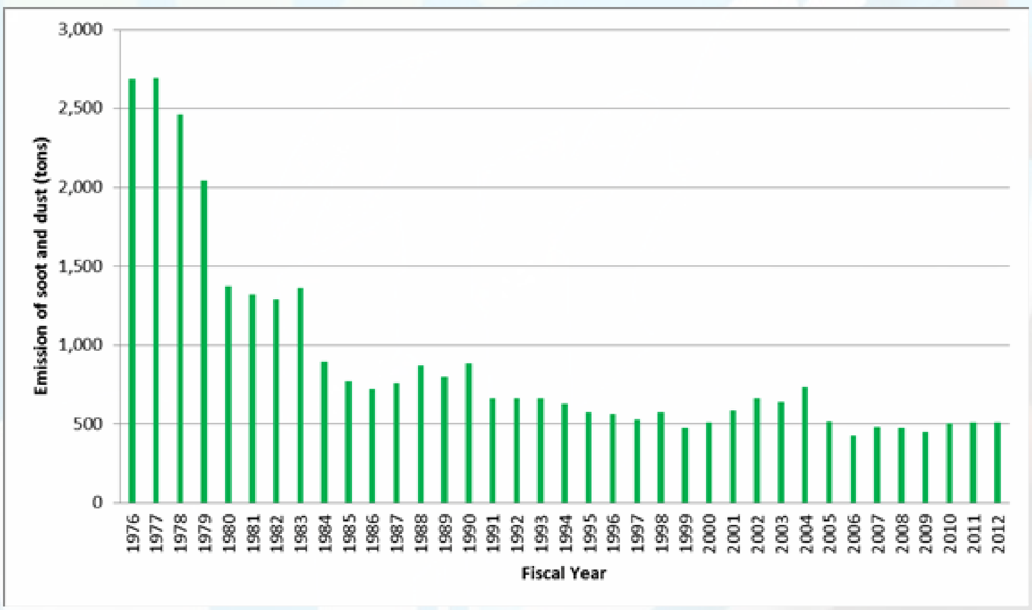


Figure 6.3 Annual Emissions of Soot and Dust from Factories in Kawasaki

Source: Kawasaki City, 2013 and Kawasaki City, n.d.

Table 6.2a Evaluation of emission control options

Source group	Control option	Expected reduction and impacts[1]	Technical feasibility[2]	Requirement of financial resources[3]	Implementation period (short / mid / long-term)	Time target for implementation[4]	Responsible agency(ies)	Any other information

1 Preferably, quantify each priority pollutant. Otherwise, a qualitative statement (low/medium/high) may be given.
2 Whether it is technically feasible (e.g., replacing coal with natural gas may not be feasible, if its sustained availability is not assured); whether any implementation issues exist (e.g., low-income group may not have finances to use liquefied petroleum gas for cooking) ; assess its control efficiency
3 Estimate the total costs (investment and maintenance costs) over the duration of implementation period, and provide sources of financing.
4 Define the expected start and completion year (e.g., 2015-2020).

Table 6.2b Evaluation of implementation barriers and required actions

		Identified barriers				Required actions			
No	Control option	Institutional, regulatory, and policy framework	Economic, investment, and market	Human resources and private sector support	Public awareness	Institutional, regulatory and policy framework	Economic, investment and market	Human resources and private sector support	Public awareness

6.1.5 Co-benefits and integration of clean air action plan and GHG mitigation plan

Air pollution control measures tend to be local or regional in scale, but their impact on climate change is long-term and global. Looking at air quality and climate change from an integrated perspective – and addressing these issues simultaneously – offers potential for large cost-reductions in public health and risks to ecosystems. Co-controlling air pollution and GHGs will be more effective than targeting each one individually, particularly for developing countries in Asia where economic and social development is a higher priority than climate change mitigation (SEI, 2008). An integrated approach will maximize synergies and co-benefits; measures to mitigate climate change can reduce air pollution, and actions reducing air pollution can reduce GHG emissions. Table 6.3 presents measures which are likely to lead both to reductions in emissions of both air pollutants and GHGs.

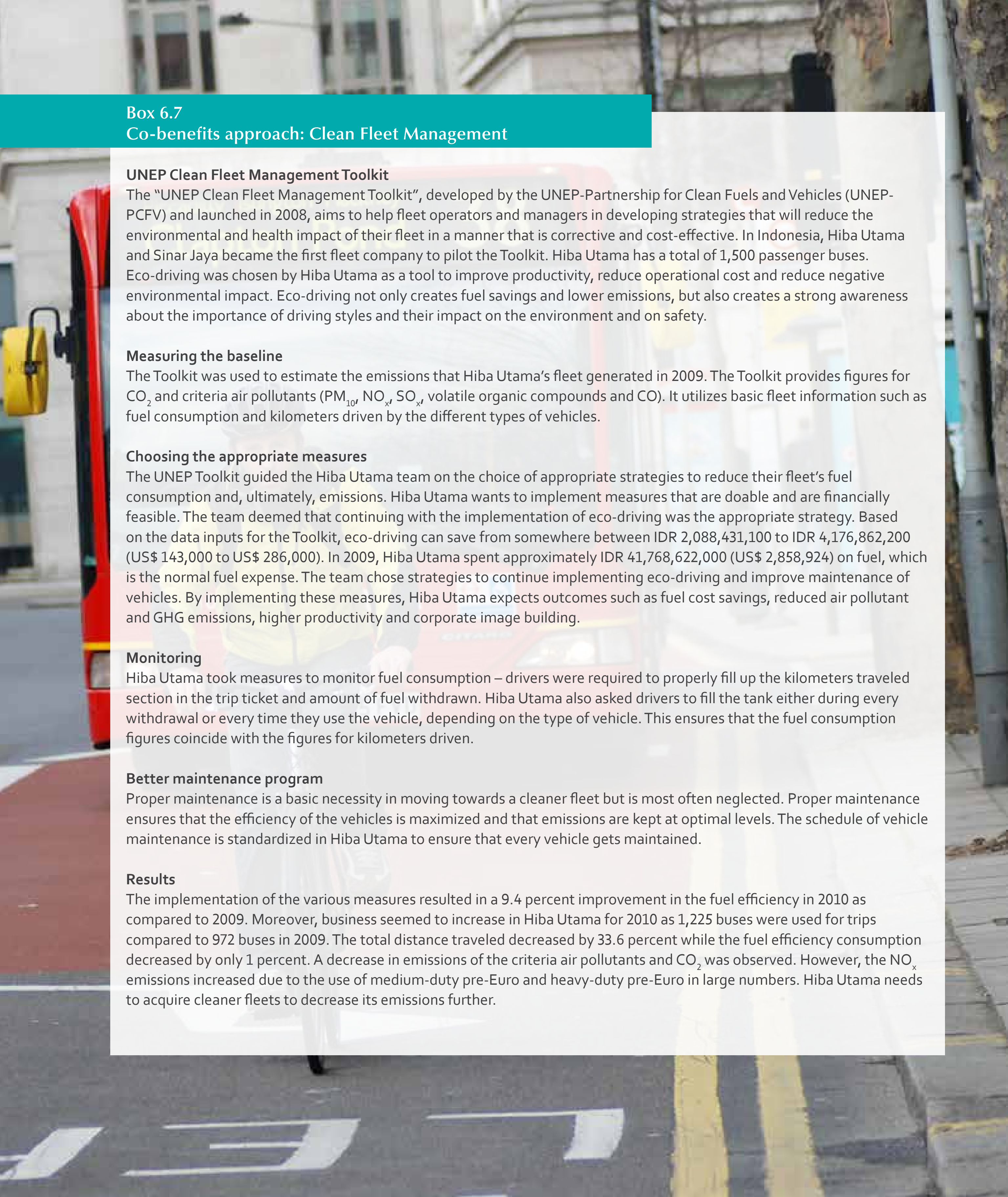
Co-controlling **air pollution and greenhouse gases** will be more effective than targeting each one individually, particularly for **developing countries** in Asia where **economic and social development** is a higher priority than **climate change mitigation**.

Table 6.3 Examples of measures to reduce emissions of air pollutants and GHGs

Measure	Effect
Switching from coal to natural gas for power generation	Reduces carbon dioxide (CO_2) emissions for each kiloWatt generated. Emissions of sulfur dioxide (SO_2) and NO_x are also reduced.
Efficiency improvements in domestic appliances and industrial processes	Reduces emissions of both types of pollutant, but efficiency measures sometimes result in increased demand, which must be avoided.
Energy conservation (use less energy)	Reduces emissions of both types of pollutant.
Use of new technologies in road transport, e.g. • hybrid vehicles • hydrogen from natural gas or from renewable energy sources • lean burn petrol vehicles fitted with nitrogen oxide traps	Reduces CO_2 emissions for each kilometer traveled and also emissions of NO_x and PM. It is essential that the whole fuel/vehicle cycle is analyzed (e.g. the emissions associated with hydrogen generation).
Demand management/behavioral change: improved public transport coupled with disincentives for private car usage.	Reduces emissions of both types of pollutant.

Source: United Kingdom Department for Environment Food and Rural Affairs, 2014

Box 6.7 illustrates an example of co-benefits approach applied by a bus company in Indonesia using the United Nations Environment Programme (UNEP) Clean Fleet Management Toolkit to monitor and evaluate the impact of the interventions on fuel efficiency and air pollutant and CO_2 emissions.



Box 6.7
Co-benefits approach: Clean Fleet Management

UNEP Clean Fleet Management Toolkit

The "UNEP Clean Fleet Management Toolkit", developed by the UNEP-Partnership for Clean Fuels and Vehicles (UNEP-PCFV) and launched in 2008, aims to help fleet operators and managers in developing strategies that will reduce the environmental and health impact of their fleet in a manner that is corrective and cost-effective. In Indonesia, Hiba Utama and Sinar Jaya became the first fleet company to pilot the Toolkit. Hiba Utama has a total of 1,500 passenger buses. Eco-driving was chosen by Hiba Utama as a tool to improve productivity, reduce operational cost and reduce negative environmental impact. Eco-driving not only creates fuel savings and lower emissions, but also creates a strong awareness about the importance of driving styles and their impact on the environment and on safety.

Measuring the baseline

The Toolkit was used to estimate the emissions that Hiba Utama's fleet generated in 2009. The Toolkit provides figures for CO_2 and criteria air pollutants (PM_{10}, NO_x, SO_x, volatile organic compounds and CO). It utilizes basic fleet information such as fuel consumption and kilometers driven by the different types of vehicles.

Choosing the appropriate measures

The UNEP Toolkit guided the Hiba Utama team on the choice of appropriate strategies to reduce their fleet's fuel consumption and, ultimately, emissions. Hiba Utama wants to implement measures that are doable and are financially feasible. The team deemed that continuing with the implementation of eco-driving was the appropriate strategy. Based on the data inputs for the Toolkit, eco-driving can save from somewhere between IDR 2,088,431,100 to IDR 4,176,862,200 (US$ 143,000 to US$ 286,000). In 2009, Hiba Utama spent approximately IDR 41,768,622,000 (US$ 2,858,924) on fuel, which is the normal fuel expense. The team chose strategies to continue implementing eco-driving and improve maintenance of vehicles. By implementing these measures, Hiba Utama expects outcomes such as fuel cost savings, reduced air pollutant and GHG emissions, higher productivity and corporate image building.

Monitoring

Hiba Utama took measures to monitor fuel consumption – drivers were required to properly fill up the kilometers traveled section in the trip ticket and amount of fuel withdrawn. Hiba Utama also asked drivers to fill the tank either during every withdrawal or every time they use the vehicle, depending on the type of vehicle. This ensures that the fuel consumption figures coincide with the figures for kilometers driven.

Better maintenance program

Proper maintenance is a basic necessity in moving towards a cleaner fleet but is most often neglected. Proper maintenance ensures that the efficiency of the vehicles is maximized and that emissions are kept at optimal levels. The schedule of vehicle maintenance is standardized in Hiba Utama to ensure that every vehicle gets maintained.

Results

The implementation of the various measures resulted in a 9.4 percent improvement in the fuel efficiency in 2010 as compared to 2009. Moreover, business seemed to increase in Hiba Utama for 2010 as 1,225 buses were used for trips compared to 972 buses in 2009. The total distance traveled decreased by 33.6 percent while the fuel efficiency consumption decreased by only 1 percent. A decrease in emissions of the criteria air pollutants and CO_2 was observed. However, the NO_x emissions increased due to the use of medium-duty pre-Euro and heavy-duty pre-Euro in large numbers. Hiba Utama needs to acquire cleaner fleets to decrease its emissions further.

Success and Challenges

The project achieved its objective on its first year of implementation. Management support was instrumental in the rapid adoption of the changes that needed to be made to realize the benefits of the chosen measures. The project pioneered in contributing to awareness raising and emissions reduction. However, substantial improvements need to be conducted by Hiba Utama. The most urgent measure that needs to be taken is replacing pre-Euro vehicles with vehicles that correspond to European emission standards. Hiba Utama needs to improve its inspection and maintenance program since in 2010, many odometers were reported broken.

Conclusions

The initial success of the project ensured its continued implementation. Hiba as a whole, is currently moving towards the adoption of the different measures that are being implemented in Hiba Utama. Moreover, Hiba Utama has adopted the recommendation of the project team to mandate a refresher course on eco-driving for those drivers who value safety and high performance.

Source: UNEP Clean Fleet Management Toolkit – Indonesia Pilot Study Report, 2010

6.2 Stages of clean air action plan development

Air quality management, in its fully developed stage, entails a CAAP that is comprehensive and routinely updated. For CAAP to be effective, its scope should respond to emerging local needs and capacities. As an initial step to enable cities to develop and implement CAAPs, Table 6.4 presents indicators that would aid cities in identifying their current state of AQM development.

The following are the key indicators that should be considered in progressing from underdeveloped to fully developed stage:

- Science-based approaches to CAAP formulation
- Level of stakeholder involvement in CAAP development
- Availability of financial resources
- Set-up of early warning system/emergency response plan
- Definition of implementation framework

Air quality management, in its fully developed stage, entails a **clean air action plan** that is **comprehensive and routinely updated**. For clean air action plan to be **effective**, its scope should **respond** to emerging **local needs and capacities**.

Table 6.4 Stages of clean air action plan development

Stages	Indicators
Underdeveloped	Air pollution control measures, policies, plans, and strategies are developed without solid support from data and assessments Addressing air pollution is generally covered in National Environmental Acts or Laws Only implementing agencies of air pollution control measures, policies, plans and strategies are involved in formulating the measures Lack of financial resources to support CAAP development An early warning system to mitigate impacts during high air pollution episodes is not available due to lack of/limited monitoring systems
Developing	Air pollution control measures, policies, plans, and strategies are based on air quality data from ad hoc monitoring Air pollution-specific policies are in place at the national and local levels Ad hoc projects to reduce emissions are available Input from stakeholders other than implementing agencies of AQM is obtained during formulation of air pollution control measures Financial resources to support CAAP development are limited and highly rely on external support An early warning system to mitigate impacts during high air pollution episodes is not available due to lack of/limited monitoring systems
Emerging	Air pollution control measures, policies, plans, strategies are based on limited air quality monitoring data for selected pollutants and hotspots, and with more support from EI results and/or SA assessments Air-pollution specific policies are in place at the national and local levels and implementation is envisaged CAAP measures to address key/major sources have been formulated but operationalization (identifying lead agencies, timeline, budget, etc.) of measures is not yet clear Sector-specific growth and development plans[3] include measures to control key emission sources CAAPs are beginning to be developed but are not aligned with sector development plans Activities to promote for multi-sectoral coordination and stakeholder engagement in CAAP formulation are being initiated There is sufficient government budget and potential funding support from other sources for CAAP development An early warning system to mitigate impacts during high air pollution episodes is in place; initial information on health and other impacts of pollution are considered

3 e.g. for industry, transport, energy, housing, and land use

Maturing	CAAPs are developed based on adequate air quality monitoring data, EI, simple dispersion models and assessment of pollutant exposure
	Air pollution-specific policies are in place at the national and local levels and are implemented
	A framework (comprised of lead agencies and stakeholders, timeline, budget, etc.) for implementing and financing of measures is included in the CAAP
	There is prioritization of measures based on emission reduction potential of key sources, cost-effectiveness, and technical feasibility
	CAAPs are aligned with sector-specific development plans[4]
	Mechanisms[5] for multi-sectoral coordination and stakeholder engagement, including public involvement are becoming more common in CAAP formulation
	There is sufficient government budget for CAAP development. The government also allots budget for the CAAP to be regularly updated in response to the needs of the area covered
	Initiatives are made to secure funding support from other sources aside from government (i.e. international organizations, partnerships with private sector) to support CAAP development
	An early warning system and emergency response plan to mitigate impacts during high air pollution episodes is in place; updated information on health and other impacts of pollution are systematically considered
Fully developed	Identification of control measures is science-based and cost-effective
	A full range of AQM activities are used as basis of CAAP development: air quality monitoring system, bottom-up EI, dispersion modeling, SA, testing compliance with emission and air quality standards, potential abatement assessment, cost and benefit analysis results, and assessment of health and environmental impacts
	Air pollution-specific policies are in place at the national and local levels and are fully implemented
	A clear framework (comprised of lead agencies and stakeholders, timeline, budget, etc.) for implementing and financing measures is defined in the CAAP
	A system for monitoring and evaluation of CAAP implementation is formulated
	CAAPs are in place with comprehensive and prioritized mitigation actions and integrated into sector-specific and socio-economic development plans including climate change mitigation
	Mechanisms for multi-sectoral coordination, stakeholder engagement, and public involvement in CAAP development are in place and fully implemented
	The government allots sufficient budget annually for CAAP development and update. Financial support for CAAP development and regular updating is sustainable
	Strategies are in place to access a wide mix of financing resources to support CAAP development
	An early warning system and emergency response plan to mitigate impacts during and to predict high pollution episodes is in place and regularly reviewed; studies on health and other impacts, socio-economic cost of pollution, and benefits of pollution control are available

4 e.g. industry, transport, energy, housing, land use

5 Examples include the formation of working group involving all concerned government, private and other sectors, roadmap development/vision and goal setting with stakeholders, public consultations and forums

6.3 Issues and challenges

Although a number of Asian cities have already developed CAAPs, they remain to be exceptions rather than the rule. Most Asian cities have yet to develop CAAPs due to the following considerations:

Institutional

- **Insufficient human resources within the government with knowledge of AQM** as well as technical skills that enable them to understand and lead the process of improving air quality.
- **Difficulty in securing support from other local agencies in developing and implementing CAAP.** The CAAP is a multisectoral and multidisciplinary issue. Other local agencies may not see the CAAP benefits and its contribution to their agency's development objectives. Hence, addressing this problem is the key in securing support.
- **Lack of coordination and a clear framework for implementation and enforcement** between relevant agencies – including regulatory and governance requirements, institutional arrangements and processes, as well as enforcement procedures. The CAAP process requires a concerted effort not only from environmental agencies but also from other sectors such as energy, transportation, industry, land use, planning and health, among others.
- **Lack of political support from decision-makers and the public, and leadership of relevant stakeholders.** Leadership plays a major role in driving the process of CAAP and ensuring that progress is being made.
- **Lack of public interest and awareness**, which might be influenced by lack of information on the health impact of air pollution as well as the benefits and the urgent need to address the underlying problems of air pollution. Efforts to gain full public support in the development and implementation of CAAP should be made to attain acceptability, consistency, and follow-through. In many Asian cities, the problem often lies with the absence of civil society groups with interest in the issue of air pollution.

Management and Technical

- **Limited information on pollutant sources, emissions and air quality levels** to identify effective measures to reduce pollutant concentrations.
- **Current practices lack the incorporation of air pollution and climate change policies with sustainable development.** At the local and national levels, AQM and climate change mitigation strategies must be integrated, especially where overlaps are apparent – such as in the energy, transportation, and industrial sectors.
- **There is lack of CAAP ownership by other relevant agencies**, including the ones responsible for development planning. This would hinder CAAP from being adopted and implemented. Relevant agencies must recognize that the air pollution issue is also a development issue.
- **There is lack of periodic monitoring and review of CAAP implementation.** These are critical in measuring the progress made. These will determine the effectiveness of control measures in achieving the air quality objectives.

Financial

In most of the developing Asian countries, insufficient financial resources is often seen as the real challenge in AQM. The allocation of public funding towards environmental management has remained a small fraction of the total development spending. There are other funding sources outside public financial sources such as public-private partnerships and grants or loans from international lending institutions that the government can tap in. However, lack of information, willingness, and attempts to access these sources undermine the efforts towards developing and implementing CAAP, policies, and measures.

6.4 Roadmap for clean air action plan development

The CAAP – intended to improve air quality and public health by identifying measures to reduce emissions from various sectors – has proven to be an effective instrument of air pollution control. Without it, managing limited resources for AQM is impossible in the first place. Hence, sufficient resources – financial and human – should be allocated for development of a CAAP as befits a city or country's stage of AQM development. Table 6.5 gives the recommended steps, following an assessment of a city's AQM status, towards progressing to the next stage and overcoming the challenges involved in developing and implementing a CAAP.

Table 6.5 Steps to follow to implement a roadmap for clean air action plan development and implementation

Developmental stages	Steps to follow
Underdeveloped	**Management Process** • Identify key stakeholders, decision makers and influencers to bring air pollution onto the public agenda • Build capacity for basic AQM planning and activities (i.e. ad hoc projects to reduce emissions) among key stakeholders, decision makers and influencers • Conduct stakeholder meetings to increase awareness on the impact of air pollution on health and the environment, and push for a political decision to include AQM as a development sector • Conduct targeted public awareness raising (e.g. through earn media communication) to educate the public and increase their interests in air pollution issues • Establish a Technical Team comprised of representatives from government and non-government stakeholder groups to oversee the process of adoption of air pollution-specific policies at the national and local levels, air quality standards and measures to reduce emissions **Technical Process** • Build capacity for identifying and monitoring hotspots using a minimal set of air pollutant concentration monitors [See *Guidance Area 1 on Ambient air quality standards and monitoring*]
Developing	**Management Process** • Continue public awareness raising to sustain public interests on air pollution and demand for control measures (e.g. include a mixed-media communication approach in conveying key messages to the public) • Strengthen coordination and communication among responsible institutions, and integration of AQM policies with other sector policies through a regular reporting mechanism • Ensure that sector-specific growth and development plans include measures to control key emission sources • Ensure sufficient government budget and potential funding support from other sources for CAAP development • Conduct stakeholder meetings and public input workshops to draw roadmap towards CAAP development and initiate formulation of CAAP measures to address major emission sources • Conduct Vision and Goals Workshop and Public Communication Strategy Workshop to define outreach and awareness program • Plan for implementation of air pollution-specific policies at the national and local levels **Technical Process** • Enhance capacity for air quality monitoring stations to deliver data on key pollutants of known quality • Build capacity for identifying air pollutant sources and estimation of emissions using available methodology, taking into account data availability [See *Guidance Area 2 on Emissions inventories and modeling*] • Consider air quality monitoring results and estimation of emissions as basis of CAAP • Build capacity for identification of initial health risks and/or other impacts of air pollution [See *Guidance Area 3 on Health and other impacts*] • Build capacity to develop early warning system to mitigate impacts during high pollution episodes

<table>
<tr><td>Emerging</td><td>
Management Process

Define roles of stakeholders including government departments/agencies and public participation in CAAP process
Conduct series of public input workshops as part of or independent of government development planning processes to gather input for air quality improvement programs and actions. Conduct Findings and Options Workshop to consolidate reporting of all findings and possible options for consideration by public and decision makers, and define roles and responsibilities of stakeholders
Establish a clear institutional framework and mechanisms (within lead agencies, stakeholders, and public sector) to support implementation of measures including monitoring and evaluation system
Ensure sufficient government budget for CAAP development and review; explore funding support from external sources
Use information on adequate air quality monitoring, initial EI, simple dispersion models, pollutant-exposure assessment, and initial health impact assessment as basis for CAAP and policy development
Implement air pollution-specific policies at the national and local levels

Technical Process

Enhance capacity for:

air quality monitoring
development of initial EI
simple dispersion models
assessment of pollutant-exposure using simplified approaches
estimation of health risks and/or other impacts
evaluation and monitoring system for implementation of emissions reduction measures

Issue regular early warning system to mitigate impacts during high pollution episodes

</td></tr>
<tr><td>Maturing</td><td>
Management Process

Establish a robust CAAP process:

Conduct Proposals Workshop to evaluate cost-effectiveness/cost-benefit, technical feasibility, and implementation strategy
Conduct CAAP Presentation and Implementation Workshop to present completed CAAP, review of remaining issues, and initial implementation steps
Establish Guidance Board and commence regular meetings. The Board could be formulated as an outcome of the initial public input workshop. The role of the Board is to guide the overall process of CAAP formulation, and review recommendations from the Technical Team. In general, the Board needs to include key government departments that will be responsible for implementing CAAP. This can be complemented by key stakeholders from outside the government to improve the ability of the Board to reflect the needs of all stakeholders.

Prepare implementation programs. The Technical Team shall take lead in the CAAP preparation and development of implementation programs for the selected actions, with input from stakeholders. The roles and responsibilities of stakeholders must be clearly identified and defined within a clear institutional framework, and agreed upon in order to commit their time and efforts.
Ensure that CAAPs are implemented with comprehensive and prioritized mitigation actions that are aligned with sector-specific and socio-economic development plans including climate change mitigation
Ensure sustainable funding for CAAP development and regular review; explore a wider range of external funding sources
Fully implement air pollution-specific policies at the national and local levels

</td></tr>
</table>

Maturing	**Technical Process** • Define the domain area (geographical boundaries for which CAAP is to be prepared) • Develop an annotated outline of the CAAP. Examples of processes for CAAP development as well as an annotated outline of Palembang City for maturing developmental stage of CAAP are provided. The process for the Germany Clean Air Implementation Plan and San Francisco Bay Area clean air plan are also described to progress to the fully developed stage of CAAP (See **Annex V-B of the Information Sourcebook**). • Review the state of air quality and emission sources in the area (air quality monitoring results vis-à-vis standards, EI, spatial distribution of pollutant concentrations, assessment of sources and pollutants of concern, and SA for selected pollutants) [See *Guidance Area 1 and 2 for guidelines*] • Assess real and/or potential health and environmental impacts, either by use of burden of disease approaches or rapid epidemiological/ecological studies, commit resources for implementation, make projections for the future, and assess the costs of control and the health and environmental benefits. Describe the CAAP outline first, followed by the process of achieving the set goals • Prepare a list of all potential control options for each of the selected priority sources with additional input obtained through public input workshops • Evaluate source mitigation and control options for their efficacy (based on cost-benefit or cost-effectiveness analysis and expected impacts). In addition, technical feasibility (practicality, "low-hanging fruits" approach, accessibility to technology, and ease of implementation), implementation period (short-, mid-, or long-term), requirement of financial resources, and responsible agencies may be tabulated, as given in the example in section 6.1.4. In some cases, social feasibility (public acceptability, security, aesthetics) may be added, as well as having co-benefits of addressing air pollution and climate change issues. • Identify implementation barriers and required actions to support and optimize implementation, such as policy and regulatory framework, human resources and private sector support, market opportunities, and public awareness. Table 6.2a and 6.2b serve as guide in evaluating the barriers and required actions to address the barriers. • Define a monitoring and evaluation mechanism that provides opportunities for mid-term corrections. The CAAP shall be periodically reviewed and upgraded. An appropriate monitoring mechanism may be set up at a Guidance Board or senior decision-making level of the government to review progress and take mid-term corrective measures. • Adopt CAAP and integrate into sector-specific, socio-economic, and city development plans (i.e. including climate change mitigation). Once approved, CAAP shall be made binding through local/national development planning system. • Issue regular early warning system and emergency response plan to mitigate impacts and predict high pollution episodes; develop a regular review process for the system

Fully developed	**Management Process** • Develop CAAP regularly with tightening air quality improvement targets, linking with socio-economic plans and climate change mitigation • Sustain a clear framework for implementation and enforcement of CAAP, including roles of related departments, multi-sectoral coordination mechanism, and involvement of public, as well as regular assessment of the CAAP • Sustain public participation in CAAP process through a clearly defined mechanism (i.e. public input workshops) • Secure financial support for CAAP development and ensure that implementation is secured within the government budget and a wide mix of external funding sources • Continually enhance the integration of all assessments into policies and strategies through a clear mechanism • Regularly evaluate technical feasibility and implementation strategies of CAAP • Regularly and systematically report CAAP implementation results to stakeholders (including policymakers and the public) to influence policies using targeted communication strategies **Technical Process** • Identify control measures, which are science-based and implemented on a cost-effective approach • Implement and continue to enhance capacity for a full range of AQM activities: air quality monitoring system, bottom-up EI, dispersion modeling, SA, testing compliance with emission and air quality standards, potential abatement assessment, cost-effectiveness and cost and benefit analysis results, and assessment of health and environmental impacts. • Establish studies on other impacts of air pollution (e.g., on buildings and agriculture) as well as ensure that studies on socio-economic cost of pollution and benefits of pollution control are available. • Conduct air quality projections to support the policy making process

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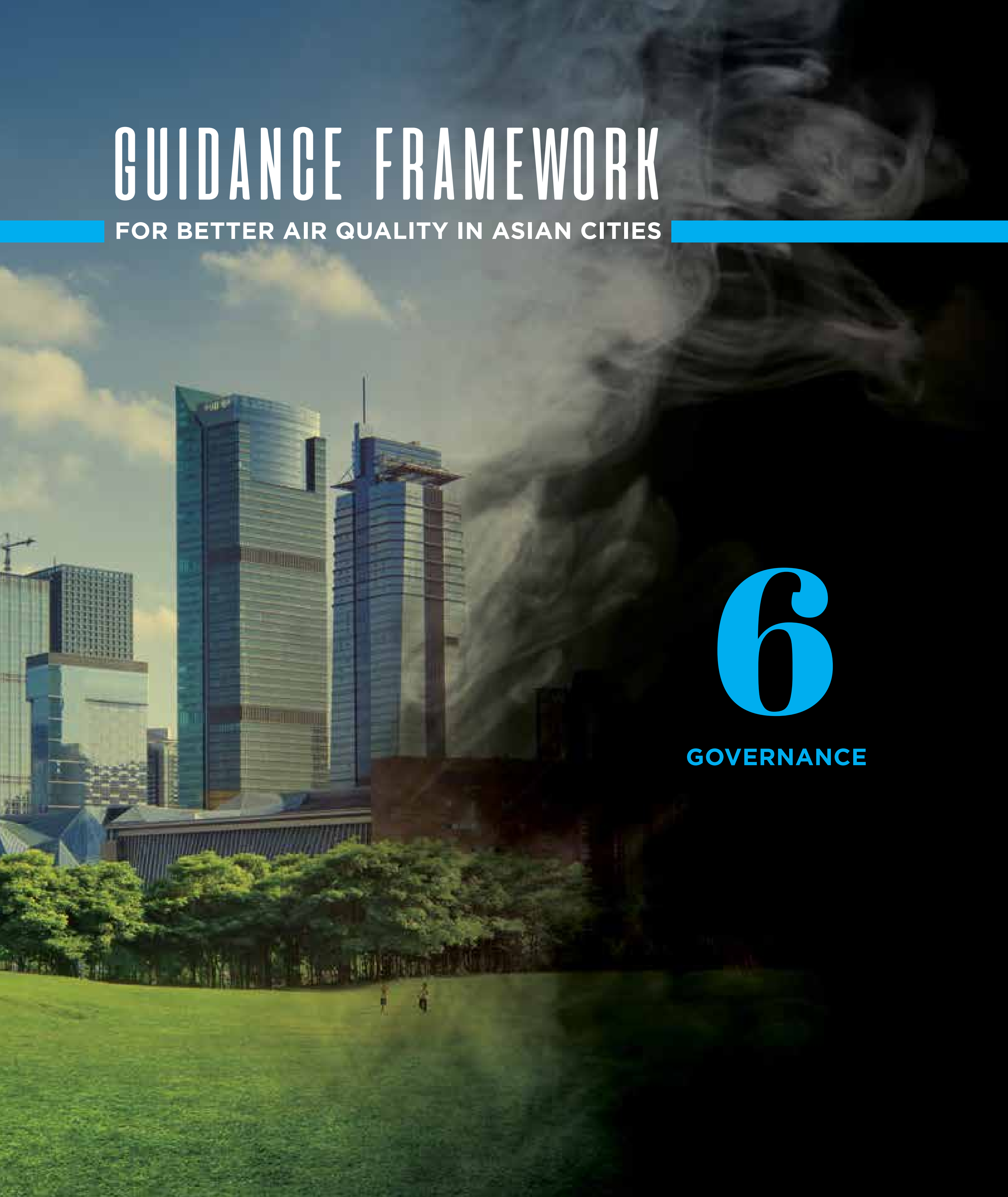
GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES

6

GOVERNANCE



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CLEAN AIR ASIA

GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES

Guidance Area 6: Governance

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ABOUT THE GUIDANCE FRAMEWORK FOR BETTER AIR QUALITY IN ASIAN CITIES

The Guidance Framework is a voluntary and non-binding guidance document developed as an outcome of the biennial Governmental Meetings on Urban Air Quality in Asia, co-organized by Clean Air Asia and United Nations Environment Programme Regional Office for Asia Pacific (UNEP ROAP). It is an outcome of an extensive development process, which began in 2006 when the Long Term Vision for Urban Air Quality in Asia (LTV) was envisioned by representatives of environment ministries in the region. The LTV describes the desired state of urban air quality in Asian cities by 2030; the Guidance Framework serves as a guide for cities and countries to achieve this vision. In 2016, the Guidance Framework was launched as a pioneering approach to resolve air pollution challenges at the local- and national-levels. Centered on identified priority areas of concern in air quality management in the region, the Guidance Framework provides cities and countries with development capacity indicators and recommended steps and actions to improve air quality.

The Guidance Framework serves as a cornerstone document of Clean Air Asia's Integrated Programme for Better Air Quality in Asia (IBAQ Programme), which supports countries and cities in implementing the Guidance Framework through a range of targeted interventions, including knowledge-sharing platforms to strengthen regional collaboration, capacity building activities such as trainings, study tours and city twinning, and technical assistance at both the national and subnational levels.

ABOUT CLEAN AIR ASIA
www.cleanairasia.org

Clean Air Asia is an international NGO established in 2001 as the premier air quality network for Asia by the Asian Development Bank, World Bank and USAID. Its mission is to promote better air quality and livable cities by translating knowledge to policies and actions that reduce air pollution and greenhouse gas emissions from transport, energy and other sectors.

Clean Air Asia became a UN-recognized partnership in 2007, its network spanning 261 organizations in 31 countries in Asia and worldwide, with nine country networks: China, India, Indonesia, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, and Vietnam. It is headquartered in Manila and has offices in Beijing and Delhi. Clean Air Asia leads efforts to enable Asia's more than 1000 cities to reduce both air pollution and CO_2 emissions, and thereby contribute to more livable and healthy cities with blue skies and a low carbon footprint. Clean Air Asia helps to reduce emissions, through policies, plans, programs, and concrete measures that cover air quality, transport and industrial emissions and energy use.

The Better Air Quality (BAQ) Conference is a flagship event of Clean Air Asia covering the key sectors of transport, energy and industry, with a particular emphasis on government policies and measures. Policymakers, practitioners and industry leaders meet at BAQ to network, innovate, learn, and share experiences. The biennial event was first held in 2002 and attracts close to a thousand participants from Asia and the rest of the world.

ABOUT UNEP
www.unep.org

The United Nations Environment Programme (UNEP) is the leading global environmental authority that sets the global environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and serves as an authoritative advocate for the global environment. UNEP work encompasses assessing global, regional and national environmental conditions and trends; developing international and national environmental instruments; and strengthening institutions for the wise management of the environment. UNEP's mission includes to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

CONTENTS

PREFACE

Air pollution is now considered the world's largest environmental health risk. There have been a number of global efforts calling for air pollution actions in recent years. These global calls for action on air pollution strengthen regional and national initiatives and highlight the need to prioritize addressing this issue through a collaborative and integrated approach.

In 2006, the First Governmental Meeting on Urban Air Quality in Asia[1] recognized the need for guidance in implementing a Long Term Vision for Urban Air Quality in Asia, which describes the desired state of urban air quality management in Asian cities. During the Third Governmental Meeting, environment ministries from the region identified key challenges they are facing to improve urban air quality.

To set the way forward in achieving the vision for cleaner air, Clean Air Asia led the development of the Guidance Framework for Better Air Quality in Asian Cities (Guidance Framework) to address the needs and challenges in the region. It aims to provide a recognized guidance on improving urban air quality and is organized around priority areas of concern in the region, which were translated into key guidance areas with roadmaps on how to progress in a step by step manner.

This voluntary, non-binding document consists of seven individually published chapters covering each of the Guidance Areas. Policy and decision makers in Asia, as well as other relevant stakeholders, can use one or a combination of the Guidance Framework chapters to develop local roadmaps or action plans depending on their priority areas of concern.

The Guidance Framework consists of seven main books with these titles:

- Introduction
- Guidance Area 1 - Ambient air quality standards and monitoring
- Guidance Area 2 - Emissions inventories and modeling
- Guidance Area 3 - Health and other impacts
- Guidance Area 4 - Air quality communication
- Guidance Area 5 - Clean air action plans
- Guidance Area 6 - Governance

These guidance areas come with an Information Sourcebook, which is a compilation of resources to support the implementation of Guidance Framework roadmaps. There is also an accompanying training course on Guidance Framework implementation, which is available online in the Clean Air Asia website and Integrated Programme for Better Air Quality (IBAQ Programme) website: www.cleanairasia.org/ibaq

The Guidance Framework was developed together with a team of international and regional experts and practitioners and has undergone an extensive review process through the Governmental Meetings and the involvement of external reviewers. The draft document was also shared in a number of international events, including the Asia Pacific Clean Air Partnership (APCAP) Joint Forum organized by UNEP ROAP in November 2015. The Guidance Framework was welcomed by participants from 24 countries in Asia and the Pacific, involving environment ministries, intergovernmental organizations, non-governmental organizations, and experts.

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1 Governmental Meetings on Urban Air Quality in Asia are biennial meetings organized by the United Nations Environment Programme Regional Office of Asia and the Pacific (UNEP ROAP) and Clean Air Asia that convene environment ministries with the aim to harmonize approaches across the region in tackling air pollution and related fields.

ABBREVIATIONS

ADB	Asian Development Bank
AQI	Air Quality Index
AQM	Air Quality Management
CAC	Command and Control
CO	Carbon monoxide
EEA	European Environment Agency
EPDC	Electric Power Development Co., Ltd
ERP	Electronic Road Pricing
EU	European Union
ICLEI	International Council for Local Environmental Initiatives
IGES	Institute for Global Environmental Strategies
MBI	Market-Based Instruments
O_3	Ozone
OECD	Organisation for Economic Co-operation and Development
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter ($\leq$ 2.5 micrometers in diameter)
PRD	Pearl River Delta
SEI	Stockholm Environment Institute
SO_2	Sulfur dioxide
UNEP	United Nations Environment Programme
USEPA	United States Environmental Protection Agency
YRD	Yangtze River Delta


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Air quality governance can spell the difference between **clean air and polluted skies**.

CHAPTER 7

GUIDANCE AREA 6: GOVERNANCE

7.1 Introduction

Environmental governance encompasses the rules, practices, policies, and institutions that define stakeholder's interaction with the environment as well as outlining their role in environmental impact (United Nations Environment Programme [UNEP], 2009). Air quality governance, in particular, can spell the difference between clean air and polluted skies. Discussions over governance, however, can be rather abstract and disengaging. Decision makers are often not involved in the day-to-day rigors of air quality management (AQM). The challenge is to provide decision makers who work on "big picture policy" as well as those engaged in "on-the-ground implementation" a common language to identify the appropriate forms of governance for their city. This chapter aims to achieve this goal.

The chapter begins by presenting regulatory instruments employed independently and in combination to manage air quality; then discusses how these instruments are embedded in different governance arrangements. It is understood that there is unlikely to be a universal approach for different contexts in Asia, hence the instruments and arrangements will vary across countries and cities. Instead, this guidance area illustrates how core governance principles can help make the policy instruments and governance arrangements actionable in many settings. The chapter then presents various stages of air quality governance and a roadmap that can help policymakers move forward until they reach the fully developed stage, where various challenges would have been addressed to harness the energies and insights of more stakeholders at different levels.

7.1.1 Objective

To provide good governance approaches that facilitates effective policy development and implementation, supporting information-sharing and accountability mechanisms, and strengthening stakeholder participation in all aspects of AQM.

7.1.2 Policy instruments

There are several policies, measures, and instruments available to policy and decision makers to manage urban air quality. A summary of types of policy instruments is provided in Table 7.1

Table 7.1 Types of environmental regulation

Type	Description	Example
Command and control (CAC)	Issue of licenses, setting of standards, checking for compliance with standards, sanctions for non-compliance	Air pollution control regulations Government monitoring Emission standards Enforcement policies
Economic instruments	Use of pricing, subsidies, taxes, and charges to alter production and consumption patterns of organizations and the public	Load-based emission charges Tradeable emission permits Differential taxes True cost pricing of resources
Co-regulation and voluntary initiatives	Formulation and adoption of rules, regulations, and guidelines in consultation with stakeholders, negotiated within prescribed boundaries Voluntary adoption of environmental management measures	National registers of pollution emission inventories Environmental management systems
Self-regulation	Self-imposition of regulations and guidelines and environmental audits by industry groups	Industry codes of practice Self-audit within industry groups Emission reduction targets

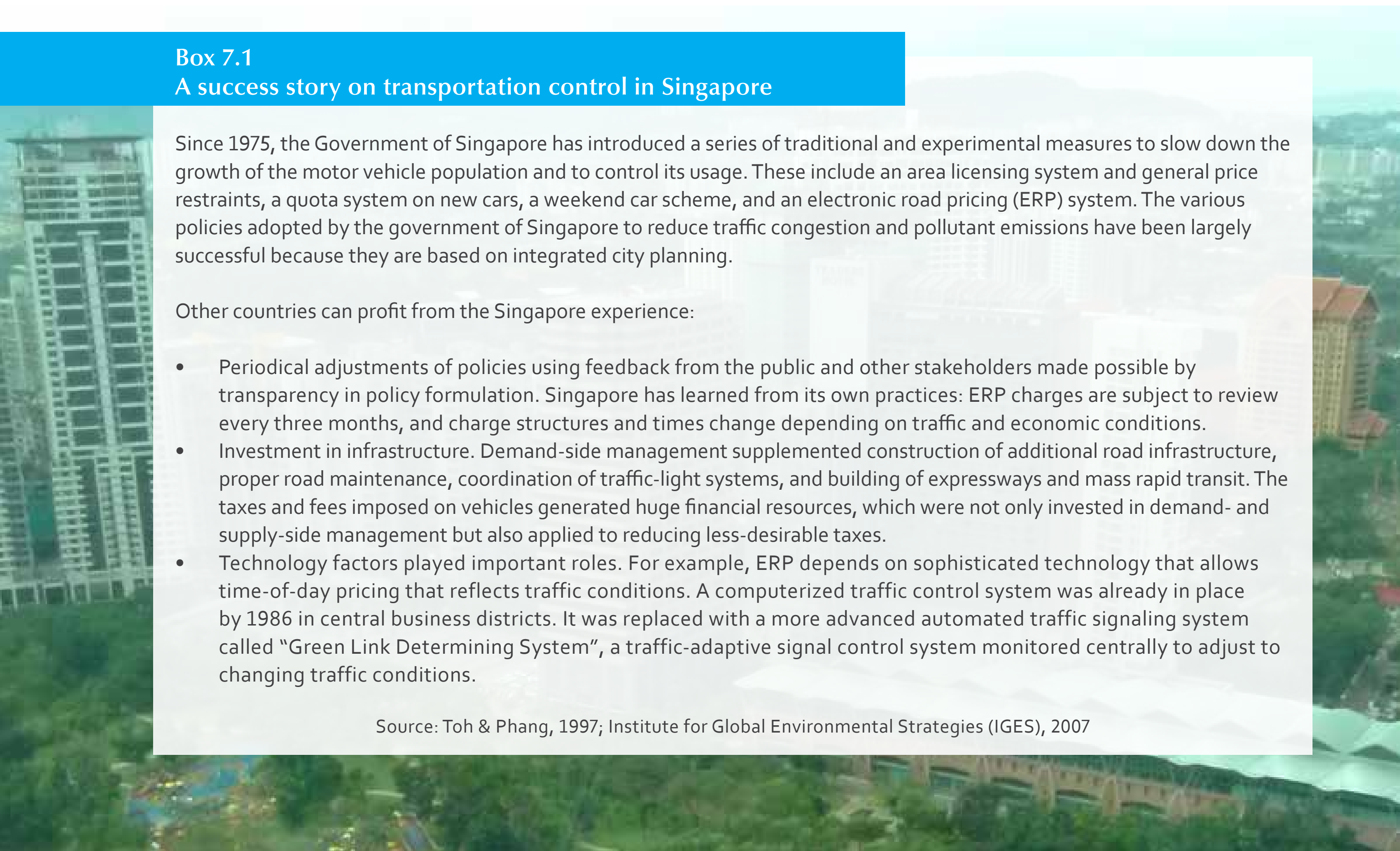
Source: Stockholm Environment Institute (SEI), 2008

To provide **good governance** approaches facilitating **effective policy development** and implementation, **supporting information-sharing** and accountability mechanisms, and **strengthening stakeholder participation** in all aspects of **air quality management.**

The CAC instruments serve as the foundation of most countries' air pollution regulations. CAC regulations "prescribe how much pollution an individual source or plant is allowed to emit and/or what types of control equipment it must use to meet such requirements" (United States Environmental Protection Agency [USEPA], 2014; Blackman & Harrington, 2000). Compliance with CAC instruments is secured through permitting, monitoring, inspection and enforcement; and penalties or other forms of administrative sanctions that are often levied if a facility or emission source fails to meet standards. It can be difficult, however, to tailor CAC instruments to different sources and they tend to offer fewer opportunities for cost-effective innovation (USEPA, 2014).

Economic or market-based instruments (MBIs) address this difficulty by putting a price on pollution directly through emission fees, taxes, and environmental subsidies or indirectly through emissions trading schemes (Blackman & Harrington, 2000). The price on pollution encourages sources to identify more cost-effective solutions or purchase credits from sources with lower abatement costs. A congestion charge or toll tax, emission and/or pollution tax or charge, fuel tax, and vehicle tax are examples of MBIs in the transportation sector (Timilsina & Dulal, 2008). Singapore's experience in utilizing MBIs to address the growth of vehicles is summarized in Box 7.1. Stakeholder engagement, transparency, infrastructure, and technology are significant factors contributing to Singapore's success controlling vehicle numbers through MBIs.

Voluntary regulations that encourage, but not prescribe, controls that should be taken are often backed up with indications of mandatory reductions following inaction. Voluntary regulations can use the implied threat of government-led action to encourage companies to identify their own cost-effective approaches to pollution controls (USEPA, 2014). Examples of voluntary regulations are the pollution control agreements used in Japan. Voluntary agreements (or pollution control agreements) are ways in which local governments create specialized agreements with individual companies to ensure environmental compliance. The Japanese city of Yokohama was able to set an example on how its pollution control agreements with Electric Power Development Co., Ltd (EPDC) ensure the company's environmental compliance and improve their public image at the same time (Box 7.2).



Box 7.1
A success story on transportation control in Singapore

Since 1975, the Government of Singapore has introduced a series of traditional and experimental measures to slow down the growth of the motor vehicle population and to control its usage. These include an area licensing system and general price restraints, a quota system on new cars, a weekend car scheme, and an electronic road pricing (ERP) system. The various policies adopted by the government of Singapore to reduce traffic congestion and pollutant emissions have been largely successful because they are based on integrated city planning.

Other countries can profit from the Singapore experience:

- Periodical adjustments of policies using feedback from the public and other stakeholders made possible by transparency in policy formulation. Singapore has learned from its own practices: ERP charges are subject to review every three months, and charge structures and times change depending on traffic and economic conditions.
- Investment in infrastructure. Demand-side management supplemented construction of additional road infrastructure, proper road maintenance, coordination of traffic-light systems, and building of expressways and mass rapid transit. The taxes and fees imposed on vehicles generated huge financial resources, which were not only invested in demand- and supply-side management but also applied to reducing less-desirable taxes.
- Technology factors played important roles. For example, ERP depends on sophisticated technology that allows time-of-day pricing that reflects traffic conditions. A computerized traffic control system was already in place by 1986 in central business districts. It was replaced with a more advanced automated traffic signaling system called "Green Link Determining System", a traffic-adaptive signal control system monitored centrally to adjust to changing traffic conditions.

Source: Toh & Phang, 1997; Institute for Global Environmental Strategies (IGES), 2007

Box 7.2
Yokohama's pollution control agreements

The success of voluntary agreements can be seen in the example of Yokohama City. During the 1960s, the air and water quality of Yokohama was severely deteriorating due to rampant industrialization. Furthermore, Electric Power Development Co., Ltd (EPDC) in 1964 also wanted to build a new coal-fired power plant in Yokohama. Knowing that the national law will not be sufficient to control possible air pollution from the power plant, the local government signed a "pollution control contract" with EPDC, wherein the company committed to "take measures to achieve agreed targets beyond the levels required by the law".

Some of the targets in the agreement include:

- The concentration of sulfur dioxide (SO_2) should be below 500 parts per million (ppm).
- The amount of smoke and dust should be below 0.6 g/Nm^3.
- EPDC should periodically monitor the density of smoke, noise level, wastewater, water quality, among others.

The EPDC was motivated to join the agreement because they needed local government approval before they can start building their power plant. Furthermore, the public was also involved in the transaction by informing them of the results of monitoring various pollutants.

Using voluntary agreements provided several unique advantages. First, the government can implement stricter standards compared to national laws based on agreement with important parties. Second, these agreements, unlike national laws, recognize the unique characteristics of environmental problems faced in different cities, Third, the government does not simply assume that all industries have the same capacity to reduce their emissions. Through constant consultation, companies and the local government can set a specific target that is more possible. Lastly, company image also improves in the community because citizens can see that these companies are environmentally conscious.

Source: Tsunoda, Inui & Takeuchi, 2002; Organisation for Economic Co-operation and Development (OECD), 2003; Matsuno, n.d.

Table 7.2 Factors considered in implementing strategies to prevent and/or control air pollution

Factor	Consideration
Technical	Effectiveness Sustainability under local conditions
Administrative	Feasibility given the existing legal and administrative framework
Economic	Costs and benefits
Social	Equity in sharing of costs and benefits Culture of compliance
Political	Public support Stakeholder pressure

Source: SEI, 2008

National and local governments often employ a combination of regulatory instruments, especially as they develop and pollution sources multiply and diversify. The types of combinations will depend on the local context as well as the sets of broader governance arrangements in which they are embedded. Some of the factors that should be considered in selecting appropriate policy instruments are presented in Table 7.2.

In many cases, effective implementation of a variety of (as opposed to just a single) policy instrument(s) have been shown to lead to air quality improvements. In 2011, the European Environment Agency (EEA) evaluated selected policy instruments that have been introduced in the recent decades in the European Union (EU) to address emissions from key sources, road transport and industrial combustion (i.e., Euro emission standards for road vehicles and the EU directives on Integrated Pollution Prevention and Control and large combustion plants). The evaluation showed significant emission reduction compared to no-policy scenarios and potential for scaling up improvements in more countries following application of the policy instruments in all European countries (EEA, 2011).

7.1.3 Governance arrangements

Both the selection and combination of regulatory instruments are affected by different types of governance arrangements. Top-down approaches to governing air quality typically involves the national government crafting air pollution control policies and regulations with moderate levels of interaction with subnational governments or polluting industries. The emphasis for top-down arrangements is on achieving compliance with government-led regulations. An advantage of top-down approaches is that actions can be rolled out quickly, especially when political will is strong as was the case in China during a series of high-profile air pollution episodes (Box 7.3). Pure top-down approaches, however, are disadvantaged by limited scope for adapting regulations to different contexts, high requirement for government resources and manpower, and fewer opportunities for learning.

Box 7.3
China fighting against air pollution in response to public concerns

Air quality became a serious concern after a severe air pollution episode in Beijing at the end of 2011 drew widespread media attention and stimulated public debate. New social media, celebrity's advocacy, as well as online posting of pollution levels (including action by the US Embassy in Beijing) further increased this attention. Of particular concern was fine particulate matter ($PM_{2.5}$) as people became aware that these fine particles posed long-term health risks, and were not regulated and monitored. The result of this attention was a series of actions that illustrated both more top-down and bottom-up approaches to governance.

The first set of actions followed a more top-down approach. In February 2012, the Chinese national government issued the New Ambient Air Quality Standards and Technical Regulation on Air Quality Index (AQI), adding air quality standards and monitoring requirements for $PM_{2.5}$, ozone (O_3) and carbon monoxide (CO). The standards and regulations will come into effect in 2016, but monitoring began in 2012. The national government also put in place a clear timeline for establishing a nationwide monitoring network. By the end of 2014, 190 cities have set up monitoring networks and released real-time air quality monitoring data to the public in line with the national government requirements.

But following these reforms, an additional set of pressures from the bottom-up led to greater efforts to tackle $PM_{2.5}$. Reports of air pollution in China made headlines again in early 2013 when $PM_{2.5}$ in Beijing reached very high concentrations, and pollution covered a wider geographical area than that in 2011. For the first time, the public had access to real-time $PM_{2.5}$ data and mobile AQI applications were widely downloaded by smart phone users. Local governments responded fast to inform the public how to protect themselves and what they could do to reduce emissions, but the public pressure on the government to act swiftly is growing stronger than ever. As part of the response to urgently address the issue, China's State Council released its Action Plan for Air Pollution Prevention and Control (Action Plan) on 12 September 2013.

Source: Clean Air Asia, 2013

To a certain extent, cities will move from the more top-down to more **multi-stakeholder and multi-level approaches** as they develop and combine more instruments **to solve air pollution** problems. It is also important to note that rarely is any one approach applied in isolation.

While top-down approaches stress compliance, bottom-up forms of governance emphasize collaboration. Bottom-up governance arrangements often encourage different stakeholders, especially local governments, to work collectively towards innovative solutions and draw upon local knowledge to improve performance (Matland, 1995). In instances such as the Tokyo Diesel case, the initiative was led by the local government. From 1999, the Tokyo governor successfully raised public awareness on diesel emission control through various communication strategies. Following the awareness-raising campaign, the Tokyo Metropolitan Government enacted innovative regulations to ban the driving of dirty diesel vehicles in the metropolitan area, which was unprecedented in the country. This triggered a suite of diesel controls that gradually began to be replicated in other parts of Japan (Box 7.4). However, a bottom-up approach does not always consider the potential for scaling up at different levels of decision-making. It can also encounter difficulties when air pollution problems cut across sectoral and administrative boundaries.

A multi-stakeholder and multi-level approach is now widely considered for problems that encompass multiple sectors and administrative borders. This approach attempts to align different actors at different levels of decision-making; aiming for this alignment not only with national and local levels, but also regional and global levels. In some instances, this can even involve many actors identifying and sharing "good practices" across jurisdictions at different levels. These practices can be transferred from city to city and country to country through flexible non-governmental networks such as Clean Air Asia or the International Council for Local Environmental Initiatives (ICLEI). It is important to underline that multi-stakeholder approaches to governance do not necessarily involve a smaller role for different levels of government: on the contrary, governments frequently need to "steer" a diverse group of stakeholders in the shared search for pragmatic solutions and scale up context-appropriate versions of those solutions.

Box 7.4
Reducing emissions from diesel vehicles in Japan

One of the more interesting diesel control programs was actually initiated not by a national government but by local governments. In 1999, before the national government introduced stricter diesel vehicle regulations, the Tokyo Metropolitan Government established a "NO Diesel vehicle campaign". This was followed a year later by enactment of the Tokyo Metropolitan Environmental Security Ordinance that had as its centerpiece diesel vehicle regulations. The regulations require in-use diesel vehicles that do not satisty particulate matter (PM) emissions standards to be retrofitted with emission control systems; otherwise the vehicles cannot be driven in Tokyo. This was accompanied by a suite of other measures designed to stop idling; prohibit use of fuel oils that discharge a greater amount of PM; and deploy vehicle pollution regulators to identify violating vehicles. Importantly, similar regulations were enforced by major prefectures and cities in the Greater Tokyo Area, and other prefectural governments (e.g., Osaka Prefecture and Hyogo Prefecture) also adopted comparable measures, leading to complementary national diesel reforms.

Source: Rutherford & Ortolano, 2008; DieselNet, 2012

Box 7.5
China's Action Plan for Air Pollution Prevention and Control (Action Plan)

China's State Council released its Action Plan for Air Pollution Prevention and Control (Action Plan) on September 12, 2013. The Action Plan sets the road map for reducing air pollution and comprehensive control from 2013-2017 in China with a focus on three key regions – Jing-Jin-Ji, YRD, and PRD. The Action Plan states that for the three key regions, annual average concentration of $PM_{2.5}$ should be reduced by 25 percent, 20 percent and 15 percent, respectively. For Beijing, annual average concentration of $PM_{2.5}$ should be controlled at 60 $\mu g/m^3$ level by 2017.

To a certain extent, cities will move from the more top-down to more multi-stakeholder and multi-level approaches as they develop and combine more instruments to solve air pollution problems. It is also important to note that rarely is any one approach applied in isolation. For example, in the case of China's air pollution episodes, there was significant pressure from the general public and proactive steps taken by local governments. The decision from China's State Council focused on three key regions – Jing-Jin-Ji, Yangtze River Delta (YRD) and Pearl River Delta (PRD) – further exhibited some of the elements of the multi-level, multi-stakeholder approach (See Box 7.5).

The types of governance and regulatory approaches will have to be tailored to the particular needs of a city. National and subnational contexts influence which policy instruments and arrangements are utilized. Different approaches to air quality governance may also be strongly influenced by the existing institutional context — i.e. China may be inherently more top-down than the Philippines. It further needs to be underlined that this is not always a perfectly sequential or linear process: most of the building blocks of the top-down approach may have to be in place for more multi-stakeholder approaches. Nonetheless, there are interrelated and mutually reinforcing core principles of environmental governance which should help address air quality challenges (See Table 7.3).

Table 7.3 Core principles of environmental governance systems

	Core principle	Description
Regulatory framework	Effective Laws	Environmental laws should be clear, even-handed, implementable, and enforceable.
Capacity and Coordination	Human and financial resources	Agencies should have sufficient human and financial resources to design and carry out activities specified in laws and policies.
	Training and Learning	Agencies should be equipped with the knowledge and tools needed to carry out activities specified in laws and policies.
	Institutional Coordination	Roles and lines of authority for AQM should be clear, coordinated, and designed to produce efficient and non-duplicative program delivery.
Participation and Accountability	Stakeholder Participation	Stakeholders should be afforded opportunities to participate in environmental decision-making.
	Accountability	Environmental decision makers, both public and private, should be accountable for their decisions.
	Disclosure/ Information Dissemination	Environmental information should be collected, assessed, and disclosed to the public.
	Dispute Resolution	Stakeholders should have access to fair and responsive dispute resolution procedures.

Source: Adapted from USEPA, 2011

The core principles can be roughly divided into three areas: regulatory framework, capacity and coordination, and participation and accountability.

The regulatory framework involves putting in place the underlying system on how to move forward with implementation from general legal mandates. The regulatory framework articulates the infrastructure by which other components – such as accountability, review, institutional framework and coordination mechanisms – are outlined.

Capacity and coordination refers to sufficient financial and human resources and clear lines of authority that government agencies and other stakeholders will typically need. The well-defined roles and responsibilities of government agencies and other stakeholders would enhance effectiveness and minimize conflict or possible inaction due to overlapping authorities. Both capacity and coordination can be further bolstered by well-designed training programs that equip stakeholders with the tools and knowledge needed to carry out provisions in policies and laws. The end-result will be effective laws that are implemented in a manner that help resolve issues as intended.

In terms of participation and accountability, the process of designing and implementing policies will typically be enhanced with context-appropriate channels for stakeholders to offer inputs into those policies. This will not only help enrich the design of policies but ensure that agencies charged with implementing those policies are accountable for their performance. Increased transparency and stakeholder participation in the process could lead to positive reception and buy-in of air pollution control policies implementation. Mechanisms that spell out rules for settling disputes can help resolve claims of unfair enforcement and build additional faith in the policies and implementing agencies.

As suggested in Figure 7.1, the core principles within and across these categories can reinforce each other. Figure 7.1 also illustrates that in many cases, these core principles will help put in motion the development of different policy instruments and governance arrangements outlined previously in the chapter. As with the instruments and arrangements, the application of these principles will vary across cities and countries depending on the existing institutional context.

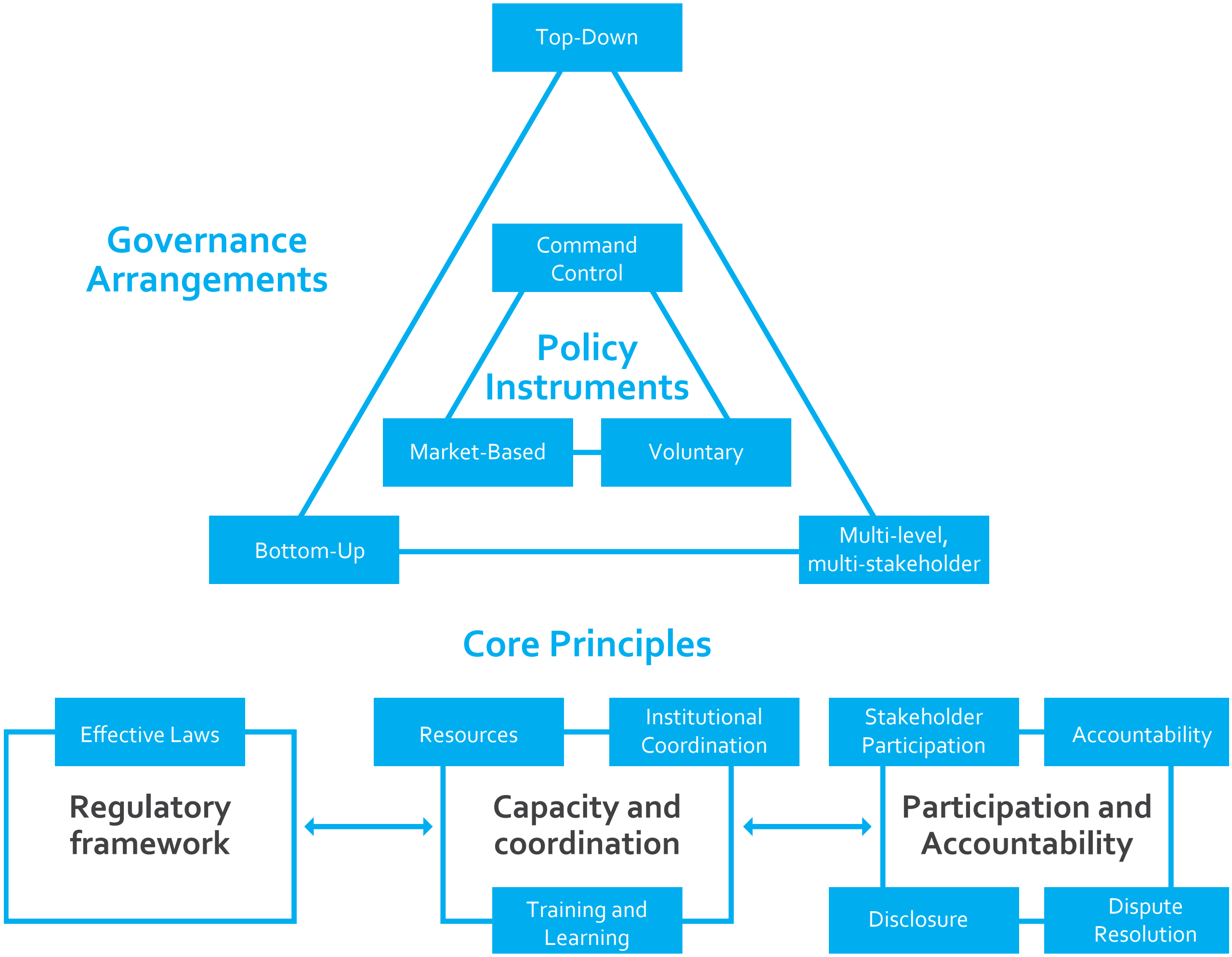


Figure 7.1 Environmental Governance Framework

7.2 Stages of air quality governance

Governance is essential to improving air quality. As a starting point, Table 7.4 presents indicators that would aid cities in identifying their current state of AQM for governance. The key factors for consideration include:

- Clear, implementable, and enforceable environmental policies and measures, and an enabling environment for implementation of measures;
- Clear institutional mandate and effective institutional arrangements between and within government agencies and offices involved in AQM;
- Meaningful stakeholder participation and engagement including access to environmental information, and
- Provision for accountability through review and evaluation of compliance and enforcement.

Table 7.4 Stages of air quality governance

Stages	Indicators
Underdeveloped	Mandate for AQM is not clear. Political support for AQM is lacking. Insufficient human and financial resources. Capacity developing activities are primarily ad hoc, and rely heavily on external organizations. Absence of mechanisms for stakeholder engagement and participation.
Developing	Overlapping mandate and responsibilities for AQM. Limited coordination between different ministries/ agencies and local government working on AQM components. Political support for implementation of clean air measures is inadequate. Limited understanding of level of enforcement of policies and measures. Focus is chiefly on CAC regulations and top-down forms of governance. Stakeholders are engaged on an ad hoc basis.
Emerging	Clear mandate for AQM at the national and subnational level identified. Growing political support for implementation of clean air measures. Strategies to evaluate compliance and enforcement of policies exist for specific sectors. Financial support is available from national/local government. Opportunities for capacity development on AQM are available. Knowledge of different forms of regulation and governance growing. Mechanisms to engage various stakeholders through information disclosure exist or are in place.
Maturing	Clear institutional mandate of different ministries and local departments on AQM, including coordination with neighboring cities. Political and public support for implementation of clean air measures is adequate. Strategies to evaluate compliance and enforcement of policies to address air pollution are in place. Sufficient human and financial resources are available. Capacity development systems exist at the national and subnational levels. Mechanisms to engage various stakeholders to support national and subnational government in implementing clean air policies exist or are in place. New approaches to regulation are piloted and lessons learned are growing in number and scope.
Fully developed	Institutional mandate of different ministries/agencies and local departments on AQM, including coordination with neighboring cities, is well-defined. Strong political and public support for implementation of clean air measures. A system is in place to evaluate compliance and enforcement of policies and feeds back to policy development process. Sufficient human and financial resources are available. Innovative strategies to secure financial resources are also in place. Continuous capacity development systems exist. A process to integrate a variety of regulatory approaches and engage various stakeholders in AQM is institutionalized.

7.3 Issues and challenges

Asian cities and countries face a number of institutional, management, and financial challenges in moving from one stage of air quality governance to another.

Institutional

- **Unclear and/or overlapping mandates and roles** for various agencies and stakeholders involved in AQM. Given that air pollution is a complex environmental issue, it is a concern not only for environmental agencies but also for energy, transport, industry, planning, health, and meteorology agencies at both national and local levels.
- **Ill-defined coordination and communication mechanisms between various agencies and institutions**. Absence of well-designed coordination mechanism can lead to inter-agency conflicts that can hinder the development and weaken enforcement of policies and regulations (SEI, 2008). These problems are particularly acute for air pollution issues that cross geographical boundaries.
- **Need for institutional capacity strengthening.** At the extreme, countries and cities may even lack human resources to understand urban air quality, effectively leaving the issue off the government agenda. In some countries and cities, addressing air pollution is already mandated to government agencies; however, agencies and institutions are not well equipped with knowledge of systematic AQM approaches, technical skills, and other critical enablers of implementation. Many government agencies in developing Asian countries lack capacities for enforcement and monitoring compliance (World Bank, 2007).
- **Few systematic and needs-based capacity building mechanisms are available** for policymakers, regulators, and various stakeholders to address air pollution that can help determine levels of capacity and potential gaps.
- **Minimal opportunity for stakeholder engagement and participation.** The lack of mechanisms on how various stakeholders can be engaged in AQM can be problematic on several counts. First, there are fewer opportunities to identify workable solutions from those emitting or affected by pollution. Provisions for civil society to file appropriate civil, criminal, or administrative action in courts, for instance, can discourage polluters from exceeding standards. Second, stakeholder engagement to fill capacity gaps is not tapped. Knowledge and resources of stakeholders which could complement the work of the regulatory agencies are not utilized; there is a need to maximize opportunities for cooperation under a notion of shared responsibility for air quality improvement.

Management

- **Lack of appropriate monitoring and review system** constrains the ability to measure progress in AQM. Several Asian countries and cities are unable to determine whether the air quality actions have resulted in improvements in air quality levels. In the same manner, limited review system hinders understanding whether the mitigation action is addressing the key emission sources.
- **Limited political and public support for air quality action due to communication gaps.** A lack of vision, political will, and public support can undermine even well-designed regulations. Effectively communicating the severity of health impacts of air pollution to constituents in terms of economic value is one way to gain political support for air quality management (SEI, 2008) [See *Guidance Area 3 on Health and other impacts and Guidance Area 4 on Air quality communication*].

Financial

- **Insufficient financial and human resources** can undermine institutions charged with enforcing regulations. Lack of resources is often a symptom of both limited financing from public sources as well as limited attempts to tap innovative ways of accessing resources such as private-public partnerships.
- In much of developing Asia, the **percentage of public finance allocated to environmental protection has remained a small fraction** of gross domestic product (GDP); let alone air pollution.

7.4 Roadmap for improving air quality governance

To progress towards a fully developed stage of air quality governance, there are a number of steps at each stage that the city – and if applicable, provincial, or national authorities – should take (refer to Table 7.5). **Annex VI of the *Information Sourcebook*** provides additional information on moving forward with these recommendations.

Table 7.5 Roadmap for improving air quality governance

Developmental stages	Steps to follow
Underdeveloped	**Management Process** *Institutional coordination, capacity and training* • Define essential AQM roles and responsibilities • Conduct stakeholder mapping and determine whether existing organizations can fill needed AQM roles and responsibilities • Vest authority for AQM with an existing or new lead agency/department based on stakeholder mapping • Assess overall budget for AQM and allocate government funding to cover essential roles and responsibilities *Stakeholder engagement, participation and accountability* • Involve prominent figures/local champions in publicizing the formation of the AQM agency to mobilize general public, media, and other stakeholder support • Design complementary public advocacy and awareness campaigns (with engagement of above champions) to place air quality squarely on the policy agenda [See *Guidance Area 4 on Air quality communication*] **Technical Process** • Seek technical assistance from international agencies, international non-governmental agencies, and bilateral agencies in establishing AQM agency, filling budgetary needs, and strengthening stakeholder communication • Seek city partnerships to learn how others cities set up AQM agency, allocate budgets, and communicate with other stakeholders
Developing	**Management Process** *Institutional coordination, capacity and training* • Assess capacity needs through a training needs assessment and hire needed additional staff within budgetary limits • Actively engage prominent public figures/local champions in public advocacy and awareness campaigns to share essential air quality information • Design communication, data sharing, and reporting mechanisms within lead agency based on organizational structure • Clarify institutional relationships with other relevant city agencies (i.e. transport) and national environmental agencies/air pollution divisions • Determine where and how cooperation should be strengthened with relevant city and national environmental agencies/air pollution divisions • Continue to assess and allocate government funding while mobilizing additional resources through city taxes and fiscal policies as well as national and international finance *Stakeholder engagement, participation and accountability* • Use advocacy and awareness campaigns to promote public and stakeholder participation in activities to reduce air pollution (i.e. car free day)

Developmental stages	Steps to follow

Developing	• Clarify organizational structure and division of labor for core AQM functions within lead AQM agency, potentially including: (i) pollution prevention; (ii) risk assessment and reduction; (iii) scientific research and technology; (iv) regulatory education; (v) regulatory development; and (vi) enforcement[2]
	
	Technical Process
	• Design effective enforcement program with the following components:
	  ◦ Creating enforceable requirements for emission sources
	  ◦ Identifying which sources are subject to which regulatory requirements and provisions.
	  ◦ Promoting and monitoring regulatory compliance
	  ◦ Responding to violations
	  ◦ Clarifying roles and responsibilities
	• Evaluating the success of the program and holding program personnel accountable for performance

Emerging	**Management Process** *Institutional coordination, capacity and training* • Conduct capacity building activities through existing in-house training programs where available or outside organizations where expertise is lacking • Clarify roles and responsibilities of other relevant government agencies and non-governmental stakeholders (such as civil society, academe, research institutes, media, private sector, among others) to fill possible capacity needs or related AQM functions • Continue to assess and allocate government funding while mobilizing additional resources through city taxes and fiscal policies as well as national and international finance • Develop communication, data sharing, and reporting mechanisms for other relevant city and central government agencies *Stakeholder engagement, participation and accountability* • Develop mechanism for public information dissemination (i.e. sharing air quality data) to enhance transparency, strengthen accountability, and build political will • Develop stakeholder engagement and consultation mechanisms to provide input and oversight on some core AQM functions, including: (i) pollution prevention; (ii) risk assessment and reduction; (iii) scientific research and technology; (iv) regulatory education; (v) regulatory development, and (vi) enforcement **Technical Process** • Design AQM policies and measures using clear and enforceable language and identify and implement appropriate regulatory instruments, possibly combining CAC with MBIs [See *Guidance Area 5 on Clean air action plans*] • Develop mechanisms to collect information and assess regulatory compliance through (i) inspections; (ii) self-monitoring, self-record keeping, and self-reporting; (iii) citizen complaints/monitoring; and (iv) area monitoring

2 Urban Air Quality Management Strategy in Asia. Guidebook. https://www.elaw.org/system/files/handbook.pdf

Developmental stages	Steps to follow
Maturing	**Management Process** *Institutional coordination, capacity and training* • Enhance capacity building activities with possible re-assessment of needs • Strengthen and broaden communication, data sharing, and reporting mechanisms for other relevant city and central government agencies • Begin initial collaboration with neighboring cities for regional AQM, possibly starting with information sharing and data exchanges • Continue to assess and allocate government funding while mobilizing additional resources through city taxes and fiscal policies as well as national and international finance • Explore innovative financing mechanisms, including partnering with private sector *Stakeholder engagement, participation and accountability* • Strengthen and broaden mechanism for public information dissemination (i.e. sharing data on air pollution, health impacts, climate change, and other co-benefits) • Strengthen and broaden stakeholder engagement and consultation mechanisms to provide input and oversight on relevant AQM functions **Technical Process** • Continue to identify and implement appropriate regulatory instruments, possibly combining CAC with market-based and other instruments (such as voluntary) [See *Guidance Area 5 on Clean air action plans*] • Strengthen and broaden mechanisms to collect information and assess regulatory compliance through (i) inspections; (ii) self-monitoring, self-record keeping, and self-reporting; (iii) citizen complaints/monitoring; and (iv) area monitoring • Review and evaluate effectiveness of local clean air action plan, building on information gathered during compliance monitoring activities
Fully developed	**Management Process** *Institutional coordination, capacity and training* • Continue to conduct capacity building activities, with re-assessment of training needs, as necessary • Establish and strengthen partnerships with organizations who can help build capacities in other cities • Collaborate with neighboring cities on regional AQM, possibly including harmonization of standards, joint monitoring and development of management measures, and collaborative capacity building • Continue to assess and allocate government funding while mobilizing additional resources through city taxes and fiscal policies as well as national finance • Explore innovative financing mechanisms, including partnering with private sector *Stakeholder engagement, participation and accountability* • Continue to strengthen and broaden mechanism for public information dissemination (i.e. sharing data on air pollution, health impacts, climate change and other co-benefits) • Continue to broaden stakeholder engagement and consultation mechanisms to provide input and oversight on relevant AQM functions • Sustain political and public support through mechanisms that enhance transparency, accountability, and communication strategies [See *Guidance Area 4 on Air quality communication*]

Developmental stages	Steps to follow
Fully developed	**Technical Process** • Continue to identify and implement appropriate regulatory instruments, possibly combining CAC with market-based and other instruments (such as voluntary) [See *Guidance Area 5: Clean air action plans*] • Continue to strengthen and broaden mechanisms to collect information and assess regulatory compliance through (i) inspections; (ii) self-monitoring, self-record keeping, and self-reporting; (iii) citizen complaints/monitoring; and (iv) area monitoring • Review and evaluate effectiveness of local clean air action plan, using environmental results and other indicators to assess compliance rates, indirectly measuring compliance, number of enforcement responses, monetary penalties assessed

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Integrated Programme for Better Air Quality in Asia

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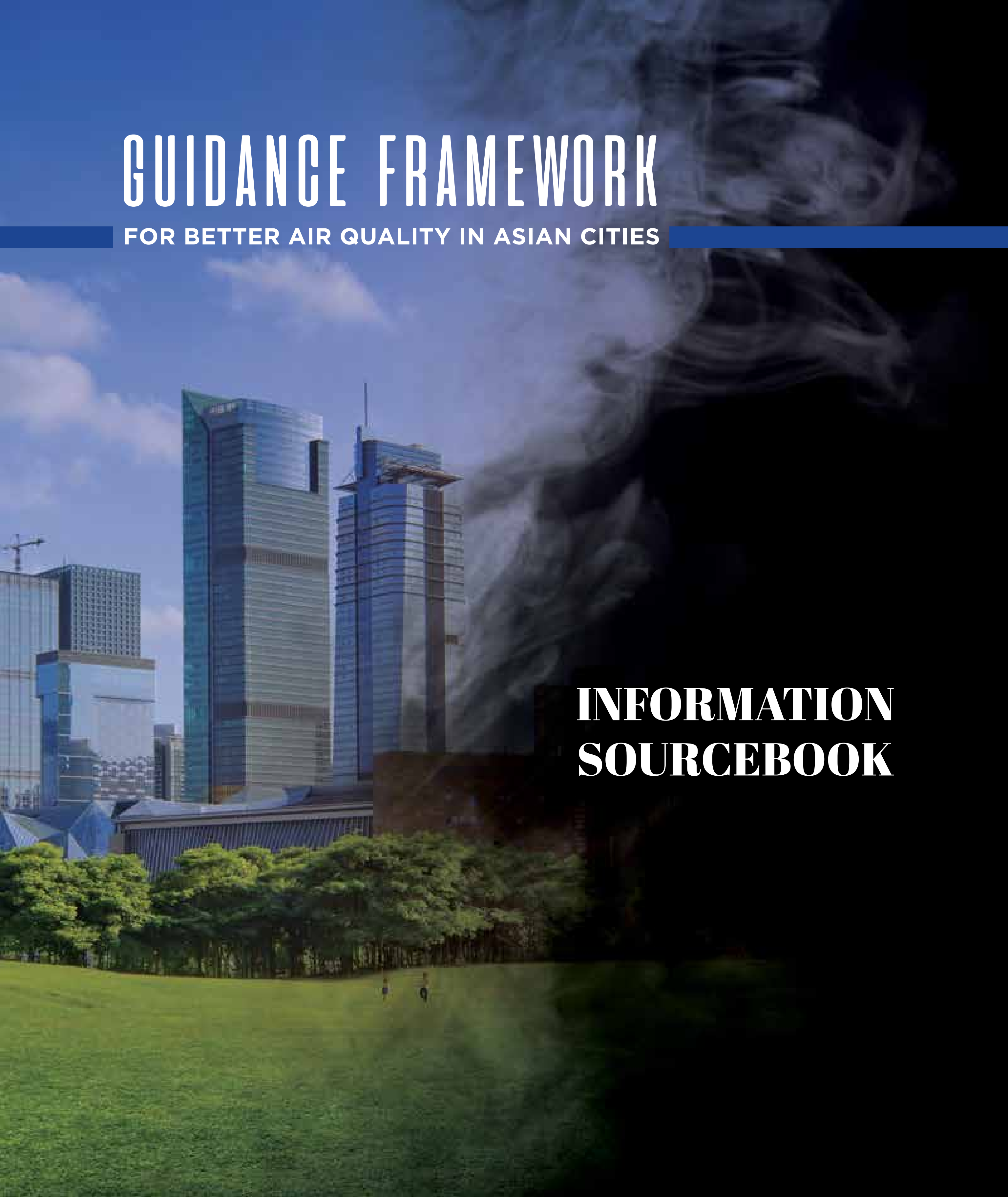
GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES



INFORMATION SOURCEBOOK

Integrated Programme for Better Air Quality in Asia

CLEAN AIR ASIA

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GUIDANCE FRAMEWORK
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Information Sourcebook

ABOUT CLEAN AIR ASIA

www.cleanairasia.org

Clean Air Asia is an international NGO established in 2001 as the premier air quality network for Asia by the Asian Development Bank, World Bank and USAID. Its mission is to promote better air quality and livable cities by translating knowledge to policies and actions that reduce air pollution and greenhouse gas emissions from transport, energy and other sectors.

Clean Air Asia became a UN-recognized partnership in 2007, its network spanning 250 organizations in 31 countries in Asia and worldwide, with 8 country networks: China, India, Indonesia, Nepal, Pakistan, Philippines, Sri Lanka and Vietnam. It is headquartered in Manila and has offices in Beijing and Delhi. Clean Air Asia leads efforts to enable Asia's more than 1000 cities to reduce both air pollution and CO_2 emissions, and thereby contribute to more livable and healthy cities with blue skies and low carbon footprint. Clean Air Asia helps to reduce emissions through policies, plans, programs, and concrete measures that cover air quality, transport and industrial emissions and energy use.

The Better Air Quality (BAQ) Conference is a flagship event of Clean Air Asia covering the key sectors of transport, energy and industry, with a particular emphasis on government policies and measures. Policy makers, practitioners and industry leaders meet at BAQ to network, innovate, learn and share experiences. The biennial event was first held in 2002 and attracts close to a thousand participants from Asia and the rest of the world.

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CONTENTS

PREFACE

Air pollution is now considered the world's largest environmental health risk. There have been a number of global efforts calling for air pollution actions in recent years. These global calls for action on air pollution strengthen regional and national initiatives and highlight the need to prioritize addressing this issue through a collaborative and integrated approach.

In 2006, the First Governmental Meeting on Urban Air Quality in Asia[1] recognized the need for guidance in implementing a Long Term Vision for Urban Air Quality in Asia, which describes the desired state of urban air quality management in Asian cities. During the Third Governmental Meeting, environment ministries from the region identified key challenges they are facing to improve urban air quality.

To set the way forward in achieving the vision for cleaner air, Clean Air Asia led the development of the Guidance Framework for Better Air Quality in Asian Cities (Guidance Framework) to address the needs and challenges in the region. It aims to provide a recognized guidance on improving urban air quality and is organized around priority areas of concern in the region, which were translated into key guidance areas with roadmaps on how to progress in a step by step manner.

This voluntary, non-binding document consists of seven individually published chapters covering each of the Guidance Areas. Policy and decision makers in Asia, as well as other relevant stakeholders, can use one or a combination of the Guidance Framework chapters to develop local roadmaps or action plans depending on their priority areas of concern.

The Guidance Framework consists of seven main books with these titles:

- Introduction
- Guidance Area 1 - Ambient air quality standards and monitoring
- Guidance Area 2 - Emissions inventories and modeling
- Guidance Area 3 - Health and other impacts
- Guidance Area 4 - Air quality communication
- Guidance Area 5 - Clean air action plans
- Guidance Area 6 - Governance

These guidance areas come with an Information Sourcebook, which is a compilation of resources to support the implementation of Guidance Framework roadmaps. There is also an accompanying training course on Guidance Framework implementation, which is available online in the Clean Air Asia website and Integrated Programme for Better Air Quality (IBAQ Programme) website: www.cleanairasia.org/ibaq

The Guidance Framework was developed together with a team of international and regional experts and practitioners and has undergone an extensive review process through the Governmental Meetings and the involvement of external reviewers. The draft document was also shared in a number of international events, including the Asia Pacific Clean Air Partnership (APCAP) Joint Forum organized by UNEP ROAP in November 2015. The Guidance Framework was welcomed by participants from 24 countries in Asia and the Pacific, involving environment ministries, intergovernmental organizations, non-governmental organizations, and experts.

1 Governmental Meetings on Urban Air Quality in Asia are biennial meetings organized by the United Nations Environment Programme Regional Office of Asia and the Pacific (UNEP ROAP) and Clean Air Asia that convene environment ministries with the aim to harmonize approaches across the region in tackling air pollution and related fields.

ABBREVIATIONS

AAQS	Ambient Air Quality Standards
API	Air Pollution Index
AQI	Air Quality Index
AQM	Air Quality Management
BAAQMD	Bay Area Air Quality Management District
BAU	Business as Usual
BC	Black Carbon
CAAP	Clean Air Action Plan
CAHA	Climate and Health Alliance
CAIPs	Clean Air Implementation Plans
CAMx	Comprehensive Air Quality Model with Extensions
CASC	Clean Air for Smaller Cities in the ASEAN Region Project
CH_4	Methane
CMB	Chemical Mass Balance
CO	Carbon monoxide
CO_2	Carbon dioxide
DENR	Department of Environment and Natural Resources
EANET	Acid Deposition Monitoring Network in East Asia
EEA	European Environment Agency
EC	Elemental Carbon
EF	Emission Factor
EU	European Union
GAPF	Global Atmospheric Pollution Forum
GAINS	Greenhouse and Air Pollution Interactions and Synergies
GHG	Greenhouse Gas
GIZ	Deutsche Gesselschaft für Internationale Zusammenarbeit
HCMC	Ho Chi Minh City
HFC	Hydrofluorocarbons
IATC	Inter-Agency Technical Committee
INECE	International Network for Environmental Compliance and Enforcement
IPCC	Intergovernmental Panel On Climate Change
MOEJ	Ministry of the Environment of Japan
NGO	Non-Governmental Organization
NH_3	Ammonia
NMVOC	Non-Methane Volatile Organic Compounds
NOx	Nitrogen oxide
NO_2	Nitrogen dioxide
N_2O	Nitrous oxide
OC	Organic Carbon
OECD	Organisation for Economic Co-operation and Development
O_3	Ozone
PCA	Principal Component Analysis
PCD	Pollution Control Department
PFC	Perfluorinated Compounds
PM	Particulate Matter
PMF	Positive Matrix Factorization
PM_{10}	Particulate Matter ($\leq$ 10 micrometers in diameter)
$PM_{2.5}$	Particulate Matter ($\leq$ 2.5 micrometers in diameter)
PNS	Philippine National Standards
PPP	Public Private Partnership
PSAT	Particulate Matter Source Apportionment Technology Matter
RIAS	Rapid Inventory Assessment Technique
SA	Source Apportionment
SEI	Stockholm Environment Institute
SIM-AIR	Simple Integrated Model for Better Air Quality
SLCPs	Short-Lived Climate Pollutants
SF_6	Sulfur hexafluoride
SOx	Sulfur oxide
SO_2	Sulfur dioxide
SOP	Standard Operating Procedure
SVPCF	Special Vehicle Pollution Control Fund
TSP	Total Suspended Particles
T4CA	Train for Clean Air
UNEP	United Nations Environment Programme
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WHO	World Health Organization
WMO	World Meteorological Organization
WS-I	Water Soluble Inorganic Ions

TABLES AND BOXES

INTRODUCTION

The Guidance Framework for Better Air Quality in Asian Cities (Guidance Framework) intends to provide a recognized guidance in implementing the Long-Term Vision for Urban Air Quality in Asia, which describes the desired state of urban air quality in Asian cities by 2030. The Guidance Framework serves as a guide for policymakers and decision-makers to progress through development stages of air quality management (AQM). The document is organized around identified priority areas of concern in the region – translated into six guidance areas – which provide key indicators of AQM development stages to aid cities in the identification of additional and necessary action to effectively progress towards better air quality. Roadmaps indicating recommended steps or action points that are suited for each level of development are provided to help steer cities to advance from one stage to another.

The Information Sourcebook is a compilation of resources to support the implementation of Guidance Framework roadmaps. Published data and other relevant information are collated into tables and case studies that are integrated into stepwise processes to provide concrete models to execute recommended steps. The Information Sourcebook also provides links to online sources for updated information from other organizations and AQM stakeholders.

ANNEX I. GUIDANCE AREA 1: AMBIENT AIR QUALITY STANDARDS AND MONITORING

A simplified step-wise guide to improve air quality standards and monitoring systems is discussed below, accompanied by case studies to better illustrate the recommended steps.

PROCESS OF IMPROVING AMBIENT AIR QUALITY STANDARDS AND MONITORING SYSTEMS

Step 1. Harmonize ambient air quality standards

In the absence of globally agreed quantitative targets with clear timelines that can catalyze the development and implementation of national policies, the World Health Organization (WHO) Guidelines can be a very good starting point for discussions on a global agreement on air. These guidelines were based on rigorous, scientific, and systematic processes involving both the scientific and policy communities. Harmonization of ambient air quality standards (AAQS) within Asia or with global guidelines could fast track pollution reduction efforts, especially in countries lagging behind in AQM. This could also replicate successful policies and technologies applied in Europe, North America and some Asian and Latin American cities. For this to work, countries must internally adopt a phased approach to achieve more stringent AAQS and work towards eventually matching WHO guideline levels.

Step 2. Monitor compliance to AAQS

Capital and operational costs for air quality monitoring equipment can be very expensive to bear, especially for cities that do not have high incomes. The choice of air quality monitoring equipment need not always favor the more expensive and sophisticated option. The choice of equipment should take into account the purpose or objective of the air quality monitoring activity, costs, and the sustainability of the monitoring program. Results of air quality monitoring activities should also be linked closely with awareness and communication plans that not only inform stakeholders but also raise public consciousness of air pollution issues [See *Guidance Area 4 on Air quality communication].*

A city can choose from among the different types of equipment according to their needs and capabilities, both technical and financial (Table A1.1). To further improve monitoring compliance to AAQS, low-cost sensors (US$200-US$1500) which are specific to certain pollutants have been developed. The United States Environmental Protection Agency (USEPA) has released a guidebook that can be used by interested buyers to avail of these low cost-sensors. The USEPA also recommended a set of criteria that people can use in purchasing sensors. Key considerations include: criteria pollutant selection, detection range and detection limit, precision and bias, calibration requirements and response time (Williams et al., 2014).

Currently, various funding mechanisms are used by cities to establish and operate air quality monitoring systems. A combination of various mechanisms - government-appropriated budget, grants/loans, proprietary innovative technologies, tax-generated funding, and private sector, among others – could be explored to sustain air quality monitoring systems in Asian cities.

Table A1.1 Advantages, cost and accuracy of air quality monitoring sampling systems

Sampling	Sample Acquisition/ (Average Time)	Type of sample collection	Amount of air sampled (liters/min)	Cost (USD)	Advantages	Disadvantage
Passive	Integrating / (1–60 d) (minimum) Passive sampling is aimed to get average pollutant levels over a period of time, usually 1–60 d.	Manual	Depends on site (0–3 lpm) The ~3 lpm is meant to be natural wind flow and can be zero.	Sampling: Oct-70 Analysis: 10–70 per parameter	Low cost of capital outlay, samplers can be deployed in large numbers, useful for screening and mapping	Unproven for some pollutants, longer averaging time, may be labor intensive in deployment and post sampling analysis depending on the number of samples and location, slow data throughput, requires laboratory analysis
Active	Integrating / (4–24 hrs)	Manual	Low volume (4 lpm)	~4000	Low cost of capital outlay, easy to operate, effective for long term sampling Data continuity over time is good; better time resolution and better accuracy	Labor-intensive deployment and post sampling analysis, slow data throughput, requires laboratory analysis, provides daily averages only
			Low volume (16.7 lpm)	~10,000	Easy to operate, has Federal Reference Method (FRM) approval, ideal for health-related studies	
			High volume (40 lpm)	~20,000	Easy to operate	
		Automatic	Low (16.7 lpm)	~50,000	Easy to operate, can be left unattended for a longer period of time	

Sampling	Sample Acquisition/ (Average Time)	Type of sample collection	Amount of air sampled (liters/min)	Cost (USD)	Advantages	Disadvantage
Active	Continuous/ (1–60 min)	Automatic	Low (1–4 lpm)	10,000–50,000	Gives historical data set, has FRM approval, easy to operate, highly-resolved data Provides data on near real time basis thus facilitates better AQM in terms of putting up and implementing plans to deal with episodic high pollution levels	High costs, sophisticated operations, calibrations, availability of spares, etc.
	Semi-continuous/ (30 min–1 hr)	Automatic	Low (1–16.7 lpm)	~1,000,000	deal for in depth chemical speciation/ profiling and analysis	Very high cost on capital outlay, needs highly technical person to operate and analyze data

Notes:
lpm = liters per minute
Active-integrating automatic = Active means having a pump; integrating means only one single reading over the monitoring period
Active continuous automatic = Continuous means sampling can be carried out over the entire monitoring period with a pre-set sampling time period
Active semi-continuous automatic = Semi-continuous means sampling can be discontinuous owing to limitation of power supply and other restrictions during the entire monitoring time. One has to restart the monitoring equipment.
Integrating = Only a single pollutant concentration can be obtained for the entire monitoring period; there is no breakdown of concentration over time.

Source: Updated from Asian Development Bank (ADB) & Clean Air Asia, 2014. Adapted from Schwela, 2011

Step 3. Review AAQS to achieve WHO Guidelines and interim targets
As described earlier, an AAQS review process can be expensive and it is recommended that standard setting and review make use of the outcomes of the processes in WHO, USEPA and/or other developed countries. The cost of review should not be a limiting factor though for a country to review and revise their air quality standards as illustrated by India's experience in Box A1.1.

Step 4. Plan the sustainability of air quality monitoring network systems
A common challenge for most Asian cities is sustaining their air quality monitoring networks for the long-term. Many of the air quality monitoring systems established through foreign grants in Asia have ended soon after the project grant ended. Thailand however, offers a good case study for other countries to learn from.

Box A1.1
Review and revision of air quality standards

India adopted its first set of air quality standards (AQS) in 1982, which included TSP, PM_{10}, SO2, NO2, CO, and Pb. Ammonia was later added to the list in 1998. These standards were mostly adopted from developed nations. However, they had the unique feature of different types of areas – industrial, residential, and sensitive areas – having separate sets of standards. India took its first major standards revision in 2007 with a thorough review of approach, and health impact information–indigenous studies, data generated through monitoring network and international initiatives. The review recognized that clear demarcation between industrial and residential areas no longer existed, and that every citizen across the country has the right to have uniform air quality. The revised standards were uniform across the country, independent of land use. PM2.5, in view of its severe health impacts, and other pollutants – benzene, benzo(a)pyrene, Pb, Ni, and As – were added. Although database on ambient levels of these new parameters are almost non-existent, India invoked the precautionary principle where it recognized international studies on severe health risks from these pollutants. The exercise of standard setting (for new pollutants) and revising old standards was very transparent and involved wider consultations with industries, various governmental agencies, state regulatory agencies, non-governmental organizations and the public.

As = Arsenic; CO = Carbon monoxide; NO_2 = Nitrogen dioxide; Pb = Lead; Ni = Nickel; PM_{10} = Particulate matter (≤ 10 micrometers in diameter); $PM_{2.5}$ – Particulate Matter (≤ 2.5 micrometers in diameter); SO_2 = Sulfur dioxide; TSP = Total suspended particles

As was the case in most Asian countries, air quality monitoring activities in Thailand were initiated through bilateral assistance or loans and sustainability was a problem. From having only eight stations in Bangkok in 1983, Thailand air quality monitoring network now operates 63 fixed stations and six mobile monitoring units. Thailand was able to sustain and expand its monitoring network because of thorough planning from end-to-end, considering their monitoring objectives, operational requirements, timelines, and budget allotment. Thailand's planning strategies included setting a timeline or lifespan for the stations; and anticipating and forecasting need for maintenance, replacement, relocation, and upgrade. Continuous review exercises to improve the air quality monitoring system have also been done very effectively. Thailand's Pollution Control Department (PCD) undertakes annual planning to determine which management option to undertake depending on the annual budget allocated for air quality monitoring (Table A1.2).

Table A1.2 Management options for Thailand's monitoring network based on budget availability

Budget allocation	Management Option
If there is sufficient budget for all stations	All stations will be under a service contract
If there is sufficient budget for most stations	Most stations will be under a service contract while some are operated by PCD
If the budget is insufficient	Most stations will be operated by PCD while some may be considered for shutdown or PCD may discontinue measurement of some pollutants

In addition to enhancing local air quality monitoring capability internally, countries can also benefit from activities involving neighboring countries, as was the case for Acid Deposition Monitoring Network in East Asia (EANET) (Box A1.2).

Source: Suwanathada, 2012

Box A1.2
Regional collaboration on air quality monitoring (EANET Monitoring)

One of the challenges in advancing air quality monitoring capacities in Asia is the lack of regional cooperation. However, starting in 2001, 10 countries in Asia, namely China, Indonesia, Japan, Malaysia, Mongolia, the Philippines, Korea, Russia, Thailand and Vietnam started collaborating on acidification monitoring within the Acid Deposition Monitoring Network in East Asia (EANET). Since then, the number of countries has grown to 13, which now includes Cambodia, Lao People's Democratic Republic and Myanmar.

The monitoring activities of these countries include wet deposition (rainwater composition), dry deposition (air concentration), soil and vegetation, inland aquatic environment, and catchment-scale monitoring; all following harmonized methodologies and reporting formats. As of 2013, wet deposition monitoring has been performed at 54 sites, including 20 remote, 13 rural, and 21 urban sites. The dry deposition monitoring has been implemented at 45 sites; including 17 remote, 12 rural, and 16 urban sites.

Automatic monitors were used in 22 sites, including 21 sites for PM_{10}, 19 sites for ozone, and two sites for $PM_{2.5}$. Soil and vegetation monitoring as well as inland aquatic environment monitoring has been conducted in 28 plots in 10 countries and 18 lakes/rivers in 10 countries, respectively. Monitoring results are used to evaluate the state of acid deposition as well as its impacts on ecosystems.

EANET remains to be the longest running regional cooperation on air quality monitoring in Asia. The success of the EANET monitoring activities on acidification indicates a potential for a wider regional ambient air quality monitoring network in Asia.

Source: Asia Center for Air Pollution Research, 2010

Step 5. Upgrade and improve air quality monitoring systems
Air quality monitoring activities entail huge capital and operational investments, and they should be maximized and used for other AQM-related activities such as health impact studies [See *Guidance Area 3 on Health and other impacts*]. Despite their costs, some countries invest further to upgrade and improve their AQ monitoring capabilities which in turn also help improve their AQM systems and consequently reduce risks form air pollution. Below are three different examples from Japan and neighboring countries (Boxes A1.3 to A1.5).

Box A1.3
Advanced warning/alert system of air pollution in Japan

Japan has advanced an air pollution warning/alert system when the air quality becomes hazardous to public health. In Japanese " Air Pollution Control Law" developed in 1968, administrative measures for the emergent status of serious air pollution for five air pollutants (SOx, SPM), CO, NO_2 and Ox) were stipulated. Moreover, in 2013, the Ministry of the Environment of Japan (MOEJ) and local governments developed "Tentative Guideline on Raising Alert for $PM_{2.5}$ Air Pollution". Recently, warnings and alerts were issued/raised for Ox and $PM_{2.5}$ in Japan. The criteria of issuing warning, serious warning, and most serious warning of Ox are 120 ppb, 240 ppb, and 400 ppb (all hourly data), respectively. The national AAQS of Japan for Ox (developed in 1973) is 60 ppb (around 118 $\mu g/m^3$, hourly data). The criterion for raising $PM_{2.5}$ alert is 70$\mu g/m^3$ (daily average), which is twice the national AAQS (daily average: 35$\mu g/m^3$). Warnings for Ox, and/or alerts for $PM_{2.5}$ air pollution issued (or raised) by relevant local governments, are disseminated through television, radio, newspaper and internet to the people in the polluted area. The information on the warning/alert is also now automatically sent to registered individual mobile phone users. Real time issuing of Ox warning, serious warning and/or most serious warning is also shown on the website of the MOEJ (in Japanese) in the system of " Atmospheric Environmental Regional Observation System: AEROS" ("Soramame-kun"). Real time alert system for $PM_{2.5}$ air pollution is shown on the websites of the relevant local governments.

CO = Carbon monoxide; SOx = Sulfur oxides; SPM = Suspended Particulate Matter; Ox = Oxidants

Source: Japan Ministry of the Environment. (n.d.)

Box A1.4
Monitoring supersites for improved understanding of secondary particulate matter mechanisms in Japan, Republic of Korea, etc.

Particulate matter (PM) is both a primary pollutant directly emitted by sources and a secondary pollutant formed by complex atmospheric interactions of various pollutants from different sources. This duality makes PM level management and impact reduction even more complex. In addition to its adverse effects on public health, fine PM such as $PM_{2.5}$ also relates closely with environmental acidification as well as eutrophication, especially when sulfates and nitrates are its major components.

In order to measure the PM concentration and clarify its pollution mechanism, "supersites" for PM observational research have been established in some East Asian countries including Japan and Korea. These supersites were installed with sophisticated instruments such as high resolution-time of flight-aerosol mass spectrometer, scanning mobility particle counter, aerodynamic particle counter, single particle soot photometer and automatic ion analyzer, among others. These equipment are operated with high resolution-time in the supersites.

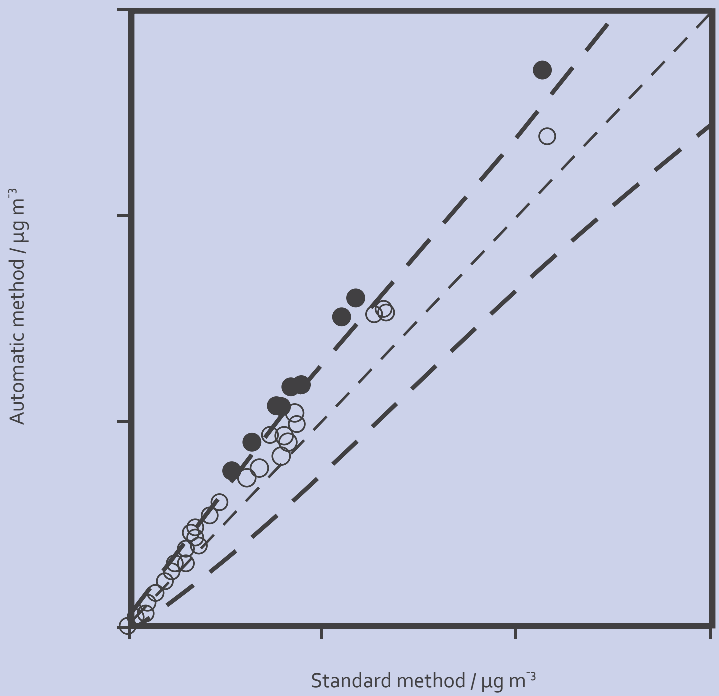
Comprehensive data are now being collected and analyzed to clarify the pollution mechanism of PM. While these equipment have largely been for domestic use, it is expected that they will contribute to a regional monitoring network and in the future, be utilized for a forecasting system of regional air pollution of $PM_{2.5}$.

. Source: Park Seung–Shik et al., 2014

Box A1.5
Necessity of equivalence assessment for an automated measuring equipment of $PM_{2.5}$ in Japan

It was stipulated in the notification of the Ambient Air Quality Standard of Japan that automated measuring equipment recognized to have equivalence to the standard measuring method should be used. The outline of the equivalence assessment test is described below.

It is advisable to conduct an equivalence assessment test for as broad a range as possible, covering both the low and high concentration ranges. Also, measurement of PM2.5 is affected by some phenomena – e.g., deliquescing of sulfates if the relative humidity is 80 percent or higher, and evaporation of nitrates at high temperatures. Taking these phenomena into account, it has been decided that periods and places chosen must characterize factors affecting the measurements of PM2.5. For this reason, it has been decided that the tests shall be conducted in summer and winter in urban and rural areas. The equivalence assessment of automated measuring equipment and the standard measuring method should follow the assessment method based on the QC techniques. The equivalence assessment is done by counting the number of the values outside the control limits drawn on both sides of the y=x diagonal. Errors between the values gained from the standard measuring method and those from the automated measuring equipment shall also be considered among the values gained from the standard measuring method plotted on the x-axis and those gained from the automated measuring equipment plotted on the y-axis (Figure 1). The maximum tolerable number of the values outside the control limits is calculated based on single sampling inspection plans having desired operating characteristics by variables.



Values measured based on the standard measuring method (µg/m³)

Figure 1 Image of equivalent test for automatic monitor

**Bold broken lines show control limit area. Open and closed circles show data within and out of acceptable range, respectively.*

Source: Asia Center for Air Pollution Research, 2015

ANNEX II. GUIDANCE AREA 2: EMISSIONS INVENTORIES AND MODELING

Basic information about emission factors (EF), source apportionment (SA) approaches, types of receptor-based models, types of dispersion models, capabilities of air quality monitoring and dispersion modeling, and factors leading to uncertainties in emissions inventories (EI) are provided below. A Toolbox with illustrative case studies for developing EI and SA is then presented covering management and technical processes.

A. Basic Information

Box A2.1
Available information sources for emission factors

- Compilation of emission factors AP-42 in the US Environmental Protection Agency (USEPA) Air CHIEF Programme (USEPA, 2015a; 2014b);
- Online database WebFIRE with emission factors for criteria pollutants and hazardous air pollutants (USEPA, 2015b);
- Motor Vehicles Emission Simulator (MOVES) (USEPA, 2015c);
- EEA – EU EMEP/CORINAIR emissions inventory (European Environment Agency [EEA], 2013; 2014);
- Handbook of Emission Factors for Road Transport (HBEFA, 2014);
- Manual and Workbook of the Global Atmospheric Pollution Form (GAPF, 2012):
- Rapid Inventory Assessment Technique (RIAS) developed by WHO (1993).
- Simple Integrated Model for Better Air Quality (SIM-air), primarily a training tool for a support system for decision making (Guttikunda, 2015).

Table A2.1 Properties of source apportionment approaches

Top-down SA Approach	Bottom-up SA Approach[1]
Measures ambient air pollution at receptor sites	Uses individual sources, processes to determine EFs and applies EFs and activity rates to estimate emissions
Compares elemental composition with source profiles	If source-specific EFs are not available, surrogate values are used
Uses receptor-based modelling	In order to estimate air pollutant concentrations at receptor sites dispersion (source-based) models are used, however, results must be validated by some monitoring
Needs lower computational requirements	Requires substantial financial resources to obtain high reliability

Source: European Commission, 2013

1 Equivalent to EI Approach

Table A2.2 Capabilities of air quality monitoring and dispersion modeling

Task	Air quality monitoring capability	Dispersion modelling capability
Spatial distributions	Yes, but only cost-effective if passive monitors are used	Yes
Temporal distributions	Yes, if automatic continuous monitors are employed or time resolution is sufficient	Yes, if continuous emission date and meteorological field data are available
Bottom-up source apportionment (source-oriented)	No	Yes
Top-down source apportionment (receptor-oriented)	Yes, if receptor monitoring and modelling are applied simultaneously	
"Exotic" compounds (e.g. gaseous mercury)	No if monitoring methodology does not exist or is too expensive	Yes
Realization of planned projects	No	Yes
Hot spot determination	Yes, with sufficient a-priori knowledge	Yes
Forecasting air quality	No	Yes
Estimating outdoor exposures	Yes, if personal monitors are applied	Yes, if time pattern of human activities is available
Estimating indoor exposures	Yes, if personal monitors are applied	No

Box A2.2
Available information sources for emission factors

- Compilation of emission factors AP-42 in the US Environmental Protection Agency (USEPA) Air CHIEF Programme (USEPA, 2015a; 2014b);
- Online database WebFIRE with emission factors for criteria pollutants and hazardous air pollutants (USEPA, 2015b);
- Motor Vehicles Emission Simulator (MOVES) (USEPA, 2015c);
- EEA – EU EMEP/CORINAIR emissions inventory (European Environment Agency [EEA], 2013; 2014);
- Handbook of Emission Factors for Road Transport (HBEFA, 2014);
- Manual and Workbook of the Global Atmospheric Pollution Form (GAPF, 2012):
- Rapid Inventory Assessment Technique (RIAS) developed by WHO (1993).
- Simple Integrated Model for Better Air Quality (SIM-air), primarily a training tool for a support system for decision making (Guttikunda, 2015).

Box A2.3
Available types of dispersion models

There are several types of models, which are of relevance in dispersion modeling:

i. Steady state: Meteorological variables such as wind speed, wind direction, turbulence, and others are assumed time-constant (e.g., CALINE3, ADMS-5, ADMS-Urban, ADMS-Roads, ISC3 (USEPA, 2014a);

ii. Non-steady state: Meteorological variables such as wind speed, wind direction, turbulence, and others are assumed time-varying (e.g., CALPUFF, HYROAD, PANACHE, SCIPUFF, EPISODE (USEPA, 2014a);

iii. Photochemical models: Simulations of pollutant concentrations in the atmosphere using a set of mathematical equations characterizing the chemical and physical processes in the atmosphere (e.g., Model-5/CMAQ (Community Multi-scale Air Quality), CAMx (Comprehensive Air quality model with Extensions), WRF-Chem (Weather Research and Forecasting model coupled with Chemistry), and many others (USEPA, 2013b; National Center for Atmospheric Research, 2015); and screening models: simplified models that are useful for initial assessments, determining a stack height, rapid assessments, and emergency planning (Cambridge Environmental Research Consultants 2015).

Box A2.4
Factors leading to uncertainties in emissions inventory

Emissions inventory uncertainties are due to structural inaccuracy and input value inaccuracy. They include, but are not limited to:

- Lack of information about the emission processes and the variability of emissions on the required spatial and temporal aggregation level;
- Emission sources may be missing due to misunderstanding of the emission process;
- The mathematical formulation in an EI may be wrong if the assumed linear relationship between emissions and activities is not warranted;
- Emission factors, which are derived through limited measurements, may not provide realistic estimates. Moreover, dependence on international EFs in the absence of local ones may further add to EI uncertainty;
- Extensive use of secondary information, which itself may have uncertainty, results in EI uncertainty. Similarly, limited primary surveys on activity data may also fail to represent real-life situations (e.g., in the case of vehicles, data on actual numbers, kilometer traveled, and age, among others, may have numerous uncertainties);
- Lack of unified source classification scheme across countries, across regions within a country, or even across cities within a region, leading to difficulties in emission comparison and in support of regional modeling study. This limitation can be overcome by the use of the UN International Standard Industrial Classification of all economic activities or the CORINAIR Selected Nomenclature for sources of Air Pollution (UN, 2008; EEA, 1999);
- Lack of well-organized domestic source-based chemical compositions, leading to poorly characterized PM and Volatile organic compounds (VOC) speciation;
- Untimely update of EI and non-indication of changes in emissions arising from rapid economic growth and control measures implemented recently;
- Lack of independent assessment of the reliability and uncertainty analysis of EIs for further improvement;
- Lack of necessary framework or mechanism for regular updating of information (e.g., changes in economic activities or implementation in control measures) that may be required for updating of EI; and
- Incomplete understanding of developments in the future make emission scenarios inaccurate

Box A2.5
Case study for CO_2 reduction in the transport sector in Japan and worldwide

Objective

To reduce road-transport carbon dioxide (CO_2) emissions worldwide through application of four "best practice" approaches utilized in Japan: (1) improvement of fuel efficiency; (2) effective utilization of motor vehicles; (3) improvement of traffic flow; and (4) diversification of automobile energy involving auto manufacturers, government, fuel suppliers, and vehicle users.

Methods

Use of a top-down EI approach for the calculation of CO_2 emissions (E_{CO_2}) in road transport as the product of emission intensity (E_{int}) and activity volume (A_{vol}) through sequential equations:

$$E_{CO_2} = E_{int} * A_{vol}$$

Emission intensity Eint is calculated as the product of on-road fuel efficiency (E_{orf}) and the CO_2 emissions coefficient (E_{coeff}) in units [g CO_2/l]:

$$E_{int} = E_{orf} * E_{coeff}$$

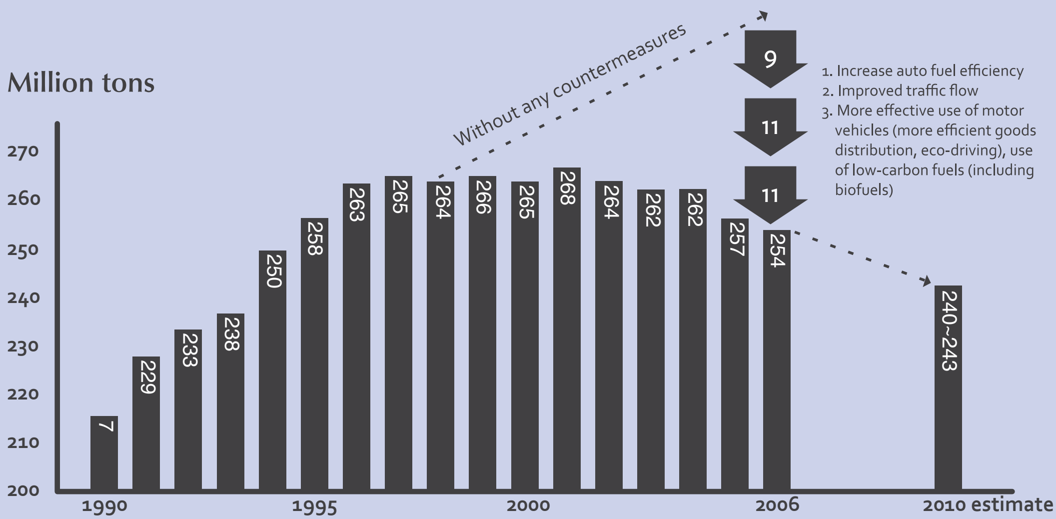
Activity volume is calculated as the product of the number of vehicles and vehicle kilometers travelled VKT [vehicle-km]. On-road fuel efficiency (E_{orf}) is calculated as the product of the certified fuel efficiency (CFE) in units [km/l] and a travelling coefficient (T_{coeff}), which is a measure of congestion and extent of eco-driving:

$$E_{orf} = CFE * T_{coeff}$$

Results

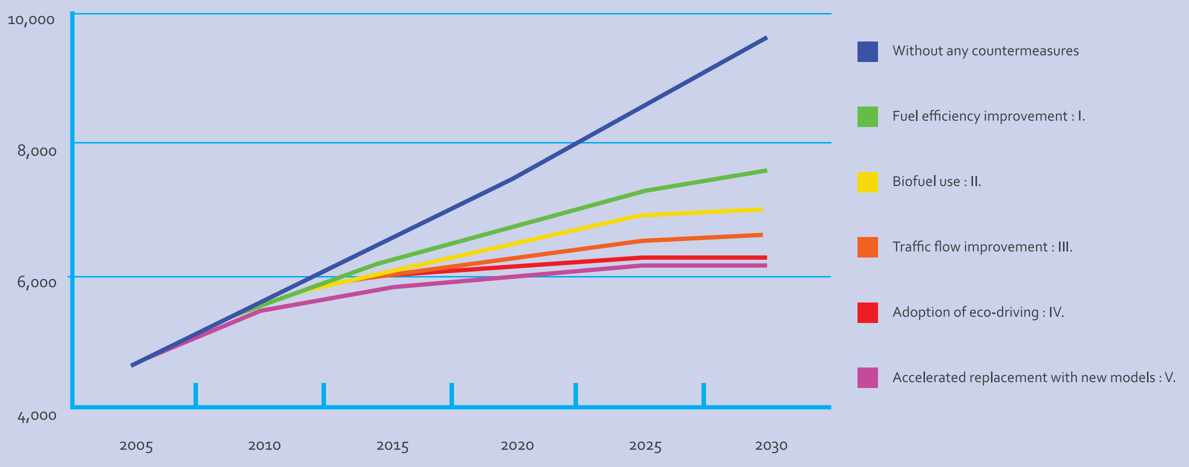
In Japan's transport sector, the CO_2 emission peaked in 2001 and declined since then (see figure below)

CO_2 Emissions in Japan's Transport Sector



The projection of CO_2 emissions in the global transport sector between 2010 and 2030 through implementation of best practices - fuel efficiency improvement, alternative fuel use, traffic flow improvement, adoption of eco driving, and accelerated model replacement is shown in the figure below, showing a high potential for a dramatic reduction of CO_2.

(Million tons CO_2) A Case Study: CO_2 Reduction Potential In the World's Road Transport Sector



Source: Sasanouchi, 2008

B. ToolBox: Establishing emissions inventory, source apportionment and dispersion modeling for Asian cities

Management process

The development processes of EI and SA begin with identifying the objective and scope, the organization of key implementers, assessment of resources, and dissemination of results to relevant stakeholders.

Step 1. Define objectives and scope
The first step in the management process is to clearly define the objectives and scope, which may address the geographical domain (city/regional/national level), extent of details (e.g., inclusion of only major source categories such as industries, automobiles, domestic cooking and heating, etc.), and pollutants PM, SO_2, greenhouse gases (GHGs), etc.).

Step 2. Identify and involve stakeholders
All major stakeholders should be involved, particularly those who are potential sources for data (e.g., transport department, academic experts, among others). Stakeholder involvement is essential in developing emission reduction action plans. Lack of stakeholder participation could be resolved through the establishment of a cooperation framework by the local or national government among the technical team, data providers, and experts to set up a stable inventory system. The Ministry of Environment should lead this activity.

Step 3. Allocate financial resources
Adequate financial resources must be allocated to support field campaigns, required human resources, database management, among others. City governments can work with a local environmental protection agency and other organizations to gain access to additional training and possible funding. City-level initiatives should be aligned with the national development agenda wherein the EI and SA processes can be institutionalized to ensure continuity of the analysis.

Step 4. Organize a technical team to develop a sophisticated EI and SA
The technical team, to be led by the local government and must be carefully chosen to secure guidance on various relevant aspects (e.g., a statistician may advise on size of

sample surveys, academe can provide inputs on newer developments and data evaluation techniques). For less sophisticated EIs such as the GAPF or the WHO RIAS, one expert will be sufficient for all types of sources. The team should include experts (at least one or more, as needed) on emissions of industrial manufacturing (three or four);

- power plants
- transport issues
- Other sources
- air pollution monitoring
- dispersion modeling
- receptor-based modeling
- statistics
- data analysis

Step 5. Set up a communication strategy
Results of the EI and SA should be disseminated among all stakeholders to achieve recommendations for the development of CAAPs. This also contributes to strengthen the use of EI and SA in developing strategies to address major air pollutant challenges.

Technical process

Part I. Setting up an emissions inventory

Building and compiling an EI includes several steps. This section describes the general process of developing an emission inventory (GAPF, 2012; ACAP, 2011; SEI, 2008).

Step 1. Designing an inventory
The first step in compiling the EI is to determine the objective and design. This step includes the definition and selection of the target area (e.g., city, province) and the pollutants of concern. Box A2.5 describes the Clean Air for Smaller Cities Project with focus on developing EI guidelines and formulating EIs for medium-sized cities. Generally, the target species of EI include the criteria pollutants such as SOx, nitrogen oxides (NOx), CO, and TSPs, VOCs, and GHGs such as CO_2, methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs), perfluorinated compounds (PFCs) and sulfur hexafluoride (SF_6). As indicated in Chapter 3 - Table 3.4, the criteria pollutants should be targeted at the underdeveloped stage of the development of national, provincial, or city level EIs. As the development progresses, GHGs and toxic air pollutants should be included.

The objective of the inventory will determine the EI approach, the requested accuracy and/or reliability, spatial distribution, and temporal change may vary. An EI generally determines total air pollutant emissions in a predefined period (e.g., annually or every two years) in a target area and is the basis for developing policies addressing emissions within the framework of AQM. If the EI is designed for planning and selection of mitigation technologies, the spatial resolution should be at each technology level (e.g., type of boiler, incinerator, and emission control devices). For EIs designed to provide data to a simulation model, spatial distribution should be at a grid level (e.g., area sources), line level (roads or road segments), and point level (e.g. large industrial facilities and power plants).

Examples of the classification of source categories and sub-categories are shown in Box A2.6. The emission sources in the target area and the detailed procedure should be considered through survey of the existing EIs (if available), peer reviewed academic papers, national documents, and local knowledge and expertise. The first priority should be given to key sources, which are those with the largest emissions. However, sources with smaller emissions of a highly toxic compound (e.g. dioxins) may also be given a high priority. For this reason, prioritization of sources may be achieved by use of information on the toxicity of emitted compounds in addition to emitted masses of pollutants[2]. Source prioritization has to be made by judicious assessment of expected impacts. For example, ground level sources with high emission rates may get priority over elevated sources with similar emission rates.

2 This was the procedure used in the Northrhine Westphalian clean air implementation plans in the 1980s.

Box A2.6
The Clean Air for Smaller Cities Project

The ASEAN – German Technical Cooperation agreed on a project 'Clean Air for Smaller Cities in the ASEAN Region' (CASC) to be implemented in collaboration with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) between 2009 and 2015. The objective of the project is to support medium-sized cities in the ASEAN in developing and implementing 'clean air plans' (CAPs) to improve air quality and support sustainable urban development. Participating countries include Cambodia, Indonesia, Lao PDR, Malaysia, the Philippines, Thailand, Vietnam and Myanmar.

The project has succeeded in:

- Conducting 'Vision and Goal' workshops for clean air and subsequent public participation meetings in 6 cities;
- Organizing national and ASEAN-wide workshops on AQM issues;
- Providing input on the formulation of criteria for environmentally sustainable urban development on the ASEAN level
- Developing and implementing air quality monitoring strategies for 11 cities;
- Developing Clean Air Plans for 6 cities;
- Elaborating immediate action plans in urban transport for 5 cities
- Developing guidelines for EIs and clean air planning; and
- Formulating EIs for 11 cities

The EIs for 6 cities have been completed:

- Chiang Mai, Nakorn Ratchasima (Korat) in Thailand;
- Palembang, Surakarta (Solo) in Indonesia;
- Iloilo, and Cagayan de Oro in Philippines.

The EIs for Melaka (Malaysia), Vientiane (Lao PDR), Bac Ninh, Can Tho (Vietnam), and Phnom Penh (Cambodia), are expected to be completed in 2015. All EI teams (contracted local consultants) followed the same methodology and received technical advice from CASC's contracted international experts. The CASC has established a standardized modular training system on AQM called 'Train for Clean Air' (T4CA). The target audience includes decision makers, technical staff, non-governmental organizations and the media.

Source: GIZ, 2015

Box A2.7
Emission source category

Examples of source categories are shown in the following table. The classification in this table is based on the Guidelines for Developing Emission Inventory (ACAP, 2011). Some emission sources are classified into different categories, depending on the definition in a document (e.g. in Intergovernmental Panel for Climate Change [IPCC] 2006), the source categories are classified into Energy, Industrial Process and Product Use, Agricultural, Forestry and other Land Use, and Waste). Double counting may occur when several documents are referred to as sources and should be noted by the EI compilers. Alternative source classifications are published by UN (2008) and European Environment Agency (EEA) (1999).

Source Category	Description of Category
Fuel consumption (Stationary Sources)	Emissions from stationary combustion of fuels for energy classified into several sub-categories: power plant, energy transformation, industry and others (commercial/ facility, residential houses and agriculture/forestry/fishery)
Fuel consumption (Mobile Sources)	Emissions from fuel consumption for transportation such as cars, aircraft, vessels, and trains
Fugitive emission sources	Emissions from non-combustion of fuels including extraction, processing, storage, transportation and its usage
Industrial process	Emissions from industrial processes (e.g. chemical industry, metal industry, pulp and paper industry, and drink/food products industry) using coal and cokes as raw materials or reducing agent; the emission from combustion in industrial process is included in the combustion category and not in this category
Solvent and other products	Emissions from the usage of solvent and other products containing VOCs (e.g. painting, adhesives, glue, dry-cleaning and specific chemical product manufacturing categories)
Agricultural activities	Emissions from livestock breeding, savanna fires (both intentional and accidental fires), burning of agricultural carcass and fertilizer usage categories
Forest fire	Emissions from forest and natural grassland (except savanna), either from human or natural causes
Waste Treatment	Emissions from general waste, industrial waste and toxic waste (medical waste) incinerated emissions; main sub-categories are waste incineration and open burning
Natural Sources	Emissions from non-methane volatile organic compounds (NMVOCs) from vegetation, SOx from volcanic activities, and NOx and ammonia (NH_3) from soil

Step 2. Data Collection

Default EFs given by manuals and documents published by international organizations and institutions (e.g., AP-42 by USEPA) can be used for an initial inventory for non-key sources. However, before adapting such default EFs for key sources, a thorough review for their applicability should be undertaken (ACAP, 2011). For example, EFs may be available for controlled and uncontrolled emissions for coal-fueled boilers. If the level of control for boilers in the study area is different from the one used for EF, then uncontrolled EF corrected for efficiency of control system in use, can be applied. Rationale for selection of EF may be documented.

To improve the inventory, local EF and/or actual measurements (e.g., emission monitoring data for testing compliance with emission standards), if available, may be preferred (Box A2.7).

Activity rate for industries can basically be collected from national statistics and surveys if no information is available on activities from emission declarations of industrial managers. Basic information about the population, transportation, industry, fuels and other information can be used to calculate preliminary emission estimates as surrogate parameters.

Reliable data may also be available for some component of an EI (e.g., for some industrial sites from measurements of stack emissions). In other cases, emissions can be calculated from estimates of process inputs.

Established international air quality models may be adapted to suit local conditions necessary to acquire more rational emission results. Localization of international air quality models is achieved by taking into account the different operating conditions, fuels, and resource materials (SEI, 2008) that have implications on the total emissions from a specific source. Emission forecasts can provide important information for setting air pollution prevention plan (ACAP, 2011). The WHO and the GAPF developed sources of information on how to prepare rapid EIs.

At the maturing and fully developed stages of AQM (Chapter 3 - Table 3.2), it is preferable to obtain the data from the actual situation through direct measurement with experts. Such a survey can be very resource-demanding and should be made in collaboration with experts and other relevant stakeholders (i.e., private sector, local government, and non-government organizations, etc.).

Box A2.8
Road traffic emissions inventory in Ho Chi Minh City

Objective

To evaluate an inventory for vehicle emissions in Ho Chi Minh City (HCMC) and compare the results of Business as Usual (BAU) scenarios for 2015 and 2020 with emission reduction scenarios.

Methods

Emissions of traffic are estimated with the EMISENS model. This model uses a methodology based on an EI top-down and bottom-up approach; computes emission and uncertainties of input parameters by Monte Carlo method; the model formulation is based on COPERT IV. Traffic flow was manually counted in different streets of HCMC. Five vehicle categories were defined: cars, light trucks, heavy trucks, buses, and motorcycles. Streets were grouped in three main categories: highway, urban, rural; urban streets were subdivided in three subgroups: main urban, suburban, industrial. Emission factors for NOx, CO, and NMVOC were taken from a study in HCMC. The EF for SO_2 was taken from a China study. The default EF of COPERT IV for NH_4 was used. The hourly street mileage was estimated as the product of street length and the vehicle flow for each vehicle category. Space and time distributions of hourly street mileages and spatial distributions for the number of vehicles and the number of trips per vehicle category were created with appropriate software. The BAU scenario for 2015 assumes a per year increase of motorcycles by 5.4 percent and automobile of 14.5 percent. Same per year increases were assumed for BAU in 2020. In addition, the increase of bus numbers were assumed to be 3000 in 2015 and 4500 in 2020. Emission reductions in 2015 are assumed to be 30 percent, 20 percent, and 19 percent for cars, buses, and trucks, respectively; in addition, metro line usage was assumed to replace 25 percent of motorcycles. In the 2020 scenario, metro line usage was assumed to replace 50 percent of the total number of motorcycles

Results

The publication is a work in progress. The fleet distribution is characterized as follows: 92 percent motorcycles, 3.5 percent cars, 2.8 percent light trucks, 1.1 percent heavy trucks, 0.1 percent buses. Hourly street mileage and EFs are responsible for the largest part of uncertainty. Motorcycles are the main sources of traffic emissions, contributing 94 percent of CO, 68 percent of NMVOC, 61 percent of SO_2, and 99 percent of CH_4 (see Table below). If motorcycles will be reduced by metro line usage as assumed, the emissions should have been reduced by 10 percent in 2015.

Pollutant	Total emission [ton/hour]	Motorcycle emission [ton/hour]	Total uncertainty [%]
NOx	3.4	-	20
CO	331.4	311.5	34
SO2	0.7	0.4	27
NMVOC	46.2	31.4	28
CH4	2.0	2.0	50

Source: Ho & Clappier, 2011

Step 3: Calculation

Emissions of air pollutants are calculated using EF, activity rate, and abatement of emissions, as shown in Box A2.8.

As noted in Chapter 3 Issues and Challenges section, emission calculation often requires the technical knowledge of emission sources. In that case, the GAPF Air Pollutant Emission Inventory Manual includes an Excel-based workbook template, which is intended to provide a structure for input activity rate and EF, areas for calculation of intermediate and final emissions, areas for tabular reporting of results, and areas for annotations of data sets for accomplishing inventory preparation functions. The IPCC also developed the software for implementing the simplest methods, which is included in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Step 4: QA/QC procedure

Even a well-organized EI is subject to uncertainty (Box A2.9). The QA/QC procedures for all EI components – such as the use of secondary data, primary activity rate, EF, random calculation checks, and comparison with other EFs and existing EI – must be established and applied with the documented uncertainties. The principles for QA/QC developed by IPCC (2006) are also generally applicable to non- GHG inventories.

Box A2.9
Calculation of emission

Emissions of air pollutants are calculated using EF, activity rate, and recovery of emissions, as shown in equation (1) (USEPA, 1999-2015). Abatement recovery can be taken into account by applying a different technology-specific EF. For some sectors, the equation is more complex than equation (1) and includes more than one EF or type of activity rate.

$$\text{Emission} = EF \bullet A \bullet (1-R/100) \quad \text{Eq.(1)}$$

EF: Emission Factor for the uncontrolled process. Emission factors are the average rate of emission of a pollutant per unit of activity for a given source. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant. For a coal-fired power plant, the unit of EF is kg of emitted PM divided by tonne of coal. For a vehicle, the unit of EF is kg of PM/1000 km or kg of PM per tonne of fuel.

A: Activity rate which indicates the extent of activity causing emissions per time unit (e.g. year).

R: Recovery = Control efficiency which refers to the level of pollutant that a particular control device produces.

Box A2.10
Quantification of uncertainties of a bottom-up emissions inventory in China

Objective

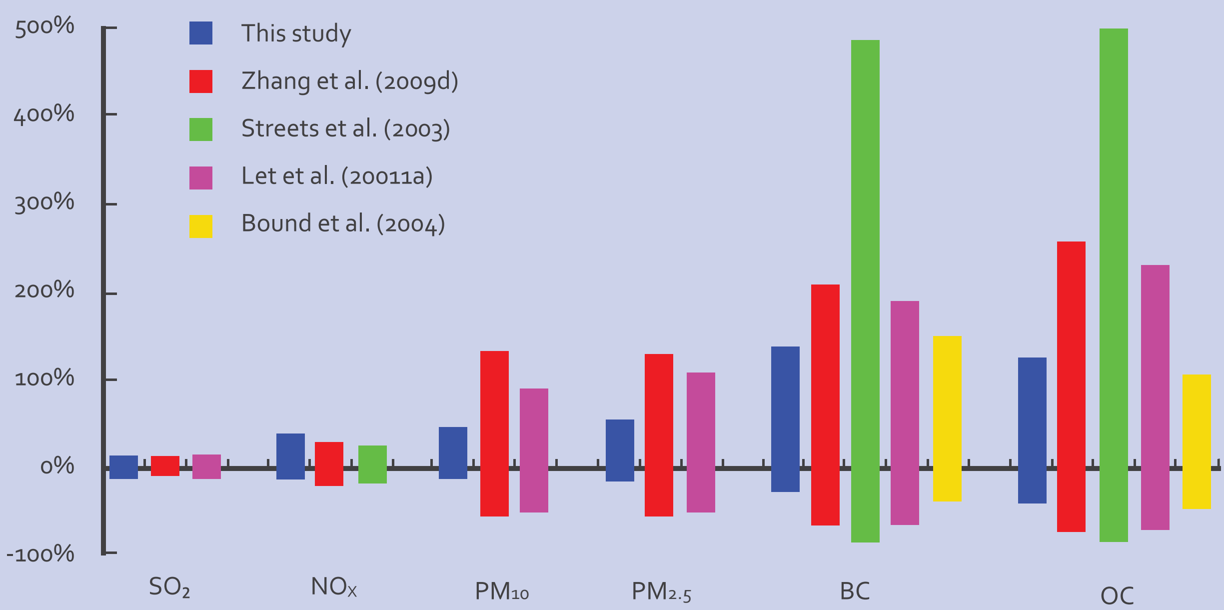
To evaluate the uncertainties (expressed as the 95 percent confidence interval (CI) around the central estimate) of a bottom-up EI of SO_2, NOx, total PM, PM_{10}, $PM_{2.5}$, black carbon (BC), and organic carbon (OC) from all anthropogenic sources in China.

Methods

Emissions from stationary sources are evaluated from activity level, unabated EF, penetration rate of emission control technology, and the removal efficiency for each species, province, sector, fuel type, and emission control technology, respectively. In addition, the sulfur content of fuel is also considered for SO_2; for PM the ash content, the ash release ratio and the size particle fraction are included in the emission calculations. The uncertainties of activity levels, penetrations of different technologies, emission factors, and PM size distributions, carbonaceous fractions of PM, and removal efficiencies in building up the emissions inventory are estimated using Monte Carlo calculations. A sensitivity analysis was also conducted to determine the reliability of the uncertainty estimation.

Results

The EI uncertainties of the study as compared with previous studies without Monte Carlo estimations are shown in the figure. Estimated uncertainty ranges for SO_2 and NOx are very similar among all available studies. The Monte Carlo-estimated uncertainties for the other compounds are significantly smaller than those found in the previous studies.



Source: Zhao et al., 2011

Step 5: Publication
Outputs from EIs can be published and presented using several styles. For transparency and comparability, the output should be reported in a manner uniform with other inventories. The IPCC Guidelines for National Greenhouse Gas Inventories provide one format of reporting. Supporting data and assumptions in emissions calculation are important for data comparability and transparency, and should be documented.

Part 2. Source Apportionment (Receptor-based modeling)

To progress through the roadmap (Chapter 3 - Table 3.2), cities should have the capability of making PM speciation measurement and conducting EI and receptor modeling. Model settings need to be localized as much as possible. Source apportionment results need to be revisited in a timely manner, with the frequency and coverage an important factor determining the stage of development. Source apportionment by EI and receptor modeling is a systematic project that needs strong financial support, professional management and technical coordination among different parties concerned. In order to fulfill a successful Source apportionment, cities should conduct the following:

Step 1: Define methodological framework
Major components of the methodological framework include selection of model, input data requirements, sampling and analytical protocols, process data QA/QC and checks, data handling, analysis, interpretation, and dissemination.

Receptor models use pollutant concentration data to estimate source contribution whereas dispersion models use emissions, meteorological data, and chemical transformation to estimate pollutant concentrations. Receptor models use chemical and physical characteristics of pollutants in source emissions and ambient concentrations, and analyze mass balance to quantify SA. Receptor modeling approach can be applied only for those pollutants (e.g., $PM_{2.5}$, PM_{10}, and VOCs), which have distinct source-specific chemical characteristics (e.g., road dust PM_{10} emissions may contain high fraction of silica compared to combustion sources that may have high carbon constituents). Receptor models do not require meteorological data as input, and only need chemically-speciated ambient pollutant concentration values and different source emissions in the area (known as source profiles). Receptor models that require good laboratory facilities for analyzing various chemical species can guide broader strategies and resource allocations to deal with major source types. Types of receptor models are provided in Box A2.10.

Application of receptor modeling for SA and choice of model would depend on pollutant(s) of concern (e.g., $PM_{2.5}$, PM_{10}; not for SO_2), data constraints (e.g., no meteorological data available; availability of source profiles), and resources. The CMB8 model can be used even for one sample (although it will be appropriate to use it for multiple samples representing temporal and spatial variations of the study area), whereas the two other models require a matrix of a large number of samples. Similarly, in the absence of source emission profiles, PMF or UNMIX may be used. Box A2.11 shows the results of a PMF application in Xi'an, PR China.

Box A2.11
Types of receptor-based models

i. ENVIRON (2013) has developed a reactive tracer method for PM SA called PM SA Technology (PSAT). PSAT has been implemented in the Comprehensive Air Quality Model with extensions (CAMx) system to provide SA for primary and secondary PM species to geographic source regions, emissions source categories, and individual sources (ENVIRON, 2013). Information on PM SA from PSAT can be used for assessments to identify what sources contribute significantly to PM and visibility problems. In general, PSAT helps to understand model performance and improve model inputs/structure; identify which sources contribute significantly to air pollution; and design the most suitable and cost-effective PM control strategies (Yarwood et al., 2007).

ii. USEPA (2013) advocates the chemical mass balance (CMB) model – based on source emission profiles – and two models which generate source profiles from ambient air pollutant concentrations – UNMIX and Positive Matrix Factorization. The USEPA-CMB model (version 8.2, CMB8) quantifies the contributions from chemically distinct source-types by requiring speciated profiles of potentially contributing sources and the corresponding ambient data from analyzed samples collected at receptor sites. The source code of the model and a users' manual is available free of charge (USEPA, 2010).

iii. The USEPA UNMIX model (version 6.0) estimates the number of sources, source compositions and source contributions to each given sample of PM concentrations of chemical species measured in the ambient air of a receptor location. Chemical profiles of the sources are generated internally from the ambient data, using a form of factor analysis (USEPA, 2014c); thus, identifying sources without source profiles.

iv. The USEPA PMF model is a mathematical receptor-based model that provides scientific support for exposure research and a wide range of air pollution data analyses. The PMF model reduces the large number of elemental compounds in air samples to interpretable factors (i.e. source types) with a robust uncertainty estimate. The latest version of USEPA PMF version 5 is available for download together with a user's guide (USEPA, 2014d). A document which discusses the PMF methodology titled "EPA positive matrix factorization 5.0 fundamentals and user guide" is also available for download (USEPA, 2014e).

Step 2. Implementing receptor-based modeling techniques
Stage-specific recommended steps are provided for cities to progress through the roadmap of SA (Chapter 3 Table 3.2)

Guidelines for Developing Stage of AQM:

i. A proper planning of ambient sampling and analysis is the first step; monitoring locations, frequency, and number of samples may judiciously be decided so as to capture temporal, spatial and activity variations. The air pollution hotspots, residential areas with exposure potential, and areas of special interest (e.g., background, ecological sensitive area) are considered possible monitoring locations.

ii. Selection of chemical species for analysis should include key species expected from sources in the area (e.g., K^+ from vegetative burning). In the case of CMB application, species measured in ambient samples should match with the source profiles (e.g., if species "Hg" is not included in source profiles, its measurement in ambient samples may not be of much use). Generally, EC, OC, elements, and ions are measured if adequate for SA of $PM_{2.5}$ and PM_{10}. Analyzing molecular markers (which are signature species for a particular source type (e.g., stigmasterol for biomass burning), provided it is included in source profiles), if possible, may be useful. However, analysis of molecular markers requires specialized instrumentation and skills. A good laboratory facility that can analyze required chemical species needs to be identified. In such cases wherein a laboratory is not available locally, analytical work could be outsourced to a reputed laboratory.

iii. Detailed standard operating procedures (SOPs) and QA/QC must be prepared and followed to ensure data quality. All possible sources of artifacts and performance checks may be incorporated to minimize errors (e.g., even selection and handling of filter papers may be source of error). Personnel involved must be adequately trained for their respective jobs, and SOPs should be available where measurements are done.

Guidelines for Emerging Stage of AQM:

i. Selection of source profiles and species are important for receptor model run evaluated with CMB. Source profiles may be evaluated for their suitability. Sources with co-linear profiles may be examined for appropriate use. The species that exhibit co-linearity may be excluded or source profiles may be grouped together to generate new profiles. For example, if EC fraction in diesel vehicle and diesel generator sets are

Box A2.12
PMF analysis of PM1 in Xi'an, China

Objective

To evaluate PM_1 concentrations at Xi'an as well as concentrations of water-soluble inorganic (ws-i) ions, organic carbon (OC), and elemental carbon (EC).

Methods

24-h PM_1 filter samples were collected in winter 2007/2008, in summer and autumn 2008 using a MiniVol sampler (total 123 samples). Aerosol mass loading were determined gravimetrically, using a standard operating procedure. One fourth of each filter sample was used to determine the mass concentration of ws-i ions (SO_4^{2-}, NO^{3-}, Cl^-, F^-, Na^+, NH_4^+, K^+, Mg^{2+}, and Ca^{2+}). In addition, PM_1 sample filters were analyzed for EC and OC with the use of a Desert Research Institute thermal and optical analyzer. Source apportionment by PMF was performed for ws-i ions and carbonaceous species.

Results

The annual arithmetic mean PM_1 concentration was 127 µg/m³ exceeding the WHO $PM_{2.5}$ guideline value by a factor of 12.7. All PM_1 samples but one exceeded the WHO 24-h $PM_{2.5}$ guideline values by an order of magnitude. The annual averaged ws-i ion concentration was 48 µg/m³, accounting for almost 39% of the measured PM_1 mass. Carbonaceous aerosol and an unidentified fraction, suggested to be mineral dust contributed 30% each. The PMF analysis of EC and OC species and ws-i ions apportioned 30%, 21%, 17%, 15%, 9%, and 8% of PM_1 mass to secondary aerosols, coal combustion, gasoline exhaust, re-suspended dust, diesel exhaust, and biomass burning, respectively.

Ca^{2+} = Calcium; Cl^- = Chloride; Fl^- = Fluoride; K^+ = Potassium; Mg^{2+} = Magnesium; Na^+ = Sodium; NH_4^+ = Ammonium; NO^{3-} = Nitrate; SO_4^{2-} = Sulfate

Source: Shen et al., 2010

identical, exclusion of EC may be considered or profiles for diesel vehicles and generator sets may be combined together (average of two) to get a new profile of diesel combustion. Contribution of diesel combustion thus obtained may then be distributed to vehicle and generator set in proportion to their emission quantities. Species that have low abundances and high measurement uncertainties may also be excluded. As such, selection of input parameters for the model run should be based on local experience and scientific judgment.

ii. Model output should be evaluated using statistical tools, which are defined in guide manuals. A good model fit (which provides adequate solution to mass balance equations, and explains source contributions reasonably well) may be considered. When the data comes from multiple monitoring locations, the result may either be averaged to obtain overall SA in the study area or dealt separately to obtain contribution range and site-specific SA. The obtained SA results can form the basis for developing AQM plans.

Guidelines for Maturing Stage of AQM:

i. An integrated database on (i) sources in the area, (ii) source profiles, and (iii) ambient measurements may be developed. Emission quantity estimates, though not necessary for applying receptor model, may be useful in interpretation of results. Source profile database (e.g. SPECIATE database by USEPA, Indian source profiles for stationary and vehicular sources by the Central Pollution Control Board) may include local (if available) as well as reported (from literature) profiles for the desired sources and species. Database on ambient samples for all the measured species and their uncertainties, as per the model input format, may be prepared. Data validation checks (e.g., plotting cation versus anion; total measured mass versus restructured mass using sum of species) may be performed to assess data quality.

ii. For more reliable SA, local emission profiles may be developed for sources of concern; a database on source-profiles established, periodically reviewed and improved. Source apportionment studies may be performed at predefined intervals, during pollution episodes, or whenever significant changes in source contributions are expected due to implementation of mitigation measures and/or variations in types and extent of source emissions.

Guidelines for Fully-developed Stage of AQM:

- Conduct parallel PM sampling at multiple sites. Source apportionment by receptor modeling needs parallel measurement of PM components at multiple stations within the territory of a city. In order to more accurately depict the pollution characteristics of a city, stations shall be setup to cover areas with different environmental backgrounds or emission characteristics. Multiple high-volume samplers and multi-channel mid-volume samplers with different filter substrates are usually required to measure different components of PM. Stringent sampler calibration and inter-comparison shall be made prior to the sampling campaign to avoid any systematic error inherent in the samplers. A well-trained sampling team is needed to perform sampling tasks simultaneously at multiple sites. A detailed sampling plan is needed with back-up scheme in case of unexpected incidents at some or all stations. A detailed SOP is required to make sure all teams are following the same sampling protocol. The SOPs shall include, but are not be limited to, operation and maintenance of the sampler, treatment and storage of samples, data management and data backup, QA/QC, incident response, etc. It is suggested to refer to USEPA's "Guideline on Speciated Particulate Monitoring", "Particulate Matter ($PM_{2.5}$) Speciation Guidance", and "Quality Assurance Guidance Document 2.12" (USEPA, 1998). Calibration and traceability chains shall be established. To better characterize sampling uncertainties, at least 10% of collocated, duplicated, and blank sampling shall be conducted (Hyslop and White, 2008).

- Conduct SA with multiple receptor models. Principal Component Analysis (PCA), PMF and UNMIX shall be conducted for SA analysis. Pros and cons of each model shall be recognized and differences among SA results, if any, shall be interpreted. To improve the reliability and robustness of the results, receptor modeling results should be compared with source models wherever necessary for verification.

- Conduct three-dimensional air quality modeling and validate with receptor modeling. With the establishment of local EI, cities should establish integrated numerical modeling system comprised of three modules: emission, meteorology, and chemistry transport. Some widely used modules, such as the Weather Research and Forecast model, Sparse Matrix Operator Kernel Emissions Processing System, CAMx, etc. can be used for all or any modules in the modeling system. Modeling system shall be set up on a nested domain with the coarsest grid size of no more than 100km in each horizontal direction and the finest grid size of no more than 5km. The system should be upgraded regularly for any areas for improvement identified (e.g., domain, physics options, chemistry mechanism, parametric setting). The system shall have the capability to make SA into different cities and source categories. Developing such a modeling system is time-consuming and needs technical accumulation for years if not decades. An experienced team shall be formed to regularly examine the results and make adjustment or refine model settings. This is to make the simulations more reliable and closer to observations wherever available. Hardware requirement is also stringent if such a system is to be operationalized with the ability of making air quality forecasts or quick SA analysis. Source apportionment results from air quality models shall be validated by the receptor modeling results. Discrepancies between the results shall be interpreted so as to gradually improve the SA results.

ANNEX III. GUIDANCE AREA 3: HEALTH AND OTHER IMPACTS

A. Co-benefits of air pollution abatement and climate change mitigation

A wealth of information on the co-benefits of linking air pollution control and GHG reduction is already available. A United Nations Environment Programme/World Meteorological Organization (UNEP/WMO) report has recently compiled scientific studies (Table A3.1) that have shown that reductions of emissions of short-lived climate pollutants (SLCPs) can potentially prevent millions of premature deaths.

To enable effective policy decisions that integrate air pollution control and climate change mitigation, this information has to be compiled strategically (Van Aardenne, 2012), taking care to highlight co-benefits in terms of cost savings (i.e. identify potential trade-offs such as unwanted effects and inefficient policy; make issues understandable to policymakers, and so on) and focus on local assessments and action.

Table A3.1 Actions to reduce emissions of air pollutants linked to climate change

		Percent reduction in global emissions (all sectors) due to measure					
Measures	Regions	BC	OC	$PM_{2.5}$	CO	CH_4	NO_x
Improved stoves	Africa, Asia	9	51	26	21	2	0
Pellet stoves	North America, Europe	3	2	1.4	0.3	0	0
Coal briquettes	Global	6.8	1.7	1.9	2	0	0
Diesel Particulate Filters	North America, Europe, Asia & Pacific	18	3	4	1	0	24
Modern recovery coke ovens; Vertical shaft and Hoffman brick kilns; Particle control at stationary engines	Asia & Pacific	4.2	2.6	1.9	0.6	0	0
No biomass cook stoves	Africa & Asia	35	55	31	28	0	0
No high-emitting vehicles	Africa & Asia	1.6	0.7	0.6	6.2	0	5
No open burning agricultural waste	Africa & Asia	7	11	9	6	1	0

Measures	Regions	Percent reduction in global emissions (all sectors) due to measure					
		BC	OC	$PM_{2.5}$	CO	CH_4	NO_x
Extended recovery of coal mine gas	East, Southeast Asia & Pacific						
Extended recovery and flaring for oil and gas production	All regions	0	0	0	0	25	0
Reduced leakage from gas pipeline processors							
Treatment of biodegradable municipal waste	North America, Europe, Asia	0	0	0	0	9	0
Upgrading primary waste-water treatment							
Control of methane emissions from livestock	All regions	0	0	0	0	4	0
Aeration of continuously flooded rice paddies	Asia						

BC = Black Carbon; CH_4 = methane; CO = Carbon Monoxide; OC = Organic Carbon; $PM_{2.5}$ = Particulate Matter ≤ 2.5 µm aerodynamic diameter; NO_x = Nitrogen Oxides. Adapted from UNEP/WMO, 2011

B. Case studies on estimating co-benefits of addressing air pollution and climate change

The Climate and Health Alliance (CAHA) and the Climate Institute have estimated the benefits of preventing chronic respiratory and cardiovascular diseases associated with carbon-intensive lifestyles in Australia (CAHA, 2012). For example, coal-fired power in Australia burdens the community with a human health cost of approximately US$2.15 billion annually from lung, heart and nervous system diseases (Biegler, 2009). The same author estimated the health costs of pollution from vehicles (cars, trucks and other modes of fossil-fueled transport) at approximately US$2.6 billion per year. Thus, a total of US$4.75 billion could be saved by shifting to cleaner energy and transport in Australia (CAHA, 2012).

The European Commission has assessed the costs and benefits of a 30 percent GHG mitigation target for the European Union (EU), comparing three scenarios (European Commission, 2012): (1) baseline scenario reflecting current and policy measures implemented at the EU and national levels as of 2009; (2) reference scenario reflecting full implementation of the legally binding targets of the C & E Package in 2020; and (3) 30 percent Reduction Commitment scenario – a 25 percent domestic GHG emission reduction scenario in 2020 plus a 5 percent additional reduction to be met through the use of international emission reduction credits.

The paper estimates that the 25 percent domestic GHG emission reduction scenario is expected to avoid mortality benefits for the EU as a whole ranging between € 3.3 and 7.6 billion.

The European Commission RTD Climate Cost project uses a baseline scenario and a mitigation (GHG reduction) scenario in order to provide the economic benefits of GHG mitigation in the period 2010 to 2050 (Holland et al., 2012). In the baseline scenario it is assumed that no further climate and air pollution policies are implemented beyond that in place in 2010 taking into account the emission trading scheme market in the EU, the prospect of future climate policies in other countries, the consequences of the financial crisis of 2008/9 and the evolution of oil prices. The baseline scenario excludes the implementation of the 20 percent GHG reduction target and the target for the replacement of fossil fuels by renewable energy. The mitigation scenario assumes a 60 percent reduction of global GHG emission by 2050 as compared to 1990 and concomitant reduction in agriculture, land use change and deforestation with the aim to achieve a less than 2 °C temperature increase beyond the pre-industrial level. The difference between the two scenarios provides the physical and economic benefits of GHG mitigation. The impact pathway has five steps:

1. Quantification of emissions;
2. Analysis of pollutant dispersion and chemistry across Europe, China and India by use of the Greenhouse and Air Pollution Interactions and Synergies, (GAINS) model, assessing the air pollutant concentrations;
3. Quantification of the exposure of people and material receptors to air pollution ($PM_{2.5}$ and ozone (O_3);
4. Quantification of the impacts of air pollution using established exposure-response relationships by use of the Atmospheric Long-range Pollution Health/environment Assessment model and the GAINS model;
5. Valuation of the impacts using a 'willingness-to-pay approach.

The estimations of the difference between baseline and mitigation scenarios with respect to life expectancy, using the GAINS model, showed net benefits of mitigation in Europe of 0.2 months, 0.5 months and 1.1 months in 2020, 2030 and 2050, respectively due to $PM_{2.5}$ exposure (Rafaj et al, 2011). The benefits of avoided total life years lost in Europe in 2050 amount to approximately 480,000 each year. Holland et al. (2012) also estimated the co-benefits for other positive health impacts – avoided deaths due to short-term O_3 exposure, avoided cases of hospital admissions from respiratory and cardiovascular ailments due to exposure to $PM_{2.5}$, avoided sick days, among others. These estimates amount to 27,000 avoided incidences and 120 million avoided minor symptom days each year. These benefits were monetized to an estimated amount of €9, €20, and €9 43 billion per year in 2020, 2030, and 2050, respectively.

In a similar approach, Holland et al. (2012) analyzes the co-benefits of GHG mitigation and air pollution reduction in China and India where $PM_{2.5}$ concentration are much higher than in Europe and significantly above the WHO guideline value. The mitigation scenario, as compared to the baseline scenario, increases the life expectancy in 2050 by nearly 20 months in China and 30 months in India. The mitigation scenario projection reduces the premature deaths attributable to O_3 annually by 20,000 cases in China, and 55,000 cases in India, relative to the baseline projection. An attempt to quantify the co-benefits of mitigating GHGs and controlling air pollution on global and regional scales has also been undertaken by West et al. (2013).

On the basis of various scenarios, they found that global GHG mitigation measures would avoid 219,000-591,000 global premature deaths in 2030, and 724,000-1.43 million deaths in 2050.
They monetized these benefits to be between US$315 billion and US$2,392 billion in 2030 and between US$857 billion and US$6,515 billion in 2050. Notably, this study "for the first time allows the translation of climate change mitigation measures into their associated air-pollution-related human health benefits on both regional and global scales" (Thurston, 2013).

C. Process of developing and implementing health impact assessments

Health and environmental impact studies are an important ingredient in clean air action plans (CAAPs). It is advisable to estimate the health impacts due to air pollution by impact modeling and/or short-term and long-term impact estimation by means of epidemiological health impact studies [see *Guidance Area 5 on Clean air action plans*]. In order to achieve this objective, the implementation of a health surveillance system is of great importance. In general, health surveillance programs collect mortality and morbidity information for selected health impacts.

The goals of public health surveillance in the context of air pollution-related health impacts are to:

- Act as a sentinel for emerging health challenges;
- Understand the pattern of the health impact (disease) challenge;
- Define the scope of the challenge;
- Identify and target populations for an intervention and prevention process, and
- Evaluate the effectiveness of the intervention and prevention process.

In order to cost-effectively perform an epidemiological study on health impacts of air pollution, it is necessary to carefully plan the study. The steps in performing such a study are outlined below.

Step 1. Deciding whether to do an epidemiological study on air pollution-related impacts

Frequently in AQM, a decision is required whether to conduct a formal study, or simply to base action on existing knowledge. If a reliable body of evidence on air pollution exposure and associated health effects exists, an epidemiological study may not be needed. Such evidence may persuade decision-makers that it is worthwhile to take preventive action. The following questions should be answered before proceeding to a full-scale study on health effects due to air pollution:

- Does human exposure and do health impacts exist?
- Do the observed health impacts require an initial risk assessment?
- What questions could a study answer? This includes a clear statement of the hypotheses to be tested about the form of an exposure-response relationship.
- Which feasibility issues exist?
    - Types of data that need to be collected
    - Access to existing data
    - Required size of the study population
    - Availability of an adequate sampling procedure for selecting a study population
    - Capability for estimating and/or measuring air pollutant concentrations and health impacts;
    - Ability to identify and control for confounding factors
    - Availability of personnel and resources
- Are there ethical considerations to be considered such as protecting subjects of a study from undue harm, loss of confidentiality, and informing them of possible risks and benefits?

Step 2. Apply epidemiological principles

A fundamental concept of an epidemiological study of air pollution-related health impacts is the population at risk. The population at risk consists of those individuals in the general population who could develop the health impact when exposed to air pollution. It is generally not necessary or desirable to study the entire population at risk and more strategic to study a selected sub-population instead, which is considered as the target population. The source population is the population at risk from which participants in the study will be sampled. The study population is a sample of individuals from the source population included in the study (Rothman & Greenland, 1998).

In order to investigate the occurrence of health effects due to air pollution, the size of the population at risk and the time period of exposure must be known. Occurrence of effects can then be calculated as a function of the number of exposed individuals who exhibit the heath impact per unit size of the population (e.g. cases per 1,000 people) for a specified time period or a specified point in time. Occurrence of health impacts is expressed as prevalence based on the number of cases that exist at a specific point in time, or incidence, based on the number of new cases that occur during a given period.

A measure of prevalence is the prevalence proportion, which is defined as the number of existing subjects at a point in time divided by the size of the population. Prevalence proportion is a useful measure of the burden of disease (e.g.

Lim et al., 2012; WHO 2015). Prevalence proportion is also an appropriate measure for chronic diseases such as asthma or chronic bronchitis.

A second measure of prevalence is the prevalence odds, which is defined as the number of subjects with the disease divided by the number of subjects who do not show the disease.

On the other hand, there are three incidence measures: incidence rate, incidence proportion, and incidence odds. The incidence rate – defined as the impact-occurrence per unit time – is frequently used in cohort studies. The incidence proportion is defined as the number of subjects who developed the disease as a consequence of exposure to air pollution divided by the total number of exposed subjects in the study; it is conceptually the same as the probability or risk of an individual developing the health outcome, as estimated by studying a population. The incidence odds – defined as the ratio of the number of subjects who experience the health outcome to the number of persons who do not experience the health effect – is used to calculate the odds in case-control studies.

An epidemiological study seeks to estimate the effect of exposure to air pollution by comparing effect occurrence in an exposed group with effect occurrence in a non-exposed group. These comparisons result in quantitative estimates of the relative risk as the ratio of incidence rates, incidence proportions and incidence odds. The effect of an exposure to air pollution is often expressed by calculating the proportion of the effect incidence among the exposed population that can be attributed to the exposure – the attributable risk.

The goal of any epidemiological study is to obtain as accurate an estimate as possible of the quantitative relationship between an air pollutant and the health outcome and to minimize the potential for error[3].

Step 3. Exposure assessment

The principal methods for assessing exposure to air pollution are classification, measurement and modeling. Classification refers to the ordinal identification of subgroups of subjects. The simplest classification is dichotomous, i.e. exposed and not exposed subjects. Exposure measurement is the determination of air pollutant concentrations and their durations. In exposure modeling, mathematical models are used to predict air pollutant concentrations from known emissions and meteorological factors for the dispersion of air pollutants. If the effects of air pollutant exposure are to be estimated with minimal bias and maximum efficiency, accurate and precise measures of exposure are crucial. Increasing accuracy and precision of exposure measurement, however, also increases the cost. Conversely, the precision of effect estimates may decrease if the study size is reduced due to high cost of exposure measurement. As funding of epidemiological studies is limited, available resources must be used wisely.

Instruments to measure actual exposure to pollutants include questionnaire data, existing concentration data from active monitors, passive monitors, and automatic analyzers located at urban sites or other indicators such as those derived from satellite observations. Levels of exposure to outdoor air pollutants will vary depending on the proportion of time people spend outdoors, and the capacity of the individual pollutants to enter the indoor environment. Time is also spent at work, at school and in transit. In colder climates, the time spent outdoors is typically only a few hours or less. In recent years, cheaper portable sensors measuring personal exposure have been developed (Steinle et al., 2014; University of Birmingham, 2014; Next City, 2015).

Concentrations of pollutants in ambient air may vary considerably over time due to meteorological factors such as wind speed and direction, turbulence, and height of the mixing layer. Also, short-term variations in emission activity can lead to significant short-term variations in air pollution. Dispersion models can estimate air pollution concentrations at specific locations if the quantity, height and location of emission sources are well known. Extremely varied topographical conditions common in urban areas require the use of sophisticated dispersion models in order to estimate exposure reliably.

Step 4. Health effects assessment

Health effects data may be classified as either primary or secondary: Primary data are those collected specifically for a particular study, e.g. via a questionnaire or medical examinations. Secondary data are those data that have been collected from purposes other than for a particular study and must be abstracted from existing records. Existing secondary data sources for epidemiological studies of air pollution-related health impacts include death certificates, hospital records, chronic and infectious disease registries, birth defect registries, employment and school records, hospital admissions, emergency department visits, and outpatient visits. In many countries, laws exist which expressly require reporting of morbidity and mortality data relating to chronic or infectious diseases. Institutions and health care agencies are compelled by such laws to report cases of select diseases or mortality to a central registry.

3 Error is classified as systematic (i.e. deviation from the 'true' value) or random. Random errors are due to the variability of rare health events and can be reduced by a larger study. The term bias is used generally to refer to the presence of systematic errors. These include confounding, selection bias and information bias.

In order to provide the best information possible for an epidemiological study, capabilities for linking data sources are beneficial to facilitate the study (USEPA, 2005; 2011; Lam, 2014). In tapping into data sources, emphasis should be placed on analyses of changes over a long period of time of air pollution exposures and impact occurrence (Huang et al., 2014).

Step 5. Study design and methods
The objective of an epidemiological study is achieved by comparing the health outcomes of individuals who have been subject to different exposure levels (i.e., exposed, unexposed or lesser-exposed). If the air pollutant that caused the observed health impact is only vaguely suspected or even unknown, the first step in investigating the health effect could be a descriptive study. This is a study that defines the population group of interest, estimates incidence or prevalence of the disease, and identifies a potential air pollutant that might have caused the impact. A descriptive study can be useful in creating hypotheses for further study but does not analyze the statistical association between exposure and impact.

An analytical study can be carried out if a specific cause-effect relationship is suggested to exist. Such studies test a hypothesis about cause and effect or evaluate a quantitative relationship between exposure and impact. Conceptually, analytical studies are based on following a population over a period of time during which the population is at risk. Table A3.2 lists the most commonly used types of epidemiological studies.

Table A3.2 Types of epidemiological study design

Study type		Alternative name of study	Unit of study	
Descriptive			Individuals or populations	Distribution of disease
Analytical				
	Ecological	Correlational	Groups of people	Comparison of aggregate measures of exposure with aggregate measures of health outcome rates
	Cohort	Follow-up	Individuals	Comparison of incidence rates for multiple health outcomes among groups of individuals with different exposure status
	Case-control	Case-reference	Individuals	Association between exposure and a health outcome by comparing cases (individuals who develop the outcome) and controls (individuals who do not develop the outcome)
	Cross-sectional	Prevalence	Individuals	Association between exposure and disease prevalence (the proportion of the population affected by the health outcome at a particular point in time or during a short period of time)

Study type		Alternative name of study	Unit of study	
	Time series	Temporal-comparison ecological	Individuals; groups of people	Association between a variable exposure and a variable health outcome
	Proportionate mortality/ morbidity		Groups of people	Comparison of the distribution of health outcomes in one study population to the distribution of the same outcomes in another population

Source: WHO, 1999

In ecological studies, the investigator analyzes hypothesized associations between air pollutant exposures and health impacts using populations, rather than individuals. This study design plays a larger role in air pollution epidemiology because large populations are exposed in a similar manner. Air pollution in an urban area is likely to cause exposure to most inhabitants; their exposure might be uniformly different from that in a rural area. The health effects due to exposure to different concentrations of an air pollutant might be compared between areas (Pan et al., 2014).

In a cohort study, a sample of individuals selected from the population at risk of developing a particular health outcome are divided into groups according to their exposure status. The groups are followed over time and the incidence of the health outcome within each group will be determined. A cohort study estimates incidence rates and effect indicators such as relative risks and attributable risks. A cohort study is termed historical if it examines past events and prospective if the data are collected as the exposure events unfold. Cohort studies have been used effectively to assess the long-term health effects of exposure to air pollutants (Hoek et al., 2013; Zhang et al., 2015). Table A3.3 compares the prospective and historical approach for cohort studies.

Table A3.3 Comparison of prospective and historical approach in cohort studies

Attribute	Prospective	Historical
Information	More complete and accurate	Less complete and accurate
Discontinued exposure	Not useful	Useful
Emerging, new exposures	Useful	Not useful
Expenses	More costly	Less costly
Completion time	Longer	Shorter

A case-control study examines the association between air pollutant exposure and a health impact by comparing individuals of a source population who develop the health impact (cases) and individuals who are a sample of the same source population and have not developed the health impact (controls). The study then examines the prior exposure status of the cases and controls by examining existing records, questionnaire information, or measuring biomarkers of past exposure. Case-control studies have been extensively used to study the role of air pollutants in the development of cancers (Loomis et al., 2014).

Cross-sectional studies examine the proportion of the population affected by a health impact of air pollution at a particular point in time or during a very short period. Exposure, personal characteristics and health impacts are measured at the same time. This study type examines impact prevalence or the association between exposure and health impact. Cross-sectional studies are usually performed in communities in response to concern about air pollution exposure before cohort or case-control studies are undertaken (Gao et al., 2014).

Time series studies are based on cohort, cross-sectional and ecological studies. In this study type, repeated observations of exposure and health impact are made over time with the same study population. The analysis compares variation in exposure status over time with changes in health impact over time. Time series studies are most appropriate if the time period between air pollutant exposure and health impact is short – e.g in the case of respiratory symptoms (Xie et al., 2014). Table A3.4 summarizes the strengths and limitations of the different study designs.

Table A3.4 Strengths and limitations of different study designs

Type of study	Strength	Limitation
Ecological	Usually based on existing data	Results sometimes difficult to interpret due to limited information on factors that could bias the findings
	Relatively inexpensive to conduct	Identifying causal exposure can be difficult due to correlation between pollutants
	Useful for studying rare impacts caused by relatively rare exposures	Exposure misclassification can lead to overestimating of effect indicators
	Source population can be large	Study of time trends may be complicated due to changes in demographics, changes in monitoring indicators, and disease coding schemes
	Can clearly demonstrate that a change in exposure levels is followed by a change implausible health outcomes	
Cohort	Most definitive study design	Can be expensive
	Temporal relationship between exposure and health outcomes clearly determined	Likely to be infeasible if the latency period between exposure and health impact is lengthy
	Allows analysis of multiple health impacts	If the health impact is rare, study can be inefficient because the study population must be large
	Exposure status is determined before health impacts occur	Identifying and following cohorts in a general population is difficult
Case-control	Efficient for studying rare impacts and impacts with long latency periods between exposure and effect	Identifying the control population can be difficult
	The role of multiple air pollutants can be studied	Greater bias in classifying exposure status
	Effective for studying dynamic populations	Questionnaires can produce a recall bias in cases and controls
	Less expensive and time-consuming	Cannot yield estimates of incidence rates
Cross-sectional	Less expensive and time consuming	Difficult to interpret findings
	Effective to study factors that do not change as a result of impacts and air pollutant exposures	Questionnaires may lead to recall bias
		Cross-sectional associations between exposure and prevalent health impacts may be subject to inaccuracy

Source: WHO, 1999

Step 6. Analysis and interpretation of an epidemiological study

The approach to data analysis involves effect estimation, i.e. combining the data with a statistical model in order to ascertain whether risk of impacts due to air pollution differs between exposed and non-exposed groups. When interpreting whether an observed association between exposure and response may be causal, it is important to know whether effect estimates change by a gradient of exposure. The approach is to compare subgroups of the study population, characterized by different levels of exposure, to a non-exposed group. For the causal interpretation of long-term health impacts of air pollutant exposure, the time pattern of the study exposure is also important.

Basic data analysis includes:

- initial exploration of data and descriptive analysis
- determination of statistical distribution of data
- measures of central tendency (mean, median)
- standard errors and 96 percent confidence intervals

More sophisticated statistical methods include the application of:

- hypothesis tests that the effect indicator in the exposed group differs from that in the non-exposed group such as the χ^2 (chi-square) test;
- stratified analysis;
- linear multiple regression;
- multivariate regression; and
- treatment and analysis of misclassification

Step 7. Practical issues in study implementation

In study implementation, these are the practical issues that should be addressed:

i. Conduct background research. This includes the definition of the nature of the problem, the review of prior studies, and establishing study approaches and data collection methods.
ii. Develop study design and methods. This includes setting the objectives and hypotheses, the preparation of a study protocol, a statement concerning ethical issues, and assessing the feasibility of the study.
iii. Assemble a study team.
iv. Prepare for study by contacting community and government officials, planning the logistics, readying the study material and instruments, training staff, and if necessary, conducting a pilot study.
v. Conduct main study.
vi. Complete data management and analysis.
vii. Report study findings.

Step 8. Epidemiological studies for policy and management

Epidemiological studies have an important role to play in AQM. To protect the population from the adverse effects of air pollution, environmental managers and regulators must have credible scientific information about the link between human exposures and air pollution-induced disease. Epidemiology is the core scientific discipline that provides information upon which public health actions and decisions are based. Epidemiology is also the basis in the area of risk assessment and standard setting (Schwela, 2014).

Step 9. Valuation of epidemiological studies

The valuation of the health impacts due to air pollution is also an important step in epidemiological studies. Measures of emissions reduction are often not envisaged due to the perception that this is a costly exercise. However, many studies have shown that the benefits of avoided health impacts attributable to air pollution may far outweigh the cost of measures to reduce emissions (Gunatilake et al., 2014). A cost-benefit analysis is an important component of AQM. This is illustrated in Figure A4.1.

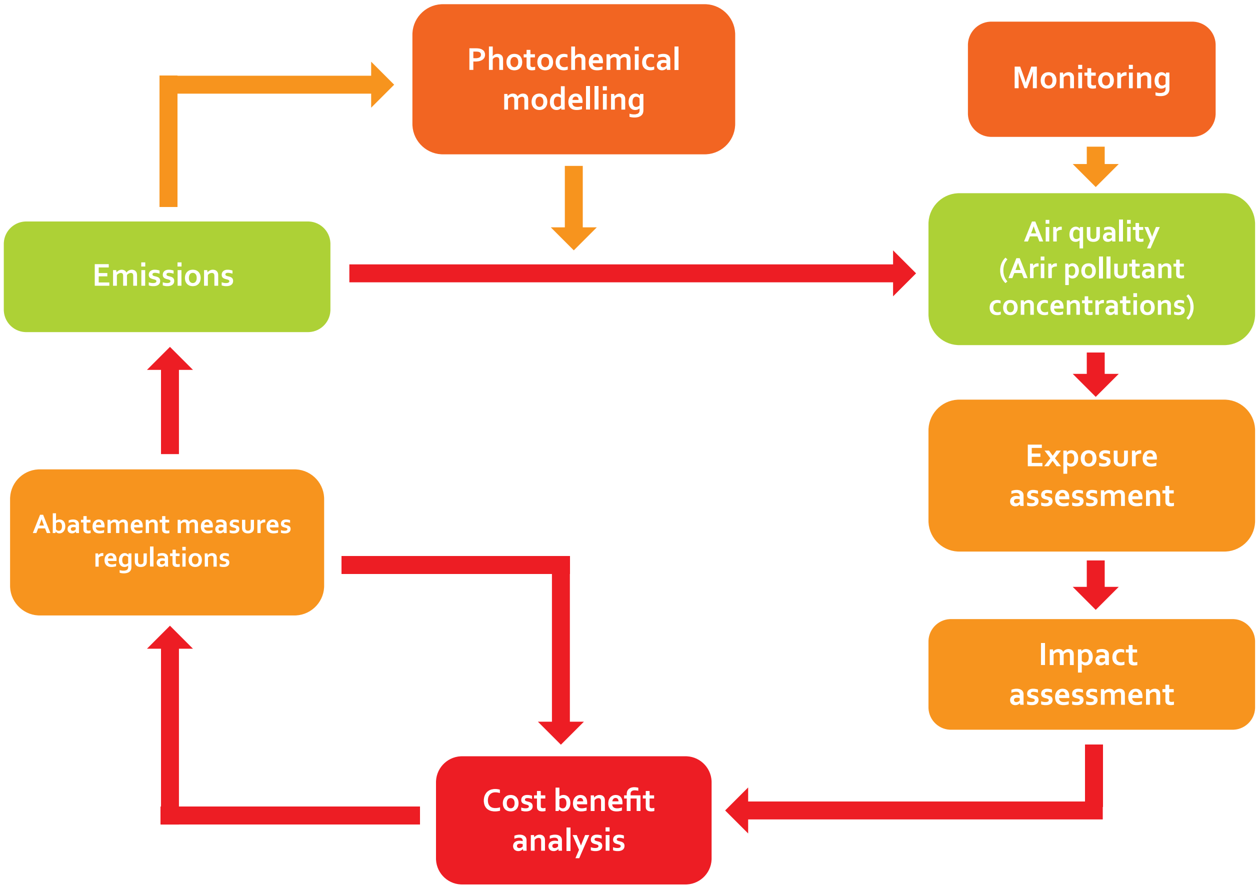


Figure A3.1 A simplified AQM system related to cost-benefit analysis
Red arrows: Main system loop; Green arrows: Subsystem loops and data elements

ANNEX IV. GUIDANCE AREA 4: AIR QUALITY COMMUNICATION

Process of developing an Air Quality Communication Plan

In-house capacity is required to ensure that Communications staff has knowledge of air quality issues, the marketing skills, and technical ability to develop a wide range of creative awareness-raising initiatives aimed at a range of stakeholders.

In order to inform, educate, and strengthen stakeholder participation in all aspects of AQM, it is necessary to develop an appropriate strategy and plan. The eight key steps in developing an air quality communication plan are outlined below.

Step 1. Determine communication goals

At the outset, identifying the aim of communication and the level of ambition is important. This could range from increasing awareness and knowledge, to influencing attitudes, and even changing the behavior of the intended target audience (e.g., motivating individuals and communities to change behaviors to reduce pollutant levels and health risks).

In considering the aim of the communication plan, the following questions should be asked:

- Which target group needs this information?
- How useful is the information to the target group?
- How much knowledge does the target group have on this subject?
- What format should the information take?
- What is the best channel of communication to reach the intended target group?

Step 2. Identify the target group

A message targeted at a specific group – e.g., policy makers, media, environmental and health professionals, sector pollution managers and workers, healthcare providers, the public and vulnerable populations – in a format and tone that they understand is likely to be more effective than a general message aimed at everyone. It is important to identify the target group and the best communication channel to reach the group, as well as determining what kind of response you intend to elicit from the target group.

For example:

- Policymakers: To motivate action and assist in making informed decision by providing clear and understandable information and knowledge on current air pollution issues.
- General public: To inform residents of the quality of air they breathe and corresponding risks, to warn residents of high pollution episodes, and to encourage them to take action to reduce emissions.
- Academe: To engage them further in air quality research that supports local AQM.

Each audience has different concerns about the health effects attributable to poor air quality, levels of knowledge and goals. These differences influence what individuals want to hear about, how they interpret the specific information, the degree to which they believe the specific information addresses their concerns, and the technical level at which the information can be understood. Having several different messages with the same general core content is therefore effective, with each of the messages specifically tailored to each target group.

Step 3. Determine types of information needed

It is also useful to determine the type of information that needs to be conveyed, before focusing on detailed content. The type of information could be ambient AQ data, ambient air monitoring observations, integrated/modeled emissions and simulated ambient air data, and suspected or observed health impacts. These types of data differ with regard to time, place, pollutant and impact.

The type of information to be shared, the target audience and the communication channel to be used should be defined to determine the frequency of reporting. Tables A4.1 and A4.2 provide guidance on the frequency of reporting of different types of AQ information for some media vectors.

Table A4.1 Communication channels used to share information and frequency of use

Communication Vectors	Real-time	Hourly/Daily	Weekly	Monthly	Annual	As needed
Print newspapers		X				
Email/mobile alerts	X					X
Social networking sites and microblogs (e.g., Twitter)	X					
Website	X		X			
Television and radio	X	X				
Billboards in the city	X					
Published (printed) reports				X	X	X

Table A4.2 Type of information and frequency of reporting

	Real-time	Hourly/ Daily	Weekly	Monthly	Annual	As needed
General city information						
General information (population, GDP)				X	X	X
City planning developments in industry, energy, transportation				X	X	X
Status of air quality						
Real-time air quality levels, daily Air Quality Index (AQI)	X	X				
Air quality forecast		X	X			
Number of days where standard is exceeded				X	X*	
Air quality trend and tendency analysis					X	
Air quality warnings	X					X
Sources of Air Pollution					X	X
Emissions inventory						X**
Source Apportionment					X	X
Impacts of air pollution						
Health impacts					X	X
Costs of air pollution (health, economic)					X	X
Other impacts (visibility, tourism, others)					X	X
Air quality management						
Legislation and regulations on air quality						X***
Achievements on clean air management					X	X
Status of implementation of control measures				X	X	X
Planned air pollution control measures					X	X
Yearly budget for clean air management					X	

*Can also be quarterly;
**Can also range from every two to five years
***Usually when there is new legislation or revisions in existing legislation

Source: Adapted from ADB/Clean Air Asia, 2014

Step 4. Formulate the key messages

In developing messages for air quality communication, clarity of the message to be delivered and specifying the response it hopes to elicit is necessary. The message will need to break through the "information clutter" of society and should therefore be based on what the target audience perceives as most important to them and what they want to know.

In addition, key messages should be guided by the communication goal. For example, the general aim may be to inform the target group about the level of a hazardous pollutant.

The specific aim may be to encourage individuals to take personal actions to limit exposure; or to encourage the community to support political action because they are disproportionately affected. Box A4.1 provides a list of fifty voluntary actions individuals can take to reduce air pollution. Whatever the key message, careful thought should be given in developing the message and the channel through which the information will be conveyed.

Box A4.1
Individual Voluntary Actions to Help Reduce Air Pollution

On the road

1. Walk or ride a bike when possible.
2. Take public transportation.
3. Organize and condense errands into one trip.
4. When driving, accelerate gradually and obey the speed limit.
5. Drive less, particularly on days with unhealthy air.
6. Maintain your vehicle and keep your tires properly inflated.
7. Support the Smog Check Program.
8. Report smoking vehicles.
9. Travel lightly and remove any unnecessary items that may weigh down your vehicle.
10. Limit idling your vehicle to no more than 30 seconds.
11. When in the market for a new car, look for the most efficient, lowest-polluting vehicle or even a zero-emission electric car.

At home

12. Turn the lights off when you leave a room.
13. Replace energy-hungry incandescent lights with compact florescent light bulbs.
14. Ask your energy supplier for a home audit and inquire about alternative energy solutions like solar or wind.
15. Opt for a fan instead of air conditioning.
16. Use a programmable thermostat and set it to 78°F in the summer and 68°F in the winter.
17. Install low-flow shower heads.
18. Recycle paper, plastic, metals and organic materials.
19. Use an EPA-approved wood burning stove or fireplace insert.
20. Don't use your wood stove or fireplace on days with unhealthy air.
21. Don't heat your home with a gas stove.
22. Use a surge protector for multiple appliances and turn it off when products are not in use.
23. Add insulation to your home.
24. Wash laundry in cold water and line dry.
25. When ready to replace, look for energy star appliances.
26. Use a propane or natural gas barbecue rather than a charcoal one.
27. Microwave or use a toaster oven for small meals.
28. Have your gas appliances and heater regularly inspected and maintained.
29. Use washable dishes, utensils and fabric napkins rather than disposable dinnerware.
30. Choose products that use recycled materials.
31. Eat locally, shop at farmers markets and buy organic products.

32. Buy products from sustainable sources such as bamboo and hemp.
33. Use durable reusable grocery bags and keep them in your car so you're never caught off guard.
34. Paint with a brush instead of a sprayer.
35. Store all solvents in airtight containers.
36. Use an electric or push lawn mower.
37. Use a rake or broom instead of a leaf blower.
38. Use water-based cleaning products that are labeled 'zero VOC'.
39. Insulate your water heater and any accessible hot water pipes.
40. Eliminate use of toxic chemicals at home; opt for natural substitutes
41. Plant a tree! They filter the air and provide shade.
42. Let your elected representatives know you support action for cleaner air.

At Work

43. Carpool.
44. Telecommute.
45. Start a recycling program.
46. Print and photocopy on both sides of paper.
47. Bring your lunch to work to avoid mid-day outings.
48. Turn off office equipment – computers, printers, and fax machines – after hours.
49. Harness the power of the sun: open the blinds and turn off the lights.
50. Dress for the weather and adjust layers before adjusting the thermostat.
51. Buy products from sustainable sources such as bamboo and hemp.
52. Use durable reusable grocery bags and keep them in your car so you're never caught off guard.
53. Paint with a brush instead of a sprayer.
54. Store all solvents in airtight containers.
55. Use an electric or push lawn mower.
56. Use a rake or broom instead of a leaf blower.
57. Use water-based cleaning products that are labeled 'zero VOC'.
58. Insulate your water heater and any accessible hot water pipes.
59. Eliminate use of toxic chemicals at home; opt for natural substitutes
60. Plant a tree! They filter the air and provide shade.
61. Let your elected representatives know you support action for cleaner air.

Source: California Environmental Protection Agency, 2011

Factors that help determine target group acceptance include:

- Clarity – Messages must be jargon-free and the information should be clearly conveyed to ensure understanding.
- Consistency – All messages should be consistent. The main points should be stressed, repeated, and never hidden or lost within less strategic information.
- Credibility – The spokesperson and source of the information should be believable and trustworthy.

Step 5. Choose the means of communication

Communications channels transmit the messages to the target group or audience (Table A4.3).

The choice for channels of communication is also influenced by the available budget. Channels take numerous forms and make possible a wide range of tactics for outreach work (Box A4.3). These include:

- Non-media communication: e.g., telemarketing, exhibitions, fairs, and "open door" events. A wide audience cannot be reached by means of non-media communication.
- Media communication: e.g., electronic media (television, radio, video, smartphone, Internet, CD-ROM)

Table A4.3 Questions to consider in communicating to different target groups

Target Group	Sub Groups	Key message	Communication channel
Who is the target group?	*What is the composition of the target group?*	*What do we need to know?*	*What is the most effective channel to reach them?*
Urban citizens	Town occupants Motorists and public transport and non-motorized transport users Pedestrians, cyclists, tourists, parents of babies and small children Sports people (outside) Shop owners	General city information (population, GDP) City planning developments in industry, energy, transportation Real-time air quality levels, daily AQI, air quality forecast Number of days where standard is exceeded air quality trend and tendency analysis, air quality warnings Health impacts Costs of air pollution (health, economic, etc.) Other impacts (visibility, tourism, others) air quality legislation and regulations Annual achievements on clean air management Status of implementation on control measures Planned air pollution control measures Yearly budget for clean air management	Sample Channels Television stations Radio stations Newspapers Websites Community centers Street festivals City government offices (e.g., Division of Motor Vehicles) Shopping centers Parks Schools, colleges, and training centers Libraries Recreation centers (e.g., basketball courts or soccer fields) Community non-profit offices Transportation depots/stations Supermarkets Fast food restaurants Literature Racks
People sensitive to air pollution	Older people Parents of babies and small children Asthmatics, patients' association groups People with allergies Heart and lung patients		
Health professionals	General practitioners Specialists (hospital) Public health service		
Managers	Industry, transport, power plants		
Non-governmental organizations	Interest groups (in general) Consumer organizations Environmental groups		
Academe	Research institutions Universities Individual researchers		

Box A4.3
World Health Organization and air quality communication

Insufficient public awareness of health risks associated with air pollution leads to inappropriate or lack of action to address or prevent exposure of vulnerable groups to air pollution. Communicating information on air quality and its negative effects on human health is embodied in national legislations and policies; it should be strategically structured to influence public perception of the health effects of air pollution.

The WHO periodically issues advisories concerning recent evidence of air pollution effects on human health. In March 2014, the WHO issued press releases as an example of how air pollution risks to human health is communicated, along with the coverage received in the Asian media.

EMBARGO: DO NOT PUBLISH, DISTRIBUTE OR REPRODUCE UNTIL 00:01 GMT ON TEUSDAY 25 MARCH 2014

News release WHO/06
25 March 2014

7 MILLION DEATHS ANNUALLY LINKED TO AIR POLLUTION

GENEVA : 25 March 2014 - In new estimates released today, the World Health Organization (WHO) reports that in 2012 around 7 million people died - one in eight of total global deaths - as a result of air pollution exposure. This finding more than doubles previous estimates and confirms that air pollution is now the world's largest single environmental health risk. Reducing air pollution could save millions of lives.

In particular, the new data reveal a stronger link between both indoor and outdoor air pollution exposure and cardiovascular diseases such as strokes and ischaemic heart disease as well as between air pollution and cancer. This is in addition to air pollution's role in the development of respiratory diseases, including acute respiratory infections and chronic obstructive pulmonary diseases.

The new estimates are not only based on more knowledge about the diseases caused by air pollution, but also upon better assessment of human exposure to air pollutants through the use of improved measurements and technology. This has enabled scientists to make a more detailed analysis of health risks from a wider demographic spread that now includes rural as well as urban areas.

<u>WHO Headquarters Press Release on Deaths Linked to Air Pollution</u>

Air pollution is now the world's largest single environmental health risk which leads to cardiovascular diseases—ischemic heart disease (40%), stroke (40%), chronic obstructive pulmonary disease, lung cancer (6%), and acute lower respiratory infections in children (3%). The WHO estimates indoor air pollution was linked to 4.3 million deaths in 2012 and there were 3.7 million deaths in 2012 from urban and rural sources worldwide. Excessive air pollution is often a by-product of unsustainable policies in sectors such as transport, energy, waste management, and industry. The WHO and health sectors have a unique role in translating scientific evidence on air pollution into policies that can deliver impact and improvements that will save lives.

<u>Response by the WHO Western Pacific Regional Office (WHO WPRO)</u>

The Western Pacific bears a disproportionately high burden—41% of deaths globally—due to indoor and outdoor air pollution. Addressing air pollution effectively will help in reducing the health burden from non-communicable diseases, which are a particularly significant challenge in the Western Pacific Region.

The WHO WPRO has been working closely with Member States to help strengthen their capacities to conduct health risk assessments and management to reduce air pollution. Through the Regional Forum on Environment and Health in Southeast and East Asian countries, WHO promotes collaboration between the health and environment sectors within governments and across civil society to address major environmental health challenges.

WHO issues new data and a warning on the health impacts of air pollution

An estimated 2.8 million deaths in the Western Pacific Region in 2012 from heart disease, lung cancer and other illnesses linked to air pollution

News release

WHO

25 March 2014-The World Health Organization warns that air pollution is taking a mounting toll on health globally with the deaths of an estimated 7 million people in 2012 linked to dangerous air. The figures reflects a strong connection between air pollution-both outdoors and in the home-and a range of illnesses, including heart disease, stroke, and lung cancer.

The issuance of press releases prompted responses from other countries. A summary of press coverage in response to WHO Press Release on Air Pollution is presented below:

Western Pacific Countries	Press Coverage
China	The government of China should be praised for initiating several new measures to fight air pollution *(China Daily Asia)* Chinese leaders have taken note to reduce reliance on coal and introduce more energy-efficient construction methods *(The New York Times)* Community party leaders should change growth policies and enforce regulations that would lead to cleaner air *(The New York Times)*
Japan	Tokyo, Seoul, and Beijing should take action to improve relations between the three countries by collaborating on the common problem of $PM_{2.5}$ air pollutants and bolstering exchange *(The Asahi Shimbun)*
Korea	The government of Korea need to take integrated action by launching a cooperative organization among affected countries in Northeast Asia (*Korean Joong Ang Daily*) The Seoul government has made efforts to tackle the problem by strengthening its monitoring system and toughening regulations *(Yonhap News)*
Malaysia	With appropriate legislation, inter-government agreements, and public willingness, the problem could be solved *(BERNAMA)*
Mongolia	The WHO's recently released report confirms that the government of Mongolia should take initiatives to address problems of air pollution. The government has taken action through the "Ulaanbaatar Clean Air Project" in partnership with the World Bank to produce less particulate matter emissions *(Tempo)*
Philippines	Countries need to rethink policies, pointing to the impact in the developed world of a shift to cleaner power sources, more efficient management of energy demand, and technical strides in the auto industry *(The Manila Times)*

WHO is the directing and coordinating authority for health within the United Nations System. It is responsible for providing leadership on global health matters, shaping the health research agenda, setting norms and standards, articulating evidence-based policy options, providing technical support to countries, and monitoring and assessing health trends.

The publication of the WHO press release on air pollution had an impact on the global public health agenda — it provided a strong basis for media to prompt governments to develop or strengthen policies on air pollution and public health.

Scientific information released by international agencies can provide a strong evidence base that enables the media and other stakeholder groups to request government action on air pollution and health. How the media used the information in WHO's press release varied by country and was dependent on their experience of air pollution. It is necessary to translate and communicate complex information and data into a form that is understandable by the public. National data may have a greater influence to foster policy change; nonetheless, the dissemination of the health effects of air pollution based on global and regional data sets a broader perspective of the global response to the environmental and health burden. It is vital to examine how key messages and scientific information can be presented to ensure effective communication. In addition, further information on policy settings by other countries, best practices\ and technology know-how may be useful for policy makers to facilitate multisectoral engagement on air pollution and public health. Fact sheets provided by WHO can be useful in doing this.

Sources: WHO, n.d.; WHO, 2014; Keung, 2014; Wong, 2014; Nakano, 2014; Ji-Hye, 2014; Yonhap News Agency, 2014; Bernama.com, 2014; Tempo, 2014; The Manila Times, 2014

Step 6. Engage Stakeholders

Identifying different tools and ways of engaging a wide range of stakeholders in AQM is necessary. Stakeholders include individuals, small businesses, local governments, industries and other interested parties affected by air pollution. Table A4.4 presents the range of stakeholder engagement while Table A4.5 presents the different tools that stakeholders could utilize depending on their degree of involvement.

Table A4.4 Range of stakeholder engagement

Outreach	Inform	Providing information to the public and key stakeholders about the state of air quality and AQM activities. This information can help in understanding air quality problems and potential solutions. It can also assist stakeholders in providing feedback to authorities for AQM.
	Connect	The provision of public information on a website. This can help the public understand air quality problems and potential solutions. It also provides an interactive source of information that allows stakeholders to engage with air pollution issues by leaving feedback and comments at any time.
Engagement activities	Involve	Involving different stakeholders – such as community groups, industrial, energy and transport managers, local governments and residents – in the formulation of AQM measures to ensure that they are comprehensive and effective.
	Comment	Seeking stakeholder comment and input on the formulation of AQM projects and programs. This usually occurs after a solution has been proposed.
	Collaborate	Collaborating with interested parties to gather ideas and feedback on air quality issues.
	Partner	Harnessing partnerships with groups, organizations or businesses to promote key messages and achieve positive change.

Source: Bay Area Air Quality District, 2013

Table A4.5 Tools for stakeholder participation in air quality management

Tools	Inform	Connect	Involve	Comment	Collaborate	Partner
Website	•	•				
Printed materials	•	•				
Telephone communications	•		•	•	•	
Email communications	•		•	•		
Direct mail	•				•	
Public notices in newspapers and advertisements	•					
Media news releases	•					
Door-to-door outreach				•		
Community events and booths			•	•	•	•
Social media	•		•		•	•
Text messaging and applications	•		•	•	•	
Public comments during board and council meetings			•	•		
Public hearings			•	•		
Written comments	•			•		
Comments by phone	•		•	•		
Workshops			•	•	•	
Webinars			•	•	•	
Small group meetings					•	•
Presentations to standing committees, commissions and boards			•	•		
Direct conversation			•	•	•	
Task forces			•	•	•	•
Focus groups			•			
Surveys			•			
Technical working group meeting			•	•	•	
Industry compliance training programs			•	•	•	
Grants and incentives	•	•	•		•	

Source: Bay Area Air Quality District, 2013

Step 7. Planning and budget
Outlining each step of the communication strategy is important. What type of information should be disseminated? When will it be communicated, to which target group, and under what conditions? Making a communication calendar clarifies when the means should be developed to have them ready in time. After developing a plan, a budget must be allocated to ensure its implementation.

Step 8. Evaluation
To determine the impact of the communication, its effects need to be measured, which could be done by developing performance indicators. A common way of measuring impact is by determining the knowledge, attitude, and/or behavior levels before and after the communication activity.

ANNEX V. GUIDANCE AREA 5: CLEAN AIR ACTION PLANS

A. Components of Clean Air Action Plan Development

Table A5.1 Recommended components of a clean air action plan

Heading	Details
Executive Summary	
Introduction and Background	City overview: Geography and meteorology Population and urbanization Economic and industrial development Energy and transport
Legal Framework/Legislative and Policy Context	
Roles and Responsibilities (National/Provincial/Municipal)	
Current status and challenges of air quality Baseline assessment	
– Current status, Air Pollution Index (API) and comparisons to objective/standard	
– Emissions inventory and key pollutants	
– Causal analysis of effects and attribution to individual sources	
– Air pollution trends and tendencies analysis	Trends in air pollutant concentration
– Impact on public health and the environment	Evaluation of health effects, exposure to pollution investigation Environmental and economic impacts
Guiding principle	
Target and goals	Long-term environmental/development planning
Development of the Action Plan	Steps, time span, participants and process
– Process of development	
– Focus areas and main tasks	Specific planning linked with/refer to other government departments plan
– Expected impacts	Probability of success and risk factors for control measures and possible economic and social impacts
Implementation of the Action Plan	
– Analysis of costs and feasibility	Reachability analysis (qualitative) Cost and impact on air quality
– Institutional arrangements (enforcement procedures, roles and responsibilities)	
– Steps, working periods, timeline	

Supporting Policies	Specific planning linked with/refer to other government departments plan
– Monitoring and evaluation	Annual self-review Mid-term evaluation by independent party
– Resource commitment (Institution, financing, policy, technology, social)	
Key Projects	Key projects and their relevance to control measures (indicated by number) Specific sources of funding, how to guarantee the investment
– Analysis of costs and feasibility	
– Expected impacts	

Source: Clean Air Asia, 2012

B. Case Studies of CAAP Development

Case Study 1: Clean air plan development for Palembang City, Indonesia

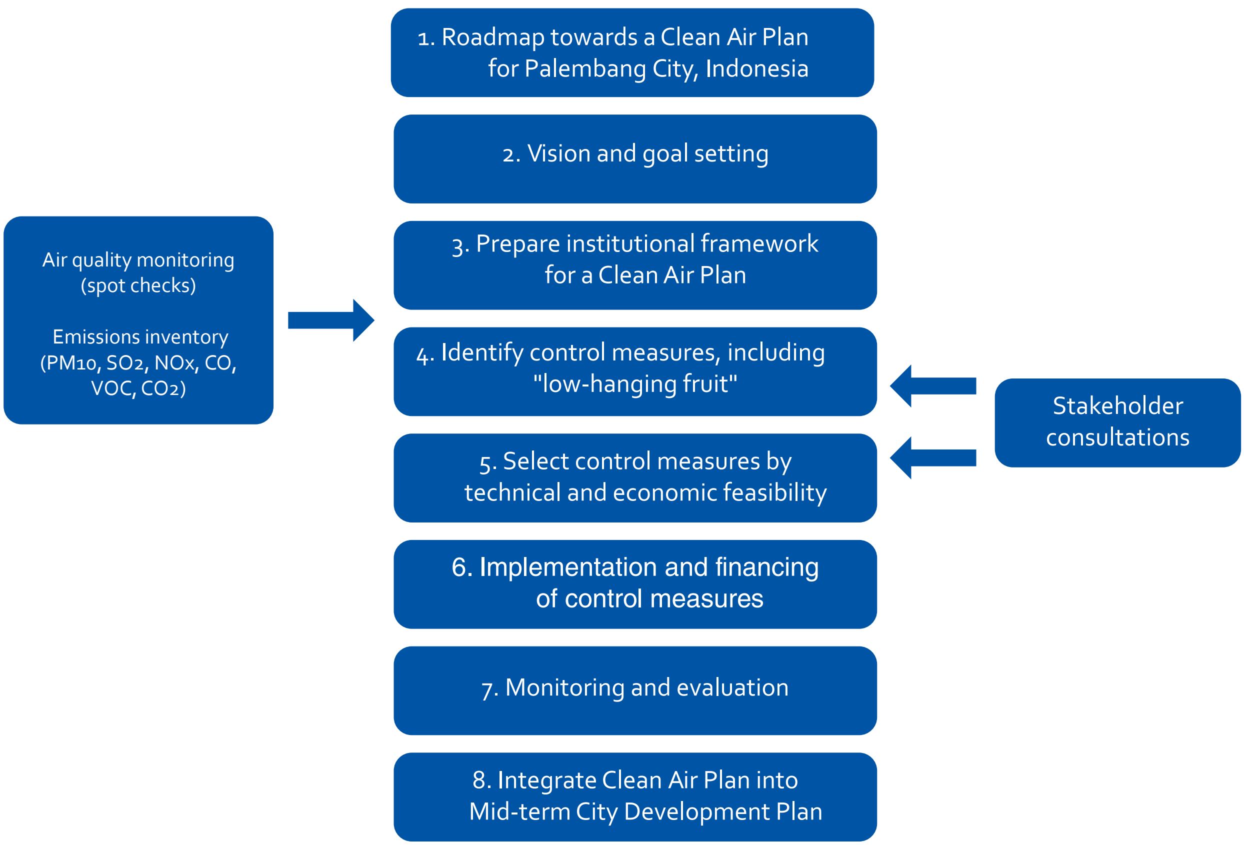


Figure A5.1 Clean Air Action Plan development for Palembang City, Indonesia

Source: ASEAN-GIZ CASC, 2014

The City of Palembang has completed its first CAAP in 2013 (ASEAN-GIZ CASC, 2014) (Figure A5.1). The process involves:

- **Roadmap development**, which documents some key issues and challenges facing Palembang's air quality at present and in the future, and describes the data and analytical requirements, time frame, as well as resources needed to establish a technically sound and practical CAAP for the city;
- **Vision and goal setting** through a participatory process;
- **Creation of an institutional framework for CAAP**, which consists of the establishment of a Technical Team and a Guidance Board to guide the process of developing and implementing CAAP. A brief description of the function and composition of the Technical Team and Guidance Board is presented in Box A5.1;
- **Air quality monitoring improvement** to provide information on the status of air quality in the city;
- **EI**, which identified the industrial and transport sector as the main contributors; and
- **CAAP development**, with a list of measures also submitted for integration in the mid-term development planning for 2013–2018 and GHG mitigation plan on the provincial level. The control measures proposed in CAAP Palembang included six transportation control measures and one stationary control measure. An annotated outline of the CAAP of Palembang is provided in Table A5.1.

Lessons learned in the CAAP development process for Palembang City include:

- There was limited data for detailed assessment (e.g., emissions reduction cost-effectiveness);
- The recent election and major shift in bureaucracy necessitate reiteration of political commitment by the city government;
- There was limited participation from civil society due to lack of interest;
- There was a need for a formal process for CAAP adoption in order to buy-in commitment of various stakeholders;
- The CAAP should fit the government development planning cycle for integration in the development plans; and
- The CAAP matrix (overview of control measures) should serve as a quick reference for integration in the development plans by policy-makers.

Box A5.1
Institutional framework for CAAP in Palembang, Indonesia

Two primary bodies are responsible for oversight of the process to develop and implement the CAAP for Palembang, namely the Guidance Board and the Technical Team.

1) Guidance Board
The Board was formulated as an outcome of the initial public input workshop to establish a vision for Palembang. It includes the key government agencies that are responsible for implementing the CAAP, as well as representatives of provincial government, non-governmental organizations (NGOs) and the private sector. The multi-sectoral group was utilized to establish the scope for a comprehensive CAAP and was eventually made responsible for reporting to – and receiving additional guidance from – the full multi-stakeholder group at subsequent workshops.

2) Technical Team
The Technical Team allows for the processing of complex information to support the actions of the Guidance Board. The team comprises of a small working group of select government staff with the addition of consultants and university experts. The Technical Team is responsible for the identification of data needs, evaluation of appropriate mechanisms, and formulation of recommendations for review by the Guidance Board. The Technical Team interacted directly with the GIZ team tasked to support them.

Table A5.2 Clean Air Action Plan of Palembang City, Indonesia

1. Introduction: Background and Objective
2. Emissions inventory and air pollution in Palembang
- Summary of EI
o Emissions from industrial sources
o Emissions from mobile sources
- Air pollution in Palembang
3. Institutional framework for a clean air plan in Palembang
- Clean air action plan and local mid-term development plan
- Clean air plan and local greenhouse gases mitigation strategy planning for South Sumatra province and the city of Palembang
- Vision and goal for Palembang clean air action plan
- Addressing air pollution in Palembang
- Additional assessment for transportation sector
o Initial remarks on roadway development
o Semi bus rapid transit "TransMusi"
- Promotion of non-motorized transport
o Car free day and awareness raising
o Pedestrian and bicycle
- Parking
- River and intermodal transport
4. Proposed actions and measures
- Measures for AQM aspects
o Setting up legal and institutional framework for AQM
o Improving EI and air quality monitoring systems
- Measures for the transportation sector
o TransMusi fleet expansion and system improvements
o General improvements for reducing TransMusi travel time
o Encourage use of bicycles as a "feeder" for TransMusi
o Review of CNG (Compressed Natural Gas) conversion program
o Development of integrated public transport stations
o Improvements of inspection and maintenance system for public transport and logistical fleet
o On-spot emissions check for private vehicle
o Parking
o Park and ride
o Study for the development incentives for the area surrounding TransMusi stops along River Musi
- Measures for the industrial sector

5. Estimated emissions reduction from proposed actions
- Estimated emissions reduction from TransMusi fleet expansion and system improvements
- Estimated emissions reduction from integrated multi-modal stations
- Estimated emissions reduction from improvement of compulsory I&M (Inspection and Maintenance) system
- Estimated emissions reduction from improvement of voluntary I&M system
6. Clean air plan implementation and financing
7. Clean air plan monitoring and evaluation

Source: ASEAN-GIZ CASC, 2014

Case Study 2: Clean air action plan development for San Francisco Bay Area

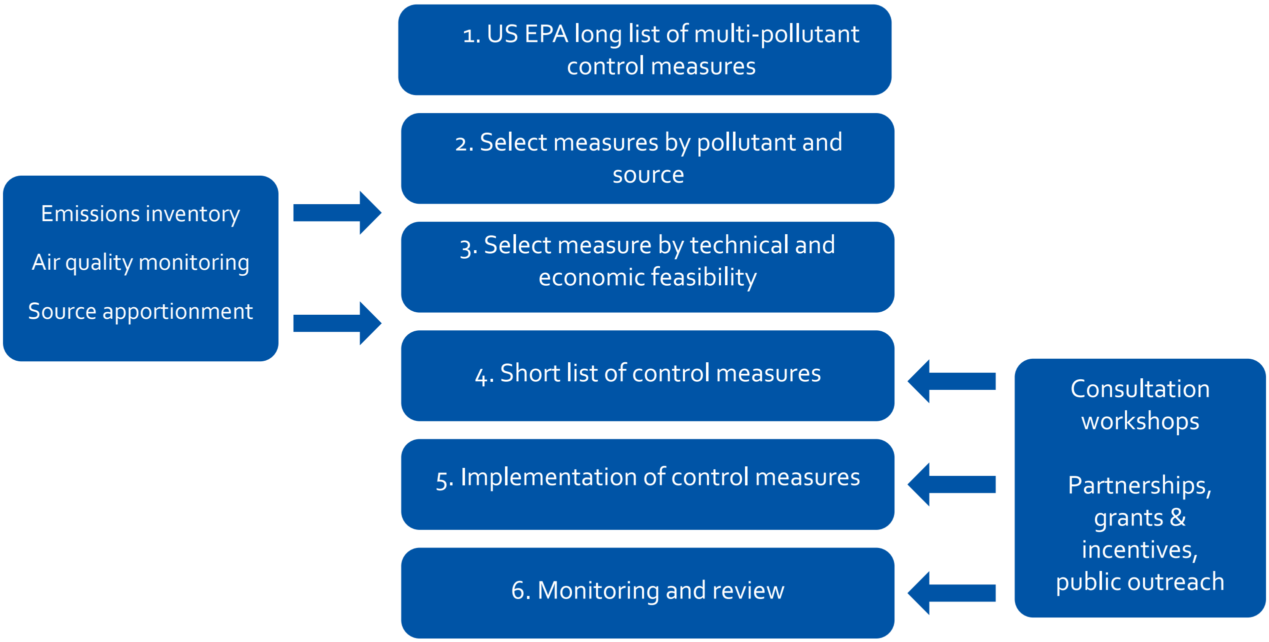


Figure A5.2 San Francisco Bay Area 2010 Clean Air Action Plan development
Source: Bay Area Quality Management District, 2010

The Bay Area 2010 Clean Air Action Plan (Figure A5.2) provides a comprehensive plan to improve air quality and protect public health in the area (Bay Area Air Quality Management District (BAAQMD), 2010). The plan defines a control strategy that the district and its partners will implement to: reduce emissions and decrease ambient concentrations of harmful pollutants; safeguard public health by reducing exposure to air pollutants that pose the greatest health risk, with an emphasis on protecting communities most heavily impacted by air pollution; and reduce GHG emissions to protect the climate.

The plan addresses four categories of pollutants:

1) ground-level ground-level O_3 and its key precursors, reactive organic gases and nitrogen oxides (NOx);
2) PM – primary $PM_{2.5}$ and precursors to secondary $PM_{2.5}$;
3) air toxics, and
4) GHGs.

The control strategy builds on a solid foundation established by the 2005 Ozone Strategy and previous ozone plans prepared in the period 1991-2005. The 2010 control strategy proposes a total of 55 control measures, including 18 stationary source measures, 10 mobile source measures, 17 transportation control measures, six land use and local impact measures, and four energy and climate measures. The last two categories of measures are identified as new categories in addressing emerging challenges and opportunities. An update to the 2010 Clean Air Action Plan is currently underway. In addition to measures to lower the exposure of Bay Area residents to the specified air pollutants in the near-term, the 2015 Clean Air Action Plan will include a regional climate protection strategy to achieve significant long-term reductions in GHGs BAAQMD, 2015).

Case Study 3: Clean air plan development for Germany

In Germany, the enforcement of emission and air quality standards ensures that actions are taken to control polluting sources in order to comply with the standards. In the third quarter of the last century, the air pollutant situation in some areas (e.g., the Rhein-Ruhr area) was characterized by a multitude of different types of sources; hence, causal assessment of public health risks with respect to a single source or group of sources became extremely difficult. As a consequence, and on the basis of the "polluters pay principle", sophisticated tools (e.g., emissions inventory, dispersion models, ground level monitoring systems, and epidemiological assessments) were developed to assess the pollution sources, air pollutant concentrations, health and environmental effects, and control measures. The tools also permitted to establish causal links between emissions, the air pollution situation, and the efficiency of the necessary control measures. The instruments used to achieve cleaner air in Germany are the Clean Air Implementation Plans (CAIPs). The outline of such a plan is defined in the Law on Protection against Harmful Environmental Exposures to Air Pollution, Noise, Vibration, and Similar Phenomena (BImschG, 1974) and its implementing regulations. The CAIPs have proven to be the most efficient instruments for air pollution abatement in Germany. In the period of 1975 to 1994, SO_2 concentrations decreased by 75 percent, PM_{10} by 40 percent, Pb and Cd by 80 percent, and NO_2 by 20 percent (Schwela and Köth-Jahr, 1994). The most recent CAIPs for the Ruhr area was published in three parts in 2011 (BR Münster; BR; LRP West). A suggested outline for fully-developed CAIP is presented in Table A5.2.

Components of a CAIP include:

- Description of the area
- Emissions inventory
- Air pollution concentration inventory – monitored and simulated
- Compliance of emissions and pollutant concentrations with respective standards
- Causal analysis of health and environmental effects and attribution to sources
- Control measures and their costs
- Benefits of avoided impacts
- Transportation and land use planning
- Resource commitment
- Projections for the future

Table A5.3 Suggested outline for fully developed stage of CAAP

1. Executive Summary and Foreword
2. Introduction and Background
3. Legal Framework/Legislative and Policy Context
4. Roles and Responsibilities in AQM
5. Baseline Assessment and AQM System
– Current status, API and comparisons to objective/standard
– Emissions inventory and key pollutants
– Analysis of effects and attribution to individual sources
– Modeling and projections for the future
– Air pollution trends and tendencies analysis
– Impact on public health and the environment
6. Formulation Basis and Guidelines
7. Vision, Goals, and Targets
8. Development of the Action Plan
– Process of development
– Focus areas and main tasks
– Expected impacts
9. Implementation of the Action Plan
– Analysis of costs and feasibility
– Institutional arrangements (enforcement procedures)
– Steps, working periods, timeline
10. Supporting Policies
– Monitoring and evaluation
– Resource commitment (Institution, financing, policy, technology, social)
11. Priority Projects
– Analysis of costs and feasibility
– Expected impacts

ANNEX VI. GUIDANCE AREA 6: GOVERNANCE

Process of Enhancing Environmental Governance

Enhancing environmental governance requires: (1) designing effective environmental policies and measures; (2) designing clear institutional arrangements on AQM; (3) mobilizing financial resources; (4) mobilizing political support; (5) strengthening capacity for AQM, and (6) strengthening capacity for AQM.

1. Designing environmental policies and measures:

a. Using clear and enforceable language

To ensure effectiveness, it is necessary that air pollution control measures are enforceable. This can be done by ensuring that measures are within a framework of enforcement.

(1) Mandating authority for enforcement. Examples include authority to issue permits, conduct inspection, collect fees, require monitoring and reporting and to take legal action.
(2) Setting clear institutional framework which describes who or which agency/department is responsible for implementation. This can also include mechanisms for stakeholder involvement.
(3) Related laws fostering fair judgment and preventing bribery or falsification of data.
(4) Compatibility, and not conflict, with existing laws.

There are many approaches which can be used to help ensure that the air pollution control measures will be enforceable. The International Network for Environmental Compliance and Enforcement (INECE) provides a sample checklist (INECE, 2009) which can be considered, especially during the design process which can contribute to making these measures enforceable.

Essentially, these are based on the following approaches:

(1) Balance stringency of measures with feasibility
(2) Develop an atmosphere for compliance by demonstrating value and demonstrating options and feasibility
(3) Ensure that the measures or regulations are clear and practical
(4) Analyze the regulated sector/community's ability to complete and the size of the regulated sector
(5) Design mechanisms for stakeholders' involvement and participation in enforcement.

b. Using a full range of complementary policy instruments

There are several tools available for AQM. Section 1.1.2 of Chapter 7 on *Guidance Area 6: Governance* summarized the types of policy instruments which countries and cities can use to reduce air pollution. Chapter 6 on *Guidance area 5: Clean air action plans* also provides a comprehensive listing of various measures which can be implemented to reduce emissions from various sources. It is recommended to explore this wide range of available instruments and select appropriate and complementary measures to achieve air quality improvement.

2. Designing clear institutional arrangements on AQM

Establishing or strengthening the national and local institutional set-up for AQM will ensure capability to implement AQM policies, enforce laws and regulations, and review their effectiveness. As a first step, this will necessitate establishing a lead agency for the implementation of environmental goals, policies and strategies. It can assist in consolidating responsibilities and avoiding duplication of work. An essential next step is defining, documenting, communicating and enforcing roles and responsibilities. In these steps, human resources, specialized skills, technology and financial resources will be essential to the implementation and control of AQM.

Clear definition of roles and responsibilities between various stakeholders involved in AQM is important to avoid inefficiencies. Well-designed institutions that clearly delineate roles and responsibilities and routinely incorporate international best practices will be crucial. Some of the key functions which should be considered in defining the roles are (i) pollution prevention; (ii) risk assessment and risk reduction; (iii) scientific research and technology; (iv) regulatory education; (v) regulatory development, and (vi) enforcement (Shah et al., 1997).

It is not necessary that these functions are performed solely by government agencies, but would also be supported by other stakeholders in AQM in the city or country. For instance, there are several ministries involved in AQM in addition to environment ministries. These include transport, energy, health, local governments, urban development, education, climate change and others. Strengthening institutional linkages between these relevant ministries would help maximize limited resources and bring about co-benefits.

It is also recognized that existing governance approaches in the country or city would affect how AQM is implemented – for instance, assessing centralization of AQM at the national level or decentralization at subnational levels. There are advantages and disadvantages to both approaches. INECE (2005) presented case studies on both approaches from the United States and the Netherlands discussing how the system worked for both cases and how they have been able to address the disadvantages of a centralized or decentralized system.

Another aspect which needs to be considered is coordination and cooperation with neighboring cities and regions, recognizing the transboundary nature of air pollution. This can include measures such as harmonization of standards, joint monitoring and development of management measures, and collaborative capacity building projects. Identifying the proper motivation for regional environmental management could facilitate active cooperation between parties. Regional air pollution control could be cost-effective in the long run, provided that there is a clear and appropriate plan of action and alignment of objectives with the development goals of the cities or countries involved (INECE, 2005). Setting up an effective institutional framework would be key to advance air quality improvement through regional action (INECE, 2005).

3. Mobilizing financial resources

In terms of financial resources, various funding mechanisms can be used to improve air quality management activities. A summary of approaches which countries and cities can use is provided below, starting with the mechanisms that are more appropriate to top-down arrangements and moving to those that are compatible with more multi-level, multi-stakeholder mechanisms.

a. Mobilizing resources internally

- **Government-appropriated budget.** Most Asian countries allocate financial resources for environmental management and AQM as part of annual nationally-appropriated funds. The scale of these funds varies per country and year. This is most effective when there is a broad-based participatory approach to strategy formulation and action planning (UNEP, 2006). For example, the Government of Vietnam (2005) is mandating that the government spend 1 percent of the state budget expenditure for environmental protection. Currently, one of the challenges experienced by countries is that AQM is under-funded as it gets low-priority funding (SEI, 2008). Increasing priority for air quality action by mobilizing political will and public support can help secure higher government budget allocation for AQM.

- **Tax-generated funding resources.** It is also possible to generate funds through the collection of environmental and pollution charges. Pollution charges are calculated by establishing a base rate to emit pollutants within a certain limit; if institutions exceed, then they will pay higher than the base rate (United Nations, 2005). Most fiscal instruments such as pollution charges and fees are guided by the "polluters pay principle", where the polluter must be responsible for ensuring that the environment is in an acceptable state (Organisation for Economic Co-operation and Development [OECD], 1992). Through this principle, funds will have a preventive function by providing a deterrent in continuing air pollution and a curative function by making the polluter responsible in remediating the contaminated location (European Commission, 2012). The disadvantage of this form of funding is that it is hard to account for. Instead of going directly to the agency, the collection may go directly to the general fund of the government (UNEP, 2006). To address this limitation, it is important to become transparent on how the funds have been used for AQM.

- There are several examples from developing Asia which have used tax-generated funding resources to support air quality action. In the Philippines, there is the Special Vehicle Pollution Control Fund (SVPCF) established under Republic Act No. 8794. The funds are generated from vehicle user's charge on all motor vehicles and paid for by the owner. The collections are divided as follows: 80 percent for the special road fund, 5 percent for special local road fund, 7.5 percent for special road safety fund, and 7.5 percent for special vehicle pollution control funds (Clean Air Asia, 2010). In 2014, SVPCF amounted to PHP 80.2 million (or an estimated USD 17.2 million) and 65 percent of the fund will be used to support eight proposed projects (Land Transportation Office, 2014). In the Indian city of New Delhi, poor air quality prompted the government to impose 25 Indian rupees per liter fuel tax on diesel that was collected and transmitted into an Air Ambience Fund. The levy is collected by the Department of Trade and Taxes and used for the reimbursement, and the operations and maintenance of air quality monitoring stations (ADB & Clean Air Asia, 2014).

- **Partnerships with private sector.** A government can also form partnerships with various private institutions in order to augment limited financial resources. Private sector involvement may be advantageous, especially in the early stages of project development, as they generally have a strong financial capacity and can have an influence on air quality sources (UNEP, 2006).There are various guiding principles that guide a successful public private partnership (PPP) such as estimation of projects' affordability, competitive bidding, clear responsibility and risk-sharing agreements (OECD, n.d.). One example of a successful PPP is when Seoul reformed its bus system in 2004. Before, bus transport system in South Korea was poorly maintained due to competing private buses. To solve this problem, the government participated in a unique joint model where the government controls infrastructure and planning while the private sector handles route adjustments, service schedules and issuance of operator licenses (Putcher et al., 2005; Kim and Kim, 2012).

- **Proprietary Innovative Technologies.** Funding can also be generated by the cooperation of two private entities locally through commercial profit. The "Air de Paris" balloon in Paris, a partnership between Airparif® and Aerophile, is an effective and innovative way of engaging the general public on air quality awareness in their cities through a tourist attraction-cum-scientific tool (Bitterman, 2010). Its highly creative and eye-catching design combined with its built-in utility lends the possibility of deploying similar mechanisms that could be packaged to interested advertisers to defray operating expenses. Funds generated from the balloon may help support air quality activities in a city (ADB & Clean Air Asia, 2014). In the case of Paris, the installation of the complete system is estimated to cost about 920,000 Euros (about 1.25 million USD) (Aerophile, 2012). Based on the "Air de Paris" experience, it is estimated that income generated from balloon ticket sales, sponsorship/advertisements and events reached 1.09 million Euros (about 1.4 million USD) in one year (Aerophile, 2012). The initial investment was recovered after a year.

b. <u>Mobilizing resources externally</u>

Financial and technical assistance can also be sourced externally from donor communities and international agencies (INECE, 2005):

- **Support from international agencies, international non- governmental agencies and bilateral agencies.** Air quality initiatives can be supported by intergovernmental agencies such as the different bodies of the United Nations such as the UNEP and United Nations Development Programme (UNDP); multilateral development banks such as ADB, Africa Development Bank; and the World Bank, and international non-governmental agencies, including Clean Air Asia, International Union for Conservation of Nature, and International Council for Local Environmental Initiatives. Various air quality programs can also be supported by organizations from specific countries or bilateral agencies such as Australian Aid, Danish International Development Agency, GIZ, Norwegian Agency for Development Cooperation, Swedish International Development Authority, and United States Assistance for International Development.

- **Utilizing international instruments and conventions.** International financial mechanisms can also be tapped to support air quality action. These include (1) the Global Environment Facility which is a financial mechanism designed to assist developing countries to address major environmental problems and (2) the Clean Technology Fund , a funding window of the Climate Investment Funds which provides scaled-up financing to middle income countries to contribute to the demonstration, deployment and transfer of low carbon technologies with a significant potential for long-term GHG emissions savings.

4. Mobilizing political support

A strong sense of political will among key policy actors at the national and subnational levels is important in the planning, implementation and review stages of air quality measures. A lack of vision and political will can undermine even well-designed regulations. In the absence of visible leadership, implementing agencies, businesses and civil society are far less likely to work together in a collective effort to improve air quality. The support of political leaders can ultimately contribute to the allocation of sufficient and appropriate financial and human resources – essential elements of a sound and robust approach to air quality governance. These efforts often go hand in hand with capacity building as financing can solidify knowledge and technical competence.

The involvement of a public figure as a champion promoting awareness campaigns can also significantly enhance public information, education and communication. Providing more information can help create a deeper understanding of the air quality issues that can, in turn, help implement integrated AQM plans and actions [See *Guidance Area 4 on Air quality communication*]. While this may not facilitate provision of sufficient resources and capacity to implement management measures, it may trigger policy changes elsewhere. For instance, China's political leadership in tackling air pollution has made it possible in recent years to have a concerted effort in establishing action plans (Box A6.1).

Box A6.1
China's post-2020 climate action target

In an unprecedented move, China has announced its post-2020 actions on climate change. Domestic air pollution is forcing the country to embark on a trajectory away from the consumption of coal. Corresponding actions are undertaken by the Chinese government to reach its goal of cutting the intensity of its carbon consumption by 40 percent–45 percent by 2020 from its 2005 levels. This will contribute significantly to the reduction of air pollution in the country and address global warming at the same time.

Source: UNEP, 2014

Prior to implementing strategies, the AQM strategy design phase should include working group members who are directly involved in the implementation phase. These are often the members who will adopt the strategy and can be from the national and local agencies concerned. It is expected that they hold consultations with their constituencies or organizations to facilitate the adoption of a selected strategy (UNEP, 2006).

In sustaining political support, transparency and accountability in public service delivery is essential (SEI, 2008). Stakeholders seek and uphold the value of responsibility in key government agencies and officials to work for the public's interest. By this, stakeholder support can be guaranteed and the mobilization of technical and financial resources will be easier for a successful strategy implementation.

Apart from political will within and among key actors, public pressure can also incite political action. Public disclosures of performance put public pressure on both the regulator (to do their job well) and the regulated (to comply with the environmental laws, rules, and regulations). This has been proven effective in many countries and even in the Philippines since companies value their public image.

5. Strengthening capacity for AQM

Underlying the effectiveness of environmental governance is the capacity of institutions to provide the fundamental structure within which the different approaches and core principles will be in place; stakeholders can take advantage of and/or create spaces to participate and/or influence policies and processes; and there is space for intersection between institutions and stakeholders. The lacking/limited institutional and personnel capacity needs to be addressed regularly and systematically to facilitate rollout of policies, and identification of and implementation of measures.

Enhanced capacities of institutions and stakeholders are relevant and critical, regardless of the governance approach applied. This can also facilitate participation and inclusion of a wider range of stakeholders in the implementation of AQM measures as well as governance processes.

Key agencies must be adequately staffed, and AQM programs and methods implemented by qualified people. Currently, lacking or limited capacity is a key barrier to AQM in developing Asian countries. Therefore, capacity enhancement and training programs must be responsive to identified needs and AQM knowledge gaps of stakeholders so they can address issues more effectively. To do this, the following steps need to be undertaken:

1. **Training needs assessment.** This involves evaluation of the current level of the knowledge and skills of (staff in) institutions and identified stakeholder groups, and taking stock of training programs available that can be accessed to address the knowledge gap.
2. **Conduct of capacity building activities.** This can be done

either through existing in-house training programs, where they exist, or linked with organizations that provide training on areas/topics that have been identified in the training needs assessment. This is to avoid "reinventing the wheel" and maximizing the resources and training programs that are already available in the market.

3. **Development of training courses.** Where no training programs currently exist, training courses need to be developed in a manner that promotes and strengthens participation of other stakeholder groups (e.g., local universities and NGOs, among others) and ensures that the course development process and training delivery are sustainable. For example, there is a need for training courses to enhance participation in communication and advocacy initiatives in health projects.
4. **Facilitation of partnerships and network building.** Establishing and strengthening partnerships among key stakeholders will help create a pool of trainers and experts that can provide expert guidance, inputs, and support to training development and delivery. This will create a mechanism for sustainability of initiatives and activities related to training. Moreover, this will generate informal and ad hoc platforms that allow peer-to-peer and peer-to-expert learning; further ensuring continuous learning, provision of support, and application of tools and concepts learned from/in the training programs.

With more stakeholders involved, a collective network of expertise, knowledge, and resources can be developed to ensure that capacity building programs are up-to-date, responsive, and leads to more effective AQM. This allows for better designed mechanisms that communicate risks, inform policies, standards and regulations, and guide better implementation.

Availability of and access to new knowledge and up-to-date information is likewise important for an institution or stakeholder group's continuous learning process. For sustainability, in-house capacity building programs that will address and routinely update skills and knowledge of an institution's staffing/human resources is critical. Otherwise, collaboration with other institutions/organizations that provide training can also be an option so the city/ministry can maximize its resources while still ensuring that their staff's knowledge and skills are updated.

Other less technical capacity building activities – e.g., resource mobilization, proposal writing, communicating air quality data, and mobilization of stakeholders – are equally important topics/areas by which the capacity of institutions/stakeholders can be improved and can result to significant changes in environmental governance.

6. Institutionalizing participation and engagement

Air quality management becomes more effective when key stakeholders are more involved in its design, implementation, monitoring and evaluation processes. The key stakeholders in AQM include the national and local governments, private sector, NGOs, academic and research institutions and media.

Effectively communicating the severity of health impacts of air pollution to constituents in terms of economic value is one way to gain political support for air quality management (SEI, 2008) [See *Guidance Area 3: Health and other impacts* and *Guidance Area 4: Air quality communication*]. Highlighting co-benefits of addressing air pollution with climate and other concerns (congestion, fuel savings, energy efficiency, among others) can also strengthen the political appeal of air pollution regulation. Once political support has been secured, it is imperative to maintain it through transparency and accountability; this requires participatory approaches in implementation, and timely monitoring and reporting of the implementation to key stakeholders (SEI, 2008).

The level of involvement of stakeholders can be summarized into three main types that are primarily defined by the purpose of their engagement (Table A6.1). Each process has its own value and can be linked to work towards a more complex collaborative process where issues are presented and views of different stakeholders are taken into account by AQM authority, as demonstrated in the case of the Philippines' adoption of cleaner fuels and vehicles (Box A6.2). Strategies should be prepared in the context of the specific measure or program and with sensitivity to the local situation (World Bank, 2007).

Table A6.1 Forms of stakeholder involvement and techniques

	Distinct feature	Techniques
Informative	One-way communication between the government and stakeholders mainly to provide the necessary information to stakeholders for better understanding of issues and solutions	Information dissemination through various media platforms (TV, radio, factsheets, newsletters, websites), open house, forums and conferences
Consultative	Two-way communication between the government and stakeholders to gather feedback on possible solutions to issues	Workshops, advisory committees, focus groups, public meetings, scoping meetings, dialogues
Collaborative	A more "upstream" communication between government and stakeholders where a wider range of stakeholders are involved in the decision making process	Joint working groups, steering committee, consensus decision-making,

Adapted from Taylor and McMillan, 2013

There are three major aspects where private sector and civil society can play important roles while taking into account the corresponding mechanisms/channels to best engage all key stakeholders:

1. Decision-making process: Key stakeholders need to be engaged as early as possible in the policy development process in order to gain their full support for implementation and enforcement. While formulating the policies and laws, government should hold consultations with the cross sections of private sector and civil society, and elicit views and suggestions through the electronic and print media that are made accessible to the public at large.
2. Policy implementation and enforcement stage: Government agency alone cannot deal with all issues of policy implementation and enforcement of AQM; therefore, working together with private sector and civil society and applying each stakeholder's strengths is the best way to achieve maximum effect. Having an open mind to the positive role of each stakeholder, keeping dialogues with each other, setting common objectives and creating collaboration platforms/channels to achieve set objectives should be acknowledged and promoted by stakeholders in general and, in particular, by the national and local governments which should proactively do so.
3. Policy monitoring and evaluation process: The policy monitoring and evaluation process is often neglected by Asian governments at the moment. To undertake this process most effectively, key stakeholders need to be consulted, and their views and suggestions sought.

The participation of stakeholders in the above-mentioned policymaking and monitoring and evaluation processes could be made obligatory by laws and regulations to make the best use of such mechanisms, especially in countries where the primary regulatory approach is command and control. As for the stage of implementation and enforcement, stakeholder participation can be based on how collaborative and innovative each stakeholder can be. However, one important step that can be taken to substantially change the role of civil society in enforcement is to give legal standing to public or non-governmental organizations to file public interest lawsuits in court. Such judicial interventions have been proved to trigger the evolution of more effective policies and laws in developed countries. For example, the US governance model allows for environmental NGOs to compel the USEPA to issue regulations implementing many of the federal laws that required comprehensive regulatory programs to protect the environment (INECE, 2005).

A constructive stakeholder engagement throughout the planning and enforcement process is critical in improving and developing long-term AQM actions. To sustain the relationship between stakeholders, the engagement process should be institutionalized and supported by several key practices as outlined by the World Bank (2007) and in the UNEP Urban Air Quality Management Handbook (UNEP, 2006):

- Capacity building of government agencies in conducting public consultation activities, to develop knowledge and skills in areas such as listening and communication, community outreach and partnering, issue identification and management, consensus building, vision building, negotiation and alternative dispute resolution. This can also include a "sensitivity" training to increase the understanding of the needs and perspectives of NGOs and non-public groups.
- Capacity building of local government, NGOs, and civil society institutions to better understand environmental issues and the current available solutions, and to effectively engage in public participation fora.
- Regulatory agencies as well as private companies should provide public access to credible and easily available information such as pollution control strategies.
- Documentation should use non-technical or local language and be utilized to raise public awareness on certain air quality issues

Box A6.2
Advancing cleaner fuels and vehicles in the Philippines - with a focus on multi-stakeholder engagement

The Philippine Clean Air Act of 1999 (Republic Act/ RA 8749) envisions a multi-sectoral participatory approach to achieve and maintain healthy air in the Philippines through the solicitation of ideas and recommendations from the private sector, including the industry, NGOs and the general public, among others.

One of the regulations set by the Department of Environment and Natural Resources (DENR) to reduce emissions from motor vehicles is emission standards. These are set through an Inter-agency Technical Committee (IATC) composed of representatives from concerned government agencies and stakeholders (i.e. car manufacturers, oil players, NGOs, academe). The entire process consists of consultation meetings with key stakeholders who then provide technical views/feedback on the proposed emission standards.

During the consultation process on improvement of emission standards from Euro 2 to Euro 4, the members of the IATC were informed of the reasons to push for the reform, which include (1) the need to improve the air quality - which is in exceedance of the TSP annual guideline value of 90 µg/Ncm as prescribed in the RA 8749 since 2004 (note that this is the only available monitoring data during the consultation process); and (2) to harmonize emission standards with ASEAN countries in response to the request of the Committee on Harmonization of Vehicle Standards and Regulation chaired by the Department of Transportation and Communication. Through this process, the members of the IATC recognized the air quality problem and the need to be competitive within the ASEAN region.

Several stakeholders that include car manufacturers and oil players, however, presented their case to support the allowance of a five-year compliance period with the Euro 4 standards for purposes of planning and design. One of the major issues raised by these groups is the nationwide availability of Euro 4 fuels to meet the fuel requirement of Euro 4 vehicles. Until such time that Euro 4 fuels become readily available throughout the country, and not only in select Metro Manila gas stations, the interest of the consumers must be protected. A supply problem also exists as local production of Euro 4 fuels are not yet ready by 1 July 2015. Oil suppliers shall resort to importation within the region which may inevitably cause shortage of fuel supply. The IATC found the above-cited issues to be valid and acceptable.

As a response to these concerns, the Department of Energy Technical Committee on Petroleum Products and Additives, through the Bureau of Product Standards -Department of Trade and Industry, issued the Philippine National Standards (PNS) for both automotive diesel and gasoline fuels with sulfur content of 50 ppm in 2012. In the same year (2012), Euro 4 automotive diesel (50 ppm S) became available in some re-filling stations in Metro Manila and other highly urbanized centers, like Cebu City, Baguio City, Davao City, among others. It was also agreed that heavy duty vehicles will comply with Euro 4 emission standards on a later date, citing reasons such as economic impact, small share in vehicle fleet (around 10 percent), and pending consideration in the ASEAN integration program as mentioned by the Truck Manufacturers' Association.

The multi-stakeholder and participatory approach served as a mechanism for providing mutually acceptable solutions and win-win situations. In this way, the DENR is confident that the implementation of Euro 4 standards by 1 January 2016 will be successful and sustained because stakeholders were part of the decision-making process.

Sources: Philippine Clean Air Act of 1999 (Republic Act 8749), DENR Administrative Order No. 2000-81, DAO 2010-3, PNS for automotive diesel and gasoline

7. Strengthening compliance and enforcement, evaluation and review

Ensuring compliance with air quality targets/requirements and enforcement of appropriate air pollution measures is essential to achieving air quality improvement. While Asian cities and countries recognize the importance of compliance and enforcement, it is also considered one of the challenging aspects of AQM (Box A6.3).

Box A6.3
What is compliance and enforcement?

Compliance is the full implementation of environmental requirements. Compliance is usually monitored through (i) inspections; (ii) self-monitoring, self-recordkeeping, and self-reporting; (iii) citizen complaints/monitoring; and (iv) area monitoring.

Enforcement refers to the set of actions undertaken to achieve compliance. Examples of enforcement strategies include inspection, negotiation or agreements with regulated communities/sectors which are non-compliant, legal action, and compliance promotion.

An effective enforcement program involves several components:

- Creating requirements that are enforceable;
- Knowing who is subject to the requirements and setting program priorities;
- Promoting compliance in the regulated community;
- Monitoring compliance;
- Responding to violations;
- Clarifying roles and responsibilities, and
- Evaluating the success of the program and holding program personnel accountable for its success.

These components form a framework to guide the consideration of issues pertinent to any enforcement program, at any stage of development.

Source: INECE, 2005

Compliance monitoring and enforcement programs have been generally based on the principles of deterrence (to prevent or discourage from acting), detection (compliance monitoring), and sanctions (such as fines or penalties) (Institute for Governance and Sustainable Development and INECE, 2005). It has been observed that most of the factors which affect compliance are linked with the behavior of the regulated community (see Table A6.2).

Table A6.2 Factors affecting compliance

Factors motivating compliance	Barriers to compliance and factors encouraging noncompliance
Economic	
Desire to avoid a penalty Desire to avoid future liability Desire to save money (or access to incentives) by using more cost-efficient and environmentally sound practices	Lack of funds Desire to achieve competitive advantage Competing demands for resources
Social/ moral	
Moral and social values for environmental quality Societal respect for law Clear government will to enforce environmental laws	Lack of social respect for the law Lack of public support for environmental concerns Lack of government willingness to enforce policies
Personal	
Positive personal relationships between program personnel and facility managers Desire, on the part of the facility manager, to avoid legal process Desire to avoid jail, the stigma of enforcement, and negative publicity	Fear of change Ignorance about requirements Ignorance about how to meet requirements
Management	
Jobs and training dedicated to compliance Bonuses or salary increases based on environmental compliance	Lack of internal accountability for compliance Lack of management systems for compliance Lack of compliance training for personnel
Technological	
Availability of affordable technologies	Inability to meet requirements due to lack of appropriate technology Technologies that are unreliable

Source: INECE, 2005

Perception of the regulated community/sectors to the enforcing agencies is an important factor affecting compliance. It is necessary for the government or enforcing agency to impart a reputation that they are capable of imposing penalties and sanctions stipulated for noncompliance. Governments/regulating agencies also need to ensure the target audiences know about them and the regulations they have set in place to improve air quality. This relates to implementation of a good communication plan [See *Guidance Area 4 on Air quality communication*].

As such, air pollution control programs will generally be most effective if they include a range of approaches to changing behavior through (i) promoting compliance through education and incentives, and (ii) identifying and taking action to achieve compliance.

In both approaches, it would be necessary to consider the context in the national and subnational levels in developing the compliance strategies and enforcement programs. Understanding of the regulated community/sector would be useful in ensuring that the program design will meet its desired objectives. Table A6.3 illustrates examples of how specific compliance strategies became successful.

Table A6.3 What contributed to success in environmental enforcement?

Perception	Actual
• Generally, individuals and corporations constitute the regulated, or potentially regulated, community. For environmental compliance purposes, however, even these groups may be too broad for effective policymaking, especially where the intent is to influence or alter corporate behavior.	• Internal corporate structure and penalty/reward systems influence how corporations address compliance internally or react to external enforcement by government bodies. • It is noted that environmental inspectors tend to associate compliance with dedicated environmental staff who have sufficient rank and authority to influence corporate decision-making
• One of the most tangible consequences of government actions to achieve deterrence, apart from jail sentences, are civil and criminal penalties.	• For many firms, deterrent impacts which penalties generate may pale in comparison with the potential impacts of market forces such as consumer demand, stakeholder loyalty, declining stock prices in response to pollution liability fears, poor eco-efficiency that shareholders relate to reduced profitability and liabilities from negative publicity. • Note that market forces are capable of generating financial pressures with a greater order of magnitude than those posed by most penalties.
• Increasing penalties are sufficient to lead to measurable compliance improvements.	• This may not necessarily occur if relatively higher penalties remain too low for the regulated community/sector.

Source: Institute for Governance and Sustainable Development and INECE, 2005

Monitoring of compliance follows along with implementation of the enforcement strategies. As previously mentioned (Box A6.3), information for compliance monitoring can be collected through (i) inspections; (ii) self-monitoring, self-recordkeeping, and self-reporting; (iii) citizen complaints/monitoring; and (iv) area monitoring (including ambient air quality monitoring, remote sensing, use of satellite measurements). There are various advantages and disadvantages which should be considered when selecting which strategy for compliance monitoring is utilized (Table A6.4).

Table A6.4 Advantages and disadvantages of primary sources of compliance information

Information source	Advantages	Disadvantages
Inspections	Provide the most relevant and reliable information	Can be very resource-intensive. Must be carefully targeted and planned.
Self-monitoring, self-recordkeeping, self-reporting	Provide much extensive information on compliance. Shift economic burden of monitoring to the regulated community. May increase level of management attention devoted to compliance.	Rely on integrity and capability of source to provide accurate data. Place a burden on regulated community and increase the paperwork for the compliance program.
Citizens monitoring	Can detect violations that are not detected by inspections or industry self-monitoring, reporting, and record keeping.	Sporadic. Cannot control the amount, frequency, or quality of information received. Only a few violations noticed by citizens.
Area monitoring	Useful for detecting possible violations without site inspection. Also useful for determining whether permit or license requirements are providing adequate environmental protection.	Can be difficult to demonstrate a connection between the pollution levels detected and a specific source. Resource-intensive in areas of multiple sources.

Source: INECE, 2005

Systematic monitoring, review and evaluation is a key part of the implementation of AQM strategies as it enables an assessment of the effectiveness of implementation, including achievement of target and milestones and amendment of implementation measures (when they are inadequate) (SEI, 2008).

There are various measures of success to evaluate effectiveness of air quality actions. Based on the Foundation Course on Urban Air Quality Management (SEI, 2008), some indicators to assess progress include the reduction of:

- concentration levels and exposures;
- air pollution-related burden of disease;
- emitted amounts of harmful substances;
- effects on the environment;
- energy used by all stakeholders, and
- air pollution emissions

These are mostly classified as environmental results. It may also be possible to design indicators for compliance rates; indirectly measuring compliance monitoring, number of enforcement responses, monetary penalties assessed, among others.

ANNEX VII. DEVELOPMENT STAGES OF AIR QUALITY MANAGEMENT

NAME ____

ORGANIZATION ____________________________________

STAGES of Guidance Area 1: Ambient Air Quality Standards and Monitoring

Instructions: For each row, check the indicator that best describes the condition of air quality management in [country or city] per category. Count the number of checks per stage and write the stage with the highest tally in the blank provided after the table. The column with the highest tally is the AQM stage of [country or city] based on this initial assessment.

Indicator Categories	Stages				
	Underdeveloped	**Developing**	**Emerging**	**Maturing**	**Fully developed**
Development of AAQS and alignment with other targets; Setting up an adequate AQ monitoring system; Monitoring compliance	☐ Absence of ambient air quality standards (AAQS). ☐ Absence of ambient AQ monitoring system. ☐ No monitoring of compliance to the AAQS performed	☐ AAQS for some/ selected criteria pollutants are available. ☐ Monitoring activities are only project-based or on an ad hoc basis. ☐ Existing monitoring data is used to check compliance to AAQS but not sufficient to designate attainment[1] and non-attainment areas[2]	☐ AAQS for all criteria pollutants are available. ☐ AQ monitoring system covers selected pollutants of concern and hotspots. ☐ There are quality assurance/quality control procedures as part of the AQ monitoring have a potential to be strictly implemented.	☐ AAQS for criteria pollutants are in line with World Health Organization (WHO) air quality guidelines and interim targets ☐ Standards for other pollutants are being considered. ☐ AAQS are considered during the formulation of other sector/ development plans.	☐ AAQS are in line with WHO air quality guidelines and/ or interim target values. ☐ AAQS for criteria pollutants and other toxic pollutants are mandatory. ☐ AAQS are aligned with development/ sector plans and policies[3]

1 Attainment areas are those which meet AAQS.
2 Non-attainment areas are those which do not meet AAQS.
3 e.g. airport expansion, vehicle emissions standards, and others

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
			■ Compliance to AAQS is routinely monitored. ■ Attainment and non-attainment areas are assessed.	■ AQ monitoring system covers all criteria pollutants ■ AQ monitoring system includes continuous monitoring stations, with a mix of different station types: background, roadside, industrial and residential. ■ Quality assurance/ quality control procedures are strictly followed. ■ Compliance to AAQS is routinely monitored. ■ Attainment and non-attainment areas are regularly assessed.	■ AQ monitoring system covers all criteria pollutants and others -- VOCs, toxics, etc. ■ AQ monitoring system includes continuous monitoring stations, different station types; cover sensitive receptor sites, as necessary ■ Adequate size and scope of monitoring system based on population, size and characteristics of the area. ■ Quality assurance and quality control procedures are strictly followed. ■ A process for review of AQ monitoring system exists.

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
					☐ Compliance to AAQS is routinely monitored. Data trends are analyzed.as part of compliance monitoring. ☐ Attainment and non-attainment areas are designated and regularly assessed. ☐ Non-attainment areas are closely monitored and pollution control strategies evaluated in line with achieving the AAQS.

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
AAQS Review Process	☐ No review process in place	☐ No review process in place	☐ There is an ad hoc review process for AAQS ☐ A phased approach is used to achieve more stringent AAQS aligned with World Health Organization air quality guidelines or interim targets.	☐ A review system for AAQS is in place, review is conducted regularly[4]	☐ AAQS are reviewed regularly (at least every five years) to improve and protect vulnerable population groups and areas. ☐ Review of AAQS takes into account multiple pollutant control approaches.

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
Sustainability of AQ monitoring system	☐ Lack of human and financial resources to support operation of monitoring system	☐ Human resources, technical capacity and financial resources are available for project-based or ad hoc monitoring only.	☐ Human resources, technical capacity and financial resources are sufficient to support AQ monitoring for selected pollutants and hotspots.	☐ Human resources, technical expertise and financial resources are sufficient to sustain AQ monitoring systems for all criteria pollutants, which has a mix of different types of monitoring stations. ☐ There are initiatives made to secure funding support from other sources (aside from government) to support AQ monitoring systems.	☐ Human resources, technical expertise and financial resources are sufficient to sustain operation of AQ monitoring systems of adequate size and scope. ☐ Strategies are in place to access a wide mix of financing sources[5] to sustain AQ monitoring systems.
Tally of checks	____________	____________	____________	____________	____________

Current stage of [country or city] for Guidance Area 1: Ambient Air Quality Standards and Monitoring: ______________________________

NAME ____

ORGANIZATION ________________________________

Stages of Guidance Area 2: Emissions inventories and modeling

Instructions: For each row, check the indicator that best describes the condition of air quality management in [country or city] per category. Count the number of checks per stage and write the stage with the highest tally in the blank provided after the table. The column with the highest tally is the AQM stage of [country or city] based on this initial assessment.

Indicator Categories	Stages				
	Underdeveloped	**Developing**	**Emerging**	**Maturing**	**Fully developed**
Capacity for conducting emissions inventory (EI) (frequency, scope and approach)	☐ Absence of EI[6]	☐ Rapid EI methods[7] are conducted for criteria and/or other air pollutants[8] ☐ An ad hoc EI may be compiled using a top-down EI approach with default emission factors (EFs) and surrogate activity data.	☐ Rapid EI for major sources of criteria pollutants are more regularly compiled using top-down and bottom-up approaches.[9] ☐ Rapid EI for toxic pollutants[10] are being planned.	☐ EI for criteria pollutants are systematically and routinely compiled (with an initial inclusion of toxic pollutants) using a bottom-up approach. All relevant sources are covered. ☐ More sophisticated EI approaches are starting to be applied	☐ EIs for criteria, toxic pollutants are compiled with a bottom-up approach at pre-defined intervals[11] covering all relevant sources.Review of AAQS takes into account multiple pollutant control approaches. ☐ Sophisticated EI processes are used and routinely updated ☐ Emissions are measured cost effectively and as regularly as possible.

6 An emissions inventory (EI) is a listing, by source, of the amounts of air pollutants -- including greenhouse gases (GHGs), volatile organic compounds (VOCs), among others -- actually or potentially discharged into the atmosphere of a community during a given time period (OECD, 2001; EEA, 2013; SEI, 2008)

7 e.g. Global Air Pollution Forum (GAPF) Emissions Manual (http://www.sei-international.org/gap-the-global-air-pollution-forum-emission-manual) or Rapid Inventory Assessment Technique (RIAS) (http://whqlibdoc.who.int/hq/1993/WHO_PEP_GETNET_93.1-A.pdf)

8 Note: If EFs are not provided – top-down approach is conducted using default EFs and surrogate data; If local EFs are provided - bottom-up approach is conducted (See Note 4)

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
			Default EFs and EFs obtained from local academic research are used. There are initial plans to use more sophisticated approaches[12]	Local EFs and some actual emissions measurements are used. EIs make us of higher tier activity data.	
Verifying accuracy and reliability of EI	There is no validation of EI results	There is no validation of EI results Quality assurance/quality control (QA/QC) manuals are developed.	There is initial validation of EI results QA/QC procedures are regularly implemented	Validation of EI results is more regularly performed QA/QC procedures are routinely implemented.	EI results are routinely validated QA/QC procedures are routinely implemented[13] and regularly reviewed and updated[14].
Capacity for conducting source apportionment (SA)[15] (frequency, availability of source profiles and scope)	SA is not conducted PM source profile is not collected	SA is not conducted PM source profile is not collected	SA for criteria pollutants is conducted on an ad hoc basis by research/academic institutions[16]	SA for criteria pollutants is conducted using different approaches by research/ academe and government agencies (i.e. CMB, UNMIX, PMF)	SA for criteria pollutants are routinely performed by research/ academe and government agencies (i.e. CMB, UNMIX, and PMF)

9 The top-down EI approach uses national- or regional level emission estimates using surrogate parameters (i.e. population, employment, energy consumption, vehicle number, etc), typically used when local data are not available and resources are limited (SEI, 2008). The bottom-up EI approach, on the other hand, gathers information from individual sources, processes, activities and their levels, and subsequently estimates emission factors (EFs).
10 For instance, benzene, perchloroethylene, dioxins, asbestos and heavy metals
11 e.g. annually or every two years
12 e.g. annually or every two years
13 Every year
14 Every year
15 Source apportionment determines source types from the elementary composition of pollutant concentrations taken at receptor sites.
16 e.g. using Chemical Mass Balance (CMB)

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
	No ambient air quality monitoring at receptor sites	Ambient air quality monitoring and meteorological monitoring systems are being developed and are being considered for emission-exposure-impacts modeling	PM source profile data from external and local information sources are used to describe source profiles for major local sources.	SA for toxic pollutants initiated PM source profile data needed for CMB are collected from mostly from local information sources and assumed to describe source profiles for the majority of local sources SA is conducted on both general conditions and pollution episodes	SA for toxic pollutants is routinely performed PM source profile data are all from local sources, are routinely updated and combined in a database
Dispersion modeling	Dispersion modeling is not conducted[17]	Dispersion modeling is not conducted but capacity is being developed for dispersion model applications[18]	Simple steady state models are conducted to estimate pollutant concentrations using meteorological measurement inputs	More advanced steady state dispersion models are used for exposure estimation using local data[19]	All models (steady state, non-steady state, photo-chemical[20]) are routinely applied and validated to estimate expo-sure, using rou-tinely updated meteorological data and local data[21]

17 Dispersion modeling or source-based SA identifies relevant sources and uses default or locally measured EFs and local activity rates to estimate emissions in units.

18 Applications include exposure estimates and selection of appropriate AQ monitoring sites

19 Such as land use, topographical data and meteorological data

20 Photochemical models simulate the impacts from all sources by estimating pollutant concentrations and deposition of both inert and chemically reactive pollutants over large spatial scales. (http://www3.epa.gov/scram001/aqmindex.htm)

21 Such as land use and topographical data

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
		Meteorological databases are being developed	Non-steady state models are beginning to be explored	Dispersion models incorporate local land use and emissions profile data Non-steady state models are becoming more common Capacity to forecast future emissions and dispersion is being developed.	Local concentration data is used for model verification and performance evaluation New localized models are developed Localized AQ models are updated as regularly as possible. Dispersion models developed are used with incorporation of local land use and emissions profile data. Capacity to forecast future emissions and dispersion is well established.

Indicator Categories	Stages: Underdeveloped	Developing	Emerging	Maturing	Fully developed
					Dispersion modeling results are used for studies that measure impacts of air pollution on public health and the environment.
Verifying accuracy and reliability of SA models	No SA models have been developed		Initial attempts to validate SA are made. SA and dispersion modeling results sometimes align. Air quality monitoring at receptor sites is being established	Initial attempts to validate SA are made. SA and dispersion modeling results increasingly align. Air quality is monitored at several receptor sites during all seasons for model verification and performance evaluation.	Air quality is monitored at several receptor sites during all seasons to cover both general and episodic conditions. Local data is routinely used in SA validation. Results from SA and dispersion models are aligned; reasons are identified for divergent results. SA model validation and performance evaluation use local data.

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
Use of EI and modeling results in AQM	☐ EI and modeling results are not used in AQM		☐ EI, SA, and dispersion modeling results are used in identifying AQ policies or measures.	☐ EI, SA, and dispersion modeling results are used as important inputs in AQ policy development, implemen -tation, and evaluation ☐ EI, SA, and dispersion modeling results are used to review or assess progress or achievements of AQ policies or measures. ☐ The role of EI and SA in AQM is understood and appreciated by policy-makers and the public in general.	☐ EI, SA, and dispersion modeling results are used in an integrated manner for AQM.

Tally of checks ____________ ____________ ____________ ____________ ____________

Current stage of [country or city] for Guidance Area 2 Emissions inventories and modeling: ______________________________

NAME ______________________________

ORGANIZATION ______________________________

STAGES of Guidance Area 3: Health and Other Impacts

Instructions: For each row, check the indicator that best describes the condition of air quality management in [country or city] per category. Count the number of checks per stage and write the stage with the highest tally in the blank in the space provided after the table. The column with the highest tally is the AQM stage of [country or city] based on this initial assessment.

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
Information for estimating health and other impacts	☐ A health surveillance system is not available[22] ☐ Meteorological and air quality databases for emission-exposure-impacts modeling are not available	☐ A health surveillance system is being developed ☐ Meteorological and air quality databases are being developed for emission-exposure-impacts modeling	☐ A health surveillance system starts to provide reliable data ☐ Meteorological and air quality databases are beginning to be established and used for emission-exposure-impacts modeling assessment techniques.	☐ A health surveillance system is in place and is becoming a basis of health impact assessment due to air pollution. ☐ Meteorological and air quality databases are routinely used for emission-exposure-impacts modeling.	☐ A health surveillance system makes available reliable data and is always taken as the basis of health impact assessment due to air pollution ☐ Meteorological and air quality databases are regulated to be routinely used for emission-exposure-impacts predictions.

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
Estimating health impacts of air pollution	☐ Anecdotal observations of and information on health impacts by health authorities are not available	☐ Initial observations on health impacts due to air pollution exposure exist.	☐ Routine observations on health impacts due to air pollution exposure are becoming more and more common.	☐ Systematic epidemiological studies on health impacts due to air pollution exposure are performed including exposure and health impact assessment studies of major facilities or areas and of vulnerable populations using rapid	☐ Systematic epidemiological studies on health impacts due to air pollution exposure are performed including exposure and health impact assessment studies of major facilities or areas and of vulnerable populations using sophisticated assessment techniques.
Capacity for estimating health and other impacts of air pollution	☐ Lack of capacity for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to health impact assessment • exposure assessment • health and environmental impact assessment	☐ Capacity is being developed for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to health impact assessment • exposure assessment • health and environmental impact assessment	☐ Capacity is regularly enhanced by training for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to health impact assessment • exposure assessment health and environmental impact assessment	☐ Capacity and understanding of issues is increased for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to health impact assessment • exposure assessment • health and environmental impact assessment	☐ Capacity is sustainably enhanced for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to health impact assessment • exposure assessment • health and environmental impact assessment

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
Estimating environmental, economic, other impacts, and cost-benefits valuation	■ Studies on socioeconomic cost of pollution and benefits of pollution control are not available. ■ Cost effectiveness/cost- benefit analysis is not conducted.		■ Limited studies on socioeconomic cost of pollution and benefits of pollution control are available, mostly performed by academic/ research institutions. ■ Cost effectiveness/ cost- benefit analysis is intermittently conducted by academic/research institutions.	■ Studies on socioeconomic cost of pollution and benefits of pollution control are becoming available, performed by both academic/ research institutions and the government. ■ Cost effectiveness/ cost- benefit analysis isconducted by academic/ research institutions and the government.	■ Studies on socioeconomic cost of pollution and benefits of pollution control are available, performed by academic/ research institutions and the government. There is a process in place for estimating socio-economic costs adapted to local conditions. ■ Cost-effectiveness/ cost-benefit analyses routinely performed by academic/ research institutions and the government following a localized system for estimating costs and benefits.

22 Note: A health surveillance system collects data on mortality and morbidity for selected health impacts.

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
Use of health and other impact studies	☐ No data is available on health impact assessments, studies on socioeconomic cost of pollution, and cost-effectiveness/ cost-benefit analysis.		☐ Presentation of results of health impact assessments, studies on socioeconomic cost of pollution, and cost-effectiveness/cost-benefit analysis considers its use in AQM policy development, implementation, and evaluation	☐ Presentation of results of HIA, studies on socioeconomic cost of pollution, and cost-effectiveness/ cost-benefit analysis systematically considers its use in AQM policy development, implemen-tation, and evaluation	☐ Presentation of results of HIA, studies on socioeconomic cost of pollu-tion, and costef-fective-ness/ cost-benefit analysis systematically considers its use in AQM policy development, implementa-tion, and evaluation
Tally of checks	______________	______________	______________	______________	______________

Current stage of [country or city] for Guidance Area 3 Health and other impacts: __________________________________

NAME ____

ORGANIZATION ________________________________

STAGES of Guidance Area 4: Air Quality Communication

Instructions: For each row, check the indicator that best describes the condition of air quality management in [country or city] per category. Count the number of checks per stage and write the stage with the highest tally in the blank provided after the table. The column with the highest tally is the AQM stage of [country or city] based on initial assessment.

Indicator Categories	Stages				
	Underdeveloped	**Developing**	**Emerging**	**Maturing**	**Fully developed**
Development of communication strategies	☐ Limited or no communication activities are conducted	☐ Communication activities for policymakersand the public are implemented on an ad hoc or project basis	☐ Communication activities for policymakersand the public are becoming more common	☐ Communication[23] strategies for policymakers and the public are developed and implemented ☐ Communication strategies are institutionalized and systematized in AQM	☐ Communication strategies for policymakersand the public are developed and implemented. ☐ Communication strategies are institutionalized and systematized in AQM

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
Types of information communicated	☐ Air quality monitoring data is not communicated	☐ Limited AQ data (processed) from ad-hoc or project-based monitoring activities are used in communication activities ☐ Information available is dated/ not updated	☐ Processed AQ monitoring data, air quality index (AQI), general information on pollution sources are used in communication activities ☐ Air quality information available is updated, but not on a regular basis ☐ Press releases on the state of air quality are issued, on a case-to-case basis ☐ Advisories are made during events of high air pollution but no system is in place.	☐ Processed AQ monitoring data, AQI, information on pollution sources from EI/SA, local data on impacts of air pollution and AQM action plans are used in communication activities. ☐ Air quality information is updated on a regular basis ☐ Press releases on the state of air quality are regularly issued ☐ Advisories are systematically released during events of high air pollution.	☐ Comprehensive and non-technical information on status of AQ management (processed air quality monitoring data), AQI, more detailed information from EI/SA, local impacts, AQM policies and action plans to control air pollution) are used in communication activities. ☐ Air quality information is updated on a real-time basis ☐ Press releases on the state of air quality are routinely issued ☐ Advanced public warnings/ forecasts are accurately issued and system is in place to advice subsequent action.

23 Communication strategy includes the selection of appropriate communication objectives and the identification of effective methods to achieve those objectives

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
Access to information / Communication channels used	☐ Air quality data or any other relevant information is not shared with the public	☐ Air quality data is available to the public through request	☐ Public can download general information on air quality online ☐ One or two media channels[24] are used to communicate AQ	☐ Public can download more information on air quality online such as processed monitoring data, trends in air quality, health impacts of air pollution ☐ A wider selection of modern communication channels is used	☐ Public can download detailed information on state of air quality, local impacts (health, environmental, etc.), policies and action plans for specific areas online. ☐ Multiple communication channels and innovative solutions/technologies are utilized.
Level of public awareness	☐ Limited public awareness of the need for understanding sources and health impacts of air pollution in AQM.	☐ Low level of public awareness of the need for understanding sources and health impacts of air pollution.	☐ Public awareness of the need for understanding sources and health impacts of air pollution is starting to become routinely considered.	☐ Public awareness of the need for understanding sources and health impacts of air pollution is becoming standard	☐ Public awareness of the need for understanding sources and the health impacts of air pollution is extensive.

Tally of checks ______________ ______________ ______________ ______________ ______________

Current stage of [country or city] for Guidance Area 4: Air Quality Communication: ________________________________

24 Examples of media channels: print media, email/mobile alerts, social media (e.g. Twitter, Facebook), website, television and radio, billboards, printed reports

NAME ______________________________

ORGANIZATION ______________________________

Stages of Guidance Area 5: Clean air action

Instructions: For each row, check the indicator that best describes the condition of air quality management in [country or city] per category. Count the number of checks per stage and write the stage with the highest tally in the blank provided after the table. The column with the highest tally is the AQM stage of [country or city] based on this initial assessment.

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
Science-based approach to CAAP formulation; AQM Plans, Policies and Measures	☐ Air pollution control measures, policies, plans and strategies are developed without solid support from data and assessments ☐ Addressing air pollution is generally covered in National Environmental Acts or Laws	☐ Air pollution control measures, policies, plans and strategies are based on air quality data from ad hoc monitoring. ☐ Air pollution-specific policies are in place at the national and local levels. ☐ Ad-hoc projects to reduce emissions are available	☐ Air pollution control measures, policies, plans and strategies are based on limited air quality monitoring data for selected pollutants and hotspots, and with more support from EI results and/or SA assessments ☐ Air pollution-specific policies are in place at the national and local levels and implementation is envisaged. ☐ CAAP measures to address key/major sources have been formulated but operationalization (identifying lead agencies, timeline, budget, etc.) of measures is not yet clear.	☐ Clean Air Action Plan (CAAP) is based on adequate air quality monitoring data, EI, simple dispersion models and assessment of pollutant-exposure. ☐ Air pollution-specific policies are in place at the national and local levels and are implemented. ☐ A framework (comprised of lead agencies, timeline, budget, etc.) for implementing and financing of measures is included in the CAAP.	☐ Identification of control measures is science-based and cost-effective. ☐ A full range of AQM activities are used as basis of CAAP development: air quality monitoring system, bottom-up EI, dispersion modeling, SA, testing compliance with emission and air quality standards, potential abatement assessment, cost and benefit analysis results, and assessment of health and environmental impacts.

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
			■ Sector-specific growth and development plans[25] include measures to control key emission sources. CAAPs are beginning to be developed but are not aligned to sector development plans.	■ There is prioritization of measures based on emission reduction potential of key sources, cost-effectiveness and technical feasibility. ■ CAAPs are aligned with sector-specific development plans[26]	■ Air pollution-specific policies are in place at the national and local levels and are fully implemented. ■ A clear framework (comprised of lead agencies, timeline, budget, etc.) for implementing and financing of measures is defined in the CAAP. ■ A system for monitoring and evaluation of CAAP implementation is formulated. ■ CAAPs are in place with comprehensive and prioritized mitigation actions and integrated into sector-specific and socio-economic development plans[27] including climate change mitigation

25 e.g. for industry, transport, energy, housing, land use
26 e.g. industry, transport, energy, housing, land use
27 e.g. industry, transport, energy, housing, land use

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
Level of stakeholder involvement in CAAP formulation	■ Only implementing agencies of air pollution control measures, policies, plans and strategies are involved in formulating the measures.	■ Input from stakeholders other than implementing agencies of AQM is obtained during formulation of air pollution control measures.	■ Activities to promote for multi-sectoral coordination and stakeholder engagement in CAAP formulation are being initiated	■ Mechanisms[28] for multi-sectoral coordination and stakeholder engagement, including public involvement are becoming more common in CAAP formulation.	■ Mechanisms for multi-sectoral coordination, stakeholder engagement and public involvement in CAAP development are in place and fully implemented.
Availability of financial resources	■ Lack of financial resources to support CAAP	■ Financial resources to support CAAP development are limited and highly rely on external support	■ There is sufficient government budget for CAAP development. ■ There is funding support from other sources for CAAP development	■ There is sufficient government budget for CAAP development. The government also allots budget for the CAAP to be regularly updated in response to conditions and needs of the area covered. ■ Initiatives are made to secure funding support from other sources[29] (aside from government) to support CAAP development.	■ The government allots sufficient budget annually for CAAP development and update. Financial support for CAAP development and regular updating is sustainable. ■ Strategies are in place to access a wide mix of financing sources[30] to support CAAP development.

28 Examples include formation of a working group involving all concerned government, private and other sectors, roadmap development/vision and goal setting with stakeholders, public consultation and forums.
29 e.g. international organizations, partnerships with private sector
30 e.g. international organizations, partnerships with private sector

Indicator Categories	Stages				
	Underdeveloped	**Developing**	**Emerging**	**Maturing**	**Fully developed**
Set-up of early warning system/ emergency response plan	☐ An early warning system to mitigate impacts during high air pollution episodes is not available due to lack/ limited of monitoring systems.		☐ An early warning system to mitigate impacts during high air pollution episodes is in place.	☐ An early warning system and emergency response plan to mitigate impacts during high air pollution episodes is in place.	☐ An early warning system and emergency response plan to mitigate impacts during and predict high air pollution episodes is in place and regularly reviewed.

Tally of checks ______________ ______________ ______________ ______________ ______________

Current stage of [country or city] for Guidance Area 5 Clean Air Action Plans: ___________________________________

NAME ____

ORGANIZATION ______________________________________

STAGES of Guidance Area 6: Air Quality Governance

Instructions: For each row, check the indicator that best describes the condition of air quality management in [country or city] per category. Count the number of checks per stage and write the stage with the highest tally in the blank provided after the table. The column with the highest tally is the AQM stage of [country or city] based on this initial assessment.

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
Institutional mandate and coordination	☐ Mandate for air quality management (AQM) is not clear ☐ There is no focal/lead agency for AQM	☐ Ministries/agencies, local government assigned to perform AQM are designated in legislation but responsibilities are not clear or overlap ☐ There is limited coordination among different ministries, subnational/local governments working on AQM components	☐ Clear institutional mandate for AQM at the different ministries/agencies (national) and local level is in place and responsibilities are defined ☐ Coordination mechanisms (e.g. communication, data sharing, reporting) among national and local government offices is improving	☐ Clear institutional mandate for AQM at the national and local levels is in place and key functions[31] are well-delineated ☐ There are clear institutional arrangements for different government levels and neighboring cities/regions to work together in AQM[32]	☐ Clear institutional mandate for AQM at national and local departments is well-defined, key functions are well-delineated and effectiveness of institutional arrangements is regularly reviewed ☐ Institutional arrangements among neighboring cities/regions are well-defined and include collaborative initiatives to maximize resources[33]

31 e.g. pollution prevention, risk assessment and reduction, research, regulatory development, etc.
32 regional air quality management – e.g. alignment of AQM policies, harmonization of standards, sharing of air quality monitoring data
33 e.g. joint activities on monitoring, development of management resources, capacity building

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
Mobilizing political support	Political support[34] for air quality management is lacking	Inadequate political support[35] for implementation of clean air measures	Growing political support for implementation of clean air measures	Adequate political[36] and public support (seen through reports and social media) for implementation of clean air measures	Strong political[37] and public support for implementation of clean air measures.
Capacity for AQM	No financial support is available from national/local government. Capacity developing activities are primarily ad hoc, and comprised mostly of programs by external organizations.	Limited financial support and human resources provided from national/local government. Ad hoc/ project based air quality activities supported by international/ development agencies Opportunities for capacity development on air quality management are being developed.	Financial support and human resources are provided by national/local government to support AQM implementation Opportunities for capacity development on air quality management are available	Human and financial resources provided by the national/local government to support AQM implementation are sufficient. There are mechanisms in place to secure funding support from other sources (aside from government) to support AQM.	Human and financial resources provided by the national/local government to support AQM implementation are sufficient. Innovative strategies are in place to secure a wide mix of financial sources[38] Capacity development systems are continuously implemented and improved, and institutionalized

34 Example of political support: Endorsement/sponsorship of legislation on air quality by lawmakers; Involvement of a political leader as a champion to promote awareness; AQM action plans are shared by the government to national/international audience and declared as priority
35 Example of political support: Endorsement/sponsorship of legislation on air quality by lawmakers; Involvement of a political leader as a champion to promote awareness; AQM action plans are shared by the government to national/international audience and declared as priority
36 Example of political support: Endorsement/sponsorship of legislation on air quality by lawmakers; Involvement of a political leader as a champion to promote awareness; AQM action plans are shared by the government to national/international audience and declared as priority
37 Example of political support: Endorsement/sponsorship of legislation on air quality by lawmakers; Involvement of a political leader as a champion to promote awareness; AQM action plans are shared by the government to national/international audience and declared as priority
38 e.g. international organizations, partnerships with private sector

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
				☐ Capacity development systems exist at the national and subnation-al levels	
Employing a mix of suitable policy instruments	☐ Limited air pollution regulations and governance in place	☐ Air pollution regulations and governance mostly employ command and control instruments[39].	☐ Air pollution regulations are starting to employ a mix of different policy instruments such as command and control and economic instruments[40]. Choice of instruments are based on local context and existing governance arrangements	☐ Air pollution regulations employ a mix of different policy instru-ments such as command and control, economic instruments, co-regulation, voluntary initiatives and self-regula-tion[41] based on local context and existing governance arrangements	☐ Air pollution regulations employ a mix of different policy instru-ments based on local context and existing governance arrangements-Lessons learned from regulation and governance of policies are growing in num-ber and scope New approach-es to regulation are piloted
Stakeholder participation and engagement	☐ Absence of mechanism for engaging various stakeholders in air quality management	☐ There are initiatives to establish a mechanism for engaging various stakeholders and these are starting to be implemented	☐ Stakeholder engagement activities are mostly aimed at information disclosure[42]	☐ Various stake-holders are en-gaged through consultative mechanisms to gather input during policy preparation/implementa-tion/evalua-tion[43]	☐ Mechanisms for collaboration with stakehold-ers are institu-tionalized. A wider range of stakeholders is involved in the decision-making process[44]

39 Command and control instruments include issuing licenses, setting standards, checking for compliance with standards, sanctions for non-compliance
40 Economic instruments include use of pricing, subsidies, taxes, and charges
41 Co-regulation and voluntary initiatives include formulation and adoption of regulations and guidelines in consultation with stakeholders and voluntary adoption of environmental management measures
42 Examples: Information dissemination through media (TV, radio, factsheets, newsletters, websites), open house, forums and conferences
43 Examples: Workshops, advisory committees, focus groups, public meetings, scoping meetings, dialogues
44 Examples: Formation of Joint working groups, Steering committee, Consensus decision-making

Indicator Categories	Stages				
	Underdeveloped	Developing	Emerging	Maturing	Fully developed
Strengthening compliance and enforcement, evaluation and review	☐ Absence of strategies to evaluate compliance and enforcement of policies addressing air pollution[45]	☐ Strategies to evaluate compliance and enforcement of policies are being developed for limited/ selected sectors (e.g. transport, industries)	☐ Strategies to evaluate compliance and enforcement of policies exist for specific sectors.	☐ Strategies to evaluate compliance and enforcement of policies to address air pollution exist for all relevant sectors in AQM. ☐ Mechanisms for responding to violations or non-compliance are included	☐ A system is in place to evaluate compliance and enforcement of policies and feeds back to policy development process. ☐ Mechanisms for responding to violations or non-compliance as well as specific key performance indicators are included
Tally of checks	____________	____________	____________	____________	____________

Current stage of [country or city] for Guidance Area 6: Air Quality Governance: ______________________________

45 Examples: Government inspections or area monitoring, self-monitoring and self-reporting, citizen complaints/monitoring

ANNEX VIII. GUIDANCE FRAMEWORK ROADMAPS

Underdeveloped	

Ambient air quality standards and monitoring	**Management Process**
	• Create mass advocacy and awareness campaigns to bring air pollution into the publicagenda and push for a political decision to establish and adopt AAQS [See Guidance Area 4Air quality communication].
	• Conduct stakeholder meetings and public input workshops so that the process of establishing AAQS recognizes and involves major stakeholders – AQ experts, epidemiologists, toxicologists, medical professionals, ecologists, environmentaleconomists, industries, government line ministries, and non-governmental organizationsrepresenting the public. The consultative approach and collective wisdom may providewider acceptability of the standards and its rationale, and ensure effective implementationthrough stakeholders' participation.
	• Identify thought leaders, decision-makers and influencers to ensure linkages of AAQS withother sector policies.
	• Establish Technical Team from different government and non-government stakeholdergroupswho will be responsible for the oversight of the process to develop AAQS for criteriapollutants. The team would be a small working group of select government staff, with thepossible addition of consultants or university experts.
	• Adopt AAQS (if there is none yet), to mandate routine AQ monitoring
	• Conduct AQ monitoring to support standards development
	• Define AQ monitoring objectives and data quality objectives
	• Identify capacities, skills and training needs for staff
	• Consider partnering with local university or research institute to support AQ monitoringactivities
	
	Technical Process
	• Determine selection of pollutants and averaging periods, basis for which may include:
	  ◦ Whether or not substances or mixtures pose widespread problem in terms of sources and potential for exposure is large
	  ◦ Availability of significant information on health effects (e.g., WHO guidelines, USEPA criteria documents, other air pollution epidemiological studies)
	  ◦ Past trends in ambient air levels (e.g., rising PM2.5 levels due to urbanization and motorization)
	  ◦ Guidance from international standards and established standards from neighboring Asian
	• countries with similar socioeconomic and environment conditions
	• Choose AQ monitoring equipment within available budget and manpower resources
	• Develop capacity for simple monitoring (e.g., manual samplers) and prioritize pollution hotspots
	• Build capacity for at least one station for air pollution monitoring of key pollutants

Emissions inventories and modeling	**Management Process** • Identify potential stakeholders from different levels of government and from othernongovernment,academe, and private sectors • Ensure buy-in of decision makers from the identified stakeholders through seminars,workshops, and policy papers that encourage awareness on importance of EI and SAstudies on AQM • Establish a working group of technical experts and an advisory group of policymakers anddecision-makers • Assess existing technical capacity of working group and identify training or resource needs • Research around the region for case studies and approaches that may be adapted for localimplementation of EI or SA • Secure funding from internal (in-country) and external (international) sources **Technical Process** • Identify and secure activity data needed using rapid assessment procedures (GAPF, 2012;WHO, 1993) • Determine the objective, design and scope, extent of details and pollutants for EIdevelopment and implementation work plans. Refer to basic considerations in Box 3.1 • Build the technical capacity of compiling EI for criteria pollutants for main source categories by top-down approach with statistical information, default EFs, and surrogateactivity data • Participate in regional EI networks (i.e. Acid Deposition Monitoring Network in East Asia[EANET]) and assess methods that may be adapted for local EI • Build capacity for dispersion model applications for local air quality simulation using thetop-down EI • Develop quality assurance/quality control (QA/QC) guidance manual for EI

Health and other impacts	**Management Process** • Start to conduct health and environmental impact assessment (WHO, 2004b; USEPA, 2011b) • Start to prepare an air quality monitoring system **Technical Process** • Learn from international experiences and studies on health impacts and consider the heathfactors in the policy, plan and strategy development process
Air quality communication	**Management Process** • Adopt AAQS (if none yet adopted) to mandate AQ monitoring [See Guidance Area 1: Ambient air quality standards and monitoring] • Build capacity for communicating AQ information to policymakers and the public **Technical Process** • Build capacity to measure, collate, and process AQ data from ad hoc or project-basedmonitoring activities for use in communication activities
Clean air action plans	**Management Process** • Identify key stakeholders, decision-makers and influencers to bring air pollution onto thepublic agenda • Build capacity for basic AQM planning and activities (i.e. ad hoc projects to reduce emissions)among key stakeholders, decision-makers and influencers • Conduct stakeholder meetings to increase awareness on the impact of air pollution on healthand the environment, and push for a political decision to include AQM as a development sector • Conduct targeted public awareness raising (e.g. through earn media communication) toeducate the public and increase their interests in air pollution issues • Establish a Technical Team comprised of representatives from government and nongovernment stakeholder groups to oversee the process of adoption of air pollution-specificpolicies at the national and local levels, air quality standards and measures to reduce emissions **Technical Process** • Build capacity for identifying and monitoring hotspots using a minimal set of air pollutantconcentration monitors [See Guidance Area 1 on Ambient air quality standards and monitoring]
Governance	**Management Process** Institutional coordination, capacity and training • Define essential AQM roles and responsibilities. • Conduct stakeholder mapping and determine whether existing organizations can fillneeded AQM roles and responsibilities • Vest authority for AQM with an existing or new lead agency/department based onstakeholder mapping • Assess overall budget for AQM and allocate government funding to cover essential rolesand responsibilities Stakeholder engagement, participation and accountability • Involve prominent figures/local champions in publicizing the formation of the AQM agencyto mobilize general public, media and other stakeholder support • Design complementary public advocacy and awareness campaigns (with engagement ofabove champions) to place air quality squarely on the policy agenda [See Guidance Area 4 on Air quality communication]. **Technical Process** • Seek technical assistance from international agencies, international non-governmentalagencies, and bilateral agencies in establishing AQM agency, filling budgetary needs, andstrengthening stakeholder communication • Seek city partnerships to learn how others cities set up AQM agency, allocate budgets, andcommunicate with other stakeholders

Developed	
Ambient air quality standards and monitoring	**Management Process** • Continue awareness campaigns to sustain public interest on air pollution and demand formore stringent AAQS for all criteria pollutants • Strengthen implementation of AAQS through development of clean air action plans andreporting of progress [See Guidance Area 5 on Clean air action plans] • Strengthen co-ordination and integration of AQM policies with other sector policies and plans(e.g., transport, energy, industry, among others) • Create project opportunities with other sectors (e.g., health, transport) to link AQmonitoring activities • Refine AQ monitoring objectives and data quality objectives • Identify capacities and skills and training to strengthen staff resources • Start reporting AQ data to public [See Guidance Area 4 on Air quality communication] • Collaborate with local or international academic organizations for AQ monitoring studies • Identify funding sources for AQ monitoring activities • Prepare AQ monitoring plans and guidelines • Provide sustainable training to address staff movements and technological developments **Technical Process** • Develop at the national level standard/uniform methodologies for AQ monitoring to guide cities • Build capacity for AQ monitoring system to cover selected pollutants of concern and hotspots, monitor compliance to AAQS, and ensure that major cities have at least one monitoring station todesignate and assess attainment and non-attainment areas • Build capacity for ad hoc review of AAQS • Expand AQ monitoring network by adding more stations or pollutants monitored or improving frequency according to monitoring objectives and to support compliancemonitoring to AAQS • Develop QA/QC plan, SOPs, and guidelines at the national level for AQ monitoring to guide cities • Develop QA/QC measures • Improve data management and AQ monitoring data use for health assessments • Build capacities for use of monitoring in AQ modeling – e.g. dispersion modeling [See Guidance Area 2 on Emissions inventories and modeling] and health assessments [See Guidance Area 3 on Health and other impacts]
Emissions inventories and modeling	**Management Process** • Involve more stakeholders • Establish a cooperation framework by the local or national government among the working group (i.e. technical team, data providers), advisory group, and experts to set upa stable EI system • Develop a sustainable data collection plan with relevant organizations producing datainputs for EI • Develop a review process involving experts and stakeholders for continual improvementin EI for use in AQM policies • Enhance technical capacity for EI through sustainable training **Technical Process** • Build the capacity for compiling mixed top-down and bottom-up EI for criteria and other pollutants • Evaluate the applicability of default EFs and EFs obtained from academic and/or other countries' research • Assess capacity to use more sophisticated EI approaches (i.e. USEPA, EEA) • Adapt applicable methods used in regional EI networks and disseminate results • Develop a review process and conduct regular validation of EI to ensure good data quality • Prepare and implement monitoring plan (sampling locations, schedule, among others) for collection of ambient samples, and arrange for necessary monitoring and analyticalinstruments. Refer to available literature (e.g., CPCB, 2006; 2007a) • Identify laboratories within the region capable of doing analysis for major PMcomponents, e.g. ions, elements, organic carbon (OC) and elemental carbon • Collect ambient sample(s) and send for analysis for key chemical constituents tolaboratories (in-country or abroad) with the appropriate technical capacity • Build capacity for initial SA for criteria pollutants on an ad hoc basis or by research/academic institutions • Evaluate applicability of any PM source profiles available (external or from local studies)for major local sources for major local sources

	• Initialize characterization of local source profiles and apply in CMB runs • Use CMB model to determine SA, and compare results with similar reported studies • Develop QA/QC procedures for SA • Secure appropriate receptor model software and source profiles (e.g., SPECIATE[USEPA, 2014b], CPCB, 2010) • Initialize use of dispersion models for exposure (concentration) simulation • Analyze the correlation of SA results from dispersion and receptor-based models, andprovide recommendations to improve their alignment • Develop and propose
Health and other impacts	**Management Process** • Ensure that health risk estimations are used to inform policy makers and are beingconsidered in the policies and plan development • Prioritize identification of air pollution control plans and policies that consider impacts onhealth **Technical Process** Enhance capacity for: • Estimating exposure (Global Atmospheric Pollution Forum (GAPF), 2011); • Initial estimates of health risks and/or other impacts (WHO, 2004b); and • An initial health surveillance approach (WHO, 2014d; Nsubuga et al., 2006).
Air quality communication	**Management Process** • Enhance capacity to communicate AQ information to policymakers and the public in amore systematic way • Build capacity to issue ad hoc press releases on state of AQ and advisories duringpollution episodes • Start building capacity for information technology to ensure online accessibility ofgeneral AQ information to the public **Technical Process** • Strengthen capacity to measure, collate, process, and update AQ monitoring data and general information on pollution sources for use in more regular communicationactivities • Develop capacity to use one or two media channels to communicate AQ Information • Adopt an AQI
Clean air action plans	**Management Process** • Continue public awareness raising to sustain public interests on air pollution and demand forcontrol measures (e.g. include a mixed-media communication approach in conveying keymessages to the public) • Strengthen coordination and communication among responsible institutions, and integration ofAQM policies with other sector policies through a regular reporting mechanism • Ensure that sector-specific growth and development plans include measures to control keyemission sources • Ensure sufficient government budget and potential funding support from other sources for CAAPdevelopment • Conduct stakeholder meetings and public input workshops to draw roadmap towards CAAPdevelopment and initiate formulation of CAAP measures to address major emission sources • Conduct Vision and Goals Workshop and Public Communication Strategy Workshop to defineoutreach and awareness program. • Plan for implementation of air pollution-specific policies at the national and local levels **Technical Process** • Enhance capacity for air quality monitoring stations to deliver data on key pollutants of knownquality • Build capacity for identifying air pollutant sources and estimation of emissions using available methodology taking account data availability [See Guidance Area 2 on Emissions inventories and modeling] • Consider air quality monitoring results and estimation of emissions as basis of CAAP • Build capacity for identification of initial health risks and/or other impacts of air pollution [SeeGuidance Area 3 on Health and other impacts] • Build capacity to develop early warning system to mitigate impacts during high pollutionepisodes

Developed	
Governance	**Management Process** Institutional coordination, capacity and training • Assess capacity needs through a training needs assessment and hire needed additional staffwithin budgetary limits • Actively engage prominent public figures/local champions in public advocacy andawareness campaigns to share essential air quality information • Design communication, data sharing and reporting mechanisms within lead agency basedon organizational structure • Clarify institutional relationships with other relevant city agencies (i.e. transport) andnational environmental agencies/air pollution divisions. • Determine where and how cooperation should be strengthened with relevant city andnational environmental agencies/air pollution divisions. • Continue to assess and allocate government funding while mobilizing additional resourcesthrough city taxes and fiscal policies as well as national and international finance Stakeholder engagement, participation and accountability • Use advocacy and awareness campaigns to promote public and stakeholder participation inactivities to reduce air pollution (i.e. car free day) • Clarify organizational structure and division of labor for core AQM functions within lead AQM agency, potentially including: (i) pollution prevention; (ii) risk assessment and reduction; (iii) scientific research and technology; (iv) regulatory education; (v) regulatorydevelopment; and (vi) enforcement. **Technical Process** • Design effective enforcement program with the following components: ◦ Creating enforceable requirements for emission sources. ◦ Identifying which sources are subject to which regulatory requirements and provisions. ◦ Promoting and monitoring regulatory compliance. ◦ Responding to violations. ◦ Clarifying roles and responsibilities. • Evaluating the success of the program and holding program personnel accountable forperformance

Emerging	
Ambient air quality standards and monitoring	**Management Process** • Strengthen implementation of AAQS • Consider AAQS in the development of other sector plans • Prepare plans to sustain AQ monitoring network, starting with financing of maintenance,equipment upgrade and human resource • Enhance reporting mechanisms of AQ data to the public to increase public awareness [SeeGuidance Area 4 on Air quality communication] • Collaborate with other countries' AQ monitoring activities • Ensure initiatives are in place to secure funding support from external sources **Technical Process** • Establish attainment and non-attainment for cities or regions • Cluster cities or zones according to AQ levels, compliance, and attainment; assess for possibility ofmore stringent standards in "cleaner" cities • Conduct assessment and review on phasing-in more stringent standards for criteria and otherpollutants • Build capacity for regular review of AAQS • Cooperate with meteorological agencies for sharing of expertise in AQ data interpretationand modeling • Enhance capacities for AQ modeling work [See Guidance Area 2 on Emissions inventories and modeling] • Make use of AQ data for health assessments [See Guidance Area 3 on Health and other impacts] • Make use of AQ data for assessing effectiveness of AQ and other related sector policies [SeeGuidance Area 5 on Clean air action plans] • Expand AQ monitoring network system to include more pollutants relevant for compliance andhealth assessments • Implement continuous skills training on AQ monitoring • Share technical expertise and knowledge with other Asian countries • Implement QA/QC procedures for AQ monitoring system

Emissions inventories and modeling	**Management Process** • Set-up a framework for review and continual improvement of the EI and SA estimates,and organize long-term resources for the same • Engage and ensure buy-in of all relevant stakeholders in implementing sustainable datacollection plan • Enhance technical capacity through sustainable training • Identify and prioritize resource, equipment and infrastructure investments necessary toestablish local capacity for chemical speciation analysis **Technical Process** • Enhance capacity for routine compilation of EI for criteria pollutants (with initialinclusion of toxics and GHGs) • Enhance capacity for bottom-up EI approach using available local EFs and/or utilizeactual measurements for several main emission sources • Use EI results as basis for development of AQM policies, implementation and evaluation • Plan for use of rapid EIs for toxic pollutants • Build capacity to contribute to regional EI studies • Continually improve review processes and QA/QC procedures for EI and SA • Enhance capacity for SA using more sophisticated approaches • Conduct SA by at least two receptor models, e.g. CMB and PMF • Conduct SA using available local profiles needed by CMB; use international profiles forother sources • Identify a few key sources and develop local source profiles • Plan for conducting SA for toxic pollutants • Conduct sensitivity analysis using different sets of source profiles availableinternationally • Conduct PM speciation measurement and analysis in a regular manner • Evaluate model outputs by statistical tools • Develop an integrated database on source and ambient pollution characteristics • Build capacity to use more advanced steady-state models and if possible, non-steadystate models for exposure estimation using local data • Incorporate local land use and emission profile data • Validate modeling results by local measurement data • Evaluate alignment of results from receptor-based SA and dispersion models • Ensure use of EI, SA, and dispersion modeling findings to review or assess progress orachievements of air quality policies and measures
Health and other impacts	**Management Process** • Use information on health and other impacts to inform policy development • Integrate risk assessment into policies **Technical Process** Ensure: • Growing capacity for simplified approaches to estimate exposure (WHO, 2004b); and • Improved understanding of the technical and economic feasibility of major pollution controlmeasures (USEPA, 2011d; 2008b; Reis, 2005). Enhance capacity for estimates such as: • The health risks and/or other impacts (WHO, 2006); and • The economic impacts, based on international studies (Organisation for EconomicCo-operation and Development (OECD), 2014)
Air quality communication	**Management Process** • Develop and implement communication strategies for policymakers and the public • Strengthen capacity to institutionalize and systematize AQ communication to policy makers, the public, and a wider range of stakeholders • Strengthen capacity to issue regular press releases on state of AQ and systematicallyrelease advisories during pollution episodes • Ensure that the public can access more AQ information online (i.e. processed AQmonitoring data, AQ trends, health impacts) • Ensure resources are available for AQ communication **Technical Process** • Strengthen capacity to measure, collate, process, and update processed AQ monitoring data, AQI, information on pollution sources from EI/SA, local data on air pollution health impacts, and AQM action plans for use in regular and systematic communication activities • Enhance capacity to use a wider selection of modern communication channels

Emerging	
Clean air action plans	**Management Process** • Define roles of stakeholders including government departments/agencies and publicparticipation in CAAP process • Conduct series of public input workshops as part of or independent of government development planning processes to gather input for air quality improvement programs and actions. Conduct Findings and Options Workshop to consolidate reporting of all findings and possible options forconsideration by public and decision makers, and define roles and responsibilities of stakeholders. • Establish a clear institutional framework and mechanisms (within lead agencies, stakeholders, and public sector) to support implementation of measures including monitoring and evaluationsystem • Ensure sufficient government budget for CAAP development and review; explore fundingsupport from external sources • Use information on adequate air quality monitoring, initial EI, simple dispersion models,pollutant-exposure assessment, and initial health impact assessment as basis for CAAP andpolicy development • Implement air pollution-specific policies at the national and local levels **Technical Process** • Enhance capacity for: ◦ Air quality monitoring ◦ Development of initial EI ◦ Simple dispersion models ◦ Assessment of pollutant-exposure using simplified approaches ◦ Estimation of health risks and/or other impacts ◦ Evaluation and monitoring system for implementation of emissions reduction measures • Issue regular early warning system to mitigate impacts during high pollution episodes
Governance	**Management Process** Institutional coordination, capacity and training • Conduct capacity building activities through existing in-house training programs whereavailable or outside organizations where expertise is lacking • Clarify roles and responsibilities of other relevant government agencies and non-governmental stakeholders (such as civil society, academe, research institutes, media, private sector, among others) to fill possible capacity needs or related AQMfunctions. • Continue to assess and allocate government funding while mobilizing additional resourcesthrough city taxes and fiscal policies as well as national and international finance • Develop communication, data sharing and reporting mechanisms for other relevant cityand central government agencies Stakeholder engagement, participation and accountability • Develop mechanism for public information dissemination (i.e. sharing air quality data) toenhance transparency, strengthen accountability and build political will • Develop stakeholder engagement and consultation mechanisms to provide input and oversight on some core AQM functions, including: (i) pollution prevention; (ii) risk assessment and reduction; (iii) scientific research and technology; (iv) regulatoryeducation; (v) regulatory development, and (vi) enforcement. **Technical Process** • Design AQM policies and measures using clear and enforceable language and identify andimplement appropriate regulatory instruments, possibly combining CAC with MBIs [SeeGuidance Area 5 on Clean air action plans] • Develop mechanisms to collect information and assess regulatory compliance through(i) inspections; (ii) self-monitoring, self-record keeping, and self-reporting; (iii) citizencomplaints/monitoring; and (iv) area monitoring

Maturing	
Ambient air quality standards and monitoring	**Management Process** • Establish a robust health statistics database based on health surveillance [See Guidance Area 3 on Health and other impacts] • Sustain AQ monitoring network systems with proper planning and management • Develop strategies to access diverse financing sources to sustain operations • Network with neighboring countries and share data and technical knowledge through study visits **Technical Process** • Regularly assess attainment and non-attainment areas • Conduct a comprehensive review of most policy-relevant science and literature on risks andexposures that are globally and locally available • Cooperate with academe and technical agencies to conduct risks/exposure assessments • Review AAQS regularly (at least every five years) and routinely monitor compliance • Gather inputs from the academic and scientific communities, and the private and publicsectors to prepare policy-relevant issues that will frame the review • Strengthen capacity for AQ modeling, including forecasting and health assessments • Review of AQ monitoring network system, including assessment of relevance of location/siting • Ensure adequate size and scope of monitoring system
Emissions inventories and modeling	**Management Process** • Set up a comprehensive framework for development of local, regional, and national-level • EI and SA using local source profiles, and necessary infrastructure (e.g., laboratory, GISbaseddatabase system) • Set up for review and continual improvement of EI and SA estimates • Make long-term provisions for required resources (i.e. human, financial, infrastructure) • Establish a mechanism for use of EI and SA for policy decisions • Continually enhance technical capacity through sustainable trainings and participation inknowledge sharing platforms **Technical Process** • Build the operations and management system of compiled bottom-up EI for pollutants and GHGs at pre-defined intervals (i.e. annually or every two years) using more refined EIapproaches • Ensure capacity to participate in regional EI studies using refined EI approaches • Ensure regular update and review of standard operating procedures (SOPs) and QA/QCprocedures for EI and SA • Enhance technical capacity for SA studies; collaborate with academe and other researchinstitutions and explore more advanced methods • Complete local source profiles for majority of sources and maintain database for the same • Conduct receptor-based SA using a variety of models (i.e. CMB, UNMIX, PMF) • Collect PM speciation data covering spatial, seasonal variations and business as usual; aswell as episodic scenarios • Use multiple SA techniques, conduct sensitivity analysis and disseminate peer reviewedresults • Conduct regular audits of laboratory facilities and data quality checks for ensuring goodSA estimates • Develop and continually update an integrated database of speciated data, source profiles,and ambient receptor site measurements • Conduct continuous PM speciation measurement and analysis, and update SA every year • Develop localized dispersion models and apply for SA at least one month per season. • With factors leading to diverged results identified and resolved, ensure alignment of SAresults from dispersion and receptor models for most of the time. • Apply and validate all models (steady state, non-steady state, photochemical) routinelyto estimate exposure • Improve local land use and emissions profile data for incorporation into dispersion modelsdeveloped overseas. • Use EI, SA, and dispersion models in an integrated manner for AQM policymaking orevaluating policies • Build capacity to forecast future emissions and dispersion

Maturing	
Health and other impacts	**Management Process** • Establish a robust health statistics database based on a health surveillance system toenable and facilitate health studies • Translate study results into policy tools in a transparent manner • Develop and implement communication strategies targeted at policy makers and thepublic • Ensure that scenarios for future needs of AQM are developed (USEPA, 2012f) **Technical Process** Ensure that: • Exposure and HIA studies of major facilities or areas (e.g., schools, hospitals) and ofvulnerable populations (e.g., children and the elderly) are conducted (Makri&Stilianakis,2008); • Major studies on health impacts are systematically conducted (Rothman & Greenland,1998); • Studies on other impacts of air pollution (e.g., on buildings and agriculture) are available(Emberson et al., 2003; Rao et al., 2014); • Studies on social economic cost of pollution and benefit of pollution control are available(OECD, 2014); • Cost-effectiveness/cost-benefit analysis are being conducted (USEPA, 2010b; Clean Air forEurope, 2012); and • Emissions inventories and dispersion modeling are further developed (EuropeanEnvironment Agency, 2013).
Air quality communication	**Management Process** • Develop and implement communication strategies for all stakeholders • Strengthen capacity to institutionalize and systematize AQ communication to allstakeholders • Strengthen capacity to issue routine press releases on state of AQ • Systematically provide advance warnings/forecasts and public health hazards of airpollution impacts • Update AQ information online (i.e. processed AQ monitoring data, AQ trends, healthimpacts) and ensure accessibility to the public and all stakeholders • Ensure resources are available for AQ communication **Technical Process** • Strengthen capacity to communicate comprehensive and non-technical information on status of AQM (i.e. processed AQ monitoring data, AQI, more detailed information from EI/SA, local data on air pollution health impacts, and AQM action plans) for use in regularand systematic communication activities • Update AQ information on a real-time basis • Enhance capacity to use multiple communication channels and innovative technologiesto communicate AQ Information

Clean air action plans	**Management Process**
	• Establish a robust CAAP process:
	  ◦ Conduct Proposals Workshop to evaluate cost-effectiveness/cost-benefit, technicalfeasibility, and implementation strategy.
	  ◦ Conduct CAAP Presentation and Implementation Workshop to present completed CAAP,review of remaining issues, and initial implementation steps.
	  ◦ Establish Guidance Board and commence regular meetings. The Board could beformulated as an outcome of the initial public input workshop. The role of the Board isto guide the overall process of CAAP formulation, and review recommendations fromthe Technical Team. In general, the Board needs to include key government departmentsthat will be responsible for implementing CAAP. This can be complemented by keystakeholders from outside the government to improve the ability of the Board to reflectthe needs of all stakeholders.
	• Prepare implementation programs. The Technical Team shall take lead in the CAAP preparation and development of implementation programs for the selected actions, with input from stakeholders. The roles and responsibilities of stakeholders must be clearly identified and definedwithin a clear institutional framework, and agreed upon in order to commit their time and efforts.
	• Ensure that CAAPs are implemented with comprehensive and prioritized mitigation actions that are aligned with sector-specific and socio-economic development plans including climatechange mitigation
	• Ensure sustainable funding for CAAP development and regular review; explore a wider range ofexternal funding sources
	• Fully implement air pollution-specific policies at the national and local levels

	Technical Process • Define the domain area (geographical boundaries for which CAAP is to be prepared) • Develop an annotated outline of the CAAP. Examples of processes for CAAP development as well as an annotated outline of Palembang City for maturing developmental stage of CAAP are provided. The process for the Germany Clean Air Implementation Plan and San Francisco Bay Area clean air plan are also described to progress to the fully developed stage of CAAP (SeeAnnex V-B of the Information Sourcebook). • Review the state of air quality and emission sources in the are a (air quality monitoring results vis-à-vis standards, EI, spatial distribution of pollutant concentrations, assessment of sources and pollutants of concern, and SA for selected pollutants) [See Guidance Area 1 and 2 for guidelines]. • Assess real and/or potential health and environmental impacts, either by use of burden of disease approaches or rapid epidemiological/ecological studies, commit resources for implementation, make projections for the future, and assess the costs of control and the health and environmental benefits. Describe the CAAP outline first, followed by the process ofachieving the set goals. • Prepare a list of all potential control options for each of the selected priority sources withadditional input obtained through public input workshops. • Evaluate source mitigation and control options for their efficacy (based on cost-benefit or cost-effectiveness analysis and expected impacts). In addition, technical feasibility (practicality, "low-hanging fruits" approach, accessibility to technology, and ease of implementation), implementation period (short-, mid-, or long-term), requirement of financial resources, and responsible agencies may be tabulated, as given in the example in section 6.1.4. In some cases, social feasibility (public acceptability, security, aesthetics) may be added, as well as having cobenefitsof addressing air pollution and climate change issues. • Identify implementation barriers and required actions to support and optimize implementation, such as policy and regulatory framework, human resources and private sector support, market opportunities, and public awareness. Table 6.2a and 6.2b serve as guide in evaluating thebarriers and required actions to address the barriers.
Governance	**Management Process** Institutional coordination, capacity and training • Enhance capacity building activities with possible re-assessment of needs • Strengthen and broaden communication, data sharing and reporting mechanisms forother relevant city and central government agencies • Begin initial collaboration with neighboring cities for regional AQM, possibly starting withinformation sharing and data exchanges. • Continue to assess and allocate government funding while mobilizing additional resourcesthrough city taxes and fiscal policies as well as national and international finance • Explore innovative financing mechanisms, including partnering with private sector Stakeholder engagement, participation and accountability • Strengthen and broaden mechanism for public information dissemination (i.e. sharingdata on air pollution, health impacts, climate change and other co-benefits) • Strengthen and broaden stakeholder engagement and consultation mechanisms toprovide input and oversight on relevant AQM function **Technical Process** • Continue to identify and implement appropriate regulatory instruments, possibly combining CAC with market-based and other instruments (such as voluntary) [SeeGuidance Area 5 on Clean air action plans]. • Strengthen and broaden mechanisms to collect information and assess regulatory compliance through (i) inspections; (ii) self-monitoring, self-record keeping, and self reporting;(iii) citizen complaints/monitoring; and (iv) area monitoring • Review and evaluate effectiveness of local clean air action plan, building on informationgathered during compliance monitoring activities.

Fully developed	
Ambient air quality standards and monitoring	**Management Process** • Adopt international standards on air pollution • Align AAQS for criteria pollutants and other toxic pollutants with WHO AQGs and/or interimtargets • Communicate costs and benefits of AAQS to the public • Collaborate with other countries to establish regional centers for AQ monitoring **Technical Process** • Prepare cost-benefit analysis on the implementation of AAQS [See Guidance Area 3 on Health and other impacts] • Review AAQS regularly (at least every five years) or when important WHO AQGs are updated • Review linkages of AAQS with sector plans • Pending availability of funds and capacity, explore or invest in studies using sophisticated or alternative AQ monitoring methods – e.g. monitoring supersites and remote sensors – for improvedunderstanding of secondary PM mechanisms and regional transport of air pollution • Participate in studies and regional harmonization/cooperation work
Emissions inventories and modeling	**Management Process** • Set up an institutional framework for continual improvement of infrastructure including state-of-the-art laboratory facilities, techniques, documentation, and databasemanagement systems for EI and SA • Sustain use of EI and SA for policy decisions and feedback for improving EI and SA andspecific scientific inputs • Ensure allocation of adequate and sustainable technical and financial resources • Ensure that all stakeholders are regularly involved **Technical Process** • Continually enhance the operations and management system of compiled EI forpollutants, toxics, and GHGs annually or every two years • Build and sustain the capacity for EI of toxic pollutants • Participate in studies that conduct regional EI • Explore capacity building opportunities for more sophisticated SA methods • Conduct SA for toxic pollutants regularly • Collect PM speciation data regularly covering trace and molecular marker species • Upgrade source profiles in CMB applications • Establish and continually assess data quality by EI validation and SA verification • Conduct SA using multiple SA techniques with comprehensive scientific analysis of thedata and results • Organize international peer review and dissemination of results • Sustain enforcement of control measures • Sustain capability to apply steady-state, non-steady state and photochemical modeling • Enhance capacity for forecasting emissions and dispersion • Sustain an AQM system using inputs from EI, SA, and dispersion modeling to AQpolicymaking and evaluation of effectiveness or impacts of AQ policies and measures
Health and other impacts	**Management Process** • Integrate health risk assessment into policies and strategies • Develop and implement communication strategies with policy makers and the public astarget audiences **Technical Process** • Conduct health and environmental impact studies regularly and systematically. Report results to influence policies. Link health and environmental impacts projections based on scenarios with policy changes in emissions-related sectors (e.g., transport). Conduct regularly and systematically exposure and HIA of major facilities or areas (e.g., schools, hospitals) and of vulnerable populations (e.g., children, elderly, and people with existing ailments and/or disabilities). Make available studies on other impacts of air pollution (e.g., on buildings and agriculture) as well as socioeconomic cost of pollution and benefit ofpollution control. Conduct cost-effectiveness/cost-benefit analysis. • Develop regulatory air quality simulation models to support the policymaking process

Air quality communication	**Management Process** • Ensure proper implementation and review of communication strategies for allstakeholders; ensure feedback mechanism • Highlight co-benefits of AQ and GHG mitigation • Strengthen capacity to issue routine press releases on state of AQ • Systematically provide advance warnings/forecasts and public health hazards of airpollution impacts • Update AQ information on a real-time basis and make available online (i.e. processed • AQ monitoring data, AQ trends, health impacts); ensure accessibility to the public andall stakeholders • Ensure resources are available to sustain AQ communication activities • Dedicate/assign staff position for public engagement/communication **Technical Process** • Strengthen capacity to communicate comprehensive and non-technical information on status of AQM through sustainable training (i.e. processed AQ monitoring data, AQI, more detailed information from EI/SA, local data on air pollution health impacts, andAQM action plans) • Ensure routine and systematic communication activities • Update AQ information on a real-time basis • Explore innovative solutions for AQ communication
Clean air action plans	**Management Process** • Develop CAAP regularly with tightening air quality improvement targets, linking with socioeconomicplans and climate change mitigation • Sustain a clear framework for implementation and enforcement of CAAP, including roles of related departments, multi-sectoral coordination mechanism, and involvement of public, aswell as regular assessment of the CAAP • Sustain public participation in CAAP process through a clearly defined mechanism (i.e. publicinput workshops) • Secure financial support for CAAP development and ensure that implementation is securedwithin the government budget and a wide mix of external funding sources • Continually enhance the integration of all assessments into policies and strategies through a clearmechanism • Regularly evaluate technical feasibility and implementation strategies of CAAP • Regularly and systematically report CAAP implementation results to stakeholders (includingpolicymakers and the public) to influence policies using targeted communication strategies **Technical Process** • Identify control measures, which are science-based and implemented on a cost-effective approach • Implement and continue to enhance capacity for a full range of AQM activities: air quality monitoring system, bottom-up EI, dispersion modeling, SA, testing compliance with emission and air quality standards, potential abatement assessment, cost-effectiveness and cost and benefitanalysis results, and assessment of health and environmental impacts • Establish studies on other impacts of air pollution (e.g., on buildings and agriculture) as wellas ensure that studies on socio-economic cost of pollution and benefits of pollution controlare available. • Conduct air quality projections to support the policy making process
Governance	**Management Process** Institutional coordination, capacity and training • Continue to conduct capacity building activities, with re-assessment of training needs, asnecessary • Establish and strengthen partnerships with organizations who can help build capacities inother cities • Collaborate with neighboring cities on regional AQM, possibly including harmonization of standards, joint monitoring and development of management measures, andcollaborative capacity building. • Continue to assess and allocate government funding while mobilizing additionalresources through city taxes and fiscal policies as well as national finance • Explore innovative financing mechanisms, including partnering with private sector Stakeholder engagement, participation and accountability • Continue to strengthen and broaden mechanism for public information dissemination(i.e. sharing data on air pollution, health impacts, climate change and other co-benefits) • Continue to broaden stakeholder engagement and consultation mechanisms to provideinput and oversight on relevant AQM functions • Sustain political and public support through mechanisms that enhance transparency, accountability and communication strategies [See Guidance Area 4 on Air quality communication]

	Technical Process • Continue to identify and implement appropriate regulatory instruments, possibly combining CAC with market-based and other instruments (such as voluntary) [SeeGuidance Area 5: Clean air action plans] • Continue to strengthen and broaden mechanisms to collect information and assess regulatory compliance through (i) inspections; (ii) self-monitoring, self-record keeping,and self-reporting; (iii) citizen complaints/monitoring; and (iv) area monitoring • Review and evaluate effectiveness of local clean air action plan, using environmentalresults and other indicators to assess compliance rates, indirectly measuring compliance,number of enforcement responses, monetary penalties assessed

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