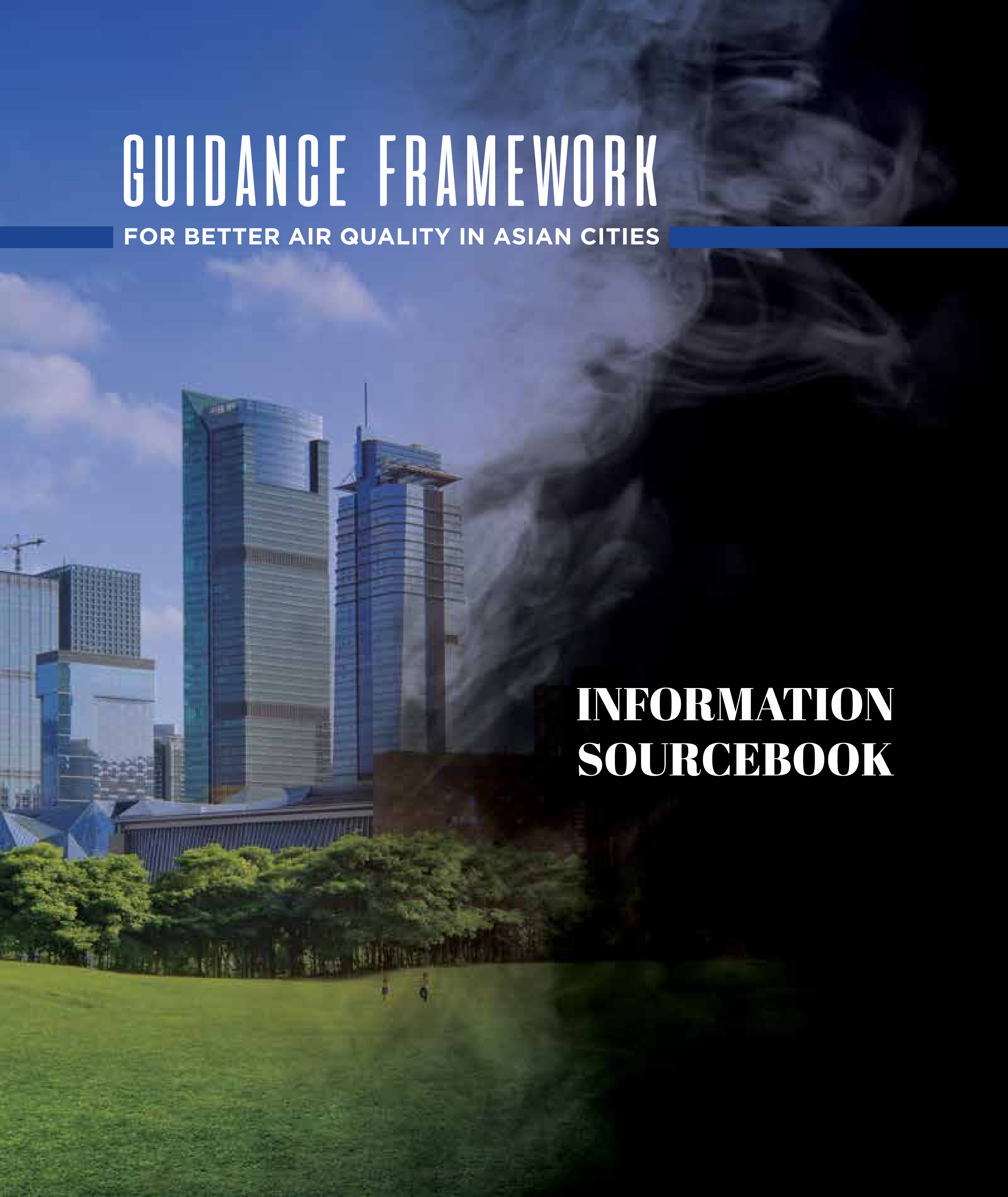
GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES



INFORMATION SOURCEBOOK

Integrated Programme for Better Air Quality in Asia

CLEAN AIR ASIA

UNEP

GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES

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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Country Networks in China, India, Indonesia, Nepal, Pakistan, Philippines, Sri Lanka, Vietnam

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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

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 (≤ 10 micrometers in diameter)
$PM_{2.5}$	Particulate Matter (≤ 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.

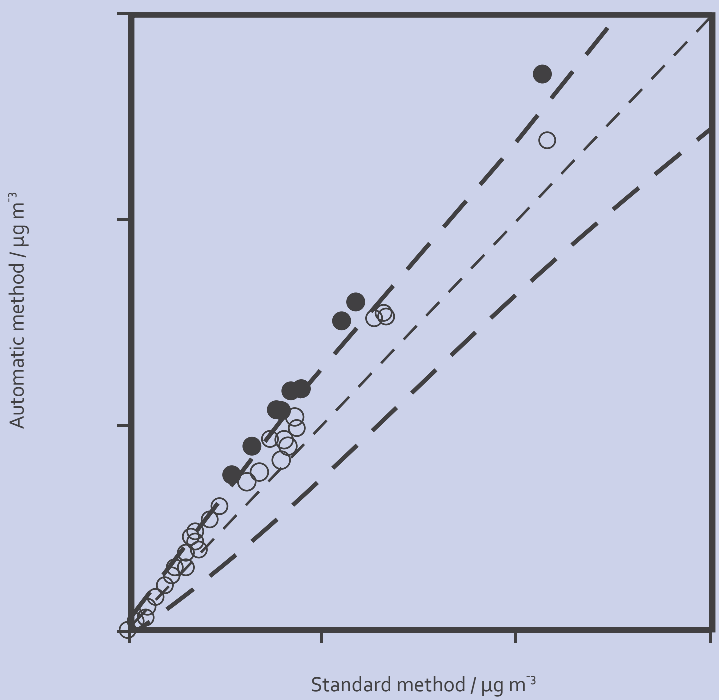
Comprehensive data are now being collected and analyzed to clarify the pollution mechanism of PM. While these equipment have largely been for domestic use, it is expected that they will contribute to a regional monitoring network and in the future, be utilized for a forecasting system of regional air 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);
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- 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]:

$$E_{int} = E_{orf} * E_{coeff}$$

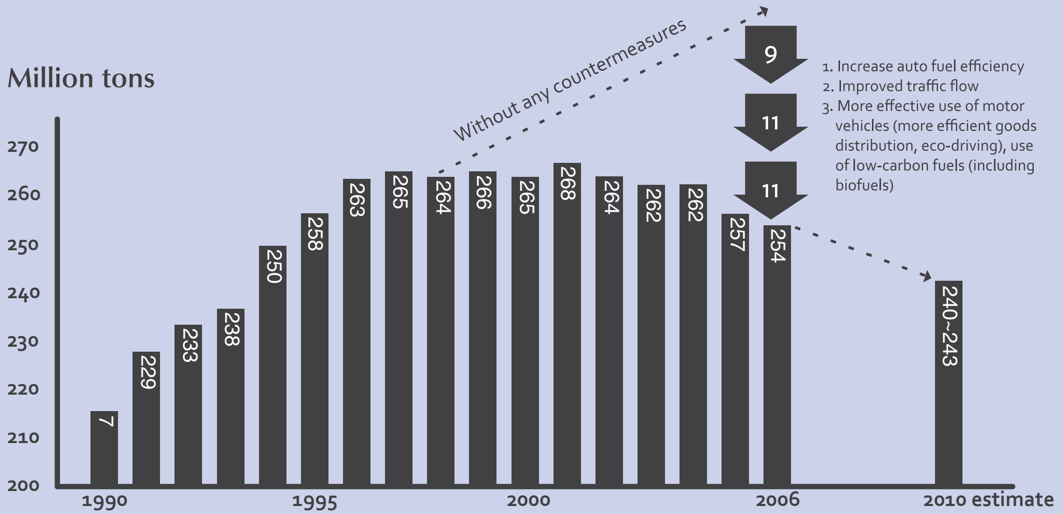
Activity volume is calculated as the product of the number of vehicles and vehicle kilometers travelled VKT [vehicle-km]. On-road fuel efficiency (E_{orf}) is calculated as the product of the certified fuel efficiency (CFE) in units [km/l] and a travelling coefficient (T_{coeff}), which is a measure of congestion and extent of eco-driving:

$$E_{orf} = CFE * T_{coeff}$$

Results

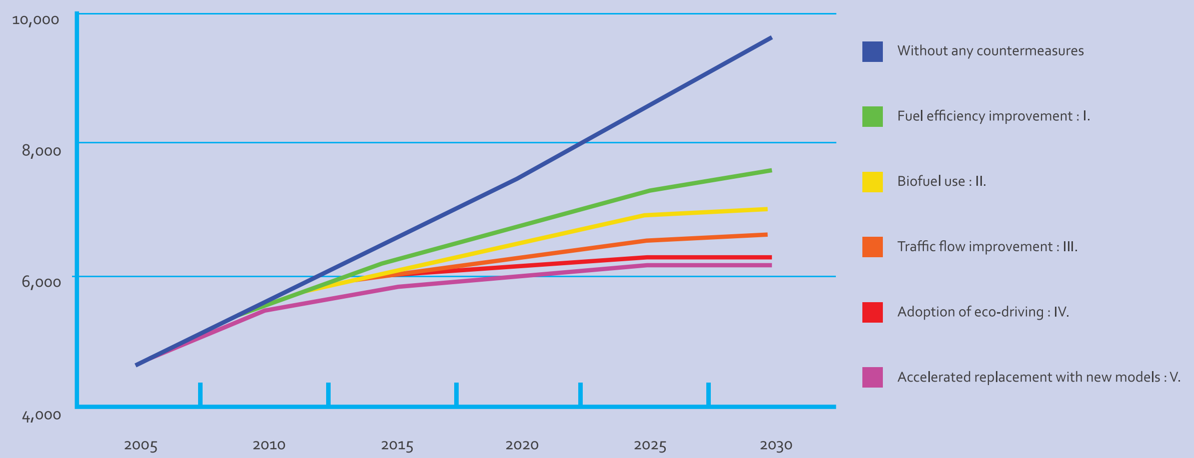
In Japan's transport sector, the CO_2 emission peaked in 2001 and declined since then (see figure below)

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

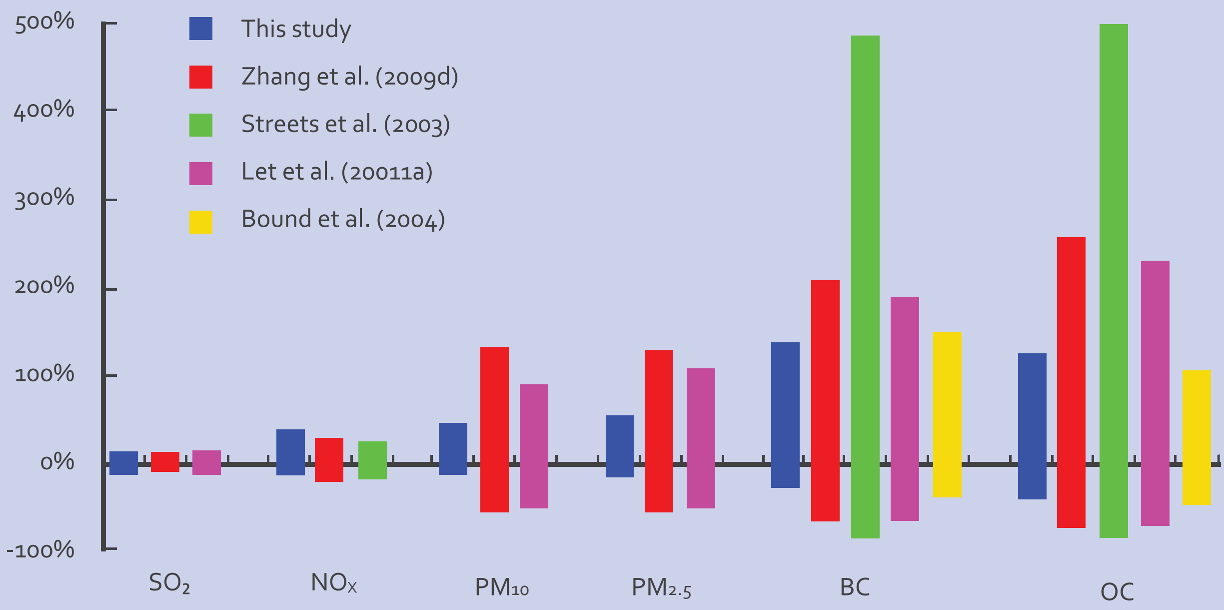
To evaluate the uncertainties (expressed as the 95 percent confidence interval (CI) around the central estimate) of a bottom-up EI of SO_2, NOx, total PM, PM_{10}, $PM_{2.5}$, black carbon (BC), and organic carbon (OC) from all anthropogenic sources in China.

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 PM_1 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

		Percent reduction in global emissions (all sectors) due to measure					
Measures	**Regions**	**BC**	**OC**	**$PM_{2.5}$**	**CO**	**CH_4**	**NO_x**
Extended recovery of coal mine gas	East, Southeast Asia & Pacific	0	0	0	0	25	0
Extended recovery and flaring for oil and gas production	All regions						
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?
    - o Types of data that need to be collected
    - o Access to existing data
    - o Required size of the study population
    - o Availability of an adequate sampling procedure for selecting a study population
    - o Capability for estimating and/or measuring air pollutant concentrations and health impacts;
    - o Ability to identify and control for confounding factors
    - o 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.

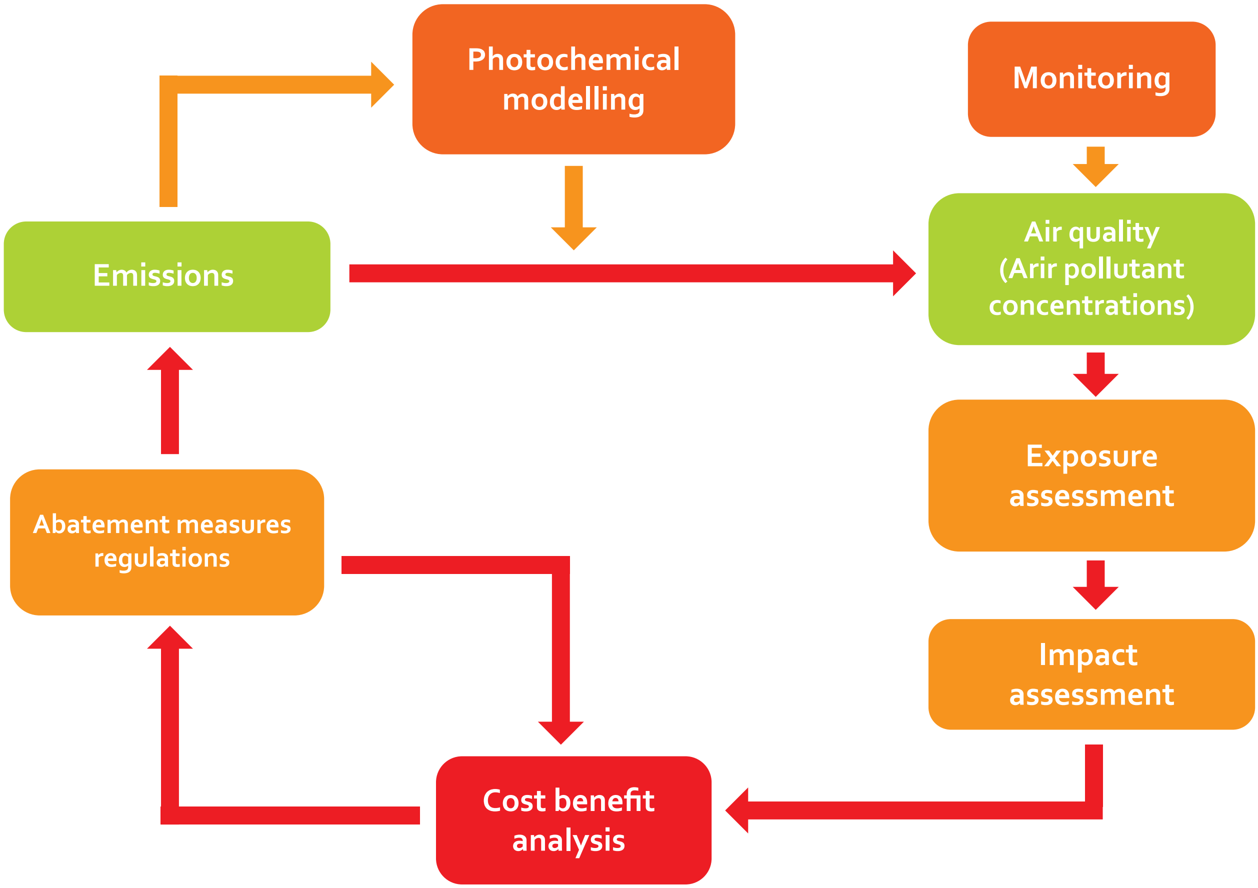


Figure A3.1 A simplified AQM system related to cost-benefit analysis
Red arrows: Main system loop; Green arrows: Subsystem loops and data elements

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.

WHO Headquarters Press Release on Deaths Linked to Air Pollution

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.

Response by the WHO Western Pacific Regional Office (WHO WPRO)

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

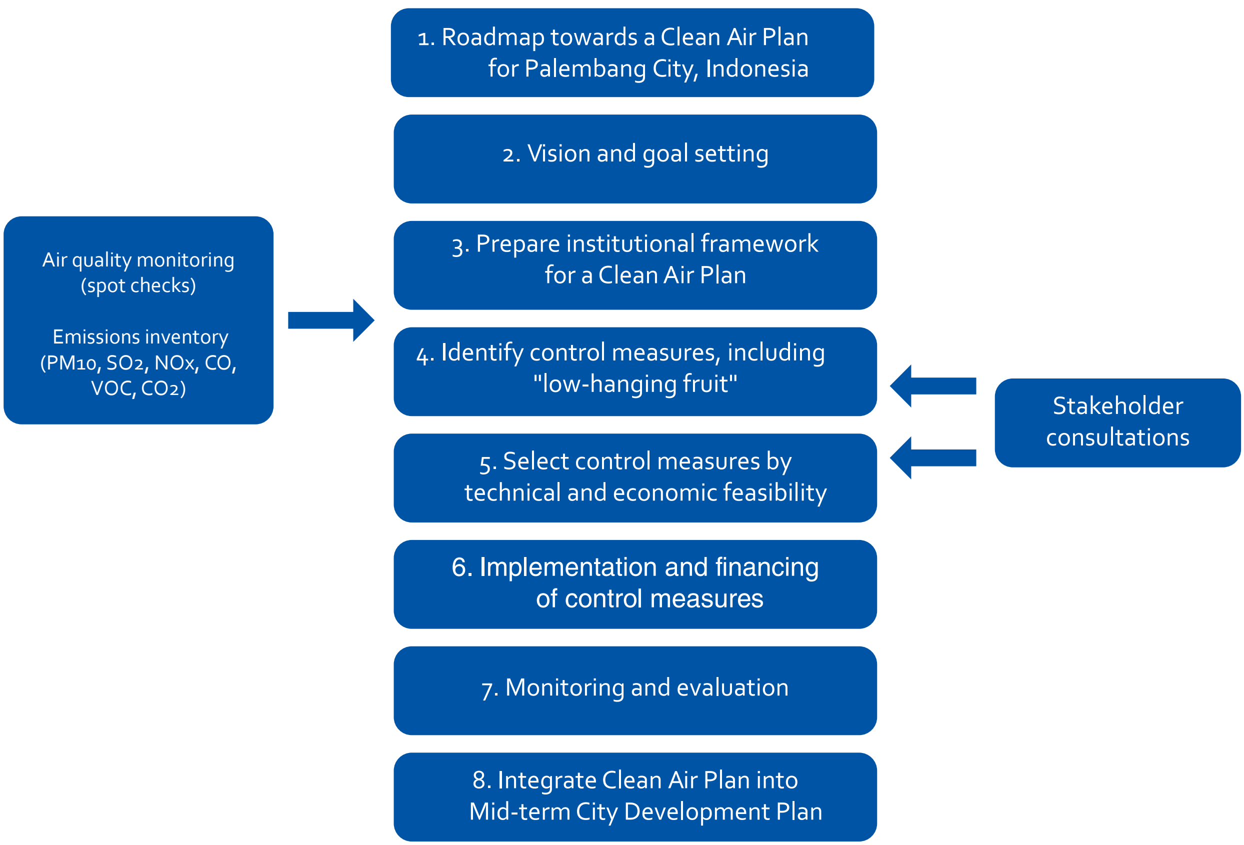


Figure A5.1 Clean Air Action Plan development for Palembang City, Indonesia

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

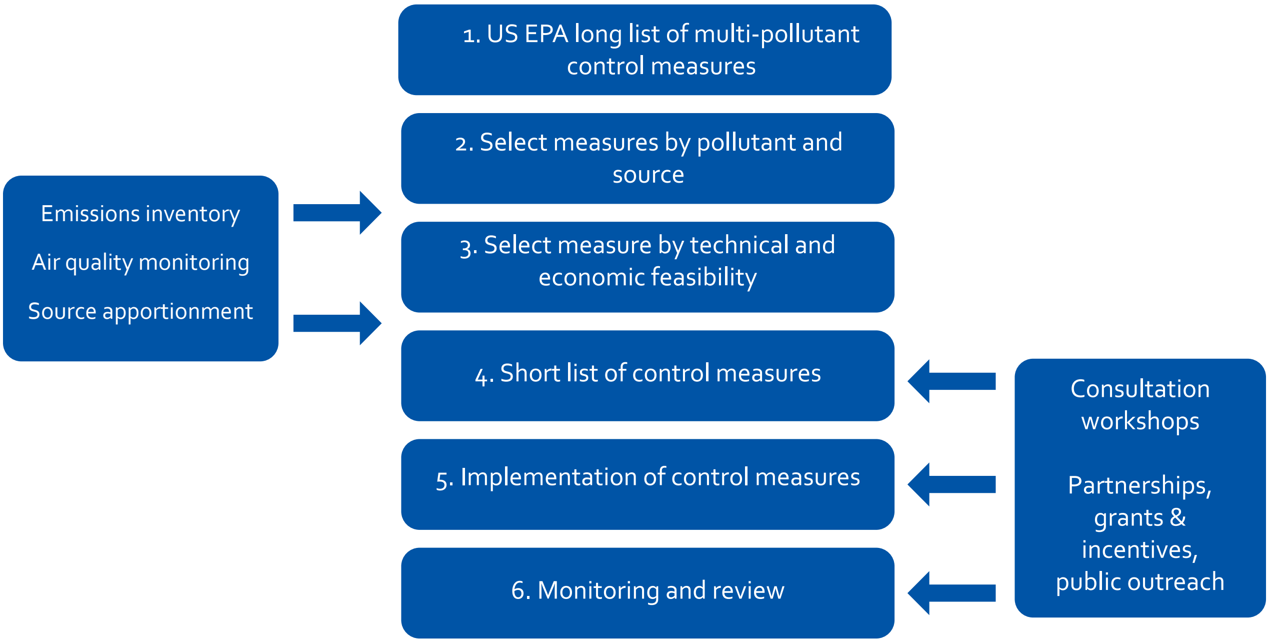


Figure A5.2 San Francisco Bay Area 2010 Clean Air Action Plan development
Source: Bay Area Quality Management District, 2010

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. <u>Mobilizing resources internally</u>

- **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 ______________________________________

<u>STAGES of Guidance Area 3: Health and Other Impacts</u>

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 subnational 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 instruments such as command and control, economic instruments, co-regulation, voluntary initiatives and self-regulation[41] based on local context and existing governance arrangements	☐ Air pollution regulations employ a mix of different policy instruments based on local context and existing governance arrangements- Lessons learned from regulation and governance of policies are growing in number and scope New approaches 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 stakeholders are engaged through consultative mechanisms to gather input during policy preparation/ implementation/evaluation[43]	☐ Mechanisms for collaboration with stakeholders are institutionalized. 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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