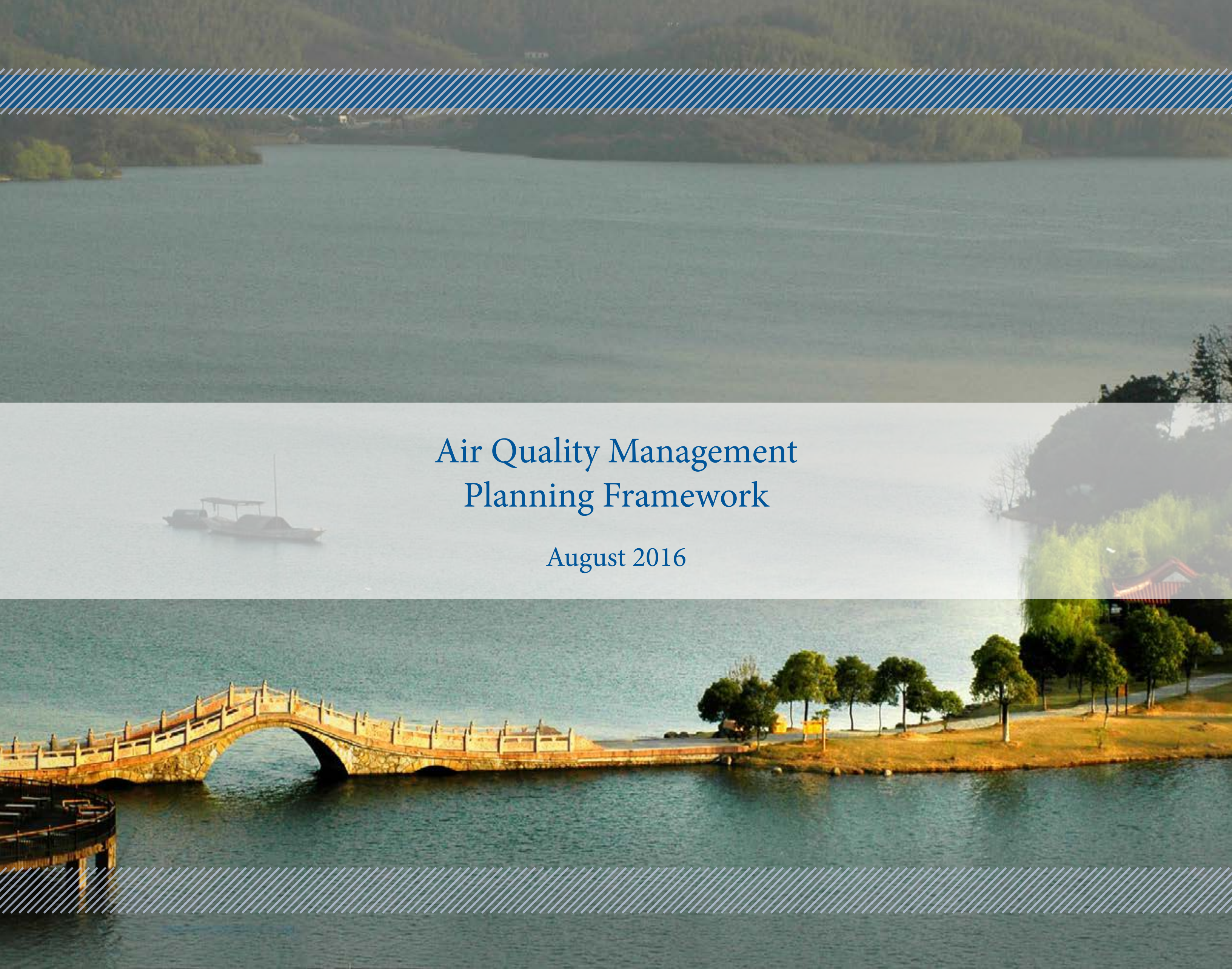

Air Quality Management Planning Framework

August 2016

Prepared for—

Jiangsu Environmental Protection Department
176 North Jiangdong Road
Nanjing, Jiangsu 210036, China

Prepared by—

RTI International
3040 East Cornwallis Road
Research Triangle Park,
NC 27709-2194, USA

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The report was prepared by RTI with strong support from team members from the U.S. and China. The RTI team was led by Rebecca Nicholson and included Stephen Boone, David Bullock, Jeremy Guo, Dr. George Gao, Huatian Zhang, David Reeves, Karen Schaffner, Jeff Coburn, Katie Hanks, Mike Laney, David Green, and Dr. Prakash Doraiswamy. Key support was also provided by Chris James and Max Dupuy with the Regulatory Assistance Project (RAP) and by Hilary Hafner and Alan Chan with Sonoma Technology, Inc. Dr. Wang Zifa from the China Academy of Sciences Institute of Atmospheric Physics also provided advice and support.

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ACRONYM	DEFINITION
ABaCAS	Air Benefit and Cost and Attainment Assessment System
AC	Activated Carbon
ACI	Activated Carbon Injection
AEO	Annual Energy Outlook
AERMOD	AMS/EPA Regulatory Model
AGU	American Geophysical Union
AIM	Architectural and Industrial Maintenance
Al	Aluminum
AOCs	Administrative Orders of Consent
AP-42	USEPA's Compilation of Air Pollutant Emission Factors
APC	Air Pollution Control
APCD	Air Pollution Control District
AQ	Air Quality
AQI	Air Quality Index
AQM	Air Quality Management
AQMD	Air Quality Management District
AQMP	Air Quality Management Plan
AQRV	Air Quality Related Values
ARB	Air Resources Board
As	Arsenic
B	Boron
BACT	Best Available Control Technology
bbl/d	Barrels per Day
BBQ	Barbecue
BEIS	Biogenic Emission Inventory System
BenMAP	Environmental Benefits Mapping and Analysis Program
Btu/scf	British Thermal Units per Standard Cubic Foot
Ca	Calcium

ACRONYM	DEFINITION
CA/FO	Consent Agreement/Final Orders
CAA	Clean Air Act
CAAC	Clean Air Alliance of China
$CaCO_3$	Calcium Carbonate
CAISO	California Independent System Operator
CALPUFF	California Puff Model
CAM	Compliance Assurance Monitoring
CARB	California Air Resources Board
Cd	Cadmium
CDS	Circulating Dry Scrubber
CEMs	Continuous Emissions Monitoring System
CFR	Code of Federal Regulations
CGA	Cylinder Gas Audit
CHIEF	Clearinghouse for Inventories and Emission Factors
CICA	Centro de Información sobre Contaminación de Aire
CIEPE	China (Nanjing) International Environmental Protection Expo
CISWI	Commercial/Industrial Solid Waste Incinerators
Cl	Chlorine
CMAQ	Congestion Mitigation and Air Quality Improvement Program
CMB	Chemical Mass Balance
CMV	Commercial Marine Vessels
CO	Carbon Monoxide
Co	Cobalt
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
COD	Chemical Oxygen Demand
CPDS	Certified Product Data Sheet

ACRONYM	DEFINITION
cPM	Condensable Particulate Matter
CPP	Clean Power Plan
Cr	Chromium
CTG	Control Techniques Guideline
Cu	Copper
CUF	Capacity Use Factor
DAHS	Data Acquisition and Handling Systems
DC	Direct Current
DfE	Design for Environment
DPM	Diesel Particulate Matter
DRC	Developmental Research Center
DSM	Demand Side Management
EAFs	Electric Arc Furnaces
EDP	Electrodeposition Primer
EDV	Belco Wet Scrubbing System
EE	Energy Efficiency
EGU	Electricity Generating Unit
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EPB	Environmental Protection Bureau
EPP	Efficiency Power Plant
ESP	Electrostatic Precipitator
F	Fluorine
FCCU	Fluid Catalytic Cracking Unit
Fe	Iron
FGD	Flue Gas Desulfurization
FLM	Federal Land Manager
fPM	Filterable PM
ft	Feet
FYP	Five-Year Plan
g O_3	Grams of Ozone

ACRONYM	DEFINITION
g O_3/g VOC	Grams of Ozone per Gram of Volatile Organic Compounds
g VOC/L	Grams of Volatile Organic Compound per Liter
g/kg	Gram per Kilogram
GB	Guo Biao, the Chinese National Standards
GC	Gas Chromatograph
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHGRP	Greenhouse Gas Reporting Program (USEPA)
GIS	Geographic Information System
gpm	Gallons per Minute
GW	Gigawatts
CGA	Cylinder Gas Audit
H_2	Hydrogen Gas
H_2O	Water
H_2S	Hydrogen Sulfide
H_2SO_4	Sulfuric Acid Mist
HAP	Hazardous Air Pollutant
HAP/liter	Hazardous Air Pollutant per Liter
Hg CEMS	Continuous Mercury Monitor
Hg/m^3	Mercury per Cubic Meter
HOV	High-Occupancy Vehicle
HR	Hour
HVLP	High Volume Low Pressure
I/M	Inspection and Maintenance
IMPEAQ	Integrated Multi-Pollutant Planning for Energy and Air Quality
IRP	Integrated Resource Planning
ITS	Intelligent Transportation Systems
JJJ	Jing-Jin-Ji
K	Potassium
K	Thousand

ACRONYM	DEFINITION
kg/MT	Kilogram per Metric Ton
km	Kilometers
km2	Square Kilometers
kPa	Kilopascal
kWh	Kilowatt Hour
LAER	Lowest Achievable Emission Rate
lb/ton	Pounds per Ton
lbs	Pounds
LDAR	Leak Detection and Repair
LNB	Low-NO_x Burner
LNG	Liquified Natural Gas
LoTOx	Belco NO_x Control Technology
LPG	Liquefied Petroleum Gas
m	Meter
m/s	Meters per Second
m^3	Cubic Meters
MEGAN	Model of Emissions of Gases and Aerosols from Nature
MEP	Ministry of Environmental Protection
mg	Milligrams
Mg	Megagrams
mg/dscm	Milligrams per Dry Standard Cubic Meter
mg/L	Milligrams per Liter
mg/m^3	Milligrams per Cubic Meter
MJ/sm^3	Megajoules per Standard Cubic Meter
mm	Millimeter
MMBtu	Million British Thermal Units
MMT	Million Tons
Mn	Manganese
MOU	Memorandum of Understanding
MOVES	USEPA's Motor Vehicle Emission Simulator
MSDS	Material Safety Data Sheet

ACRONYM	DEFINITION
MW	Megawatts
MWe	Megawatts electrical
MWh	Megawatt Hour
N_2	Nitrogen Gas
NAAQS	National Ambient Air Quality Standard Gas
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NEI	National Emission Inventory
NEMS	National Energy Modeling System
NESHAP	National Emission Standards for Hazardous Air Pollutants
NH_4	Ammonia
Ni	Nickel
NIOSH	National Institute of Occupational Safety and Health
NO_2	Nitrogen Dioxide
NO_3	Nitrate
NO_x	Nitrogen Oxide
NSPS	New Source Performance Standards
NSR	New Source Review
O_2	Oxygen Gas
O_3	Ozone
OC/EC	Organic Carbon / Elemental Carbon
ORP	Oxidation Reduction Potential
Pb	Lead
PDS	Product Data Sheet
pH	pH Values
PH	Preheater
PH/PC	Preheater/Precalciner
PM	Particulate Matter
PM/m^3	Particulate Matter per Cubic Meter
PM_{10}	Particulate Matter 10 Micrometers or Less in Diameter

ACRONYM	DEFINITION
$PM_{2.5}$	Particulate Matter 2.5 Micrometers or Less in Diameter
PH/PC	Preheater/Precalciner
PM	Particulate Matter
PM/m^3	Particulate Matter per Cubic Meter
PMF	Positive Matrix Formation
ppbw	Parts Per Billion by Weight
ppm	Parts Per Million
ppmv	Parts Per Million by Volume
PRC	People's Republic of China
PRD	Pearl River Delta
PSD	Prevention of Significant Deterioration
PtD	Prevention through Design
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RACT	Reasonably Available Control Technology
RAP	Regulatory Assistance Project
RATA	Relative Accuracy Test Audit
MEP	Ministry of Environmental Protection
RBLC	RACT/BACT/LAER Clearinghouse
RE	Renewable Energy
REZ	Renewable Energy Zones
RMB	Ren Min Bi, the Chinese Currency
RPOs	Renewable Purchase Obligation
RPS	Renewable Portfolio Standard
RSD	Remote Sensing Devices
RTO	Regenerative Thermal Oxidizer
SCAQMD	South Coast Air Quality Management District
scf/hr	Standard Cubic Feet Per Hour
SCR	Selective Catalytic Reduction
Se	Selenium
SEMC	Shanghai Environmental Monitoring Center

ACRONYM	DEFINITION
SEPs	Supplemental Environmental Projects
Si	Silicon
SiO_2	Silicon Dioxide
SIP	State Implementation Plan
SNCR	Selective Non-Catalytic Reduction
SO_2	Sulfur Dioxide
SO_4	Sulfate
SOPs	Standard Operating Procedures
TCEQ	Texas Commission on Environmental Quality
TDS	Total Dissolved Solids
THC	Total Hydrocarbons
Ti	Titanium
tPM	Total PM
tpy	Tons per Year
TSM	Transportation Systems Management
TSO	Transmission System Operators
TSS	Total Suspended Solids
TTN	Technology Transfer Network (USEPA)
$\mu g/m^3$	Micrograms per Cubic Meter
U.S.	United States
Unmix	USEPA mathematical receptor model
USTDA	U.S. Trade and Development Agency
UV/EB	Ultraviolet light/Electron Beam
V	Vanadium
VKT	Vehicle Kilometers Traveled
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compounds
WRAP	Western Regional Air Partnership
WRF	Weather Research and Forecasting
yr	Year
YRD	Yangtze River Delta
Zn	Zinc

Executive Summary

Background

The development of the Air Quality Management Planning Framework was funded by the U.S. Trade and Development Agency (USTDA) as part of a project to accelerate improvements in air quality in China by sharing U.S. best practices and fostering deployment of U.S. air pollution control technology and expertise. A grant agreement was signed between the USTDA and the Ministry of Environmental Protection of the People's Republic of China (hereinafter referred to as "MEP") in October 2013 for "Technical Assistance for The China Air Quality Management Program" (hereinafter referred to as "project"). The MEP selected the Jiangsu Province as the pilot region to implement the project. The project focused on 3 pilot cities in Jiangsu Province: Nanjing, Changzhou and Suzhou.

This report provides guidance on U.S. best practices in air quality planning and recommendations intended to assist Jiangsu Province and the three pilot cities with developing the next generation of air quality plans. Control strategies are presented for reducing emissions of $PM_{2.5}$, $PM_{2.5}$ precursors (SO_2, NO_X, and VOC), and hazardous air pollutants. Consideration is also given to energy planning and to greenhouse gas emissions, specifically CO_2. The report also provides updates on national-level air quality planning efforts in China as well as air quality planning efforts in the Jiangsu Province and the 3 pilot cities.

Current Conditions And Challenges in Jiangsu

Officials at Jiangsu Environmental Protection Department (JEPD) and the city-level environmental protection bureaus (EPBs) are working together to improve air quality in the Province, but they face a number of challenges, given the current conditions in Jiangsu: [1]

- Jiangsu has experienced rapid population growth and urbanization, leading to increased energy demand and associated air pollution challenges.
- In 2015, the annual average $PM_{2.5}$ concentration in Jiangsu was 58 μg/m^3, which decreased by 12.1% and 20.5% compared to the 2014 and 2013 concentrations, respectively. But the province and all 13 cities still exceeded the national $PM_{2.5}$ annual average standard of 35 μg/m^3.[2]
- Coal is a major energy source, providing 70% of total energy consumption, and in recent years the rate of coal consumption has been growing by up to 6%. With increasing energy demand, it will be challenging for Jiangsu to meet current goals to reduce coal consumption to a level providing 65% of total energy demand by 2017.
- Jiangsu is a highly industrialized province. It is ranked 1st among provinces in China for industrial smoke and dust emissions; 2nd in coal consumption, gross domestic product (GDP), steel production, and cement production; and 3rd in SO_2, NO_X, and VOC emissions. Fifty percent of GDP is from industry. The population of industrial facilities is constantly changing, with a number of entities being shut down or relocated each year. This dynamic situation presents challenges for constructing an accurate emissions inventory and developing an effective air quality plan.
- The terrain of Jiangsu, combined with the operation of many industrial sources in the region, presents unique air quality challenges. For example, Nanjing is surrounded by mountains on 3 sides, making it difficult for pollution to disperse during certain meteorological episodes.
- The on-road motor vehicle inventory has grown 406% in ten years, with an annual growth rate of 20%. Emissions from shipping are also a major contributor to regional air quality issues; shipping traffic in Jiangsu ports represents 21% of total shipping nationwide. The changing level of emissions from these mobile sources also presents unique challenges for developing air quality plans.

- Numerous small and residential sources of emissions, such as cooking, painting, outdoor burning, and fireworks, are also important contributors to air pollution problems in Jiangsu. Reducing emissions from small "area" sources requires effective education and outreach programs for citizens.

Emissions Inventory Development

Jiangsu EPD and city-level EPB officials are focused on developing a detailed emissions inventory that includes all sectors and pollutants. Current inventories represent about 80% of the sources within the Province. While data are available from a number of large sources equipped with continuous emissions monitoring systems, data for many other sources, particularly small and medium-sized facilities, are less available and less reliable.

In 2014, the total estimated SO_2, NO_X and smoke and dust emissions for Jiangsu Province were 904.7 kilotons, 1.2326 megatons and 763.7 kilotons, respectively. Contribution of the emissions from different sources is shown in Table ES-1 below. [3]

Table ES-1 Contribution of Air Emissions from Different Sources in Jiangsu Province (as of 2014)

	SO_2	NO_X	SMOKE AND DUST
Industrial Sources	96.19%	72.06%	94.34%
Residential Sources	3.78%	0.52%	2.38%
Centralized Garbage and Hazardous Waste Control Facilities	0.03%	0.04%	0.04%
Motor Vehicles	N/A	27.38%	3.24%

Current Pollution Control Strategies And Goals

In project meetings, officials from Jiangsu Province and city-level environmental protection bureaus identified a number of pollution control strategies, goals, and other actions to help improve air quality in the future:[1]

- Optimize energy structure and reduce coal consumption to providing 65% of total energy consumption by 2017.
- Promote usage of clean and renewable energy and increase energy efficiency (green buildings).
- Regulate small coal-fired boilers (rebuild or replace).
- Change industrial structure. Accelerate closing of obsolete industrial equipment and facilities; increase penalties for noncompliance; reduce over-capacity; and control capacity for industries that are high polluters and high energy consumers.
- Promote cleaner production, including pollution prevention through process changes, recycling, better emissions controls, and better supervision.
- Encourage cleaner/greener transportation (e.g., more stringent emissions standards, better quality diesel fuel, and increased rail transport).
- Control emissions from shipping and off-road vehicles.
- Control urban pollution (e.g., cooking fumes and VOC from use of organic solvents) and fugitive dust.
- Add green space (by 2017, green space will be 38.7% of land area).
- Support science and technology. Conduct research on control strategies, invest in the development and deployment of air pollution control technologies, and build research team through professional training and capacity building.
- Ensure monitoring (both regional ambient monitoring and monitoring at industrial sources) and develop early warning systems in cooperation with meteorological department for predicted heavy pollution episodes.
- Develop emergency response plans for different levels of

concern and provide guidance to local cities to implement these plans.

- Enhance laws, regulations and standards.
- Develop an environmental disclosure system.
  - Rank all cities and key enterprises based on air quality and emissions rates and make that information available to the public.
  - Require key enterprises to self-report emissions levels.
- Increase coordination in region and reinforce international collaboration and exchanges.
  - Make $PM_{2.5}$ control a mandatory requirement for industries
  - Implement evaluation and assessment system to measure annual performance and hold violators accountable.
- Increase public participation, outreach and education.

Key Steps In Air Quality Planning

The recommendations in this report are intended to build upon the existing efforts and progress that officials in Jiangsu and the pilot cities have made to date. The report provides background and recommendations related to the following key steps in the air quality planning process:

1. Identify the air quality goal and the date by which it is to be achieved.

The national government in China established a number of air quality goals for key regions and cities during recent years while this report was being developed. A central goal is the 20% reduction of ambient $PM_{2.5}$ concentrations over the 2012-2017 period in the Yangtze River Delta (YRD) region (in which Jiangsu Province is located). Understanding how these goals will apply to Jiangsu and any unique circumstances in Jiangsu (e.g., impacts from neighboring provinces, seasonal issues) are part of this process.

2. Characterize the nature of the air pollution problem.

Unlike the early days of air quality planning in the U.S., Jiangsu has real-time data from ambient air quality monitoring stations throughout the Province. These data can provide useful information for: notifying the public to take action on high pollution days; understanding fine particle composition and contributing pollution sources; determining air quality trends and seasonal variations; and understanding the air quality and other impacts of measures taken to reduce pollution during high-profile public events, such as the 2014 Youth Olympics in Nanjing.

3. Participate in regional planning and consultation with other provinces.

If multiple provinces are able to coordinate their emissions reductions and other actions through regional planning processes, they should be able to meet air quality goals more efficiently and with lower costs than if they all act independently. Jiangsu's expanded cooperation with other environmental agencies in the YRD region and provinces outside the region will be essential in addressing the next generation of regional air quality challenges. Regional planning can also help provinces develop the capacity of air pollution technical staff; coordinate inventories, policies, and modeling analyses; leverage resources; and build a strong foundation of expertise and working relationships for the future.

4. Develop emission inventories.

The core foundation of an air quality plan is the development and analysis of high quality emissions inventories for stationary, area, and mobile sources (for a base year and a future year). Further refinement and completion of the emissions inventory for Jiangsu Province is a critical step in developing the next generation air quality plan.

5. Conduct air quality modeling and identify new emission reduction strategies needed to achieve the air quality goal.

Air quality modeling will help Jiangsu Province and key cities understand how close to the air quality goal they may get based on implementation of programs that are already in place. If the existing strategies fall short of the air quality goal, then modeling can help identify additional local emission reduction strategies that will help each city reach its goal. The ABaCAS model (the Air Benefit and Cost and Air Attainment Assessment System), developed by a team of researchers from China and the U.S., can assist Jiangsu in this exercise. Modeling can also help integrate and assess the benefits from clean energy and energy efficiency policies and the degree to which such policies can help to improve air quality.

6. Adopt and implement effective and enforceable requirements to reduce emissions.

The emission reduction strategies adopted as part of any air quality management plan need to be based on regulations and other requirements that can be properly enforced by the appropriate authority (e.g., city EPB, provincial EPD, MEP). Regulations for industrial facilities should represent best available control technology, and they need to include test method, source monitoring, recordkeeping, and reporting requirements in addition to an emission limit.

7. Implement effective programs for permitting and enforcement.

An operating permit program is an important tool for ensuring that enterprises and EPBs have a common understanding of the specific air pollution control requirements that apply to these facilities, and that such enterprises remain in compliance.

8. Maintain an updated emergency episode program.

Emergency episode programs for taking action when air pollution levels exceed certain thresholds are essential for the protection of public health. Effective programs include early notification of the public, close cooperation with other governmental agencies, and responsibility for industry and businesses to take action during high pollution events.

9. Track progress of air quality management programs.

The most immediate way to track progress is to track changes in air quality monitoring data. These data measure the combined effects of emission reduction programs, energy planning, population growth, and other factors on air quality. Tracking the implementation of specific regulations or emission reduction measures is another effective way to track progress of an air quality plan. Evaluating changes in emissions over time is another important way to track progress, although emissions data is not immediately available for many sources. Thus, tracking progress based on emissions changes will typically have a time lag.

Control Options For Key Sectors

A significant portion of the report is focused on the emissions reduction strategies needed to achieve air quality goals and reduce emissions. These strategies are based on U.S. best practices and are provided in Chapter 9 of this report. The emission control options presented in Chapter 9 focus on the industrial sectors of importance to Jiangsu: coal-fired power plants, petroleum refineries, iron and steel manufacturing, cement manufacturing, and surface coating operations. Provincial and city officials recommended that the project focus on these sectors because of their significant contribution to air pollution in the region. Within these key sectors, the emphasis is on emission control options for the most significant emission sources (e.g., emission sources with the potential to yield the greatest opportunities for emission reductions and corresponding improvements in ambient air quality). Wherever possible, the AQMP Framework identifies control technologies that can address multiple pollutants. Because mobile source emissions are also a significant contributor to air quality issues in the Province, control options for these sources are also included.

In addition to emission control strategies, the report identifies current U.S. emission limits for selected types of facilities and pollutants, and the corresponding references to U.S. source monitoring requirements. Where available, the report presents expected emission reductions and control costs associated with a particular control technique. Information on emissions inventories, potential controls and estimated emissions reductions and costs can be used to identify cost-effective emission reduction strategies for a "future year" scenario designed to meet an air quality goal. Incorporating this "future" scenario into a regional air quality modeling framework will then allow Jiangsu to "predict" future ambient air quality conditions based on the proposed levels of emission control. ABaCAS is an integrated tool developed by researchers from China and the U.S. that can be used to develop regional control strategies to meet specific air quality goals. ABaCAS can also be used to estimate the health benefits and control costs of reducing pollutants that contribute to $PM_{2.5}$ particle concentrations. In Jiangsu Province, the health benefits associated with reducing pollutants that contribute to $PM_{2.5}$ concentrations are estimated to greatly outweigh the estimated control costs, typically by ten times or more.

This report provides additional recommendations based on U.S. "lessons learned," including technical issues that have been encountered during implementation of control strategies in the U.S. These recommendations may help Jiangsu avoid some of the difficulties that were encountered in the U.S. as air quality management practices developed.

One issue highlighted in the report is that selective catalytic reduction units (SCRs) (intended to reduce NO_X emissions at coal-fired power plants) cannot reduce NO_X emissions when the flue gas temperatures entering the SCR drop below about 330°C, a condition that frequently occurs on coal-fired units when they operate at low generating loads. This issue can lead to significant levels of uncontrolled NO_X emissions. A contributing factor may be that China's electricity grid operators currently dispatch power generation according to an "equal shares" policy, meaning that power generation is spread across many existing plants. As a result, generator capacity factors have decreased by 20% since 2008. Reform of this system is under way by the National Development and Reform Commission (NDRC), but full implementation will take several years.

In the interim, however, Jiangsu Province officials and power generators can take steps to improve the effectiveness of the emissions control equipment. This report includes recommendations to address the low load issue, recognizing that (1) power boilers cannot operate at maximum capacity at all times because the demand for electricity is variable; and (2) changes in flue gas temperatures and flow rates that occur when coal-fired boilers go from maximum load to minimum load can adversely affect the performance of some air pollution control systems. Accordingly, this report includes recommended provisions to ensure that electric utility planners specify design features on coal-fired power boilers that enable air pollution controls to reduce emissions both during periods of maximum electrical output and during periods of minimum electrical output (e.g., overnight when the demand for electricity is low). If fully implemented, these recommended changes could cost-effectively reduce NO_X emissions from coal-fired power plants operating during low load, which would further support ongoing efforts in Jiangsu to comply with hourly and daily ozone standards.

Proper and continuous operation and maintenance of installed air pollution control equipment is essential for achieving the expected emissions reductions and should be a focus area for all large industrial sources as Jiangsu looks to the next phase of air quality planning. In addition to recommendations regarding proper maintenance of air pollution control equipment, this report recommends that plant operators and environmental protection officials consider potential impacts on wastewater when selecting air pollution control technologies and potential synergies with existing control equipment.

Energy Planning

The AQMP Framework includes a chapter on energy planning in recognition of the importance of integrating energy policy into the air quality planning process. Jiangsu Province has many challenges to face as it develops and implements plans to improve air quality. The recommendations in this report recognize that it is not likely that Jiangsu will be able to implement all of them at once, and may have to defer some suggestions to the next revision of the air quality plan. It's critical, though, for Jiangsu to initiate the process towards better integration of air quality and energy policy. The majority of air pollution in Jiangsu is related to energy consumption, and the better that energy and air policies can be aligned, the more likely that the goals of both disciplines will be met, and met sooner and more cost-effectively.

Like environmental planning, power sector planning is going through its own process of reform. The "Power Sector Reform" guidance issued by the Central Committee of the Communist Party and State Council in March 2015 recognizes the need for a major review and update of power sector planning, and official announcements indicate that the 13th Five-Year Plan is addressing this topic[4]. This will be very important for reaching the Chinese government's goals for the power sector—including goals for emissions reduction—at reasonable cost.

Key Recommendations

This report provides a number of recommendations for Jiangsu to consider as the EPB staff prepare the next generation of air quality plans. The recently amended China Air Pollution Prevention and Control Law (APPCL), effective January 1, 2016, includes a number of important provisions that will help strengthen the framework for air quality management in Jiangsu Province. Detailed implementing regulations will provide crucial guidance and direction for Jiangsu Province in coming years. A comprehensive list of recommendations (with additional detail) is included in Chapter 14 of this report and were made in light of the coming implementation of the national clean air law. Some of the key recommendations include:

General

- Seek opportunities to increase the level of EPB staffing and budgets to address the significant public health challenges presented by air pollution in Jiangsu Province. Current staffing and budget levels do not appear to be adequate to implement numerous new air pollution programs and requirements in Jiangsu Province today.
- Promote opportunities to enhance regional air quality planning among multiple provinces to enable air quality professionals to learn from each other, to develop potential emission reduction strategies, and to identify potential policy solutions.
- Coordinate interagency planning and data sharing to integrate air quality, energy, and transportation planning processes.

Emissions Inventory

- Develop a high quality emissions inventory for stationary, area, and mobile sources for a base year (such as 2012) and an appropriate future year (such as 2017).
    - The inventory should follow a common data structure for emissions reporting consistent with national guidance aimed at development of a nationally consistent emissions inventory. Efforts made now to develop a nationally consistent inventory will be beneficial to future efforts in Jiangsu to develop plans addressing regional air quality issues and GHG reduction strategies.
    - The inventory at a minimum should include emissions data for the following pollutants: direct $PM_{2.5}$ (including condensable $PM_{2.5}$ emissions), SO_2, NO_X, VOC, ammonia, CO, CO_2, black carbon, and methane.
- Require point source facilities exceeding a "major source" size threshold to report their emissions annually using specific national (or provincial) emission estimation guidelines and reporting forms. Forms should include fields for reporting data for each emission unit at the source, including:
    - quantity of emissions by pollutant;
    - emission unit release parameters (i.e., location or GIS coordinates, stack height, stack diameter, release temperature and velocity);
    - annual hours of operation for the unit;
    - the type of pollution control equipment in place;
    - the annual operating hours for the control equipment; and

  - source monitoring technique used.
- Establish legal mechanisms and procedures to obtain updated emissions data from regulated entities so that the province can comprehensively update the emission inventory according to a regular schedule (such as every 3 years).

Emission Standards And Emission Reduction Strategies

- Develop emission standards that are reflective of the best available control technology (BACT) that is demonstrated and cost-effective.
  - Where possible, establish numeric emissions values with a specified averaging time appropriate for the source. Numerical emission limits allow facility operators to select the control device or system of control devices that best meet the emission limit in their specific application.
  - Consider multi-pollutant and multi-media control strategies, effects on energy-use, and any potential adverse environmental impacts when evaluating appropriate emission limits.
  - Encourage pollution prevention measures, such as substitution of fuels, feedstocks, or alternative equipment that may eliminate the need for add-on emission controls.
  - Implement standards for VOC content of paints and coatings.
- Include the following elements in emission standards:
  - emissions limit representing BACT, with a specified averaging time;
  - requirements for monitoring emissions from the source, using CEMS if possible, or control device operating parameters;
  - when control device operating parameters are used, ensure operating limits are tied directly to the performance test and that the averaging periods are short enough to ensure continuous compliance;
  - requirements for periodic source tests (when CEMS are not used) to measure emissions; and
  - requirements for periodic inspections, recordkeeping and self-reporting, use of electronic methods, standard formats, and common protocols.

Energy Planning

- Establish an integrated planning process for air, energy, and economic regulators to share data and forecasts and collaborate on their respective plans.
- The power sector planning process could start with resource planning procedures that:
  - Consider central and distributed renewable energy (RE) and end-use energy efficiency (EE) measures as cost-effective alternatives to conventional generation in meeting demand for energy services while reducing pollution emissions.
  - Integrate transmission and distribution planning with other aspects of power sector planning.
  - Quantify the environmental and public health costs and benefits associated with the resources being evaluated.
  - Identify and minimize economic, business, and environmental risk.
- Utilize the Environmental Impact Assessment (EIA) process to encourage air and energy policy integration. Use the EIA process (and any future versions of a construction and operating permit program) to ensure that new/modified sources have high thermal efficiency, use standard processes to improve coal quality, and have forecasted emissions that are consistent with air quality goals, both within jurisdictions and in areas downwind.

Air Quality Modelling

- Estimate the projected emission reductions associated with existing national policies, existing provincial emission reduction measures, and emission reductions expected in "upwind" provinces. Account for energy demand projections when developing these emissions estimates. Conduct air quality modeling to estimate air quality in the relevant future year.

- Consider using the ABaCAS system for air quality planning in Jiangsu Province to identify potential control measures to meet the air quality goal, and to estimate health benefits and costs of such measures.

Air Quality Monitoring

- Continue to operate and if possible expand the existing $PM_{2.5}$ monitoring network in Jiangsu Province. $PM_{2.5}$ speciation monitoring is very useful for identifying contributing source sectors through source apportionment analyses. The recommended minimum suite of pollutants required for effective apportionment analyses include: organic carbon, elemental carbon, ammonium sulfate, ammonium nitrate, and trace elements such as aluminum, silica, calcium, iron, potassium, and titanium. Jiangsu Province takes many of these measurements on an hourly basis, providing much statistical power to source apportionment findings.
- Refine standardized procedures for air quality monitoring, data analysis, and reporting in order to improve data quality and consistency. The standard procedures should include appropriate QA/QC programs to ensure that air quality monitoring data are reliable and provide a sound basis for policy-making.

Emergency Episodes

- Update and implement emergency episode programs for taking action when air pollution levels exceed certain thresholds. The program should include:
  - Timely air quality forecasts and communication of real-time air quality data to the public. Provide the public with information about actions they can take to reduce pollutant emissions and to limit their exposure.
  - A phased set of required actions to be implemented by governments and sources of emissions as air pollution levels increase above specific thresholds on high pollution days.
  - Facility-level Risk Management Plans for facilities in key sectors. Facilities should have emergency preparedness plans in place that require implementation of mitigation measures and other actions in the event of high pollution events or sudden, accidental releases of emissions at the facility.

Compliance And Enforcement

- Develop a strong enforcement program with national and provincial oversight.
  - Enforcement must be fair, consistent and applied evenly across regulated facilities.
  - The cost of violating the standards must be greater than cost of complying.
  - The penalty should recover the economic benefit of the emissions that should have been avoided. Penalties assessed to facilities can be used to pay for the enforcement staff and inspections.
- Coordinate with staff responsible for enforcement to establish regulations, monitoring, and permit requirements that are clear and easily enforced with a goal of improved compliance and environmental outcomes.
- Provide outreach, technical assistance programs, and training to regulated companies and enterprises on how to comply with specific regulations.
- Use electronic reporting to help make environmental reporting more accurate, complete, and efficient while helping air quality regulators better manage information, improve effectiveness and transparency.
- Establish provincial requirements for Material Safety Data Sheets (MSDS) or a similar program requiring the reporting of chemical constituents at a facility. The MSDS sheet includes information about the material and its physical and chemical properties, explains how to handle it safely, and describes how to respond to an exposure or spill.

Permitting

- Jiangsu Province should develop an operating permit program consistent with regulations and guidance developed pursuant to the permitting provisions in the APPCL.
- The program should apply to all sources above specific size thresholds. (In the U.S., all sources with a potential to emit more than 100 tons of traditional air pollutants or more than 10 tons of any hazardous air pollutant are required to obtain an operating permit.)
- The operating permit should include and serve to catalogue:
  - All requirements that apply to the source.
  - All emission standards, limits and averaging times that apply to specific emission units at the facility.
  - The related monitoring, reporting, recordkeeping, and test methods for each standard; and any other compliance requirements for the facility.
  - Any other operating limits, equipment or work practice requirements for sources at the facility.
  - Requirements for annual certification of compliance by a responsible company official.
  - Requirements to pay emission fees per ton of pollution emitted. Fees should be set at levels to adequately cover program costs.
  - Requirement for the company to report to the EPB any time it deviates from requirements in the permit.
- The permitting program should have procedures for revising permits, for governmental and public review of permits, and for neighboring jurisdictions potentially impacted by downwind emissions to be involved prior to review and approval.

Conclusions

Experience in the United States has demonstrated that the economy can have sustained growth at the same time that governments implement strong programs to reduce air pollution. Ambient air pollution is the leading cause of premature deaths globally, with an estimate of 7 million premature deaths as a result of air pollution exposure around the world in 2012.[5] Studies have estimated that the public health protection and environmental benefits of the Clean Air Act in the United States exceed the costs of its programs by a factor of 30 to 1 during the 1990 to 2020 period, with 85% of these benefits being attributed to reducing pollutants that contribute to fine particle pollution. With sustained actions to reduce air pollution and carbon emissions, similar public health benefits can be achieved in China.

Air quality planning is an iterative process, and not all of the recommendations in this report can be implemented immediately. Also, continuous review of air pollution standards is necessary to account for changes in technology both on the pollution-generating side as well as the pollution control side. The U.S. experience has shown that environmental standards can lead to innovation and sometimes result in cost savings (e.g., improved, more energy efficient equipment designs and processes) as well as more efficient use of resources and greater productivity. Improving air pollution in Jiangsu and in China offers opportunities for both environmental innovation and the development of an environmental services sector that could help address the significant challenges that exist today.

China's rapid economic growth has occurred during a period when the science and health information related to air pollution and other environmental problems has been made much more certain. At the same time, technologies and processes to reduce the harmful effects of pollution have also rapidly advanced. As a result, China's air quality planning can tackle several pollutants at the same time, which is more cost-effective, and also include processes and techniques that use energy more efficiently.

We believe that significant air quality improvements are possible in Jiangsu that will not only improve public health, but will also form the basis for a strong environmental business sector. Many technologies and tools are available today that were not available fifty years ago when governmental and industrial entities in the U.S. began to take on a number of very challenging air pollution problems. The availability of these technologies should enable Jiangsu Province to make significant progress in addressing air pollution and climate issues in coming years. China and Jiangsu Province should continue to work closely with the U.S. EPA and other partners to ensure that best available technologies are cost-effectively incorporated into the air quality planning process, along with the lessons learned from the U.S. experience.

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1 Introduction and Background

1.1 PURPOSE

This Air Quality Management Planning Framework (AQMPF) was prepared as part of a larger, 3-year air quality management project funded by the U.S. Trade and Development Agency (USTDA). The goal of the project is to accelerate sustainable air quality improvements in Jiangsu Province by sharing best practices of the U.S. Environmental Protection Agency, as well as U.S. city and state-level environmental agencies, while also fostering deployment of U.S. pollution control technologies, so as to achieve and exceed $PM_{2.5}$ reduction targets and support co-control of climate pollutants.[1]

The air quality management project began with the signing of a grant agreement between the USTDA and the Ministry of Environmental Protection of the People's Republic of China (MEP) in October 2013. The Jiangsu Province was then entrusted by the MEP to serve as the lead Chinese representative and pilot region to implement the project, including emissions inventory development and assessment, control technologies selection and the development of model air quality management plans in 3 pilot cities. The 3 pilot cities, Nanjing, Changzhou, and Suzhou, were chosen based on visibility issues, advanced economic development and a willingness to cooperate.

1.2 PROJECT TEAM

A provincial-level work group was established in the Jiangsu Environmental Protection Department (EPD), led by the International Environmental Development Center and jointly with the Air Pollution Control Division, Monitoring Center, and the Academy of Environmental Science, to enhance the project implementation and management. City-level working groups were then established in each of the three pilot cities. The working groups were formed to facilitate the achievement of the project goals and included key technical staff in the major focus areas such as air quality monitoring, emissions inventory development and benefit and attainment assessment.[2]

The Jiangsu EPD selected RTI International to implement the project from the U.S. side, with the U.S. Environmental Protection Agency staff serving as advisors on the project. The RTI International Team also included staff from The Regulatory Assistance Project (RAP), Sonoma Technology, Inc. (STI), and Triad Engineering Application, Inc. The project team is shown in Figure 1-1.

1.3 CONTENT OVERVIEW

The AQMPF includes guidance on the development of air quality management plans based on U.S. best practices. Much of the material included in the AQMPF was initially provided in the form of case studies and training sessions that took place throughout the 3-year duration of the project. The provincial-level and city-level working groups also provided key information and insights during project workshops and team meetings that helped the U.S. team members gain a better understanding of the current situation in Jiangsu and the specific challenges that needed to be addressed to meet the air quality goals. A significant portion of the report is focused on the emissions reduction strategies needed to achieve air quality goals and reduce emissions at industrial facilities. These strategies are based on U.S. best practices and are provided in Chapter 9. Provincial and city officials recommended that the project focus on industrial sectors because of their significant contribution to air pollution in the region. Table 1-1 provides a brief overview of each section of the AQMPF.

Figure 1-1 Project Team

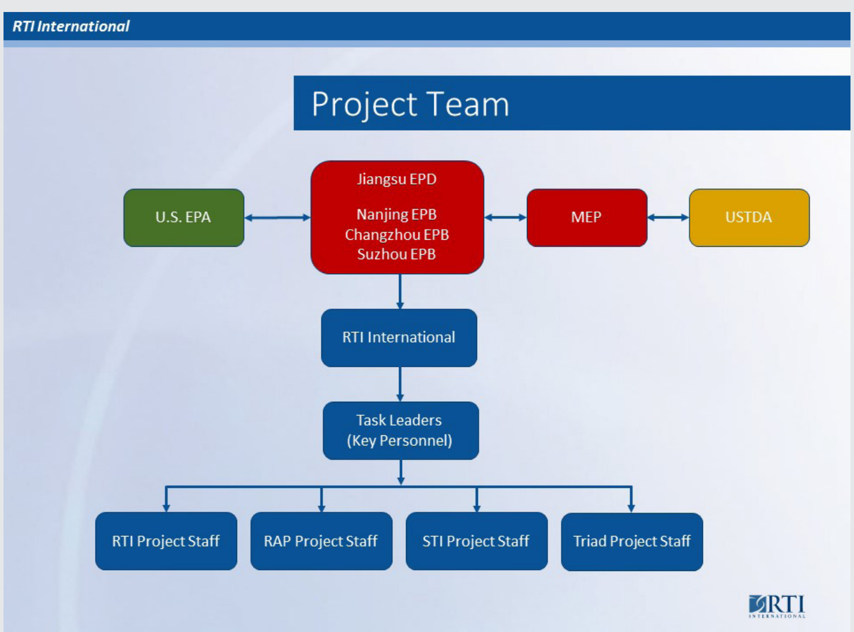

Table 1-1 Overview of the Air Quality Management Planning Framework

CHAPTER	CONTENT
Executive Summary	Summarizes key information contained in this report
1. Introduction and Background	Provides background information on the project goals and team members
2. National Goals	Provides information on specific air pollution targets at both the national and regional level, including pollution reduction targets for Jiangsu Province for the key pollutants such as SO_2, NO_X and $PM_{2.5}$
3. General Information	Provides general information and statistics on the geography, population, economy, transportation, and air emissions for Jiangsu Province and the 3 pilot cities of Nanjing, Changzhou, and Suzhou
4. Key Steps in the Air Quality Management Process	Provides brief overview of the U.S. process for improving air quality since 1970 and the simultaneous growth of the economy during that period. The 9 key steps in developing an effective air quality plan are also described in detail
5. Identify Sources of Air Pollution	Provides background on the components of emissions inventories (e.g., point sources, area sources, etc.) and how emissions inventories are used in different stages of air quality planning. Getting the most value from ambient air monitoring data and source apportionment analyses is also discussed, along with future-year emissions inventories
6. Emissions Inventory Development in Jiangsu	Provides information on the current status of emissions inventory development in Jiangsu Province and the 3 pilot cities of Nanjing, Changzhou, and Suzhou. Major contributors to pollution are discussed along with key challenges
7. Current Air Pollution Control Policies and Initiatives	Provides information on the current air pollution control policies and initiatives in place in Jiangsu Province and the 3 pilot cities of Nanjing, Changzhou, and Suzhou
8. Regional Planning and Coordination Activities	Provides information on the advantages of regional air quality planning and examples of regional air quality planning efforts in the U.S. and China
9. Control Options for Key Sectors	Presents emission reduction strategies for $PM_{2.5}$, $PM_{2.5}$ precursors (SO_2, NO_X, and VOC), and hazardous air pollutants for the industrial sectors of importance to Jiangsu: coal-fired power plants, petroleum refineries, iron and steel manufacturing, cement manufacturing, and surface coating. The section on coal-fired power plants reflects the ultra-low emissions standards adopted by Jiangsu Province and presents a framework for ongoing monitoring, recordkeeping, and reporting to ensure continuous compliance with these stringent standards. Because mobile sources are also a significant contributor to air quality issues in the Province, control options for these sources are also included. Consideration is also given to greenhouse gas emissions, specifically CO_2. In addition to emission control strategies, each section identifies current U.S. emission limits for selected pollutants, and the corresponding U.S. monitoring requirements. Where available, the sections present expected emission reductions and control costs based on U.S. experience

Table 1-1 continued

CHAPTER	CONTENT
10. Assessment of Air Quality Improvement, Costs and Benefits for Future Control Strategy Scenarios	Discusses U.S. best practices for assessing air quality improvement, costs, and health benefits for a proposed emission reduction strategy, which would include a comparison between the base case and the future case emissions inventories, using a platform such as the U.S. EPA's Air Benefit and Cost and Attainment Assessment System (ABaCAS). Additional information on the ABaCAS model is provided in Appendix A
11. Implementation and Ongoing Assessment	Discusses key components of an effective implementation and ongoing assessment program, including: schedule for implementation and compliance; measures specific to stationary sources (pre-construction permits; operating permits; monitoring, recordkeeping and reporting requirements; compliance monitoring; enforcement program); measures specific to mobile sources (inspection and maintenance program; periodic fuels testing); emergency episode program; and tracking progress
12. Energy Planning	Discusses the importance and benefits of integrating energy policy into the air quality planning process. Provides examples of best practices in energy planning based on U.S. Federal and State level experience and also from Europe and other regions
13. Challenges	Discusses the challenges that the Jiangsu EPD and city-level EPB staff face as they work to improve air quality in their areas and prepare the next generation of air quality plans. Information on the challenges was provided by the provincial-level and city-level working groups during project workshops and team meetings
14. Key Recommendations	Provides recommendations for Jiangsu to consider as the EPB staff prepare the next generation of air quality plans. Both general and specific recommendations are provided to address the key steps in air quality planning and some of the challenges described in chapter 13. Recommendations are also made in light of the recently amended China Air Pollution Prevention and Control Law (APPCL), effective January 1, 2016, which includes a number of important provisions that will help strengthen the framework for air quality management in Jiangsu province
Appendices	Appendix A is a presentation on the U.S. EPA's ABaCAS model for assessing air quality improvement, costs, and health benefits; Appendix B includes information on parameters that should be specified when establishing an emissions limit for an industrial source of air pollution in order to ensure the limit is "practically enforceable"

References

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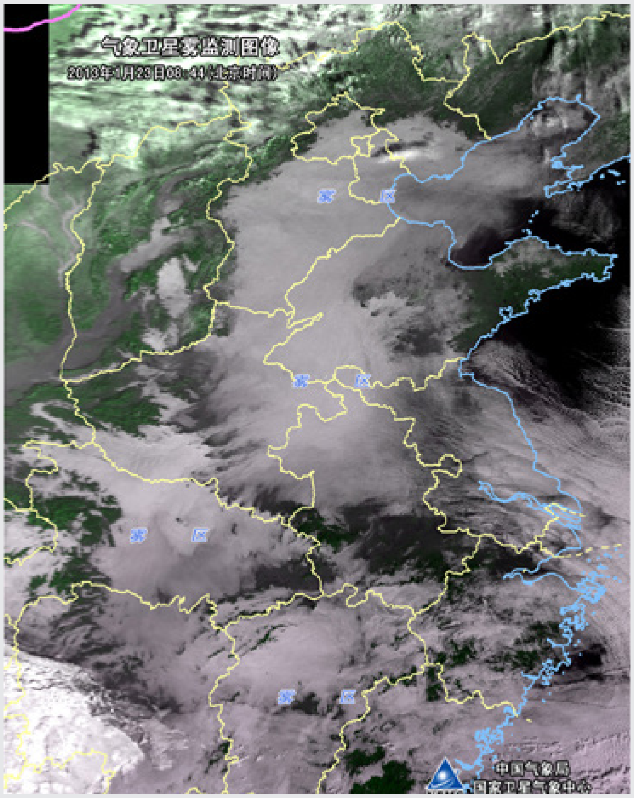
2

National Goals

As the Chinese people continue to work together to grow their economy and to improve their standard of living, they have also encountered significant air pollution problems. In the past several decades, the number of days per year with significant haze has increased in parallel with the increased productivity in China. Figure 2-1 shows a satellite image from January 2013 when the total area in China that was affected by severe haze reached 1.43 million square kilometers covering Beijing, Tianjin, Hebei, Henan, Shandong, Jiangsu, Anhui, Hubei, and Hunan.

Figure 2-1 Haze Over China[1]



The State Council first included specific air pollution reduction targets in the 10th five-year plan (FYP) for 2000 through 2005. The initial goal was to reduce SO_2 emissions by 10 percent before the end of 2005. The 11th FYP also called for a 10 percent reduction in SO_2 emissions by the end of 2010. The 12th FYP used 2010 emissions levels as the basis for three additional national goals to be achieved by the end of 2015:

- An eight percent reduction in SO_2 emissions;
- A ten percent reduction in NO_X emissions; and
- A seventeen percent reduction in CO_2 emissions relative to gross domestic product (GDP).

Mid-way through implementation of the 12th FYP (in February of 2012), the State Council took decisive action by establishing national ambient air quality standards (NAAQS) for $PM_{2.5}$ of 35 µg/m^3 (annual average), and 75 µg/m^3 (24-hour average).[2] Additionally, on December 5, 2012, the Ministry of Environmental Protection (MEP), National Development and Reform Commission (ND&RC), and Ministry of Finance (MF) issued the *Twelfth Five-year Plan on Air Pollution Prevention and Control in Key Regions* [3] (the Plan) to establish more stringent goals for improving air quality in three key regions and in ten city clusters that include 48 percent of China's population and that contribute 71 percent of China's GDP. This plan included stringent new air quality improvement goals for the key regions of Beijing-Tianjin-Hebei, the Pearl River Delta, and the Yangtze River Delta region which includes Jiangsu Province. The affected ten city clusters are comprised of 117 cities in 19 provinces. These areas have ambient concentrations that are 2.9 to 3.6 times higher than the national average. The goals in the 12th *FYP on Air Pollution Control in Key Regions* used 2010 air quality data as the basis for reductions but included more stringent goals (compared to the national goals in the original 12th FYP) to be achieved in these areas with the highest levels of pollution by the end of 2015. The targets for Jiangsu Province are shown in Table 2-1.

The 12th *FYP on Air Pollution Control in Key Regions* also established larger emission reduction goals for operators of air pollution sources in Jiangsu Province, as shown in Table 2-2. The Plan requires sources in the Yangtze River Delta region to strengthen control of the pollutants that cause acid rain (including SO_2 and NO_X).

The Plan specifically requires Jiangsu Province to strengthen controls for PM_{10} emissions, and it includes a mandate for Jiangsu Province to focus on controlling formation of $PM_{2.5}$ and ozone.

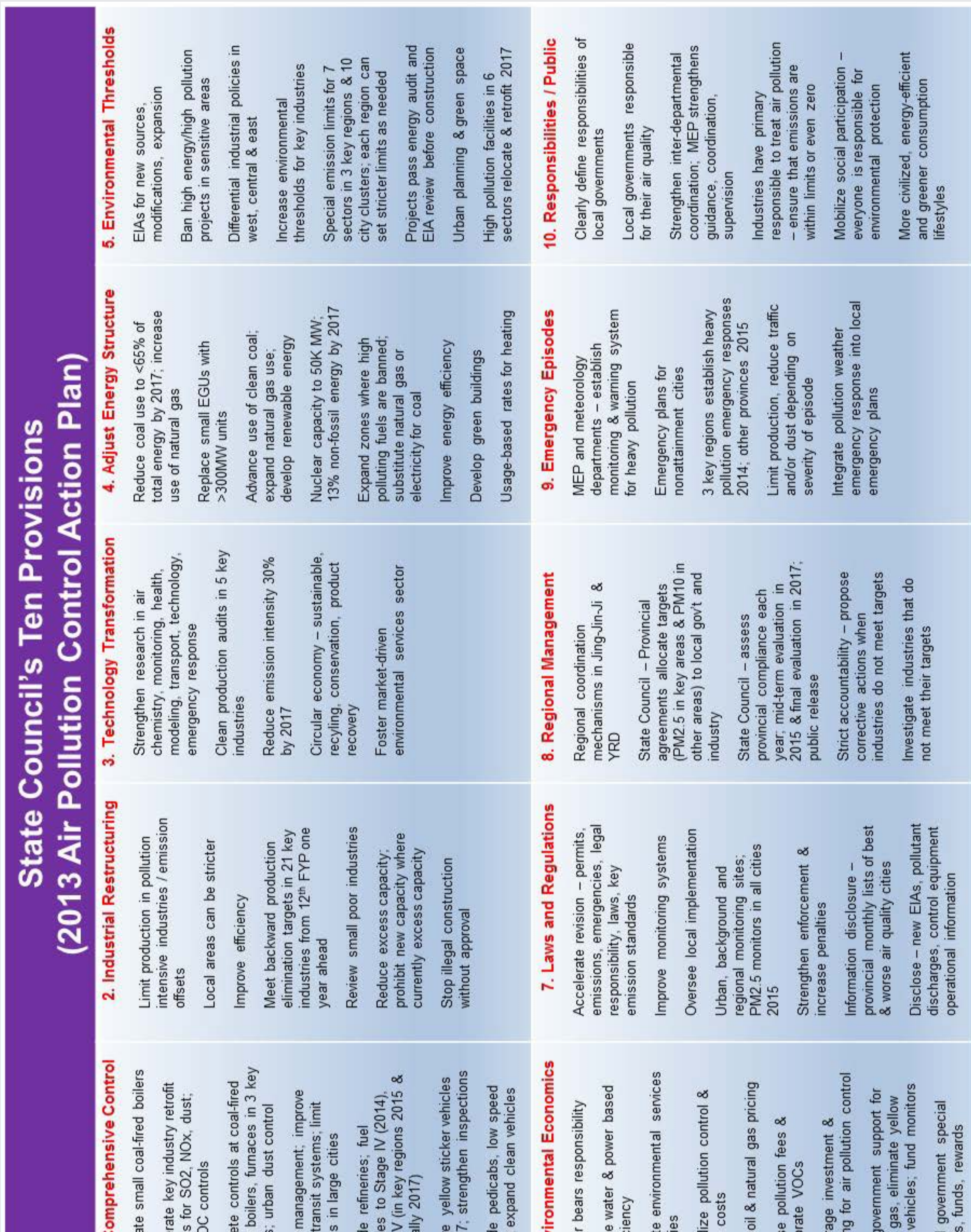
Table 2-1 Ambient Air Quality Goals for Jiangsu Province in the *12th FYP on APC in Key Regions*

AMBIENT AIR QUALITY CONCENTRATION REDUCTION TARGETS (2010 BASIS)	
Ambient PM_{10}	14% Reduction
Ambient $PM_{2.5}$	7% Reduction
Ambient SO_2	12% Reduction
Ambient NO_2	10% Reduction

Table 2-2 Emissions Reduction Goals for Jiangsu Province in the *12th FYP on APC in Key Regions*

AUTHORIZING DOCUMENT	SO_2 EMISSIONS IN JIANGSU PROVINCE	NO_X EMISSIONS IN JIANGSU PROVINCE	INDUSTRIAL PM EMISSIONS IN JIANGSU PROVINCE
National Targets in Original 12th Five Year Plan (March 2011)	8% Reduction by end of 2015	10% Reduction by end of 2015	No National Target
Targets in 12th FYP on Air Pollution Control in Key Regions (February 2012)	12% Reduction by end of 2015	13% Reduction by end of 2015	10% by end of 2015

Figure 2-2 Summary of the State Council's *Action Plan on the Prevention and Control of Atmospheric Pollution* (the Action Plan)[4]



In June of 2013, the State Council issued *The Action Plan on the Prevention and Control of Atmospheric Pollution* (the Action Plan) comprised of ten new measures to reduce air pollution. Figure 2-2 summarizes these ten measures. A critical goal in the Action Plan was to expand public transportation systems and to increase the use of clean transportation fuels (e.g., petroleum products with lower sulfur contents).

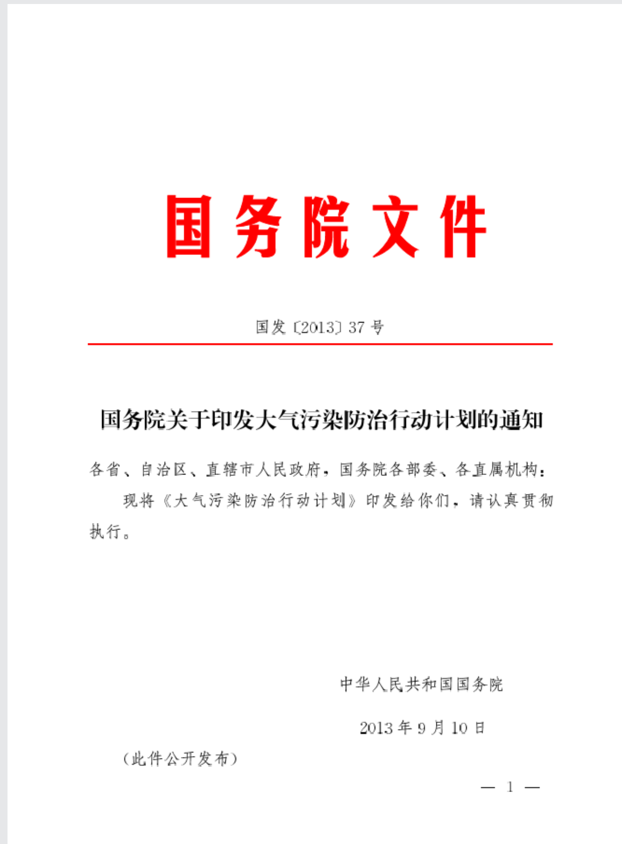
Subsequently, in September of 2013, the State Council mandated additional, more stringent air quality targets (see Figure 2-3), within the framework of the Action Plan for the key regions. [5] The September 2013 additions to the Action Plan mandated that Jiangsu Province must achieve a 10 percent reduction in PM_{10} concentrations and a 20 percent reduction in $PM_{2.5}$ concentrations by the end of 2017. These provisions are notable because they established ambitious targets for improving ambient air quality across broad regions of the country. Progress towards these targets is to be tracked from a baseline of 2012 air quality data. The September 2013 additions to the Action Plan also emphasized the doctrine that polluters must pay fees proportional to their emissions.

In November of 2014, Jiangsu Province adopted ultra-low emissions standards for coal-fired power boilers.

Table 2-3 Ultra-low Emissions Standards for Coal-fired Power Boilers in Jiangsu Province[6]

AFFECTED SOURCES	POLLUTANT	EMISSIONS STANDARD	COMPLIANCE PERIOD
Coal-fired Boilers Serving Electricity	Dust (PM)	10 mg per Normal m^3 at 6% O_2	Not specified
	NO_X as NO_2	50 mg per Normal m^3 at 6% O_2	Not specified
	SO_2	35 mg per Normal m^3 at 6% O_2	Not specified

Figure 2-3 The Action Plan from September 2013


国务院文件

国发〔2013〕37号

国务院关于印发大气污染防治行动计划的通知

各省、自治区、直辖市人民政府，国务院各部委、各直属机构：

现将《大气污染防治行动计划》印发给你们，请认真贯彻执行。

中华人民共和国国务院

2013年9月10日

（此件公开发布）

— 1 —

Subsequently, in November of 2015, the National Council adopted these ultra-low emissions standards for all coal-fired units throughout China. Table 2-3 summarizes these ultra-low emissions standards.

The national policy requiring ultra-low emissions controls on coal-fired electric utility boilers has been effective because the policy included economic provisions that allow electric utility companies to charge an additional 0.01 RMB/kWh for the electricity produced by generating units achieving these ultra-low standards.

In addition to the ultra-low emissions standards for coal-fired electric utility boilers that were adopted in the Jiangsu Province during November of 2014, Table 2-4 provides a listing of the other national air pollution control standards that apply to various industrial sources within the Jiangsu Province.

In recent years, Jiangsu Province has been making significant progress towards compliance with national air pollution emissions standards as well as improving the network of ambient monitors for assessing and forecasting day-to-day air quality conditions compared to national goals for improvements. Currently, sources of air pollution in Jiangsu are implementing the national standards presented in this section, many of which have been updated to reflect improvements in air pollution control technologies and recent mandates by the Central Committee of the Communist Party and the State Council. The current air quality emissions control standards also include an Integrated Emission Standard for sources of air pollution that do not have industry-specific standards. Leaders in the Jiangsu Province expect the contribution of

Table 2-4 National Industrial Emissions Standards for Air Pollution in China

EMISSIONS STD.	TITLE OF STANDARD	EFFECTIVE DATE
GB 16297-1996	Integrated Emission Standard of Air Pollutants	Effective 1/1/1997. Applicable for the industries where no industry-specific standard is available
GB 13223-2011	Emission Standard of Air Pollutants for Thermal Power Plants	Effective 1/1/2012
GB 16171-2012	Emission Standard of Pollutants for Coking Chemical Industry	Effective 10/1/2012
GB 28662-2012	Emission Standard of Air Pollutants for Sintering and Pelletizing of Iron and Steel Industry	Effective 10/1/2012
GB 28663-2012	Emission Standard of Air Pollutants for Iron Smelt Industry	Effective 10/1/2012
GB 28664-2012	Emission Standard of Air Pollutants for Steel Smelt Industry	Effective 10/1/2012
GB 4915-2013	Emission Standard of Air Pollutants for Cement Industry	Effective 3/1/2014
GB 13271-2014	Emission Standard of Air Pollutants for Boiler	Effective 7/1/2014
GB 31570-2015	Emission Standard of Pollutants for Petroleum Refining Industry	Effective 7/1/2015
GB 31571-2015	Emission Standard of Pollutants for Petroleum Chemistry Industry	Effective 7/1/2015

The sixteenth meeting of the Standing Committee of the Twelfth National People's Congress approved a comprehensive and strengthened revision of China's Air Law on August 29, 2015. These revisions became effective January 1, 2016. Several articles in the revised law recognize the impact that China's energy sector has had on air pollution, and further link progress to restructure China's energy sector with air quality improvements. Article 19 requires industrial and power plant sources to obtain an air pollution permit. Article 32 requires that air quality agencies include measures to support clean energy, increase the efficiency with which coal is combusted and reduce the overall quantity of coal burned. Article 41 requires air quality agencies to support co-control of several pollutants emitted by coal-fired power plants, including sulfur, nitrogen, mercury and dust. Article 42 requires China's electricity grid operators to prioritize clean energy for power plant dispatch.

MEP has been tasked with writing several regulations to implement the revised law during 2016. Jiangsu Province and its key cities will be engaged in this process, and likely asked to provide input to any proposed regulations or standards. Jiangsu and local agencies will also be obliged to include new emission standards and requirements in future air quality plans.

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3
General Information

OVERVIEW

This chapter introduces the general information for Jiangsu Province and the three pilot cities (Nanjing, Changzhou and Suzhou), including the geography, population, economy, transportation and air emissions in each jurisdiction.

3.1 JIANGSU PROVINCE[1]

3.1.1 Geography

Jiangsu Province is located in the center of the east coast of China and the downstream region of the Yangtze River. Jiangsu Province faces the Yellow Sea on the east; borders on Shanghai City and Zhejiang Province on the southeast, Anhui Province on the west, and Shandong Province on the north. The terrain in Jiangsu is flat. Jiangsu has vast plains, dense water bodies and a large number of lakes. Jiangsu has two of the five largest freshwater lakes in China: Taihu Lake, the third largest, and Hongzehu Lake, the fourth largest. There are more than 290 additional lakes in Jiangsu, including Gaobaohu Lake, Gaoyouhu Lake, Shaobohu Lake, Weishanhu Lake, etc. The highest peak in Jiangsu is the Yunu Summit of Yuntai Mountain in Lianyungang, which is 625 meters above sea level. Table 3-1 presents the major statistics of Jiangsu's geography.

Figure 3-1 Map of Jiangsu Province

Figure 3-2 Yangtze River

Table 3-1 Jiangsu's Geography

Total Area	107,200 km^2 (1.12% of China)
Total Area of Plains	69% of Jiangsu
Total Area of Water Bodies	17% of Jiangsu
Total Area of Lakes	6260 km^2 (6% of Jiangsu)
Total Area of Hills	14% of Jiangsu
Length of Provincial Border on Land	3383 km
Length of Coast	954 km
Length of Yangtze River in Jiangsu	425 km
Length of Jing-Hang Grand Canal in Jiangsu	718 km

Jiangsu is in the mid-latitude area on the east coast of the Eurasia Continent, which is the transition region between the subtropical zone and the warm temperate zone. Jiangsu's climate belongs to the East Asia monsoonal climate type. Generally, the area north of the border of Huaihe River and Northern Jiangsu Main Irrigation Canal belongs to warm temperate humid/semi-humid monsoonal climate; and the area south of the border belongs to subtropical humid monsoonal climate. Jiangsu is located next to the Yellow Sea and in the downstream region of the Yangtze River and Huaihe River, where the ocean has a significant impact on Jiangsu's climate. Due to the integrated impacts of solar radiation, atmospheric circulation as well as Jiangsu's specific geographic location and topography, Jiangsu's climate has the following features: four distinct seasons; significant monsoon; cold winter and hot summer; variable temperature in spring; clear sky and crisp air in fall; precipitation and heat in the same seasons; abundant and concentrated precipitation; significant mould rains; plentiful sunlight and heat; and frequently occurred meteorological hazards.

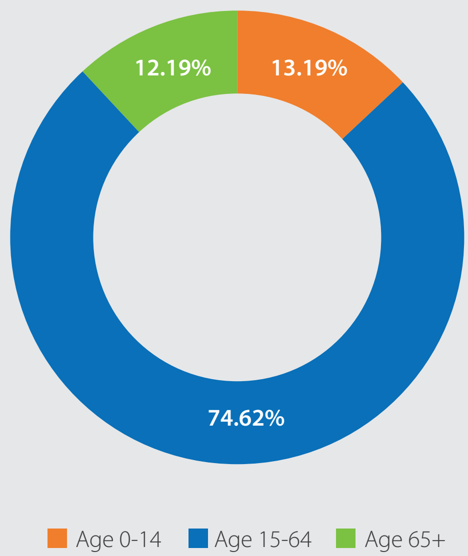
3.1.2 Population

Table 3-2 presents the major statistics of the population in Jiangsu Province.

Table 3-2 Jiangsu's Population

Total Population (Permanent Residents)	79.6 million (2014, +0.26% compared to 2013)
Urban Population	49.9 million (2012, 63.0% of provincial total)
Male Population	40.1 million
Female Population	39.5 million
Population of Age 0-14	10.5 million (13.19%)
Population of Age 15-64	59.4 million (74.62%)
Population of Age 65 and above	9.7 million (12.19%)
Annual Birth Rate	9.5% (2014, +0.01% compared to 2013)
Annual Death Rate	7.02% (2014, +0.01% compared to 2013)
Annual Natural Growth Rate	2.43% (2014, constant)

Figure 3-3 Jiansu's Population by Age



3.1.3 Economy

Table 3-3 presents the major statistics of the economy in Jiangsu Province.

Table 3-3 Jiangsu's Economy

Total GDP	6.51 trillion Yuan (+8.7%)
GDP per Capita	81,874 Yuan (+8.4%)
Added Value of Primary Industry Sector	363.4 billion Yuan (+2.9%)
Added Value of Secondary Industry Sector	3.1 trillion Yuan (+8.8%)
Added Value of Tertiary Industry Sector	3.0 trillion Yuan (+9.3%)
Public Finance Income	723.3 billion Yuan (+10.1%)
Total Retail Sales of Social Consumer Goods	2.3 trillion Yuan (+12.4%)
Total Volume of Import and Export	563.8 billion US Dollars (+2.3%)
Volume of Export	341.9 billion US Dollars (+4.0%)
Volume of Import	221.9 billion US Dollars (constant)

In 2014, Jiangsu Province made significant progress on the construction of ecological civilization to promote energy saving, consumption reduction, and elimination of outdated production capacity. According to preliminary estimates, in 2014, the province's energy consumption per GDP in unit area decreased by 5.9% compared to the previous year, which exceeded the original annual target of 3.6% and accounted for 96.0% of completion of the energy-saving target in the 12th 5-year National Plan.

Table 3-4 presents a summary of outdated and low-end production capacity eliminated in Jiangsu Province.

Table 3-4 Outdated and Low-end Production Capacity Eliminated in Jiangsu in 2014

Iron	3.8 megatons
Cement	1.5 megatons
Flat Glass	2.2 million weight boxes
Vessels	3.5 megatons load
Rare Earth	12 kilotons
Coke	580 kilotons
Pulp and Paper	120 kilotons
Chemical Fiber	120 kilotons
Printing and Dyeing	3.5 trillion meters/21.5 kilotons
Lead Battery	7,490 thousand kVAh
Textile Products	92.5 kilotons /108.5 million meters/60 thousand ingots
Casting	654 kilotons
Electroplating	400.7 kilotons
PV Manufacturing	20.6 kilotons /45 million pieces/25 trillion Watts

3.1.4 Transportation

Table 3-5 presents the major statistics of the transportation systems in Jiangsu Province.

Table 3-5 Jiangsu's Transportation

Total Mileage of Expressways	4443 km (2013, +72 km)
Total Mileage of Highways	156,000 km (2013, +1976 km)
Total Mileage of Railways	2591 km
Multi-line Rate of Railways	60.9%
Electrification Rate	61.8%

Figure 3-4 Jiangyin Yangtze River Bridge[2]

In 2013, the province's total investment in transportation infrastructure construction reached 75.5 billion Yuan, and maintained a relatively high level. Jiangsu has the most dense highway system compared to the other provinces and autonomous regions across the country. There are 8 bridges crossing the Yangtze River in Jiangsu. Nine prefecture-level cities have operational civil airports.

3.1.5 Air Emissions

In 2014, the province's total SO_2 emissions were 904.7 kilotons, where industrial sources account for 96.19%, residential sources account for 3.78%, and centralized garbage and dangerous waste control facilities account for 0.03%. Total NO_X emissions were 1.2326 megatons, where industrial sources account for 72.06%, residential sources account for 0.52%, motor vehicles account for 27.38%, and centralized garbage and dangerous waste control facilities account for 0.04%. Total smoke and dust emissions were 763.7 kilotons, where industrial sources account for 94.34%, residential sources account for 2.38%, motor vehicles account for 3.24%, and centralized garbage and dangerous waste control facilities account for 0.04%.[3]

3.2 NANJING CITY[4]

3.2.1 Geography

Figure 3-5 Sun Yat-Sen Mausoleum in Nanjing

Nanjing City is located in southwest Jiangsu, and is the capital city of the province. Nanjing is adjacent to Jianghuai Plains on the north and Yangtze River Delta on the east. The Yangtze River runs through Nanjing on the west side of downtown, which is navigable for large vessels. The downtown area is 347 kilometers away from Yangtze River Delta. Nanjing is located in the Ningzhenyang hill areas, where low mountains, hills and downlands are the majority of Nanjing's topography. Nanjing has a subtropical humid monsoonal climate, and has four distinct seasons and abundant precipitation. The mould rain season lasts from late June to early July every year. Table 3-6 presents the major statistics of Nanjing's geography.

Table 3-6 Nanjing's Geography

Geographical Coordinates	31°14'-32°37'N, 118°22'-119°14'E
Total Area	6582 km^2
Peak	Zhongshan Hill (449 m)
Total Area of Downland	53% of Nanjing
Total Area of Plains, Marshlands, Rivers and Lakes	39.2% of Nanjing
Total Area of Low Mountains	3.5% of Nanjing
Total Area of Hills	4.3% of Nanjing
Length of Yangtze River in Jiangsu	95 km
Annual Average Precipitation	117 days/1106 mm
Annual Average Relative Humidity	76%
Annual Average Temperature	15.3 °C
Annual Average Frost-free Period	237 days
Extreme Maximum Temperature	38.5°C (2009)
Extreme Minimum Temperature	-14.0 °C (1955)

3.2.2 Population

Table 3-7 presents the major statistics of the population in Nanjing City.

Table 3-7 Nanjing's Population

Total Population (Permanent Residents)	8.2 million (2014, +28,300 compared to 2013)
Total Population (Registered Residents)	6.5 million (2014, +56,300 compared to 2013)
Population of Age 0-14	820,200 (10.0%)
Population of Age 15-64	6.55 million (79.7%)
Population of Age 65 and above	845,600 (10.3%)
Urbanization Rate	80.9% (2014, +0.4% compared to 2013)

3.2.3 Economy

Nanjing's economy increases constantly. The price level slightly increased. The industrial structure continues to optimize. The added values of the three industry sectors are adjusted to 2.5: 41.7: 55.8. The industrial structure is adjusted to light and high-quality industries. In 2014, the high-tech industry output value is 574.094 billion Yuan, which accounts for 43.4% of the industries above designated size. The output value of six major advanced manufacturing industries, including automobiles, electronics, medicine, transportation equipment, electrical machinery and equipment, and instruments and meters, accounts for 44.5% of the industries above designated size, increased by 1.5% compared to the previous year. The output value of energy-consuming industries, including petrochemical, building materials, metallurgy, and power generation, accounts for 33.9% of the industries above designated size, decreased by 1.7%. The industrial production grows constantly. There are 14 coal-fired power plants, 5 gas-fired power plants, 2 iron and steel facilities, and 15 cement facilities in Nanjing.

Table 3-8 presents the major statistics of the economy in Nanjing City.

Table 3-8 Nanjing's Economy

Total GDP	882.08 billion Yuan (2014, +10.1%)
GDP per Capita	107,545 Yuan (+8.4%)
Added Value of Primary Industry Sector	22.4 billion Yuan (+3.5%)
Added Value of Secondary Industry Sector	367.1 billion Yuan (+8.8%)
Added Value of Tertiary Industry Sector	492.5 billion Yuan (+11.5%)
Annual Total Urban Consumer Price Level	+2.6% compared to 2013
Price Level of Food	+2.8% compared to 2013
Price Level of Living Supplies	+2.9% compared to 2013
Price Level of Commodity Retail	+0.9% compared to 2013
Annual Gross Industrial Output Value of the Industries and Enterprises above Designated Size	1.3 trillion Yuan (+5.3% compared to 2013)

3.2.4 Transportation

Table 3-9 presents the major statistics of the transportation systems in Nanjing City. The urban public transportation in Nanjing improves significantly.

Table 3-9 Nanjing's Transportation (as of 2014)

Total Mileage of the Urban Public Transit Network	9149 km
Total Volume of Passengers Served by the Urban Public Transportation System	1.9 billion (+3.5% compared to 2013)
Total Volume of Passengers Served by the Metro Transit System	503 million (+11.3% compared to 2013)
Total Number of Buses	8345
Number of Buses Renovated and Added	2530
Total Number of Taxis	14,628
Number of Taxis Renovated and Added	2471
Total Number of Metro Railcars	746
Number of Public Bike Service Station Added	190
Number of Public Bikes Added	7400

In 2014, Nanjing made significant progress on management and control of the pollutions from motor vehicles, and is the leader in the field in Jiangsu Province. The "National V" standards of gasoline products are implemented. The "National IV" admittance standards are implemented for the heavy diesel vehicles, and the "National V" standard reporting program is implemented earlier than the original schedule. The total area prohibited for heavy-pollution vehicles expands to 305 square kilometers. The major pollution weather and emergency warning is enforced according to the "Atmospheric Pollution Warning and Emergency Handling Procedure". The red and orange warnings were issued during severe pollution conditions, and the emergency handling actions, including production shutdown, production curtailment, road flushing and artificial precipitation, were enforced.

3.2.5 Air Emissions

In 2014, total SO_2 emissions in Nanjing were 104 kilotons, total smoke and dust emissions were 96 kilotons, and total NO_X emissions were 132.9 kilotons.[5]

3.3 CHANGZHOU CITY[6]

3.3.1 Geography

Changzhou City is located in the center of the Yangtze River Delta and south Jiangsu. It is adjacent to Wuxi City and Taihu Lake on the east, Nanjing and Zhenjiang Cities on the west, Wuxi, Jiangsu and Xuancheng, Anhui on the south, and the Yangtze River on the north. The topography of Changzhou is high-sand plains, and has both hills and flat lands. Tiammushan Ridge is in the south; Maoshan ridge is in the west; Ningzhen Ridge is in the north. There are broad plains in central and east Changzhou. Table 3-10 presents the major statistics of Changzhou's geography.

Figure 3-6 View of Downtown Changzhou[7]

Table 3-10 Changzhou's Geography

Geographical Coordinates	1119°08'-120°12'E and 31°09'-32°04'N
Total Area	4373 km^2
Annual Average Precipitation	1091.4 mm
Annual Average Temperature	16.6 °C
Annual Average Relative Humidity	74.2%

3.3.2 Population

Table 3-11 presents the major statistics of the population in Changzhou City. In 2014, Changzhou City made significant progress on urban and rural integration reform based on the goals listed in the "Three-year Action Plan of Urban and Rural Integration and Unification (2014-2016)".

Table 3-11 Changzhou's Population

Total Population (Permanent Residents)	4.696 million (2014, +0.1% compared to 2013)
Total Population (Registered Residents)	3.686 million (2014, +0.7% compared to 2013)
Population in Urban Areas	3.226 million
Male Population	1.829 million (+0.6%)
Female Population	1.857 million (+0.9%)
Population of Age 0-14	528,607 (11.51%)
Population of Age 15-64	3,614,296 (78.71%)
Population of Age 65+	449,069 (9.78%)
Annual Birth Rate	10.3‰
Annual Death Rate	6.8‰
Annual Natural Growth Rate	3.5‰
Urbanization Rate	68.7%

3.3.3 Economy

Table 3-12 presents the major statistics of the economy in Changzhou City. The economic operation is mostly stable. Development of the ten major industry chains is making progress, and the production efficiencies are increasing rapidly.

Table 3-12 Changzhou's Economy

Total GDP	490.19 billion Yuan (2014, +10.1%)
GDP per Capita	104,423 Yuan
Added Value of Primary Industry Sector	13.9 billion Yuan (+3.0%)
Added Value of Secondary Industry Sector	245.8 billion Yuan (+9.5%)
Added Value of Tertiary Industry Sector	230.5 billion Yuan (+11.4%)
Annual Gross Industrial Output Value of the Industries and Enterprises above Designated Size	1.1 trillion Yuan (+11.2% compared to 2013)

3.3.4 Transportation

Table 3-13 presents the major statistics of the transportation systems in Changzhou City.

Table 3-13 Changzhou's Transportation (as of 2013)

Total Investment on Transportation Constructions	9.9 billion Yuan
Total Volume of Passengers	175.5 million (+9.5%)
Turnover of Passenger Traffic	10.8 billion passenger-km (+11%)
Total Volume of Freight	193.3 megatons (+13.9%)
Turnover of Freight	14.1 billion ton-km (+16%)
Cargo Throughput of All Ports in Changzhou	97.0 megatons (+7.8%)
Cargo Throughputs of Ports along Yangtze River	30.6 megatons (+14.7%)
Container Throughput	148,000 int'l std. containers (+3.4%)
Passenger Throughput of Changzhou Airport	1.5 million (+40.7%)
Total Volume of Passengers Served by Public Transportation System	411 million
Ratio of Clean Fuel Buses	30%
Ratio of Clean Fuel Taxis	96%

3.3.5 Air Emissions

According to the statistical results Changzhou EPB obtained, in 2014, the total SO_2 emissions in Changzhou were 35.394 kilotons, and total NO_x emissions were 78.866 kilotons.[8]

3.4 SUZHOU CITY[9]

3.4.1 Geography

Figure 3-7 Humble Administrator's Garden in Suzhou

Table 3-14 presents the major statistics of Suzhou's geography.

Table 3-14 Suzhou's Geography

Geographical Coordinates	119°55′-121°20′E, 30°47′-32°02′N
Total Area	8488 km^2
Average Altitude	4 m
Total Area of Plains	54.8%
Total Area of Water Bodies	42.5%
Total Area of Hills	2.7%
Annual Average Precipitation	1265 mm
Annual Average Temperature	16.9 ℃

Suzhou City is located in the center of the Yangtze River Delta and southeast Jiangsu. It is adjacent to Shanghai City on the east, Zhejiang Province on the south, Taihu Lake on the west, and the Yangtze River on the north. The land in Suzhou is mostly flat. Suzhou is also a famous "water village" with many rivers and lakes. Most of the water surface of Taihu Lake is in Suzhou. Suzhou belongs to the subtropical oceanic monsoonal climate. Suzhou has four distinct seasons, mild climate, abundant precipitation, fertile land, rich products, and superior natural conditions.

3.4.2 Population

Suzhou is one of the pilot cities of the national urban and rural integration reform. Table 3-15 presents the major statistics of the population in Suzhou City.

Table 3-15 Suzhou's Population

Total Population (Permanent Residents)	10.6 million (2014, +25,300 compared to 2013)
Annual Birth Rate	11.7‰ (2014, +1.3‰ compared to 2013)
Annual Death Rate	6.7‰ (2014, -0.11‰ compared to 2013)
Annual Natural Growth Rate	4.97‰ (2014, +1.45‰ compared to 2013)
Urbanization Rate	74.0% (2014, +0.8% compared to 2013)
Population of Age 0-14	963,100
Population of Age 15-64	8,607,700
Population of Age 65 and above	889,100

3.4.3 Economy

Table 3-16 presents the major statistics of the economy in Nanjing City.

Table 3-16 Suzhou's Economy

Total GDP	1.376 trillion Yuan (2014, +8.3%)
GDP per Capita	130,000 Yuan
Added Value of Primary Industry Sector	22.4 billion Yuan (+3.5%)
Added Value of Secondary Industry Sector	367.1 billion Yuan (+8.8%)
Added Value of Tertiary Industry Sector	492.5 billion Yuan (+11.5%)
Annual Total Urban Consumer Price Level	+2.6% compared to 2013
Price Level of Food	+2.8% compared to 2013
Price Level of Living Supplies	+2.9% compared to 2013
Annual Gross Industrial Output Value	3.6 trillion Yuan (+0.2% compared to 2013)
Annual Gross Industrial Output Value of the Industries and Enterprises above Designated Size	3.1 trillion Yuan (+0.3% compared to 2013)

The industrial production grows constantly. The gross industrial output value of six major industries, including electronics, iron and steel, electrical machinery and equipment, chemicals, textiles, and general equipment manufacturing, is 2.0 trillion Yuan, decreased by 0.4% compared to the previous year. The gross output values of automobile manufacturing, electrical machinery and equipment manufacturing, chemical raw material and product manufacturing increased by

14.1%, 7.1% and 10.3%, respectively. The gross output values of electronics and iron and steel industries decreased by 4.4% and 2.1%, respectively. Development of the strategic emerging industries is constant, and the industrial economic efficiency is improving. There are 44 major power generating facilities, and 6 ferrous metal smelting and rolling processing facilities in Suzhou.

3.4.4 Transportation

Table 3-17 presents the major statistics of the transportation systems in Suzhou City.

Table 3-17 Suzhou's Transportation (as of 2014)

Total Mileage of Roads	13,212 km
Total Mileage of Highways	550 km
Total Volume of Passengers Served by Highway and Waterway Systems	400 million (+0.9%)
Turnover of Passenger Traffic by Highway and Waterway Systems	13.798 billion passenger-km (+0.5%)
Total Volume of Freight Transported by Highway and Waterway Systems	130 million tons (+9.9%)
Turnover of Freight Transported by Highway and Waterway Systems	20.05 billion ton-km (+10.0%)
Annual Volume of Passengers Served by Railway System	35.0 million (+15.2%)
Total Volume of Freight Shipped by Railway System	671,700 tons
Total Volume of Freight Arrived via Railway System	1.5 million tons
Number of Public Bikes Added	7400
Total Number of Registered Vehicles	2.4 million (+14.8%)
Total Number of Registered Private Vehicles	2.0 million (+16.6%)
Cargo Throughput of Port of Suzhou	480 million tons (+9.8%)

3.4.5 Air Emissions

In 2014, the total SO_2, NO_X, and smoke and dust emissions associated with industrial exhaust in Suzhou were 168.4 kilotons, 167 kilotons, and 71.6 kilotons, respectively.[10]

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4

Key Steps in the Air Quality Management Process

OVERVIEW

Experience in the United States has demonstrated that the economy can have sustained growth at the same time that governments implement strong programs to reduce air pollution. Figure 4-1 shows that while several key U.S. economic indicators have increased steadily since the enactment of the U.S. Clean Air Act, the aggregate emissions of six common air pollutants have steadily decreased. Ambient air pollution is the leading cause of premature deaths globally, with an estimate of 7 million premature deaths as a result of air pollution exposure around the world in 2012.[1] Studies have estimated that the public health protection and environmental benefits of the Clean Air Act in the United States exceed the costs of its programs by a factor of 30 to 1 during the 1990 to 2020 period, with 85% of these benefits being attributed to reducing pollutants that contribute to fine particle pollution. Monetized benefits of air quality programs during this time period are estimated at $2 trillion. Figure 4-2 shows the extent to which benefits exceed costs throughout the study period. With sustained actions to reduce air pollution and carbon emissions, similar public health benefits can be achieved in China.

Figure 4-1 **U.S. Economic Indicators versus Aggregate Emissions of Six Common Air Pollutants (1970 – 2013)**[2]

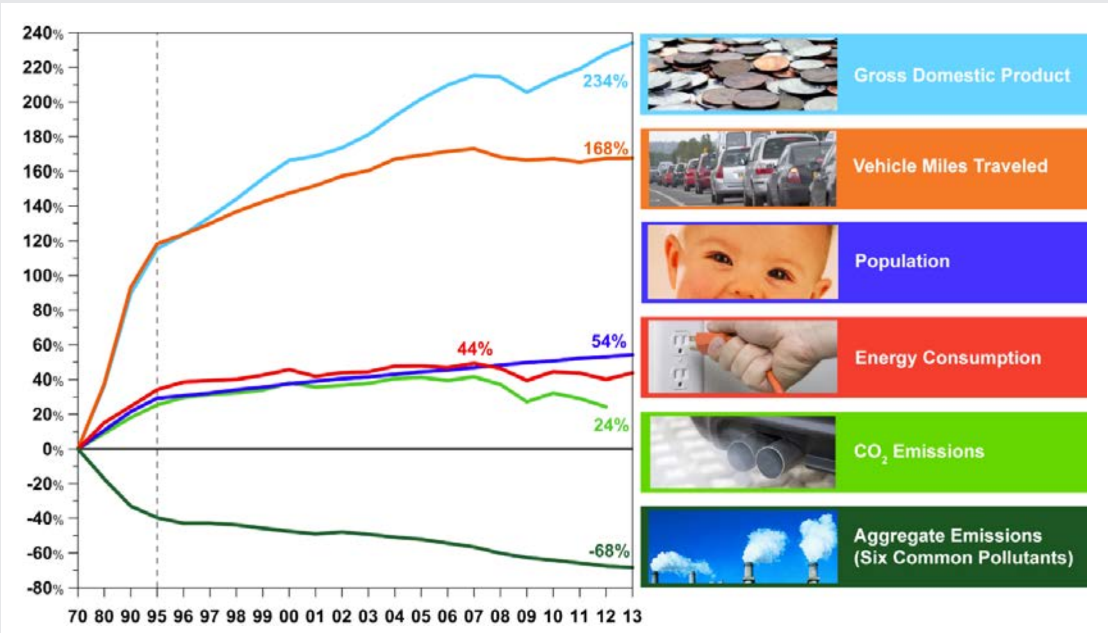
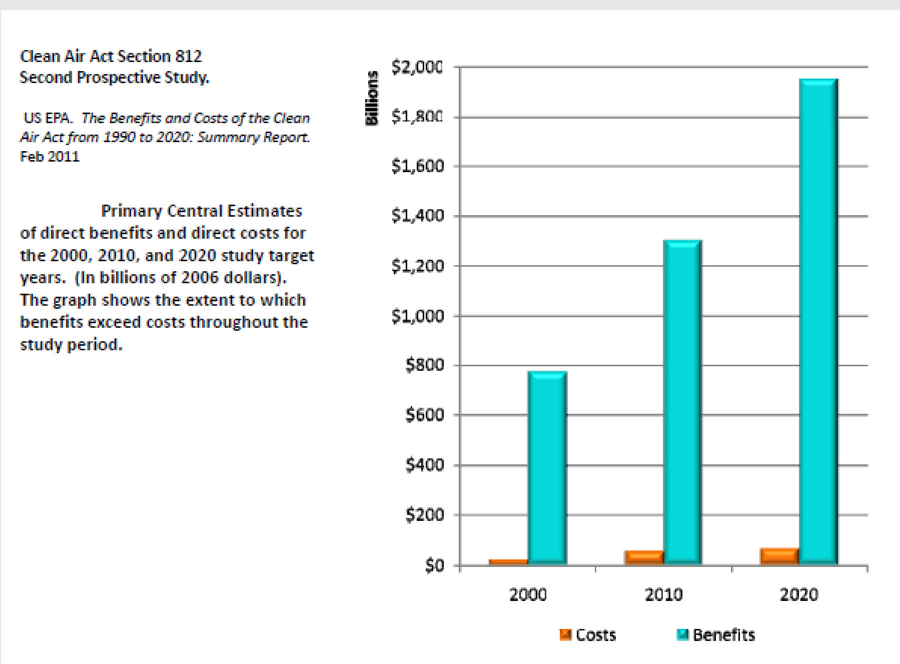


Figure 4-2 **Clean Air Act Section 812 Second Prospective Study**[3]



While the effects on public health associated with current levels of air pollution in China are substantial, there are many opportunities to make rapid improvements in air quality in Jiangsu Province and across the country. There are many advanced analytical tools, air pollution control technologies, and alternative sources of energy available today which were not available when cities in the U.S. had their most severe air pollution problems 50-70 years ago. For this reason, there should be optimism that China can tackle the current air quality challenge if well-coordinated programs are implemented to reduce pollution, develop cleaner sources of energy, and educate the public about the significant benefits of improving public health.

An effective air quality management program depends on having clear air quality goals, adequate resources for provincial and city bureaus, well-trained air pollution professionals, a solid foundation of technical data and analytical tools, strong permitting and enforcement programs, support from the general public, and well-designed technical assistance programs to provide outreach to companies and other regulated enterprises. The air quality management process for a city or province is a continuous one, involving the following basic steps described below:

1. Identify the air quality goal and the date by which it is to be achieved.
2. Characterize the nature of the air pollution problem.
3. Participate in regional planning and consultation with other provinces.
4. Develop emission inventories.
5. Conduct air quality modeling and identify new emission reduction strategies needed to achieve the air quality goal.
6. Adopt and implement effective and enforceable requirements to reduce emissions.
7. Implement effective programs for permitting and enforcement.
8. Maintain an updated emergency episode program.
9. Track progress of air quality management programs.

This section provides an overview of this AQM process, and later sections will provide additional detail on topics of particular importance, such as ambient monitoring, development of emission inventories, coordination with energy planning, and best available control technologies for key industries in Jiangsu Province. Figure 4-3 shows an overview of the AQM planning process.

Figure 4-3 Overview of the U.S. Air Quality Management Process[4]

The key steps in developing an effective air quality plan are described in the sections below.

4.1 IDENTIFY THE AIR QUALITY GOAL AND THE DATE BY WHICH IT IS TO BE ACHIEVED

As specified in the 2013 Air Pollution Control Action Plan, the current ambient air quality improvement goal for Jiangsu Province is to achieve a 20% reduction in annual $PM_{2.5}$ concentrations (from 2012 levels) by 2017. The number of ambient air quality monitors for $PM_{2.5}$ has grown significantly since 2012, and currently there are more than 100 $PM_{2.5}$ ambient monitors in Jiangsu Province. Fine particle concentrations reported for Nanjing, Changzhou, and Suzhou in 2013 are

Table 4-1 Comparison of $PM_{2.5}$ Concentration Levels and Target Reductions

CITY	2013 $PM_{2.5}$ LEVELS (ANNUAL / 24-HOUR) (in µg/m³)	2017 20% REDUCTION TARGET FOR ANNUAL STANDARD (in µg/m³)	2017 20% REDUCTION TARGET FOR 24-HR STANDARD (in µg/m³)
Nanjing	75.3 / 312	60.2	249
Changzhou	75.6 / 322	60.5	257
Suzhou	67.1 / 384	53.7	307

found in Table 4-1. If it is assumed that 2012 levels were no higher than 2013 levels, then to achieve a 20% improvement by 2017, each city will need to reduce $PM_{2.5}$ concentrations over the five-year period by 14-15 µg/m³ on an annual average basis, and by 63-77 µg/m³ for peak 24-hour levels.

It is important that the AQMP for Jiangsu Province clearly describes what will constitute achieving the 20% reduction. For example, the plan should clarify that this means achieving a minimum of 20% ambient $PM_{2.5}$ reduction from the 2012 levels at all monitors across the province.

While the 2013 Air Pollution Control Action Plan required meeting specific air quality targets by 2017, it also included longer term goals for meeting the current China $PM_{2.5}$ ambient standards by 2030. (The current annual $PM_{2.5}$ standard in China is 35 µg/m³, and the 24-hour standard is 75 µg/m³.) By keeping these longer term air quality goals in mind, city and provincial officials can ensure that emission reduction strategies to help meet the 2017 interim targets will be compatible with meeting the longer term 2030 air quality targets, and take into account important energy-air quality planning considerations as discussed in Chapter 12.

4.2 CHARACTERIZE THE NATURE OF THE AIR POLLUTION PROBLEM

It is very useful to consider multiple types of data and analyses in order to develop a common understanding of the local or provincial air pollution problem among a wide range of stakeholders who will be responsible for actions needed to improve air quality under the plan. Analyses may be conducted to answer questions such as:

- During what seasons and meteorological conditions are $PM_{2.5}$ concentrations commonly the highest?
- What is the composition of $PM_{2.5}$ mass during seasons when concentrations are highest? What is the composition on an annual average basis?
  - Composition of $PM_{2.5}$ is commonly expressed as the percentage of $PM_{2.5}$ mass that is attributed to ammonium sulfate, ammonium nitrate, organic carbon, elemental carbon, and crustal material (or dust).
  - Composition of $PM_{2.5}$ can be estimated from ambient monitoring of the components of $PM_{2.5}$ ($PM_{2.5}$ speciation monitoring), or from analyses of ambient air quality data (such as source apportionment studies.)
- Based on analyses of $PM_{2.5}$ composition, what source categories are identified as the most important contributors?

- What is the estimated $PM_{2.5}$ contribution from other provinces? Modeling analyses or other studies may already exist that provide relevant information to answer this question; or new air quality modeling can be performed.

4.3 PARTICIPATE IN REGIONAL PLANNING AND CONSULTATION WITH OTHER PROVINCES

Regional planning and consultation among multiple cities and provinces can help participants to collectively understand the degree of their air pollution contributions across boundaries. Experience in the U.S. has shown that a regional planning process enables air quality professionals to learn from each other, to discuss potential emission reduction strategies, and to identify potential policy solutions to reduce contributions to downwind provinces. Most regional organizations in the U.S. are funded by member states and local jurisdictions. They have facilitated projects such as assessments of interstate contributions of $PM_{2.5}$ and ozone, modeling analyses of potential regional control strategies, and compilations of information about control technologies for specific industries, including data on cost effectiveness and time needed for installation and operation. If multiple provinces are able to coordinate their actions through regional planning processes, they should be able to meet air quality goals more efficiently than if they all act independently.

4.4 DEVELOP EMISSION INVENTORIES

The core foundation of the AQMP will be the development and analysis of high quality emissions inventories for stationary, area, and mobile sources (for a base year and a future year). One important use of these inventories will be for conducting air quality modeling to design and evaluate potential scenarios for reducing emissions (including the use of cleaner sources of energy) in order to meet air quality goals. At a minimum, emissions data should be developed for the following pollutants: direct $PM_{2.5}$ (including condensable $PM_{2.5}$ emissions), SO_2, NO_X, VOC, ammonia, CO, CO_2, black carbon, and methane.

Particular attention should be devoted to developing and improving base year and future year emission inventory data for priority source categories. In Jiangsu Province and the cities of Nanjing, Changzhou, and Suzhou, priority categories have been identified to include: power generation; industrial categories (refineries, chemical production, iron & steel, cement manufacturing); onroad mobile sources, trucks, motorcycles; nonroad trucks and equipment; fuels for both onroad and nonroad vehicles and equipment; and a range of other sources, including boilers for smaller industry or for district heating; fugitive dust from construction, roadways, and agriculture; open burning of biomass or waste; fertilizer application; and livestock production.

The base case emissions inventory ideally is developed for one of the years on which initial air quality concentrations are calculated as the starting point for the AQMP. Progress on implementing the AQMP can then be tracked both in terms of reducing emissions and in terms of reducing air quality concentrations. In the U.S., state governments are required to update their emission inventories comprehensively every three years. In addition, many point sources (such as those with continuous emissions monitors) also have annual reporting requirements. Point source data is required to be reported if the source has the potential to emit above a particular annual threshold for any listed pollutant. This "major source" threshold is no higher than a potential to emit 100 tons per year, or as low as 10 tons per year for areas with more severe air pollution problems.

The future year base case emissions inventory should reflect the net effect of changes in emissions that are anticipated from the base year to the future year, including expected reductions due to implementation of existing air pollution control policies (such as the 10 groups of control measures outlined in the 2013 State Council Air Pollution Control Plan); reductions due to facilities that have moved or been shut down; and growth in emissions due to population growth, new industrial facilities, increased energy demand, expansion of the car and truck fleet, and estimated changes in emissions in nearby cities and provinces. In developing any future year inventory, particularly for an area with a rapidly changing economy and growing population, it will be important to develop the most accurate projections possible for future activity levels and growth factors. Another important piece of information to obtain at the individual point source level is whether and what type of pollution control equipment is in place in the source, and whether the equipment is operated continuously. This data is essential for evaluating where there are further opportunities for reducing emissions. See Chapters 5 and 6 for more information about emission inventory development.

4.5 CONDUCT AIR QUALITY MODELING AND IDENTIFY NEW EMISSION REDUCTION STRATEGIES NEEDED TO ACHIEVE THE AIR QUALITY GOAL

Due to the interrelationship of direct $PM_{2.5}$, NO_X, and SO_2 emissions on ambient $PM_{2.5}$ concentrations, a 30 percent reduction in direct $PM_{2.5}$ emissions may not achieve a 30 percent reduction in ambient $PM_{2.5}$ concentrations. Therefore, air quality modeling is an essential step in the process to identify effective and cost-efficient emission reduction strategies.

Air quality modeling will help Jiangsu Province and key cities understand how close to the air quality goal they may get based on implementation of programs that are already in place. If the existing strategies fall short of the air quality goal, then modeling can help identify additional local emission reduction strategies that will help each city reach its goal. The reduced level of emissions could be achieved in many ways, such as: national and provincial regulations requiring best available control technologies for new and existing sources, the use of lower sulfur fuel in combination with fleet turnover to cars and trucks with cleaner engines, expansion of energy efficiency measures to limit growth in energy demand, changes in the mix of power generation, reduction in open burning, and so on. Important issues to consider in identifying potential emission reductions include: what constitutes the "best" available technology or emission reduction measure for a particular source or source category; what is the associated cost of adopting and implementing the measure; and what is the time needed to make the measure operational.

In the U.S., a state with an area that is unable to attain the $PM_{2.5}$ ambient air quality standard within 6 years must adopt best available control technology and best available control measures for existing sources located in the area. "Best available controls" are defined as the maximum degree of emission reduction achievable from a source or source category which is determined on a case-by-case basis, considering energy, economic and environmental impacts and other costs. Cost-effectiveness is commonly considered on the basis of cost per ton of pollutant reduced, with costs including capital costs, cost of installation, and costs for operation and maintenance. Many sources of information are available that can help planners and facility owners in China identify the best technically feasible control technologies for different types of emissions sources and activities. Information on costs of emission controls for point sources in China has been more challenging to compile due to the dynamic nature of the economy and changing policy landscape. This information continues to improve each year and will be very important for making future regulatory decisions.

Air quality modeling then should be conducted to evaluate whether implementation of the potential additional emissions reductions in the province, combined with any projected emissions changes in neighboring provinces, would result in future air quality concentrations that would meet the air quality improvement goals for the province identified in step 1. If the additional emission reductions that have been identified do not provide for meeting the air quality goals, then further reductions need to be identified, and another modeling assessment should be conducted to determine that the goal will be met. The ABaCAS system, developed by a team of experts from China and the U.S., includes integrated modules for evaluating potential emissions reductions, costs, air quality modeling, and health benefits. Appendix A of this report presents the recent development and application of the ABaCAS system in China. It can be a useful tool for air quality planning in Jiangsu Province.

4.6 ADOPT AND IMPLEMENT EFFECTIVE AND ENFORCEABLE REQUIREMENTS TO REDUCE EMISSIONS.

The emission reduction strategies adopted as part of any air quality management plan need to be based on regulations and other requirements that can be properly enforced by the appropriate authority (e.g., through permits issued by city EPB, provincial EPD, and/or MEP). Any new emission reduction requirement should include a number of specific elements to ensure enforceability. For example, a regulation for a point source should have an emission limit with an appropriate averaging time for demonstrating compliance; requirements for monitoring emissions from the source, using continuous emissions monitoring techniques if possible, or other specified test methods and requirements for periodic tests; and requirements for periodic inspections, recordkeeping and self-reporting, using electronic methods, standard formats, and common protocols if possible. For certain types of area sources, emission reduction requirements may be expressed as work practice standards or best management practices. For mobile sources, inspection and maintenance programs are important for checking vehicle compliance with emissions standards, and periodic testing of fuels as they pass through the supply chain is also essential.

In addition, from a procedural standpoint, the enforceability of a new emission reduction regulation in Jiangsu Province may depend on specific administrative steps that need to be completed for proposal and final approval. In the U.S., each state adopts new regulations through their own administrative process, and then submits these state-enforceable regulations to the USEPA as part of the overall air quality management plan. When the USEPA approves such regulations, they also become enforceable by the federal government and by members of the public.

4.7 IMPLEMENT EFFECTIVE PROGRAMS FOR PERMITTING AND ENFORCEMENT

An operating permit program is an important tool for ensuring that enterprises and EPBs have a common understanding of the specific air pollution control requirements that apply to these facilities, and that such enterprises remain in compliance. An operating permit is a collection of all the emissions standards and related compliance requirements that apply to a specific source. These permits can include requirements such as an annual certification of compliance by a company official, self-reporting of any deviations from any provision in the permit, and requirements for sources to pay emissions fees per ton of pollution emitted. In the U.S., operating permits are subject to public review, and they are to be renewed every five years.

China's 2014 Environmental Protection law and the 2015 Clean Air law both have strengthened enforcement provisions. Experience in the U.S. has shown that key features of an effective enforcement program include: the cost of violating must be greater than cost of complying; the penalty should recover the economic benefit of violating; enforcement must be fair, consistent and applied evenly; and a strong national and provincial presence should help foster responsible local action. Compliance is also improved when effective outreach, technical assistance programs, and training in how to comply with specific regulations are provided to regulated companies and enterprises.

Significant resources (staff, training, funding) are needed to implement effective air quality management and enforcement programs. For example, the South Coast Air Quality Management District (SCAQMD) in the Los Angeles, California area has 800 staff and an annual budget of $130 million to address air pollution issues in a metropolitan area with a population of 16 million. Two-thirds of the SCAQMD budget is supported through fees on emissions sources.

4.8 MAINTAIN AN UPDATED EMERGENCY EPISODE PROGRAM

Emergency episode programs for taking action when air pollution levels exceed certain thresholds are essential for the protection of public health. Such episodes may occur under stagnant atmospheric conditions and/or in areas with a dense population of industrial sources and automobiles. Key elements of an emergency episode system include:

- Air quality monitoring network and data management system for collecting and summarizing data, such as AirNow-International.
- Air Quality Index for converting pollutant concentrations to more easily-understood health information.
- An air pollution forecast capability based on air quality modeling tools.
- A public alert system using newspapers, television, Internet and social media (e.g., AirNow-International special message or webpage, smartphone alerts).
- Provincial and city environmental departments take the lead in providing information and appropriate responses.

A typical emergency plan contains four key elements: 1) trigger levels for each pollutant based on ambient data; 2) requirements for each stage that escalate with higher pollutant levels; 3) actions that correlate to what sources and pollutants contribute to emissions; and 4) requirements for large industrial sources to submit emergency plans, and to have such plans reviewed and approved by an air quality agency. A plan may be put into effect based on peak concentrations observed at one or more monitors. A typical plan may have three stages, with actions escalating in proportion to the severity of the level of pollution:

- Stage 1: notice to public, schools, hospitals. Voluntary actions
- Stage 2: some mandatory actions plus cessation of outdoor sports activities
- Stage 3: driving bans, suspension of industrial activities, cessation of indoor and outdoor sports

Effective programs include early notification of the public, close cooperation with other governmental agencies, and responsibility for industry and businesses to take action to take action during high pollution events. As ambient standards are revised based on health information, emergency episode programs will need to adjust the pollution level stages at which various actions are required.

4.9 TRACK PROGRESS OF AIR QUALITY MANAGEMENT PROGRAMS

Three basic ways for tracking the progress and effectiveness of an air quality management plan are to track: a) the implementation of regulations and programs; b) emissions reductions; and c) air quality improvement. The implementation of regulations and programs can be tracked by various metrics, such as the number of new regulations finalized; the number of companies or enterprises that have finalized process changes or installed new emissions control technologies; or the number of permits issued.

Progress in terms of emission reductions can be assessed most easily for sources with CEMs, such as many power plants. However, to comprehensively review progress in emissions changes throughout an entire city or province for a particular year typically will take a year or more to estimate and quality-assure activity and emissions data from numerous emissions sources. The most immediate way to track progress is to track changes in air quality monitoring data. these data measure the combined effects of emission reduction programs, energy planning, population growth, and other factors on air quality.

The U.S. EPA has developed a number of tools and guidance documents to assist air quality professionals in developing air quality plans. Please refer to the U.S. EPA Air Quality Management Online Portal (https://www.epa.gov/air-quality-management-process) for more details.

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5

Identify Sources of Air Pollution

OVERVIEW

Emission inventories are a key component of air quality management planning. An emissions inventory is a comprehensive listing by sources of air pollutant emissions in a geographic area during a specific time period. Inventories are used to

- identify sources and general emission levels
- assist in siting ambient air monitors
- establish a baseline for future planning
- understand conditions leading to high concentrations and quantify regional/interregional issues (transport, background concentrations)
- develop air quality control plans and mitigation strategies by modeling future control scenarios
- establish regulations and permit conditions for industrial facilities and provide a basis for emissions trading programs
- measure progress and changes over time in achieving cleaner air
- determine compliance with emissions standards

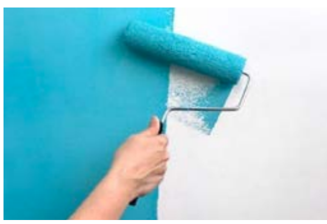
Air quality management requires emission inventory development, as well as air quality goal setting, monitoring, modeling, exposure assessment, control strategy design, regulation implementation, and public outreach. Figure 5-1 shows EPA's overall approach to air quality management.

Figure 5-1 U.S. EPA's Overall Approach to Air Quality Management[1]

5.1 EMISSIONS INVENTORY COMPONENTS AND DEVELOPMENT

Common emission source groupings include point, area, on-road mobile, non-road mobile, and biogenics as shown next.

Point sources: large stationary sources such as electric generating units, iron and steel manufacturing, oil refineries, cement plants, industrial incinerators, and chemical plants.



Area sources: collection of similar, typically smaller, emission sources within a geographic area such as gasoline stations, dry cleaning establishments, surface coating/painting, and consumer product use.

On-road mobile sources: cars, trucks, and buses.

Non-road mobile sources: aircraft, trains, and shipping.

Biogenic: natural sources such as vegetation, fugitive dust/soil, volcanoes, and lightning.

Large stationary sources, such as power plants and refineries, are treated as individual point sources in an emissions inventory. To develop a point source inventory, information on specific emissions processes and release points (e.g., stacks or vents) is required, including stack parameters such as height, diameter, and flue gas temperature. The Province has started using continuous emissions monitoring systems (CEMS) for power plants and other large facilities. CEMS data are costly, but provide reliable and temporally resolved emissions estimates. These data will be useful for regulatory and compliance purposes.

Stationary sources that are too small and numerous to inventory individually are treated as area sources. Common area sources include commercial and consumer organic solvent usage (surface coating, dry cleaning, degreasing, graphic arts, rubber and plastics); residential cooking and heating; miscellaneous industrial manufacturing operations; and gasoline service stations. Emissions for area sources are generally estimated by combining emission factors from EPA's AP-42 guidance with activity data (e.g., quantity of fuel burned) collected at the state, province, or county level. Review of available emission factors may be required to identify the most representative factors for the Province's area sources, with priority given to updating emission factors for source sectors comprising a more significant portion of the overall inventory and/or those with the most uncertainty.

On-road mobile sources include passenger vehicles, heavy-duty trucks, and buses. These sources emit a wide range of pollutants that contribute to PM, ozone, greenhouse gas, and hazardous air pollutant concentrations. In the U.S., emissions from on-road mobile sources are estimated using EPA's MOVES model, which includes a county-level database with default information on vehicle fleets (for example, populations and age distributions), vehicle activity (for example, vehicle miles traveled [VMT] and average speeds), and control measures (for example, inspection and maintenance programs). For the Province, similar information could be collected using data sources such as travel demand models, traffic counts, and vehicle registration data. Because vehicle emissions are a function of fleet mix, traffic volumes, and vehicle speeds, control programs include the retirement of older vehicles, measures aimed at reducing VMT (e.g., smart growth[2] and public transit), and congestion relief strategies (e.g., high-occupancy vehicle [HOV] lanes and freeway on-ramp metering).

Non-road mobile sources include commercial marine vessels (CMV), locomotives, aircraft, and smaller sources such as construction, agricultural, and lawn equipment. EPA's NONROAD model estimates emissions for gasoline- and diesel-powered equipment by combining engine-specific emission factors with county-level data on equipment populations and activities (e.g., annual hours of operation). However, the NONROAD model does not address CMV, locomotives, or aircraft; therefore, emissions estimates for these sources are generally prepared in a "top-down" manner using regional fuel consumption data and associated emission factors. For the Province, a top-down approach could be used for all non-road sources using available data on fuel consumption, vessel calls (number of vessels visiting a port), aircraft activity, and equipment populations.

For biogenic sources, emissions are estimated using models such as the Biogenic Emission Inventory System (BEIS) or the Model of Emissions of Gases and Aerosols from Nature (MEGAN). These models use species-specific emission rates, land cover data, and meteorological parameters (such as temperature and solar radiation) to estimate emissions. Meteorological inputs must be spatially and temporally resolved (that is, gridded, hourly data), which requires the application of a mesoscale meteorological model such as the Weather Research and Forecasting (WRF) model.

The Province states that they are 80% complete with their emissions inventory and have targeted large sectors first (which is the common approach). The Province is learning from experiments such as the enforced shut down of large emission sources during the 2014 Nanjing Youth Games. These situations provide an opportunity to observe the real-time effect of these shutdowns on air quality using ambient monitoring data. The lessons learned from these experiments will be useful in developing and refining control strategies and targeted emissions reductions.

Challenges and key issues remaining:

- Ensuring reporting of CEMS data
- Providing quality assurance of all data streams and emission inventory components
- Evaluating the emissions inventory using ambient data
- Documenting emissions inventory processes for future reproducibility/understanding (methods, data sources, assumptions, calculations)
- Refining the emission inventory for less certain, but larger emission estimates to better meet Provincial emission source characteristics
- Collecting activity data
- Measuring speciated VOC and PM to help corroborate the conceptual model of pollution in the province and support source apportionment and other data analysis efforts
- Developing spatial surrogate data for modeling applications
- Continuing training of new staff
- Coordinating with neighboring provinces and cities to develop a regional inventory for future modeling analyses
- Developing long-term research plans and shared responsibility and collaboration with other agencies and universities

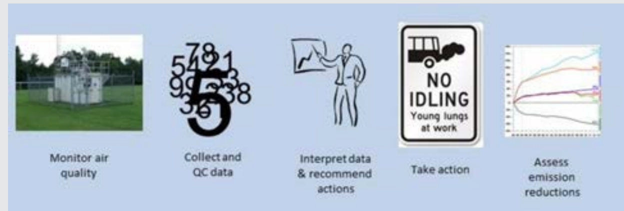
5.2 AMBIENT AIR MONITORING

Overview

Ambient air monitoring is a vital component of an air quality management plan. Ambient data aid the Province in understanding the air quality issues in the region and allow tracking to show that pollution mitigation plans are working (Figure 5-2).

Air monitoring data in the U.S. is collected to evaluate the status of the atmosphere as compared to clean air standards and historical information and provides the basis for air quality management planning. With monitored data, agencies can understand the real-world conditions, support compliance goals, mark/track progress toward air quality standards, better understand ambient conditions leading to high concentrations, and provide useful data for emissions inventory and model evaluation. The U.S. mandates that measurements be made meeting monitor siting and quality guidelines and reporting schedules. The data are used to assess compliance with air standards, oting that many of the U.S. standards require three years of data for evaluation. Data evaluations are typically conducted by agency staff with some support from their regional or national agency.

Figure 5-2 Data Flow from Measurements to Air Quality Management Plan Results[3]



Most air monitoring networks begin with a few sites that quantify $PM_{2.5}$ mass on a 24-hour basis, on a collection schedule that can range from every day, to once every six days. Typically over time, these measurements are expanded to more locations and/or to higher frequency data (typically hourly measurements) to better understand the spatial and temporal variability of the pollutant. To further understand the emissions sources and aid in control strategy development, speciated $PM_{2.5}$ measurements (sulfate, nitrate, ammonium ions; metals; organic carbon/elemental carbon [OC/EC]) are added, typically using 24-hr measurements on an every 3- or 6- day schedule. It is much more expensive, and rare, to measure PM speciation on a continuous basis, but Jiangsu Province has many of these measurements at their central sites. Speciated volatile organic compounds (VOCs) are useful for supporting air quality modeling of both $PM_{2.5}$ and ozone, emissions inventories development and evaluation, and industrial emissions regulation/compliance support. One key lesson learned in the U.S. is that collocated meteorological measurements with air quality are vital for data validation and interpretation. For all measurements, good data quality is essential.

Jiangsu Province currently operates a network of 72 national ambient monitoring stations located throughout the province. Figure 5-3 presents the distribution of these monitors throughout the province.

Figure 5-3 Map of National Ambient Monitoring Stations in Jiangsu Province[4]

Figure 5-4 presents the locations and types of ambient monitors located in Nanjing. There are 9 national monitoring stations, 11 municipal stations, 2 background stations, and a number of stations designed to monitor ambient air quality in industrial zones and key transportation corridors. These monitors collect data for SO_2, NO_X, $PM_{2.5}$, PM_{10}, CO, and O_3.

Figure 5-4 Map of Ambient Monitoring Stations in Nanjing City[5]

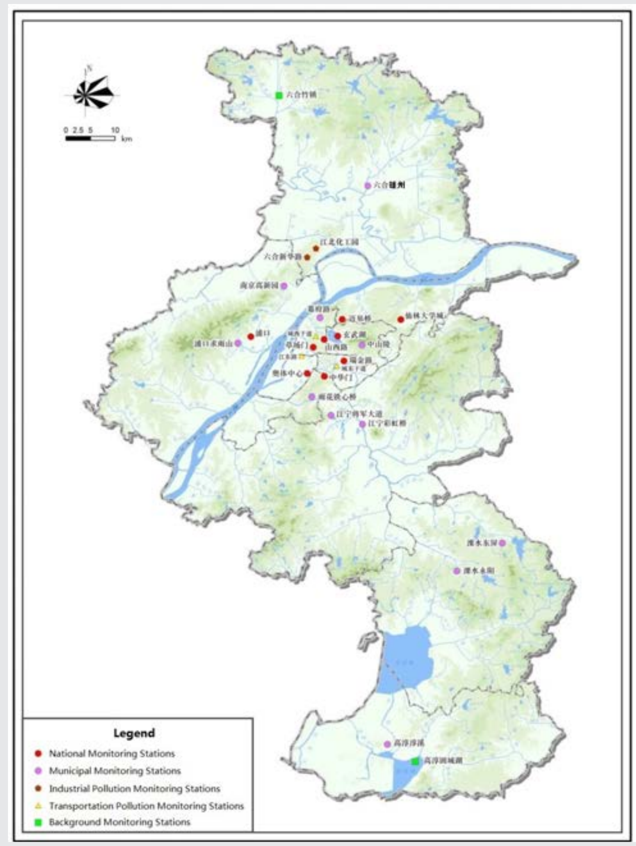


Figure 5-5 presents the ambient air monitoring network for Changzhou. There are 6 national monitoring stations, 2 provincial stations and 5 municipal stations. These monitors also collect data for SO_2, NO_X, $PM_{2.5}$, PM_{10}, CO, and O_3.

Figure 5-5 Map of Ambient Monitoring Stations in Changzhou City[6]

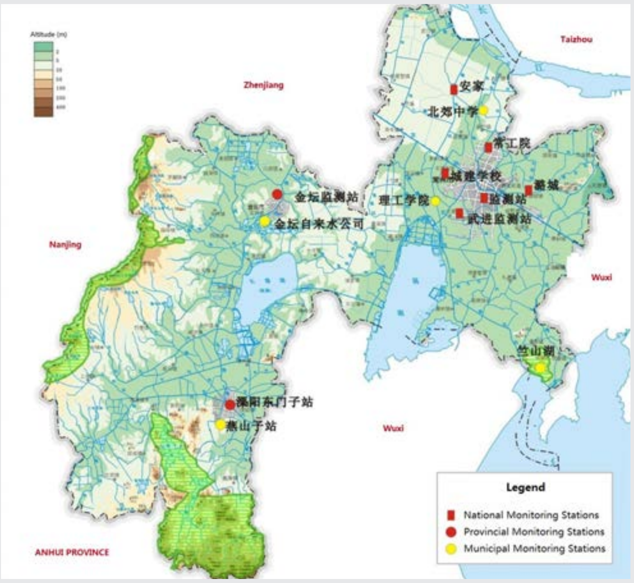


Figure 5-6 presents the ambient monitoring stations located in Suzhou. There are 8 national monitoring stations including a background station, and a number of data process and control sites, quality assurance labs and technical support labs. The monitors collect data for SO_2, NO_X, $PM_{2.5}$, PM_{10}, CO, and O_3.

Figure 5-6 Map of National Ambient Monitoring Stations in Suzhou City[7]

Getting The Most Value From Monitoring Data

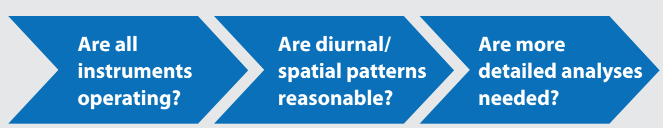
There a number of steps in ambient air monitoring. After selecting sites for monitors, the parameters to be measured, and the equipment to use, agencies need to develop quality assurance project plans (QAPPs) and standard operating procedures (SOPs), and then train staff. To ensure consistency among agencies/cities/regions, it is helpful to develop templates for what to include in a QAPP, SOP, and staff training. Collaboration among agencies helps to share the work load.

Once data are being collected, the following steps can be taken.

1. **Data review, validation, and verification.** Data review, validation, and verification is an ongoing process that is performed by the station operators and data reviewers. Data review ensures that instruments are operating properly. Data validation is an investigation into the veracity of the data and ensures that the reported data are real, ambient measurements. Data verification is checking that specific requirements, such as those specified in an agency's QAPP and SOPs have been fulfilled. Frequent review of data is vital for catching errors early to increase data completeness.

   Figure 5-7 illustrates the conceptual process for data review and validation. On a daily basis, are instruments being properly calibrated and operated following SOPs? For validation, are measurements reasonable? Have invalid data have been flagged – such as during calibrations, or when flow checks fail?

Figure 5-7 Conceptual Process for Data Review and Validation



2. **Basic data analysis.** Spatial and temporal analyses of PM data are the basis for improving our understanding of emissions and the dynamic atmospheric processes that influence particle formation and distribution. Goals of the data analyst performing these investigations can include identifying possible important sources of PM and precursors, determining chemical and physical processes that lead to high PM concentrations, and assessing efficacy of existing control strategies. Analyses are used to develop a conceptual model of processes affecting PM concentrations. Questions the analyst could address with the data include:

    a. What are the diurnal, day of week, seasonal, and annual patterns in concentrations and what do these patterns tell us about the sources of PM?

    b. What are the statistical characteristics of pollutant concentrations, and how do they change from site to site and from time to time?

    c. How do different pollutant concentrations vary in space and time relative to each other?

    d. What is the chemical composition of PM, and how does the composition change with time and by site?

    e. What local or regional sources influence a given measurement site?

    f. How did meteorology, nearby precursor and PM emissions, and natural events influence both spatial and temporal characteristics of the PM data?

    Air agencies typically perform data analysis at least annually to best understand the usefulness of the data that are being collected, assess changes that might be made in the monitoring network, and catch problems with data sets as early as possible. On a regional basis, agencies may find collaboration on data analysis as an effective way to get a "bigger picture" of the air quality.

3. **Use ambient data to "validate" the emission inventory.** Emission inventory development is a complex process that involves estimating and compiling emissions activity data from hundreds of point, area, and mobile sources in a given region. Because of the complexities involved in developing emission inventories and the implications of errors in the inventory on air quality model performance and control strategy assessment, it is important to evaluate the accuracy and representativeness of any inventory that is intended for use in air quality modeling. Furthermore, existing emission factor and activity data for sources of $PM_{2.5}$ may be limited. An emission inventory evaluation is vital to be performed before the data are used in photochemical modeling. There are several techniques used to evaluate emissions data including "common sense" review of the data; source-receptor methods such as the chemical mass balance model; bottom-up evaluations that begin with emissions activity data and estimate the corresponding emissions; and top-down evaluations that compare emission estimates to ambient air quality data. Each evaluation method exhibits strengths and limitations. Based on the results of the emissions evaluation, recommendations can be made on possible improvements to the emission inventory. Agencies responsible for developing the inventory can then make revisions to the inventory data prior to air quality modeling.

4. **Accountability.** As emission controls are implemented, it is important to assess whether the emissions changes are resulting in real changes in the ambient air quality. These trends analyses usually are most helpful with data collected both before and after the emissions changes using consistent measurement methods. Many agencies in the U.S. have long-term trend sites at which they have been monitoring air quality for many years.

5.3 SOURCE APPORTIONMENT

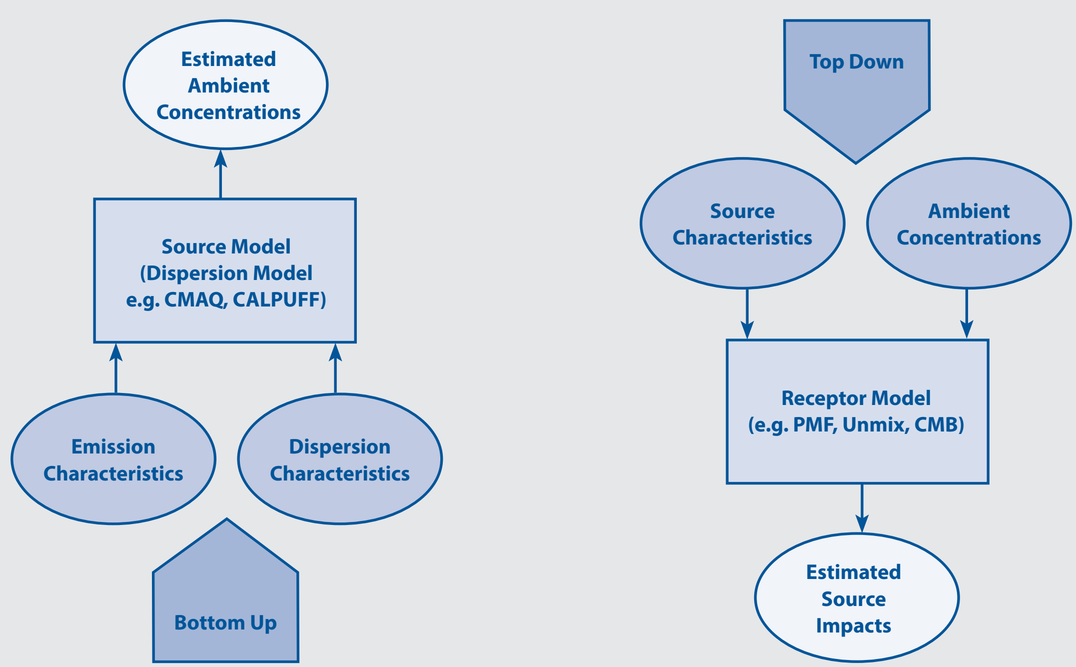
Receptor modeling, or source apportionment, is a data analysis method that gathers information on the sources of air pollutants from actual ambient conditions. The method provides air quality management planners with pollution source types contributing to the observed ambient concentrations and contribution estimates of each source type. These results are useful for developing effective air quality management plans by:

- helping identify and target the most important source sectors that contribute to high pollutant concentrations
- helping identify unknown sources
- identifying the locations of sources – by combining receptor modeling results with local meteorology or ensembles of air parcel back trajectories or combining results from multiple monitors to "triangulate" results
- providing key evidence to refine emission inventories - which are needed for input into air quality models to predict changes in air quality as the result of the implementation of various management plans
- if conducted regularly (or even continuously), tracking progress of, or response to, emissions controls

Source apportionment for PM requires speciated data – such as OC/EC, ammonium sulfate, ammonium nitrate, and trace elements (such as Al, Si, Ca, Ti, Fe, K). This is the minimum suite of pollutants required for effective apportionment. Jiangsu Province makes many of these measurements on an hourly basis which provides much statistical power to findings.

Source apportionment techniques range from data analysis, dispersion or photochemical modeling, to statistical algorithms. Data analyses include correlating pollutants associated with specific sources, correlating wind speed and direction with specific source markers, and subtracting urban-regional concentrations of a specific pollutant to understand the contribution of a specific source. Air quality modeling is typically conducted using AERMOD or CMAQ,

Figure 5-8 Differences Between a Dispersion Model and a Receptor Model[8]



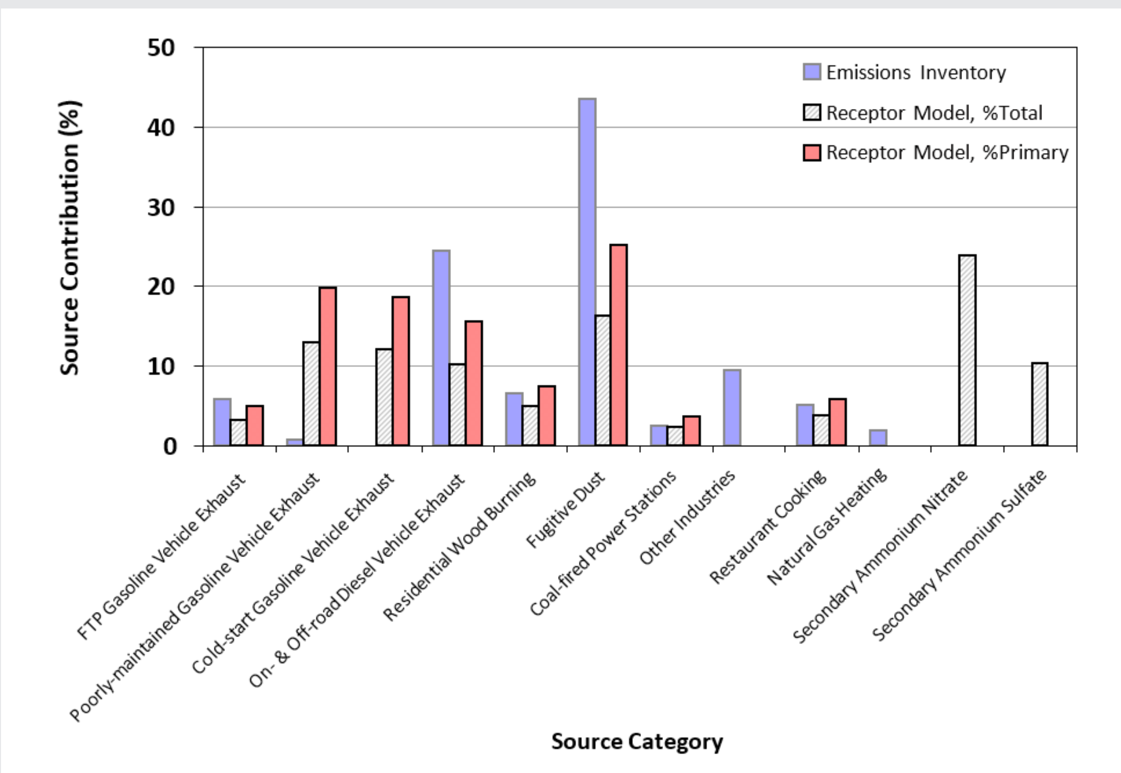
models available through the U.S. EPA. Statistical tools exist that can be applied to single samples (chemical mass balance, CMB) and multiple samples (positive matrix factorization, Unmix); these tools are also called receptor models. Figure 5-8 illustrates the differences between a dispersion model and a receptor model.

The tools have limitations that need to be well understood. Data sets for any analysis have to be quality assured, complete, and data uncertainties quantified. Many resources are available for training, but firsthand knowledge from experienced users is ideal. A lesson learned is that models and their output are only as good as the input data and the methodical and knowledgeable review of the scientist/analyst.

Source apportionment work is being carried out in China and there are some examples of work done in Jiangsu Province (for example, An et al., 2014[9]). It is evident that data are already being collected that could be used for source apportionment. Collaboration with local universities may be helpful because source apportionment analyses have been common graduate student projects in the U.S.

It has been found useful to compare source apportionment results with emission inventories. In nearly every comparison, discrepancies in the emission inventory were found that needed adjustment. Figure 5-9 shows an example of a comparison of an emissions inventory with receptor model findings for $PM_{2.5}$ in Denver, Colorado (U.S.). In this example,

Figure 5-9 Comparison of Emissions Inventory and Receptor Modeling Results for $PM_{2.5}$ in Denver, Colorado[10, 11, 12]



receptor modeling of $PM_{2.5}$ data in Denver, Colorado identified discrepancies in the emissions inventory for fugitive dust and on-and off-road diesel vehicles. These results may indicate that the inventory is over-estimating contributions from fugitive dust and vehicles considered as "high-emitters."

There are many challenges for agencies regarding source apportionment. Some of the challenges U.S. agencies have encountered include:

- Adequacy of source profiles for use in CMB and interpretation of PMF results. Many source types lack updated profiles. EPA's Speciate, a repository for emissions profiles, has not been updated in a very long time and many profiles may not be applicable to Provincial sources. In addition, it is preferable to have source profiles based on measurements using the same type of analytical techniques as the ambient measurements. Source profiles are costly to develop.
- Apportioning secondarily formed particles/components. It is considerably more difficult to relate ambient concentrations of secondary species (sulfate, nitrate, some of the organic carbon) to sources of precursor emissions than it is to identify the sources of primarily emitted particles (black carbon, metals). Much work in the U.S. has been done to trace source impacts using photochemical modeling.
- Data set preparation. It is challenging to obtain or develop realistic uncertainties for source and receptor values. Uncertainty is used to weigh the relative importance of input data to model solutions and to estimate uncertainty of the source contributions.
- Experience. Training on source apportionment methods, data preparation, and data interpretation is needed. While there are many journal articles available, learning directly from experienced practitioners is ideal.

5.4 FUTURE YEAR EMISSIONS PROJECTIONS (2017 AND 2030)

Regulatory analyses and air quality management planning require the development of future-year emissions inventories to assess the impact of various control strategies on future air quality. Future-year inventories are generally developed by applying growth factors to base-year inventory data to account for anticipated changes in emissions-producing activities. These growth factors are derived from projections of socioeconomic variables such as energy demand, resource availability, production levels, and population changes. These factors should also account for source shutdowns and relocations.

For example, in the U.S., the Energy Information Administration (EIA) publishes the Annual Energy Outlook (AEO), which presents long-term projections of energy supply, demand, and prices on the basis of results from EIA's National Energy Modeling System (NEMS). NEMS projects the production, imports, conversion, consumption, and prices of energy, subject to assumptions on macroeconomic and financial factors, world energy markets, resource availability and costs, behavioral and technological choice criteria, cost and performance characteristics of energy technologies, and demographics.

For the Province, the general approach to developing emissions projections would be to gather and evaluate forecast data from government agencies, trade associations, market research firms, or other groups that have specific knowledge of future levels of emissions activity for source categories that comprise a large percentage of pollutant emissions for a given area.

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6

Emissions Inventory Development in Jiangsu

6.1 STATUS AND METHODOLOGY

Of the 13 major cities in Jiangsu Province, the three cities chosen for this project (Nanjing, Changzhou, and Suzhou) have the most well-developed air emission inventories. Generally, the emission inventories for these cities are represented as being approximately 80 percent complete.

To-date, the focus of air emission inventory work in the province has been two-fold: developing complete lists of polluting facilities within each jurisdiction, and developing complete and accurate emissions estimates for the largest emitters. Rapid growth in each jurisdiction, and the limited resources available to each EPB, have made it difficult to develop and maintain complete lists of facilities. These same factors, plus the relative inexperience of EPB staff with air emission inventory development have made it more challenging to develop complete and accurate emissions estimates.

Larger facilities in each jurisdiction typically provide better data to the EPBs (including CEMS data for some facilities that are reported electronically directly to the relevant EPB for review and analysis), but medium and small facilities are still developing their emission inventory capabilities.

Jiangsu Province has been proactive with emission inventory capacity building efforts. In 2011, Jiangsu signed a bi-lateral memorandum of understanding (MOU) with California's South Coast Air Quality Management District (SCAQMD). Jiangsu also hosted the annual China (Nanjing) International Environmental Protection Expo (CIEPE), also known as the Conference and Product Show of Jiangsu New Environmental Protection Technology, since 2012.

In October 2013, a provincial-level work group was established within the Jiangsu Environmental Protection Department, led by the International Cooperation Center for Environmental and Economic Technology and jointly with the Air Pollution Control Division, Monitoring Center, and Academy of Environmental Science.

In April 2014, the three pilot cities established their own working groups. Key staff were specified for the three major working areas including air quality monitoring, emission inventories identification as well as benefit and attainment assessment.

In 2014, emission inventory guidance documents for $PM_{2.5}$, VOC, and ammonia were developed by the China Academy of Environmental Planning in order to implement the State Council's "Comments on Strengthen the Key Works of Environmental Protection" and "Action Plan of Atmospheric Pollution Prevention." These documents are intended to "promote the process of national atmospheric pollution prevention and control, and to enhance the relevance and effectiveness of" atmospheric $PM_{2.5}$, VOC, and ammonia control. These compilations (referred to as "guidelines") are based on "The P.R.C's National Environmental Protection Act", "The P.R.C's National Air Pollution Prevention and Control Act", "Ambient Air Quality Standard"(GB3095-2012), as well as other relevant laws, acts, standards, rules, and documents.

The Jiangsu Provincial Academy of Environmental Sciences is currently working to develop a "bottom-up" air emissions inventory for Jiangsu Province. The Academy is using air emission factors published in the U.S. EPA's AP-42, Compilation of Air Pollutant Emission Factors, but much of their work has involved characterizing the unique sources in Jiangsu Province, including doing some new air emissions measurement work.

Nanjing

Nanjing has been working on their air emission inventory for about three years, and has completed some initial work on source analysis. They have had support from Nanjing University, Tsinghua University, and the China Academy. They have also collaborated with the Shanghai Environmental Monitoring Center. They report their inventory is about 80% complete. They are now in the process of confirming data from some point sources. Their emission inventory includes stack parameters, and is updated annually. They get data from the industries included in the inventory. This includes CEMS data that is reported electronically for some facilities. EPB staff verify the data provided by facilities. Emissions are driven by production. Some large companies have dedicated staff to support emission inventory work. Nanjing has completed a 2014 emissions inventory, and has developed a 2017 inventory based on expected emission reductions resulting from the newest Action Plan. The newest Action Plan includes 72 actions for Nanjing (35 actions from the National Plan). Additional information is needed to support resulting emission projections. Tsinghua University has already conducted modeling to evaluate whether Nanjing will realize a 20 percent improvement based on the Action Plan.

Changzhou

Air emission inventory development started in Changzhou in 2010. Changzhou was one of the first Jiangsu cities to begin developing an air emission inventory. Collaboration with the Shanghai Environmental Monitoring Center has been helpful. A preliminary emission inventory was developed in 2013. That preliminary inventory included approximately 500 industrial sources, representing approximately 80 percent of the industries in the city. This inventory was based primarily on emission factors. The updated emission inventory includes approximately 1,000 sources. Emission inventory is updated annually. Air emission inventory work in Changzhou has historically focused on key industrial sources, mobile sources, restaurants/BBQ, and warehouses. A more recent focus has been on the development of emission estimates for VOC. This is in part because the chemical industry is large in Changzhou, including about 400 main companies, and an additional 400 smaller companies. VOC emissions from coating and painting operations are also significant, including emissions from automobile painting, fabric coating, textiles, and general painting operations for all kinds of manufactured products (e.g., appliances, industrial parts, etc.).

Suzhou

Suzhou is a rapidly-growing industrialized city with extensive pressure on the balance between economic growth and environmental protection. There are an estimated 160,000 enterprises in Suzhou; approximately 20,000 of these are "large" enterprises, based on revenue. It is estimated that approximately 2,400 of these enterprises are air pollution sources. As with the other cities, Suzhou has focused their emission inventory efforts on key industry sectors (e.g., coal-fired power plants, iron and steel), and on sectors with significant VOC emissions, including electronics and surface coating.

6.2 MAJOR CONTRIBUTORS TO POLLUTION

Emission inventory and source apportionment work to-date has identified major contributors to ambient air quality issues within Jiangsu Province, and within the three cities. In 2014, the total estimated SO_2, NO_X and smoke and dust emissions for Jiangsu Province were 904.7 kilotons, 1.2326 megatons and 763.7 kilotons, respectively. Contribution of the emissions from different sources is shown in Table 6-1 below.

Table 6-1 Contribution of Air Emissions from Different Sources in Jiangsu Province (as of 2014)[1]

	SO_2	NO_X	SMOKE AND DUST
Industrial Sources	96.19%	72.06%	94.34%
Residential Sources	3.78%	0.52%	2.38%
Centralized Garbage and Hazardous Waste Control Facilities	0.03%	0.04%	0.04%
Motor Vehicles	N/A	27.38%	3.24%

In addition, a study conducted by researchers at Nanjing University (2012) found that point sources were estimated to account for 83.9%, 71.2%, 63.7%, and 54.5% of the total SO_2, NO_X, $PM_{2.5}$, and VOC emissions, respectively.[2] Key sectors for the province, and for each of the three cities, are noted in Table 6-2 below.

Table 6-2 Major Air Pollution Contributing Sectors in Jiangsu Province and Three Pilot Cities

	Jiangsu Province	Nanjing	Changzhou	Suzhou
Coal-fired Power	✓	✓	✓	✓
Heavy machinery/equipment manufacturing			✓	
Petrochemical	✓	✓	✓	
Chemical	✓		✓	
Iron and Steel	✓	✓	✓	✓
Cement	✓	✓	✓	
Industrial boilers	✓	✓	✓	✓
Electronics		✓	✓	✓
Manufacturing		✓		
Biopharmaceutical			✓	
Paints and coatings				✓
Paints and coatings (including automobile, appliances, industrial parts, fabric coating, textiles, and printing)			✓	
Mobile sources			✓	✓
Mobile sources (including diesel off-road)	✓			
Mobile sources (including shipping/port emissions)		✓		
Construction		✓	✓	✓
Cooking		✓		

6.3 KEY CHALLENGES

During the city visits and discussions with Jiangsu EPD and city-level staff, a number of challenges appeared as recurring themes.

Limited resources. The provincial-level and city-level environmental agencies are relatively small, as compared with U.S. state environmental agencies. As a result, staff cannot specialize in specific areas of air quality management. Instead, staff must cover a wide range of issues and media (air, water, solid waste). Therefore, developing internal experts in specific areas of air quality management is difficult. To exacerbate the problem, there is a significant difference in the role of the environmental agency versus regulated entities as compared with the U.S. Professional development and staff retention are also reported to be concerns.

Rapid growth. With significant new construction, and accelerated shutdown of older, less-efficient facilities, the population of industrial facilities is constantly changing, making it difficult to track even basic information, such as a complete listing of industrial facilities in the province, or within a city jurisdiction. In contrast with the slower growth rate of the U.S. economy, this presents great challenges for maintaining an accurate air emission inventory, and for compliance enforcement. Related to this rapid growth, the many active construction sites and industrial facilities are spread over large areas, making data collection, inspection, and enforcement difficult. In addition, the mobile source inventory in the province has grown 406 percent in ten years, with an annual growth at 20 percent.

Need for China-specific air emission factors. There is a need to develop China-specific air emission factors to assist with improving air emissions inventories. Best practices in the U.S. include conducting air emissions testing on selected process and emission control device combinations, then developing air emission factors that can be applied to similar sources without the need for additional testing. Other provinces and cities with similar industrial operations would then be able to use those emission factors for their own air emissions inventories, and likewise share any air emission factors developed in their province or city.

Inexperienced EPB staff. Emission inventories are relatively new to many agency staff; some staff have been working on air emission inventories for only a few years. Additional experience is needed in all areas of air quality management, including basic technical foundation for the future.

Inexperienced industry environmental staff. In addition to EPB staff, the staff at the industrial facilities being asked to report air emission data are also relatively new to emission inventory reporting. These staff also require training and guidance in order to be equipped to provide complete and accurate air emission data for their respective facilities and operations.

Air emission inventory training. A common topic from many of our discussions was the need for additional training on VOC emission estimation and measurement techniques. Emission estimation techniques are also needed for the petrochemical, cement, power, and iron and steel industries. Other training may include the use of statistical sampling and models for estimating emissions from mobile and area sources. U.S. EPA, and many state air pollution control agencies, have excellent air emission inventory resources.

Equipment training. The EPB's, monitoring centers, laboratories, and universities often have state-of-the-art equipment. Assistance is needed with ways to use these equipment more effectively as part of the air quality monitoring program and air emission inventory development and verification. Training is needed in areas such as source apportionment (e.g., positive matrix formation [PMF]). Source apportionment is important because cities need to know where the $PM_{2.5}$ emissions are coming from; however, it is very resource intensive.

Data quality training. EPB staff have to deal with data quality issues. Data from power plants is not always reliable. Verifying data for facilities without CEMS can be challenging. Training is needed on best practices for quality assurance/quality control and verification techniques (e.g., statistical analyses) for the underlying data used to develop accurate air emission inventories.

Air emission control strategies training. Additional training is needed on relevant control strategies for ozone and VOCs and their effectiveness. There is a need for cost-effective, practical air emission controls and corresponding emission measurement methods. Training should emphasize multi-pollutant emission controls, and the pursuit of "win-win" approaches that will both protect the environment and save money for the company.

Authority. In some cases, the city does not have the authority to make regulations and laws on environmental issues. More regulations are needed, and are coming, at the national level. It will also be important for cities to collaborate with the provincial EPD to have them suggest new regulations to the national government, or to establish new regulations at the provincial level. With respect to emission inventory development, Jiangsu Province could elect to develop a mandatory reporting program for major industry sectors, similar to the U.S. EPA's mandatory reporting for GHG's, but covering key criteria pollutants ($PM_{2.5}$, SO_2, NO_X, VOC). Uniform guidance or requirements at the provincial level will help to collect accurate and uniform data from different cities. This would also place most of the inventory development burden on the reporting facilities.

Intense pressure to improve air quality. Fast-growing, industrial cities place great pressure on environmental protection.

In addition to the key challenges noted above, additional assistance is needed in related areas, including:

- air quality plan objectives (goal setting) and review (ongoing assessment)
- air permitting
- air quality emission standards for key industrial sectors
- air emission inventory data collection
- air emission estimation techniques for specific pollutants
- ambient air monitoring, including monitoring network evaluation
- alternative emission measurement methods (to CEMS) for small entities
- air quality compliance and enforcement
- fugitive dust emission estimating techniques (e.g., construction site dust)
- air emission estimates for small, ubiquitous sources (e.g., restaurants, street cooking, outdoor burning, fireworks, auto repair garages, and use of organic solvents)

6.4 KEY FINDINGS FROM 2014 YOUTH OLYMPICS IN NANJING

Nanjing put specific plans in place to improve air quality for the August 2014 Youth Olympic Games. The plan included the temporary shutdown of many construction sites, and the suspension of operations at major industrial facilities. Nanjing also seized the opportunity to remove many higher-polluting yellow label cars from local roadways.

The plan provided a unique opportunity to observe in real-time the response in ambient air quality associated with reducing emissions from specific sectors. The plan proved successful, reducing emissions by a large percentage, and resulting in greatly improved air quality during the Games. One of the key findings of the Olympic planning exercise was that industrial sources were a significant contributor to ambient air quality issues and therefore the Jiangsu EPD wanted to focus on industrial sources as part of this Air Quality Management Planning Framework.

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7

Current Air Pollution Control Policies and Initiatives

OVERVIEW

This chapter provides summary information on national (PRC) environmental laws and programs as well as national, provincial, and city action plans related to air pollution improvements. While the national laws continue to be reviewed and amended, China's air quality management is being assessed against China's Ambient Air Quality Standards (AAQS GB 3095-2012). In Jiangsu, city-level action plans are being implemented for Nanjing, Changzhou, and Suzhou.

7.1 GENERAL

The Ministry of Environmental Protection (MEP) issued GB 13223-2011 in December of 2011. The National Development and Reform Commission (NDRC), and Ministry of Finance jointly issued the 12th Five-Year Plan on Air Pollution Prevention and Control in Key Regions. The plan was approved by China's State Council in September 2012[1].

Other industry-specific national emission standards include the following:

- Integrated Emission Standard of Air Pollutants (GB 16297-1996);
- Emission Standard of Air Pollutants for Thermal Power Plants (GB 13223-2011);
- Emission Standard of Pollutants for Coking Chemical Industry (GB 16171-2012);
- Emission Standard of Air Pollutants for Sintering and Pelletizing of Iron and Steel Industry (GB 28662-2012);
- Emission Standard of Air Pollutants for Iron Smelt Industry (GB 28663-2012);
- Emission Standard of Air Pollutants for Steel Smelt Industry (GB 28664-2012);
- Emission Standard of Air Pollutants for Cement Industry (GB 4915-2013);
- Emission Standard of Air Pollutants for Boiler (GB 13271-2014);
- Emission Standard of Pollutants for Petroleum Refining Industry (GB 31570-2015);
- Emission Standard of Pollutants for Petroleum Chemistry Industry (GB 31571-2015)

In 2013, China's State Council promulgated the "Air Pollution Prevention and Control Action Plan (2013 – 2017)", also referred to as the "Ten Measures". This plan requires explicit control measures and air quality targets to be met by China's key regions and cities. As a result of this Plan, all provinces, autonomous regions and municipalities directly under control of the central government are making efforts to control air pollution in order to meet the targets set in the Control Action Plan. The Yangtze River Delta region, which includes Jiangsu Province, is required to reduce $PM_{2.5}$ concentrations 20% by 2017. The "Ten Measures" also provides specific targets for NO_X, and SO_2, and, for the first time, VOC. Attainment of the "Ten Measures" requirements is further linked to economic development and incentives. Cities that fail to achieve the required targets may have economic development funds withheld or reduced.

While the 2013 Air Pollution Control Action Plan required meeting specific air quality targets by 2017, it also included longer term goals for meeting the current China $PM_{2.5}$ ambient standards by 2030.

The 2014 revised Environmental Protection Law is the most stringent environmental law in China's history. Agencies now have the ability to assess higher fines for environmental violations. In addition, some cities have been fined for failure to achieve required air quality targets.

During 2015, China's Air Law was amended and significantly strengthened. The amended law provides MEP with the ability to promulgate new and revised ambient air quality standards and, for the first time, initiate a formal operating permit system. The third and final reading of China's Air Law by China's National People's Congress was completed in the fall of 2015.

Jiangsu Province

In 2014, Jiangsu Province made significant progress to promote energy saving, consumption reduction, and elimination of outdated production capacity. According to preliminary calculations, in 2014 the province's energy consumption per GDP decreased by 5.9% compared to the previous year, which exceeded the original annual target reduction of 3.6%, and achieved 96.0% of the energy-saving target in the 12th 5-year National Plan.

Coal is currently more than 70% of the total energy consumption in China and Jiangsu is the second largest user in the country - increasing by 6% annually. Efforts have begun to promote the use of clean and renewable energy and to regulate small coal boilers.

The State Council Air Pollution Prevention and Control Action Plan required the formulation of a national mid- and long-term goal to control total coal consumption. Coal use is to be reduced to less than 65% of total energy consumption by 2017. Jiangsu Province is one of 14 provinces/cities that set goals to reduce total coal consumption by 2014.

Jiangsu has identified a number of policies and initiatives to pursue at the provincial level in order to meet air quality goals, such as: [2]

- Optimize energy structure and reduce coal consumption to providing 65% of total energy consumption by 2017.
- Promote usage of clean and renewable energy and increase energy efficiency (green buildings).
- Regulate small coal-fired boilers (rebuild or replace).
- Change industrial structure. Accelerate closing of obsolete industrial equipment and facilities; increase penalties for noncompliance; reduce over-capacity; and control capacity for industries that are high polluters and high energy consumers.
- Promote cleaner production, including pollution prevention through process changes, recycling, better emissions controls, and better supervision.
- Encourage cleaner/greener transportation (e.g., more stringent emissions standards, better quality diesel fuel, and increased rail transport).
- Control emissions from shipping and off-road vehicles.
- Control urban pollution (e.g., cooking fumes and VOC from use of organic solvents) and fugitive dust.
- Add green space (by 2017, green space will be 38.7% of land area).
- Support science and technology. Conduct research on control strategies, invest in the development and deployment of air pollution control technologies, and build research team through professional training and capacity building.
- Ensure monitoring (both regional ambient monitoring and monitoring at industrial sources) and develop early warning systems in cooperation with meteorological department for predicted heavy pollution episodes.
- Develop emergency response plans for different levels of concern and provide guidance to local cities to implement these plans.
- Enhance laws, regulations and standards.
- Develop an environmental disclosure system.
    - Rank all cities and key enterprises based on air quality and emissions rates and make that information available to the public.
    - Require key enterprises to self-report emissions levels.
- Increase coordination in region and reinforce international collaboration and exchanges.
    - Make $PM_{2.5}$ control a mandatory requirement for industries
    - Implement evaluation and assessment system to measure annual performance and hold violators accountable.
- Increase public participation, outreach and education.

Nanjing

Since 2010, Nanjing has developed annual action plans for controlling air pollution. The 2014 Action Plan includes 72 actions for Nanjing (versus 35 actions from the National Plan).

Nanjing put a special plan in place to improve air quality for the August 2014 Youth Olympic Games. The plan included the temporary shutdown of many construction sites, the suspension of operations at major industrial facilities, and the removal of many higher-polluting yellow label cars from local roadways. The plan proved successful, reducing emissions by a large percentage, and resulting in greatly improved air quality during the Games. One of the key findings of this exercise was that industrial sources are a major contributor to local ambient air quality issues.

The major pollution, weather, and emergency warning system is managed in accordance with the the "Atmospheric Pollution Warning and Emergency Handling Procedure". Red and orange warnings are issued during severe pollution episodes, and emergency actions are enforced. Emergency actions may include production shutdown, production curtailment, road flushing, or artificial precipitation.

With regards to standards and permitting, Nanjing staff are moving to develop stricter local emission standards for the steel, power, and cement industries. They also plan to develop a permit program. They have already set up an emissions fee program and the revenue stays with Nanjing EPB.

Their permit program requires an environmental impact analysis (EIA) for new or modified sources to receive a permit. Nanjing requires 2:1 offsets which is more stringent than the national program. They are not approving new coal fired plants (or expansions of existing plants) and and are limiting construction or expansion for certain heavy industries.

Over the next 10 years, the plan is to relocate heavy industry facilities far outside of Jiangsu and they will have to meet stricter emission standards. Nanjing will focus on attracting lighter industry and more service industries.

The following policies/measures are in place to ensure enforcement:

1. CEMS help verify emission data for some sources.
2. On-site inspections are conducted.
3. Fines are levied for violations, such as not running emission control equipment at night. Companies can also lose credit for loans from bank and get bad publicity.

Changzhou

The Changzhou 12th 5-year plan focuses on 10 industries. The city needs to grow while addressing pollution from these industries. They are considering a new focus on service industries, but recognize that it takes time to shift the economy away from manufacturing and toward service industry.

There are additional efforts to accelerate the closing of obsolete production facilities, increased penalties for noncompliance, reduce over-capacity and high polluters. These efforts will reduce production overcapacity, control high pollution and high energy consumption sectors, and improve treatment of industrial pollution (e.g., VOC, LDAR).

In addition, Changzhou plans to start implementing a permitting program recently.

Suzhou

Air quality in Suzhou has slightly improved over the last several years, and the government is further promoting the programs. With a population of 12 million, an estimated 160,000 industrial enterprises and 2.71 million motor vehicles in Suzhou, there are multiple air emission issues and challenges. One of the biggest challenges involves fundamental environmental management training for their staff.

7.2 POWER SECTOR

As mentioned above, there is a national goal to optimize energy structure and reduce coal consumption to 65% of total by 2017. This goal involves promoting the use of clean and renewable energy, increasing energy efficiency (green buildings), and regulating small coal boilers (e.g., rebuild or replace). Jiangsu staff note the importance of energy conservation centers and the role of energy planning to help reduce emissions.

In July of 2011, the Ministry of Environmental Protection (MEP) issued stringent standards for coal-fired power boilers. Additionally in December of 2012, the State Council approved specific plans for financing and implementing air pollution control projects for coal-fired boilers used to generate electricity.

Since 2013, the national government has mandated reduced consumption of coal. There are four primary ways to reduce coal consumption: 1) close small-sized, medium-sized, and old plants (300 MW and below); 2) use natural gas; 3) use cogeneration systems; and 4) use biomass for small boilers. Add-on emission controls are another option for any remaining uncontrolled sources.

In late March 2015, the Central Committee of the Communist Party and the State Council finalized a document called "Deepening Reform of the Power Sector", also known as Document #9. This "Power Sector Reform" guidance recognizes the need for a major revamp of power sector planning, and official announcements indicate that the 13th Five-Year Plan will include some of these provisions.

China energy intensity and appliance standards have already avoided the combustion of millions of tons of coal and have avoided the consequent increases in air pollution. By 2020, energy efficiency standards are anticipated to avoid the combustion of more than one billion tons of coal.

Jiangsu has been one of the leading provinces in the area of demand side management (DSM), with an early focus on DSM during the periods of "tight" power supply in the early 2000s.[3] The State Grid Corporation DSM Instruction Center began designing and constructing "Efficiency Power Plants" (EPPs) in Jiangsu, as a pilot for the concept. EPPs are "virtual" power plants consisting of a bundle of energy efficiency investments that provide predictable load carrying capacity in much the same way that a generating unit does.[4] The Jiangsu subsidiary of State Grid has continued to expand energy-saving DSM efforts under the 2011 national "DSM Measures" issued by NDRC.

Nanjing

The Nanjing emission standards for power plants are much stricter than the national standards.

Changzhou

Changzhou has designated a coal-free zone of 406 square kilometers, in which only clean fuels are allowed. There are six main air monitors in the CBD, but the recent monitoring data is not available yet to see if there has been a detectable impact on local air quality.

The majority of electricity is generated from outside the city. There are only a few small power generation enterprises located within the city. In 2011, the total SO_2 emissions from power plants in Changzhou were approximately 12,000 tons.

In 2013, Changzhou demolished 686 coal boilers for centralized heating in 510 enterprises, and replaced them with clean energy such as natural gas and solar energy. Changzhou plans to eliminate all small coal-fired boilers less than 7 MW by the end of 2016.

Suzhou

Power plants are a significant source of PM, NO_X, and SO_X emissions and the total generating capacity of the power plants is 22,000 MW. New standards were implemented on July 1, 2014 for power boilers. Small boilers (<10 tons steam/hr) will be eliminated over the next 3 years. Boilers that are greater than 10 tons steam/hour will have the same emission standards as large power plants by 2017.

7.3 INDUSTRIAL SECTORS

Nanjing

Local emission standards for new and existing steel and cement plants are stricter than the national emission standards for these industries. Research is continuing on stricter standards for both new and existing sources in the steel, cement, and power sectors.

Changzhou

Changzhou plans to relocate small and medium-sized chemical enterprises into the existing industrial parks in order to promote their management, coordination and development.

In addition, Changzhou plans to eliminate outdated production capacity including 100 kilotons of casting, 100 million meters of dyeing and printing, and 30 million meters of textile production between 2014 and 2017.

Several small painting, printing, and chemical companies have closed which resulted in lost jobs, which is challenging. There is a need to find new opportunities for those displaced workers. In promoting new, lower emitting technologies, existing larger printing companies can better afford to upgrade technologies. Developing emission projections for 2017 is challenging because of large changes in the local chemical and printing industries. Companies are challenged by 2:1 emission offset requirement and 300 - 400 small chemical factories have closed in last 5 years. Changzhou has stopped approving applications for new projects in the printing industries at this time.

There are 3 large steel mills in Changzhou. The iron & steel sector in Changzhou had 36,000 tons of SO_2 emissions in 2011. Current emissions are much lower due to the installation of wet scrubbers and the use of magnesium catalyst. All sintering machines and pellets production equipment must be equipped with desulfurization equipment by the end of 2014.

By the end of 2015, catalytic cracking units at petroleum refineries must be equipped with flue gas desulfurization equipment and the sulfur recovery rate should be above 99%.

Suzhou

There are an estimated 160,000 industrial enterprises in Suzhou and 20,000 of those are considered large (annual revenues greater than $20 million). They are focusing on 2,400 companies for air emission reductions.

7.4 MOBILE SOURCES AND FUELS

In 2014, the State Council of PRC started a national program to eliminate 6 million yellow-label vehicles and other outdated vehicles. In 2013 there were more than 130 million yellow-labeled vehicles which account for only 10% of car ownership, but account for 50% of total vehicle emissions.

Per the CAAC China Air Quality Management Assessment Report (2015) – Lite Edition, Jiangsu Province was one of the 10 provinces/cities that fulfilled their 2014 yellow-label vehicle removal mission by more than 120%.

There are several national-level initiatives designed to encourage cleaner/greener transportation. These initiatives include stricter motor vehicle emissions standards, improving diesel fuel quality standards, and increasing the availability of rail transport.

Jiangsu did a study which showed a significant difference after application of stage I and II vapor recovery for vehicle refueling.

Nanjing

In 2014, Nanjing made significant progress on management and control of the emissions from motor vehicles, and is the leader in the field in Jiangsu Province. The "National V" standards of gasoline products are implemented. The "National IV" admittance standards are implemented for the heavy diesel vehicles, and the "National V" standard reporting program is implemented earlier than the original schedule. The total area prohibited for heavy-pollution vehicles has been expanded to to 305 square kilometers.

In 2015, new cars in Nanjing will have China V engine standards and new fuel standards (e.g., 10 ppm sulfur fuel). Nanjing conducts random inspections and sampling of fuel at gas stations. They are also introducing stage II vapor recovery for vehicle fueling. Research conducted by Jiangsu Environmental Monitoring Center has demonstrated strong effectiveness of stage II vapor recovery.

Nanjing has more than 3,000 construction sites and more than 10,000 trucks driving through the city. The trucks are driven primarily at night and are limited to specific routes during the day. There are specific requirements to have the truck bed covered and the truck must be washed off to reduce dust (PM) emissions before leaving the construction site. Spray water is also used to reduce dust around construction sites. There are new requirements for diesel engines of construction vehicles and new fuel standards under development.

The recent Youth Olympics were used as an opportunity to get rid of many yellow label cars. One measure limited drivers of yellow-label vehicles from entering inner ring of the city. If the driver gets caught entering the inner ring the owner is fined. Other measures involved paying cash for old cars and providing subsidies for a new car if the owner had a certificate showing that the old car was dismantled at the junk yard. Periodic inspections at junk yards were used to verify program requirements.

Changzhou

Changzhou plans to eliminate all yellow-label vehicles in the city by the end of 2016. Changzhou also plans to add 100 liquefied natural gas (LNG) trucks by 2018, and then 10 LNG trucks per year afterwards.

There are additional efforts to encourage clean/green transport (e.g., public transit), and to control vehicular pollution (more stringent emissions standards, better fuel standards, and intercity transit).

Suzhou

Residents currently have 2.71 million motor vehicles including hundreds of thousands of motor bikes. Suzhou will remove 200,000 yellow label cars by end of 2015.

No motorcycles can come into the city for safety and pollution concerns.

With regard to off-road equipment, they are evaluating options for the control of air emissions from large equipment used in construction.

7.5 OTHER SECTORS

Nanjing

Shipping/port emissions are an issue for Nanjing. They have a lot of shipping (transportation) on rivers and they are working toward employing an electrification system so ships will no longer have to run their engines while idling. They need better equipment for moving goods on/off ships at port; current methods are very basic.

Cooking emissions are another issue of concern and are being studied.

Changzhou

Changzhou has been working with providers of paints/coatings to set standards for VOC content. There are national standards in place but there have been difficulties with enforcement. There are three paint categories: encouraged, confined, and dismissed. Some paints/coatings are manufactured in the city, including specialized water-based paint for ships/tankers, but the overall volume is relatively small. Changzhou has a research institute working on paints/coatings.

There are requirements to paint objects smaller than a car in an enclosure. Those emissions are typically collected and routed to a thermal incinerator.

There are 30 green auto repair garages being developed to use lower-emitting paints and to serve as examples for other auto garages.

There are additional efforts to control ship and off-road vehicles, and to control urban pollution (by 2017, increase green space to 38.7%, replace and dismantle old industrial facilities, and control fugitive dust).

Fugitive dust from construction sites in China include a bigger fraction of $PM_{2.5}$ than in the U.S. There are well-established best management practices for keeping dust levels down.

For example, dust from iron ore and coke piles at the Zenith Steel Mill is watered (sprayed) regularly to control dust. The site also has a 25-meter wall at the fence line to keep dust from blowing onto nearby roadways.

Suzhou

Suzhou plans to focus on VOC controls over the next 3 years. However, standards and test methods are needed, as well as information on VOC control technologies. Suzhou is learning from other cities but wants to set up their own standards.

There are current construction dust measures in-place.

References

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2. Li, Bing. Jiangsu Kickoff Meeting Summary Report, June 13, 2014.
3. Hu, Z., Moskovitz, D., & Zhao, J. (2005). Demand-Side Management in China's Restructured Power Industry. Energy Sector Management Assistance Program, The World Bank.
4. Part A Final Report, TA 4706-PRC: Energy Conservation and Resource Management Project, The Regulatory Assistance Project, July 2007.

8

Regional Planning and Coordination Activities

OVERVIEW

Typically, air quality standards and future goals are set at a National level with implementation as the responsibility of the local agencies (in the U.S. - city, county, state). The local agencies often handle the day-to-day responsibilities of issuing permits for individual sources and monitoring air quality. Regional planning and coordination are important because air moves freely across political boundaries; thus, emissions from one area or jurisdiction affect air quality in another. Thus, collaboration and coordination among agencies are vital components of air quality management planning. Regional planning organizations (RPOs) help provide regional attention – they can be more encompassing than a citywide focus and more focused than a national view. RPOs can facilitate stakeholder engagement, communication, and cooperation. A typical flow of responsibilities in the U.S. is shown in Figure 8-1.

Figure 8-1 Example Distribution of Responsibilities for Air Quality Management in the United States

NATIONAL	REGIONAL	LOCAL
Set AQ standards & future goals	Work with local agencies	Conduct monitoring
Fund AQ monitoring & data reporting	Effectively allocate funding	Enforce compliance with regulations
	Review/accept AQMPs	Develop plans to reduce AQ impacts
	Sponsor regional research	

8.1 REGIONAL PLANNING EXPERIENCE

Jiangsu Province and its major cities (including Nanjing, Changzhou, and Suzhou) are charged with meeting ambitious air quality improvement targets established by the national government in 2013. The YRD region has recognized that collaboration and coordination among agencies are vital components of air quality management planning and has initiated a regional planning process to help address air pollution goals.

There are a number of valuable lessons to be derived from more than fifty years of air quality management experience in the United States. Urban air quality problems in the U.S. and in China continue to result from a combination of local emissions (from within the city or province) and regional emissions (from other cities or provinces). Various studies indicate that in China 25% or more of the $PM_{2.5}$ mass in urban areas can be attributed to emissions originating from outside the urban area. With significant emphasis in China now given to meeting ambient $PM_{2.5}$ air quality improvement targets for 2017, it is important for China to improve the coordination among jurisdictions so that "upwind" provinces may adopt emission reduction strategies to help reduce their contributions to "downwind" cities and provinces. Many provinces have degraded air quality partly due to emissions from upwind neighbors, and at the same time they emit pollution that negatively impacts downwind provinces and harms public health. Closure of inefficient industrial sites and older power plants has helped to alleviate chronic and hazardous pollutant concentrations in central business districts (CBD) of many cities. But, many of the operators of the closed enterprises have re-constructed outside CBD or in a neighboring province, without installing the "best emission controls". This expands the area affected by air pollution, and makes the job more difficult to attain public health standards and blue skies. Consistent emission standards should be required regionally, along with the best controls, to ensure that enterprises do not seek a competitive advantage in one area due to the lack of consistent emission standards.

Efforts to attain air quality standards in China could take an extended period of time. Thus, most jurisdictions should have a strong interest in achieving cleaner air through improved regional coordination. Additionally, there is an opportunity now to develop and expand the expertise of air quality planners across Jiangsu and other provinces in order to deal with the severe public health problems created by current high pollution levels over the coming decades.

One relevant example of regional planning in the U.S. was the establishment in the year 2000 of five regional planning organizations (RPOs) to address regional $PM_{2.5}$ concentrations and their effects on visibility impairment in protected national parks and wilderness areas. The function of the RPOs was to assist with the coordination and cooperation needed to provide the technical, scientific foundation necessary to assist state agencies with developing air quality management plans. Total funding of more than $65 million was provided by the EPA over 8 years. EPA also developed guidelines for improving coordination among states and organized biannual meetings among of all RPOs to share information and lessons. Each of the five RPOs approached its work in a unique manner, depending on the states participating, existing regional air quality management institutions, and existing technical capacity of participants.

The RPOs were tasked with compiling emissions inventories, establishing emissions tracking systems, improving regional modeling capabilities, and bolstering monitoring programs. Funding was also used to conduct data analyses, training (capacity building) for technical staff, and focused field studies and research. The RPOs in the U.S. have provided important opportunities for training technical staff on a wide range of topics including: air pollution control fundamentals, ambient monitoring quality assurance, stack testing best practices, data validation, data analysis, dispersion modeling, emission estimation and inventory development, implementing standards for stationary and mobile sources, air quality modeling and forecasting, permit writing, and planning/regulation development. Ongoing training is essential to assure best practices are being used, to provide capacity-building opportunities, and to help maintain the base of knowledge in the agency when there is staff turnover.

RPOs can facilitate stakeholder engagement, communication, and cooperation across organizations such as representatives of local government, public health, transportation, industry, business, and environmental organizations, with citizens, and with an advisory board composed of interested stakeholders. Engaging stakeholders provides them with a sense of ownership in the process and helps improve the likelihood of success in adopting and implementing emissions control programs and meeting air quality goals.

A regional planning process can provide a number of benefits:

- Build technical capacity of air quality professionals across multiple jurisdictions through collaboration and training. Less experienced staff can learn from more experienced staff from other jurisdictions and from participating academies, institutes, and universities.
- Provides assistance and training to provinces/cities currently with less-developed air quality expertise.
- Leverages resources from the central government and multiple jurisdictions to help address complex issues (such as regional air quality modeling) that may be very burdensome for an individual jurisdiction to address on its own.
- Helps bring greater consistency to technical information (such as emission inventories and control strategy information) that is essential for making sound air quality management decisions.
- Builds greater trust among stakeholders from multiple cities, provinces, central government agencies, industrial sectors, and NGOs.
- Provides a forum for policy discussions by decision makers and development of multi-jurisdictional emission reduction strategies, with important consideration given to concurrently changing policies for energy and climate.

Some U.S. states have very large air agencies, such as the California Air Resources Board (ARB) and the Texas Commission on Environmental Quality (TCEQ). In California, there are also multiple air pollution control or air quality management districts (APCD, AQMD) that operate in various parts of the state. These districts are county or regional governing authorities that have primary responsibility for controlling air pollution from stationary sources. Emission standards for mobile sources (automobiles, trucks, buses, railroads, airplanes, and marine vessels) are established by the EPA and the ARB. The larger air districts, such as South Coast Air Quality Management District (SCAQMD) in the greater Los Angeles area, are well funded through a combination of revenue generated by fees and federal grants. Smaller air districts are typically less well funded (fewer revenue sources, smaller federal grants) and need support from the ARB for some of their needs (such as developing standard operating procedures for monitoring, or training). In California, air agencies share data and approaches, learn from problems solved in each area, and heavily rely on university research.

Beijing is leading the way in regional planning in China with Jing-Jin-Ji (JJJ) regional plan development. Other regional planning efforts already underway include the Pearl River Delta (PRD), and the Yangtze River Delta (YRD), which includes southern Jiangsu Province.

In accordance with the State Council's air pollution prevention and control action plan, 3 provinces (Jiangsu, Zhejiang, Anhui), 1 municipality (Shanghai) and 8 departments of the central government (Ministry of Environmental Protection, National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Finance, Ministry of Housing and Urban-Rural Development, Ministry of Communication and Transportation, China Meteorological

Administration, and the National Energy Board) collaborated to develop a coordination mechanism in the YRD region, and established The Joint Conference on Air Pollution Prevention and Control in YRD Region. The office of the group is located within Shanghai EPB. The group also founded a panel consisting of professionals in various disciplines who are responsible for studying and investigating the air quality issues in the YRD region, and evaluating air pollution prevention and control measures and their effects.

8.2 ENHANCING COMMUNICATION

As part of implementation of air quality objectives, U.S. and other governments have found that citizen engagement is crucial. To engage citizens, agencies have found that it is important to present complex air quality information in understandable ways, particularly for health-related effects. This has been done in many countries using an air quality index (AQI). An AQI is often a combined set of air pollution measurements (such as NO_X, SO_2, ozone, PM) that are weighted based on their potential long-term or short-term health impacts.

Some agencies, including the Shanghai Environmental Monitoring Center (SEMC), are using systems like the U.S. EPA's AirNow-International (AirNow-I), to facilitate communication about air quality to their citizens. The goal of the AirNow-I system is to strengthen relationships among governments and international organizations by sharing the technology used by the EPA to transform air quality data into vital information for decision makers and the public. AirNow-I is a key system in EPA's efforts to promote good governance, environmental data exchange, and transparency abroad.

AirNow-I contains a suite of software programs that process, quality control, and distribute air quality data, as well as generate on-demand or pre-scheduled customized maps and files. This system can be combined with air quality forecasting to alert citizens of severe pollution episodes before they occur.

8.3 REGIONAL RESEARCH NEEDS

Both upwind sources and local emissions impact air quality in any given area. SO_2 and NO_X emissions react in the atmosphere to form $PM_{2.5}$; NO_X and VOC emissions react in the atmosphere to create ground-level ozone. All these pollutants can be transported great distances and affect air quality on local and regional scales. Transport of these pollutants across borders may make it difficult for downwind locations to meet air quality standards. To address pollutant transport in the U.S., the National Clean Air Act includes a "good neighbor" provision which requires EPA and states to address interstate transport of air pollution that affects a downwind states' ability to attain and maintain National Ambient Air Quality Standards. Each state is required to reduce emissions that could significantly contribute to nonattainment or maintenance of a standard in a downwind state.

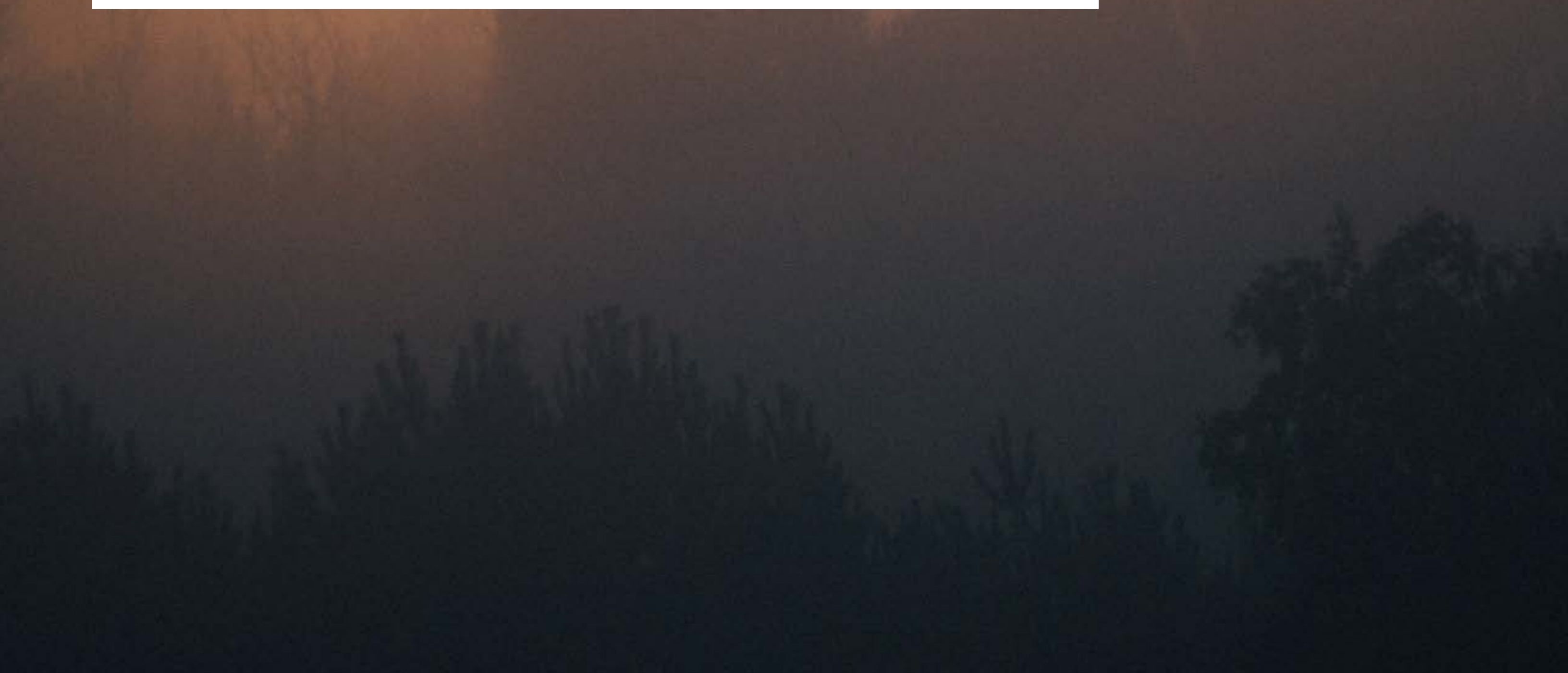
At a regional level, it is important for air agencies to identify technically and economically feasible measures and associated emissions reductions in the context of their own emissions. Agencies need to understand how much of the pollution in their area is under their control. This can be achieved by either field studies using measurements, modeling, or some combination of the two. Many regional field studies have been conducted in the U.S. and elsewhere to quantify pollutant transport and contributions to downwind air quality; these field studies were often needed as a first step because of uncertainties in the emissions inventories and a lack of understanding of the physical and/or chemical processes of pollutant transport in the area. The studies help areas focus on the emissions they can control and reduce and to collaborate with the identified upwind areas to reduce the impact of their emissions.

9

Control Options for Key Sectors

OVERVIEW

This chapter presents emission reduction strategies for $PM_{2.5}$, $PM_{2.5}$ precursors (SO_2, NO_X, and VOC), and hazardous air pollutants. The emission control options presented in this chapter focus on the industrial sectors of importance to Jiangsu: coal-fired power plants, petroleum refineries, iron and steel manufacturing, cement manufacturing, and surface coating. Within these key sectors, the emphasis is on emission control options for the most significant emission sources (e.g., emission sources with the potential to yield the greatest opportunities for emission reductions and corresponding improvements to ambient air quality). Because mobile sources are also a significant contributor to air quality issues in the Province, control options for these sources are also included. Consideration is also given to greenhouse gas emissions, specifically CO_2.



As discussed in previous chapters, Jiangsu Province has already implemented control measures for coal-fired power plants (i.e., coal-fired power boilers) and these sources have installed state-of-the-art control systems. For this industry sector, the section for coal-fired power boilers focuses on regulatory implementation efforts, including monitoring, recordkeeping, and reporting requirements, to ensure the air pollution control systems that are installed are properly and continuously operated. These implementation measures are provided to ensure that the emission reductions expected by these control systems for coal-fired boilers are actually achieved.

For the other industrial sectors, each section presents an overview of the industry sector, then highlights the primary air emission sources and relevant air emission control strategies. Applicable control technologies are identified for the range of pollutants ($PM_{2.5}$, precursors, and hazardous air pollutants) emitted from these sources. Information is presented on the typical air pollutant removal effectiveness (e.g., percent reduction) of these technologies, as applied to U.S. sources. Where possible, emission controls are identified that can address multiple pollutants (i.e., multi-pollutant strategies). The control strategies presented represent U.S. best practices for these sectors.

A selection of U.S. vendors for each of the identified emission control technologies are also presented for each industry sector. Where possible, the sections highlight U.S. vendors or suppliers who can provide state of the art emission control equipment to China.

In addition to emission control strategies, each section identifies current U.S. emission limits for selected pollutants, and the corresponding U.S. monitoring requirements (or references where the monitoring requirements may be found). Where available, the sections present expected emission reductions and control costs.

To ensure that environmental compliance officials and industrial source operators can effectively cooperate and track the parameters associated with specific emissions limits for each sector, the AQMP for Jiangsu Province should ensure that all the limits recommended for each sector are practically enforceable by including all the parameters specified in Appendix B when establishing emissions limits.

Additional recommendations for Jiangsu are provided based on U.S. "lessons learned," including, for example, issues that may have arisen during implementation of the control strategies in the U.S. These recommendations may help Jiangsu avoid some of the difficulties encountered in the U.S. as air quality management practices developed.

Information provided in this chapter can later be used in conjunction with the completed air emissions inventories to develop a "future" state where air emissions are controlled to the proposed levels. Incorporating this "future" state into a regional air quality modeling framework will then allow Jiangsu to "predict" future ambient air quality conditions based on the proposed levels of emission control.

9.1 PLAN FOR COAL-FIRED POWER BOILERS IN JIANGSU PROVINCE

As shown in Figure 9.1-1, coal is the primary source of energy used to produce electricity in China. In July of 2011, the Ministry of Environmental Protection (MEP) issued stringent standards for coal-fired power boilers. Additionally, in December of 2012, the State Council approved specific plans for financing and implementing air pollution control projects for coal-fired boilers used to generate electricity. Additional measures are planned for coal-fired power boilers in Jiangsu Province from 2014-2020 that require compliance with ultra-low emissions standards.

Figure 9.1-1 Fuel Mix for Public Power Generation[1]

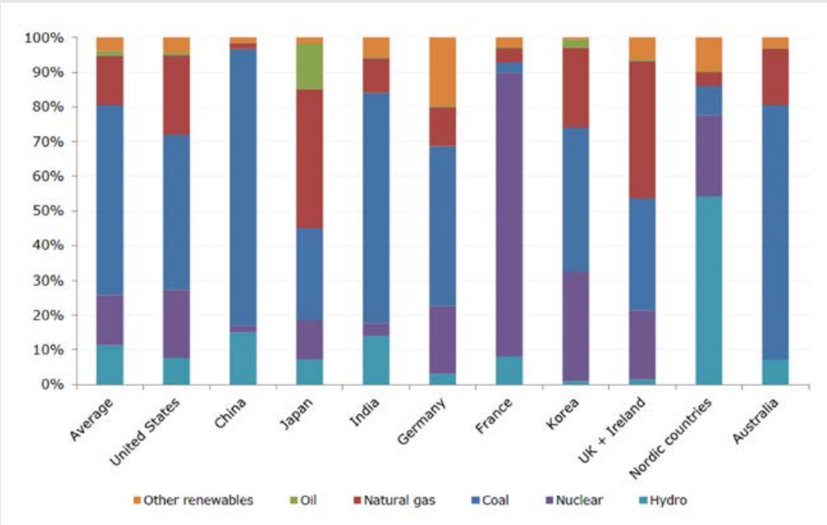


Table 9.1-1 summarizes national requirements for controlling air pollution from coal-fired power boilers. This AQMP Framework identifies specific operating parameters that should be monitored, recorded, and reported to environmental compliance officials to ensure that the coal-fired power boilers in Jiangsu Province demonstrate ongoing compliance with national standards.

Specifically, this report provides specific plans for meeting or exceeding the national standards for the following pollutants:

Section 9.1.1. Plan for NO_X Emissions from Coal-fired Power Boilers

Section 9.1.2. Plan for SO_2 Emissions from Coal-fired Power Boilers

Section 9.1.3. Plan for PM + H_2SO_4 Emissions from Coal-fired Power Boilers

Section 9.1.4. Plan for Hg Emissions from Coal-fired Power Boilers

This report recognizes that power boilers cannot operate at maximum capacity at all times because the demand for electricity is variable. This report also recognizes that changes in flue gas temperatures and flowrates that occur when coal-fired boilers go from maximum load to minimum load can adversely effect the performance of some air pollution contol systems. Accordingly, the plan includes provisions to ensure that electric utility planners specify design features on coal-fired power boilers that enable air pollution controls to reduce emissions both during periods of maximum electrical output and during periods of minimum electrical output (e.g., overnight when the demand for electricity is low).

Operators should comply with the standards discussed within this report, and should refer to the official documents at the following websites:

http://www.js.gov.cn/jsgov/tj/bgt/201411/t20141121461250.html

http://english.mep.gov.cn/standards_reports/standards/Air_Environment/Emission_standard1/201201/W020110923324406748154.pdf

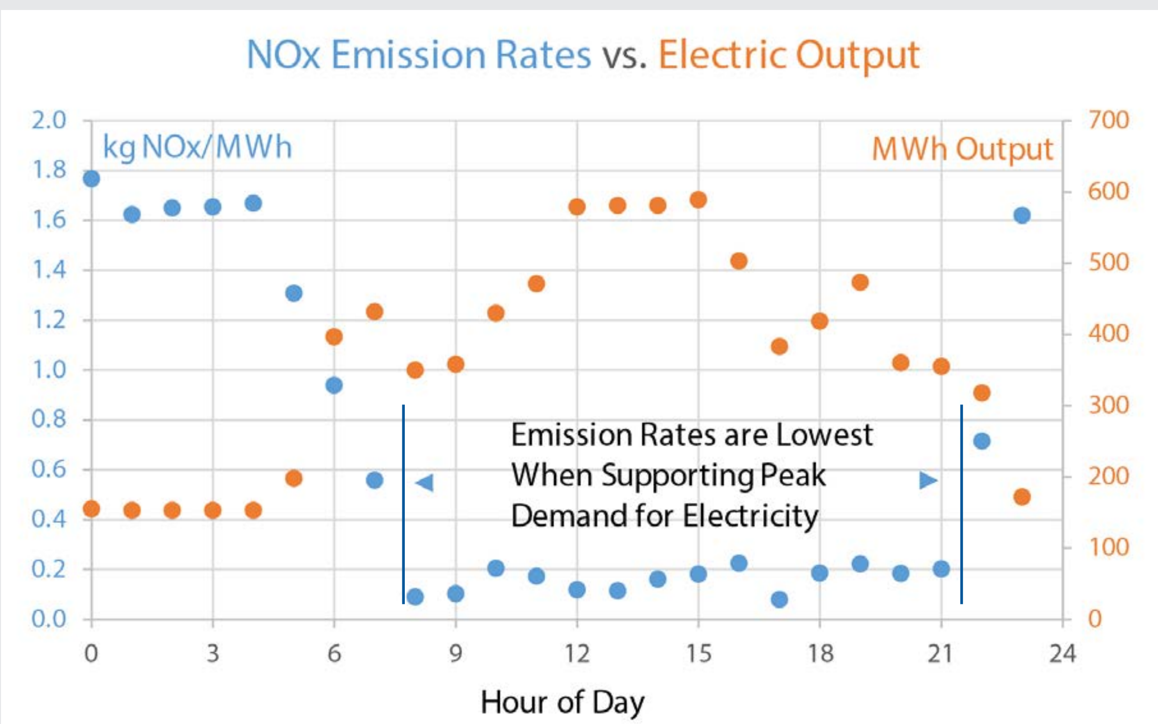
Table 9.1-1 Current National Requirements for Coal-fired Power Boilers in China

POLLUTANT	AUTHORIZING DOCUMENT	AFFECTED BOILERS	DESCRIPTION OF REQUIREMENT[2]
NO_x	Section 5.1.2 of 12th Five-Year Plan on Air Pollution Prevention and Control in Key Regions (December 2012)[3]	Existing Units With > 200 MW of generating capacity and > 20 years remaining useful life.	Install low-NO_x combustion and SCR to achieve > 85% NO_x reduction. Enhance management of existing SCRs to achieve reductions across all operating conditions (e.g., overnight).
	Jiangsu Coal-fired Power Plants Energy Saving and Emission Reduction Upgrade and Modification Action Plan (2014-2020)[4]	Units ≥ 100 MWe Generating Capacity (NO_x Group 1)	≤50 mg NO_x/m^3 at 6% O_2. NO_x as NO_2.
		Units < 100 MWe Generating Capacity (NO_x Group 2)	≤100 mg NO_x/m^3 at 6% O_2. NO_x as NO_2.
SO_2	Section 5.1.1 of 12th Five-Year Plan on Air Pollution Prevention and Control in Key Regions (December 2012)	All	Remove bypass flues for desulfurization equipment as required by rules; ensure overall desulfurization ≥ 90%.
	Jiangsu Coal-fired Power Plants Energy Saving and Emission Reduction Upgrade and Modification Action Plan (2014-2020)	Units ≥ 100 MWe Generating Capacity (SO_2 Group 1)	≤35 mg SO_2/m^3 at 6% O_2.
		Units < 100 MWe Generating Capacity (SO_2 Group 2)	≤50 mg SO_2/m^3 at 6% O_2.
PM	Jiangsu Coal-fired Power Plants Energy Saving and Emission Reduction Upgrade and Modification Action Plan (2014-2020)	Units ≥ 100 MWe Generating Capacity (PM Group 1)	≤10 mg PM/m^3 at 6% O_2.
		Units < 100 MWe Generating Capacity (PM Group 2)	≤20 mg PM/m^3 at 6% O_2.
Hg	GB 13223-2011 Emissions standard for air pollutants from thermal power plants, Table 1.	All	≤0.03 mg Hg/m^3 at 6% O_2.

9.1.1 Plan For NO_x Emissions From Coal-fired Power Boilers

Consistent with the Jiangsu Coal-fired Power Plants Energy Saving and Emission Reduction Upgrade and Modification Action Plan (2014-2020) and the State Council's *12th Five-Year Plan on Air Pollution Prevention and Control in Key Regions*, the AQMP for Jiangsu Province should require new coal-fired power boilers and existing coal-fired power boilers with ≥ 100 MW of generating capacity to install combustion technologies (i.e., burners and combustion air systems) that minimize the formation of thermal NO_x within the combustion chamber. Jiangsu's Plan should also require operators of these new and existing coal-fired boilers to install a post-combustion technology to chemically reduce NO_x formed during combustion. To meet the target limits for NO_x, the post-combustion technology specified in Jiangsu's Plan should be selective catalytic reduction (SCR). Additionally, this report recognizes that power boilers cannot operate near maximum capacity at all times. As shown in Figure 9.1-2, when power boilers that are equipped with SCR technolgies are required to operate at minimum load overnight, the temperature of the flue gas can drop below the range necessary for NO_x reduction. Therefore, the AQMP should include provisions to ensure that units equipped with SCRs are also equipped with systems to maintain flue gas temperatures between 250°C and 427°C during operations at minimum load to achieve NO_x reductions at all times consistent with Section 5.1.2 of 12th Five-Year Plan. Accordingly, the AQMP should include provisions to ensure electric utility planners incorporate design features that enable power boilers to achieve reasonable NO_x control during periods of low demand for electricity when the boiler must operate near minimum stable load and when the economizer[5] normally reduces flue gas temperatures below the minimum temperature specified for effective SCR operations.

Figure 9.1-2 Typical NO_x Emissions vs. Electricity Output Profile for a Coal-fired Unit Equipped with SCR That Must Operate at Low Loads Overnight[6]



9.1.1 (A) Plan For NO_x Group 1 Sources: Units With Electricity Generating Capacities ≥ 100 MWe

Technology Requirements

Based on the most stringent standard for NO_x (50 mg/m^3 at 6% O_2), all NO_x Group 1 coal-fired electricity generators should be required to install low-NO_x burners and combustion air systems followed by SCR technologies that are capable of reducing NO_x emissions by at least 95 percent when operating at maximum generator load. Additionally, the AQMP should require that NO_x Group 1 coal-fired electricity generators must be equipped with measures[7] to maintain flue gas temperatures in the range necessary to reduce NO_x emissions by at least 80 percent when operating at minimum stable generator load. By including specifications for SCR performance at both maximum and minimum load conditions, the AQMP will ensure that NO_x Group 1 coal-fired power boilers can comply with the national standard for NO_x emissions, on average, across all normal operating conditions.[8] These measures are necessary to reduce the 8-hour average concentrations of ozone.

Monitoring Requirements

All NO_x Group 1 coal-fired power boilers should be equipped with continuous emissions monitoring systems (CEMS) and data acquisition and handling systems (DAHS) for NO_x. The DAHS should be programmed to calculate compliance at the end of each operating day at midnight as the average concentration over the most recent 720 operating hours for new units; existing units should be allowed a longer averaging period of 1440 hours. Hours when the unit was not operating and hours when the DAHS did not record quality assured data should not be counted in the (720 or 1440) concentrations used for the daily compliance calculation.

Reporting Requirements

The AQMP should require that all operators of Group 1 coal-fired power boilers must submit to Jiangsu Environmental Protection Department a monthly summary report showing the average NO_x concentrations (at 6% O_2 as calculated per GB13223-2011 section 5.2). The monthly report should be submitted electronically within 15 days after the end of the reported month (e.g., the report for January should be submitted by February 15). The report should include the average concentration calculated at the end of each day for the preceding 720 hours (or 1440, as applicable) including only operating hours when fuel was fired in the boiler. The report should also include the following information:

1. SCR units only, method used to maintain high flue gas temperatures at SCR inlet at minimum load.
2. The date of the most recent Relative Accuracy Test Audit (RATA) for the NO_x CEMS.
3. The days during the month when the NO_x CEMS was subject to a Cylinder Gas Audit (CGA).
4. The days during the month that the NO_x CEMS failed a CGA.
5. The corrective actions taken when the NO_x CEMS failed a CGA.
6. The number of boiler operating hours required to complete the corrective action(s) before the NO_x CEMS passed a subsequent CGA. This is the number of "invalid hours" of CEMS data.
7. Certification by plant management that no "invalid hours" were included in compliance calculations during the month and that the submitted emissions calculations are accurate and complete.

Figure 9.1-3 provides a summary of the recommendations to ensure ongoing compliance for NO_x Group 1 coal-fired boilers.

Figure 9.1-3 Summary of Recommendations to Ensure Ongoing Compliance for NO_x Group 1 Coal-fired Electric Utility Boilers

AQMP Summary For NO_x Group 1

Coal-fired Electric Utility Boilers

NO_x Group 1 Includes:
Coal-fired Electric Utility Boilers serving electric generators with capacities ≥ 100 MWe.

NO_x Group 1 Technology Requirements:
The AQMP for Jiangsu Province should require that all NO_x Group 1 boilers be equipped with low-NO_x combustion systems and selective catalytic reduction (SCR) technology capable of reducing NO_x emissions by ≥ 95% at maximum load and capable of reducing NO_x emissions by ≥ 80% at minimum stable load.

NO_x Group 1 Monitoring Requirements:
The AQMP for Jiangsu Province should require that all NO_x Group 1 boilers include continuous emissions monitoring systems (CEMS) and data acquisition and handling systems (DAHS) to demonstrate compliance with the NO_x standard at midnight each day based on the average of the preceding hourly concentrations as follows:

- Group 1 boilers constructed after 12/31/2014 should calculate compliance over the most recent 720 hours during which any fuel was fired in the boiler.
- Group 1 boilers constructed before 12/31/2014 should calculate compliance over the most recent 1440 hours during which any fuel was fired in the boiler.

NO_x Group 1 Reporting Requirements:
The AQMP for Jiangsu Province should require that all operators of NO_x Group 1 coal-fired power boilers must submit to Jiangsu Environmental Protection Department a monthly summary report showing the average NO_x concentrations (at 6% O_2 per GB13223-2011 section 5.2). The monthly report should be submitted electronically within 15 days after the end of the reported month (e.g., the report for January should be submitted by February 15). The report should include the average concentration calculated at midnight for each day in the reporting month. The calculated value for each day should include the 720 hours (or 1440 hours, as applicable) that preceded midnight on the date of the calculation, including only hours when fuel was fired in the boiler. The report should also include:

1. The method use to maintain high flue gas temperatures near minimum load (SCR units only).
2. The date of the most recent Relative Accuracy Test Audit (RATA) for the NO_x CEMS.
3. The days during the month when the NO_x CEMS was subject to a Cylinder Gas Audit (CGA).
4. The days during the month that the NO_x CEMS failed a CGA.
5. The corrective actions taken when the NO_x CEMS failed a CGA.
6. The number of hours required to complete the corrective action(s) before the NO_x CEMS passed a subsequent CGA. This is the number of "invalid hours" of CEMS data.
7. A certification by the plant manager that no "invalid hours" were included in the compliance calculations during the month and that the submitted emissions calculations are accurate and complete.

9.1.1(B) Plan For NO_x Group 2 Sources: Units With Electricity Generating Capacities <100 MWe

Technology Requirements

The AQMP should also require new and existing units with <100 MW generating capacities to install combustion technologies (i.e., low-NO_x burners and combustion air systems) that minimize the formation of thermal NO_x in the combustion chamber. Sources in NO_x Group 2 should also be required to install post-combustion technology to further reduce NO_x formed during combustion. Based on the stringency of the standard for NO_x Group 2 sources (100 mg/m^3 at 6% O_2), units in Group 2 should install SCR with the design specifications shown in Table 9.1-2:

temperatures in the range necessary to reduce at least 60 percent of the NO_x exiting the furnace to N_2 and H_2O when operating at minimum load. By including specifications for SCR performance across all load conditions, the AQMP will ensure that NO_x Group 2, coal-fired power boilers can comply with the national standard for NO_x across all normal operating conditions.

Monitoring Requirements

All NO_x Group 2 power boilers should also be equipped with continuous emissions monitoring systems (CEMS) and data acquisition and handling systems (DAHS) for NO_x. The DAHS should be programmed to calculate compliance at the end of each operating day at midnight as the average

Table 9.1-2 NO_x Group 2 Post Combustion Technology Requirements

NO_x GROUP 2 POST COMBUSTION CLASSIFICATION[9]	REQUIRED POST-COMBUSTION NO_x REDUCTION TECHNOLOGY	REQUIRED DESIGN SPECIFICATION FOR MAXIMUM LOAD	REQUIRED DESIGN SPECIFICATION FOR MINIMUM LOAD	BOILER TYPES
≥ 400 ppm NO_x at 6% O_2.	SCR Required.	> 95% NO_x Reduction	> 60% NO_x Reduction	W-fired (arch-fired)
< 400 ppm NO_x at 6% O_2.	SCR Required.	> 90% NO_x Reduction	> 60% NO_x Reduction	CFB, Tangentially-fired, Wall-fired.

As shown in Table 9.1-2, the AQMP should also include provisions to ensure that electric utility planners that deploy SCR technologies must incorporate design features that enable NO_x Group 2 boilers to achieve reasonable NO_x control during periods of low demand for electricity when the boiler must operate near minimum stable load and when the economizer[5] reduces flue gas temperatures below the minimum temperature specified for effective SCR operations. The AQMP should require that NO_x Group 2 boilers that deploy SCR should include measures[7] to maintain flue gas

concentration over the most recent 720 operating hours for new units (or 1440 hours for existing units). Hours when the unit was not operating and hours when the DAHS did not record quality assured data should not be counted in the 720 (or 1440) concentrations used for the daily compliance calculation.

Reporting Requirements

All NO_x Group 2 power boilers should also submit the monthly report as described in Figure 9.1-4.

Figure 9.1-4 Summary of Recommendations to Ensure Ongoing Compliance for NO_x Group 2 Coal-fired Electric Utility Boilers

AQMP Summary For NO_x Group 2

Coal-fired Electric Utility Boilers

NO_x Group 2 Includes:
All coal-fired boilers serving electrical generators with capacities < 100 MWe.

NO_x Group 2 Technology Requirement:
The AQMP for Jiangsu Province should require that all NO_x Group 2 boilers be equipped with low-NO_x combustion systems and SCR technologies that meet the following specifications:

- For combustion systems producing ≥ 400 ppm NO_x: SCR should achieve 95 percent reduction at maximum load and 60 percent reduction at minimum load.
- For combustion systems producing < 400 ppm NO_x: SCR should achieve 90 percent reduction at maximum load and 60 percent reduction at minimum load.

NO_x Group 2 Monitoring Requirement:
The AQMP for Jiangsu Province should require that all NO_x Group 2 boilers include continuous emissions monitoring systems (CEMS) and data acquisition and handling systems (DAHS) to demonstrate compliance with the NO_x standard at midnight each day based on the average of the most recent 720 hours during which any fuel was fired in the boiler for new units and the most recent 1440 hours for existing units.

NO_x Group 2 Reporting Requirement:
The AQMP for Jiangsu Province should require that all operators of NO_x Group 2 coal-fired power boilers must submit to Jiangsu Environmental Protection Department a monthly summary report showing the average NO_x concentrations (at 6% O_2 per GB13223-2011 section 5.2). The monthly report should be submitted electronically within 15 days after the end of the reported month (e.g., the report for January should be submitted by February 15). The report should include the average concentration calculated at the end of each day for the preceding 720 or 1440 hours including only hours when fuel was fired in the boiler. The report should also include the following information:

1. The method use to maintain high flue gas temperatures near minimum load (SCR units only).
2. The date of the most recent Relative Accuracy Test Audit (RATA) for the NO_x CEMS.
3. The days during the month when the NO_x CEMS was subject to a Cylinder Gas Audit (CGA).
4. The days during the month that the NO_x CEMS failed a CGA.
5. The corrective actions taken when the NO_x CEMS failed a CGA.
6. The number of hours required to complete the corrective action(s) before the NO_x CEMS passed a subsequent CGA. This is the number of "invalid hours" of CEMS data.
7. A certification by the plant manager that no "invalid hours" were included in the compliance calculations during the month and that the submitted emissions calculations are accurate and complete.

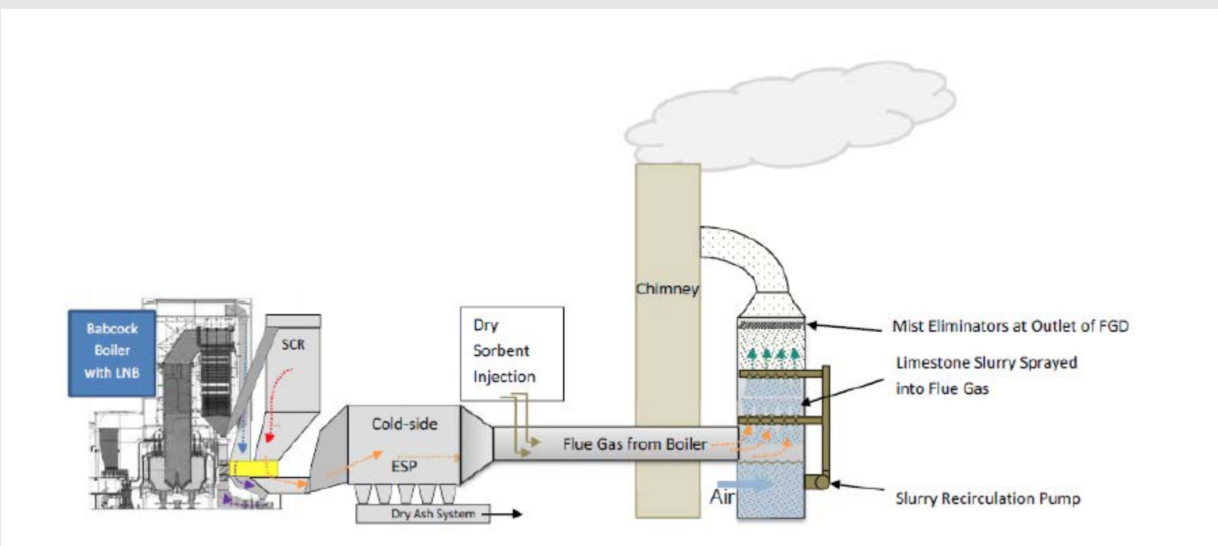
9.1.2 Plan For SO_2 Emissions From Coal-fired Power Boilers

The plan for SO_2 emissions builds on previous policies that were effectively implemented to achieve SO_2-specific goals in the State Council's 11th Five Year Plan. These policies allow operators to charge a $2.0/MWh premium if they utilize their SO_2 scrubbers continuously. Operators who do not utilize their scrubbers for at least 80% of the time must pay fines that are progressively higher as the utilization rate of the scrubber decreases.[10]

Additionally, to implement the prohibition of by-pass ducts on coal-fired boilers contained in the State Council's *12th Five-Year Plan on Air Pollution Prevention and Control in Key Regions*,[11] Jiangsu Province should implement a mandatory registration program that requires managers of existing coal-fired power boilers to certify that they have removed any previously constructed by-pass ducts that allow their boilers to operate without routing boiler flue gas though de-sulfur-ization equipment.

Also, during future environmental impact assessments for construction of new coal-fired boilers[12] that are proposed to be co-located with existing coal-fired boilers served by wet SO_2 scrubbing technologies, Jiangsu Province should require utility project planners to evaluate the environmental benefits of deploying dry SO_2 scrubbing technologies on the new coal-fired boilers. Recent coal-fired power projects in the U.S. indicate that significant synergies can be realized when wet and dry technologies are co-located at the same power plant.[13] Figure 9.1-5 provides a schematic that includes a wet scrubbing technology capable of removing 99% of the SO_2 in flue gas.

Figure 9.1-5 Simplified Schematic of Common Air Pollution Control Systems on Coal-fired Power Boilers



9.1.2 (A) Plan For SO_2 Group 1 Sources: Units Capable Of Generating ≥ 100 MW of Electrical Output

Technology Requirements

The State Council's 11th Five Year Plan and Jiangsu's Coal-fired Power Plants Energy Saving and Emission Reduction Upgrade and Modification Action Plan (2014-2020) require new units to install flue gas de-sulfurization (FGD) technologies. Either dry scrubbing technologies or wet scrubbing technologies are capable of achieving the required emissions standard for boilers serving generators with more than 100 MW of electric output capacity.[14] The factors that Jiangsu Province should consider (with regard to control of SO_2 emissions) when evaluating the environmental impacts of proposed new coal-fired electric utility boilers are summarized in Table 9.1-3.

Table 9.1-3 Factors considered by Jiangsu Province for proposed FGD technologies on New Coal-fired Power Boilers

ENVIRONMENTAL AND DEVELOPMENT FACTORS	WET SCRUBBER CONSIDERATIONS	DRY SCRUBBER CONSIDERATIONS
SO_2 Removal Efficiency > 98%, for Coals with < 1.0% Sulfur, and No FGD By-pass Ducts.	SO_2 Removals of 99% are Achievable to accommodate use of coal with <2.0% Sulfur.	98% Removal Achievable with Circulating Dry Scrubbers (CDS).
H_2SO_4 (as $PM_{2.5}$ aerosol) Removal	30 – 40% removed	>95% removed
Mercury Removal	w/ SCR and Cold-side[15] ESP >95% removed	w/ Fabric Filter >97% removed
	w/ Hot-side[16] ESP and SCR >90% removed	w/ Cold-side ESP >95% removed
$PM_{2.5}$ Emissions	w/ Cold-side ESP <10 mg/m^3	w/ Fabric Filter <10 mg/m^3
	w/ Hot-side ESP <15 mg/m^3	w/ Cold-side ESP <10 mg/m^3
Auxiliary Electricity Consumed	<2% of Generator Output	<1% of Generator Output
Wastewater Impacts	Higher Risk of Water Quality Impacts. Capital Costs ~ ($10,000 to $20,000)/MW	No wastewater produced.[17] No Capital Costs for Wastewater Treatment
Mist Eliminator Design	Periodic PM Testing Requirement or Continuous PM Monitor[18]	Not applicable.
Fabric Filter Leak Detection	Not Appliable	Bag Leak Detection Monitors.
Water Consumption[19]	~0.2 m^3/MWh	~0.1 m^3/MWh
Total Costs	($260,000 to $300,000)/MW	($320,000 to $360,000)/MW

Monitoring Requirements

All new coal-fired power boilers should be equipped with continuous emissions monitoring systems (CEMS) and data acquisition and handling systems (DAHS) for SO_2. The DAHS should be programmed to calculate compliance at the end of each operating day at midnight as the average concentration over the most recent 720 operating hours. Hours when the unit was not operating and hours when the DAHS did not record quality assured data should not be counted in the 720 concentrations used for the daily compliance calculation.

Reporting Requirements

The AQMP for Jiangsu Province should require that all operators of SO_2 Group 1 coal-fired power boilers must submit to Jiangsu Environmental Protection Department a monthly summary report showing the average SO_2 concentrations (at 6% O_2 per GB13223-2011 section 5.2). The monthly report should be submitted electronically within 15 days after the end of the reported month (e.g., the report for January must be submitted by February 15). The report should include the average concentration calculated at the end of each day for the preceding 720 hours including only hours when fuel was fired in the boiler. The report should also include the following information:

1. The maximum sulfur content of any fuel burned during the reporting period.
2. The date of the most recent Relative Accuracy Test Audit (RATA) for the SO_2 CEMS.
3. The days during the month when the SO_2 CEMS was subject to a Cylinder Gas Audit (CGA).
4. The days during the month that the SO_2 CEMS failed a CGA.
5. The corrective actions taken when the SO_2 CEMS failed a CGA.
6. The number of hours required to complete the corrective action(s) before the SO_2 CEMS passed a subsequent CGA. This is the number of "invalid hours" of CEMS data.
7. A certification by the plant manager that no "invalid hours" were included in the compliance calculations during the month and that the submitted emissions calcuations are accurate and complete.

Figure 9.1-6 provides a summary of the recommendations to ensure ongoing compliance for SO_2 Group 1 coal-fired power boilers.

Figure 9.1-6 Summary of Recommendations to Ensure Ongoing Compliance for SO_2 Group 1 Coal-fired Electric Utility Boilers

AQMP Summary For SO_2 Group 1

Coal-fired Electric Utility Boilers

SO_2 Group 1 Includes:
All coal-fired power boilers serving generators with capacities ≥ 100 MWe.

SO_2 Group 1 Technology Requirement:
The AQMP for Jiangsu Province should require that all SO_2 Group 1 boilers should be limited to using coal with a sulfur content ≤ 1.0% and should be equipped with a de-sulfurization technology that can remove ≥ 98% of the SO_2 in flue gas.

SO_2 Group 1 Monitoring Requirement:
The AQMP for Jiangsu Province should require that all SO_2 Group 1 boilers include continuous emissions monitoring systems (CEMS) and data acquisition and handling systems (DAHS) to demonstrate compliance with the SO_2 standard at midnight each day based on the average of the most recent 720 hours during which any fuel was fired in the boiler.

SO_2 Group 1 Reporting Requirement:
The AQMP for Jiangsu Province should require that all operators of SO_2 Group 1 coal-fired power boilers must submit to Jiangsu Environmental Protection Department a monthly summary report showing the average SO_2 concentrations (at 6% O_2 per GB13223-2011 section 5.2). The monthly report should be submitted electronically within 15 days after the end of the reported month (e.g., the report for January should be submitted by February 15). The report should include the average concentration calculated at the end of each day for the preceding 720 hours including only hours when fuel was fired in the boiler. The report should also include the following information:

1. The maximum sulfur content of any fuel burned during the reporting period.
2. The date of the most recent Relative Accuracy Test Audit (RATA) for the SO_2 CEMS.
3. The days during the month when the SO_2 CEMS was subject to a Cylinder Gas Audit (CGA).
4. The days during the month that the SO_2 CEMS failed a CGA.
5. The corrective actions taken when the SO_2 CEMS failed a CGA.
6. The number of hours required to complete the corrective action(s) before the SO_2 CEMS passed a subsequent CGA. This is the number of "invalid hours" of CEMS data.
7. A certification by the plant manager that no "invalid hours" were included in the compliance calculations during the month and that the submitted emissions calculations are accurate and complete.

9.1.2(B) Plan For SO_2 Group 2 Sources: Units Capable Of Generating <100 MW of Electrical Output

Technology Requirements

The national standards require SO_2 Group 2 Power Boilers to install flue gas de-sulfurization (FGD) technologies (that can remove more than 98 percent of the SO_2 from flue gas when firing coal with a sulfur content of up to 1.4 percent) or to burn lower sulfur coals in conjunction with an FGD system with a lower removal efficiency. Both dry scrubbing technologies and wet scrubbing technologies are capable of achieving the required emissions standard[20] for existing sources.

Monitoring Requirements

All existing coal-fired power boilers should be equipped with continuous emissions monitoring systems (CEMS) and data acquisition and handling systems (DAHS) for SO_2. The DAHS should be programmed to calculate compliance at the end of each operating day at midnight as the average concentration over the most recent 720 operating hours. Hours when the unit was not operating and hours when the DAHS did not record quality assured data should not be counted in the 720 concentrations used for the daily compliance calculation.

Jiangsu Province has effective programs in place for monitoring the SO_2 emission rates of Group 2 sources. All Group 2 sources are equipped with SO_2 CEMS and are electronically connected to a central monitoring station operated by Jiangsu Province. Table 9.1-4 provides a summary of the initatives in Jiangsu Province related to maintaining the environmental performance of coal-fired power boiler.

Table 9.1-4 Initiatives by Jiangsu Province for Monitoring and Maintaining Good FGD Performance on Coal-fired Power Boilers

INITIATIVE	BENEFIT
Attempt to Locate New Coal-fired Boilers with Dry Scrubbers at Existing Sites with Wet Scrubbers to Reduce Water Quality Impacts	Better management of wastewater from existing wet scrubbers will reduce build-up of dissolved solids in scrubber liquor and reduce erosion of nozzles and internal scrubber components. Also reduces water consumption.
Reduce H_2SO_4 Emissions (as $PM_{2.5}$ aerosol) from Existing Units with Wet Scrubbers	Particularly on existing units controlled by SCR, add dry-sorbent, hydrated lime injection systems in ducts upstream of wet scrubber to reduce the quantity of $PM_{2.5}$ being emitted as H_2SO_4.
Monitor chlorides content in scrubber liquor to ensure re-emission of captured mercury does not occur	When the concentration of chlorides in FGD slurry goes above threshold value oxidized Hg that is dissolved in scrubber liquor can be be converted to insoluble form and re-emitted.
Wastewater Treatment and Discharge Impacts	Monitor all discharges to surface waters (rivers, lakes etc.) to ensure high levels of heavy metals (selenium, arsenic, mercury) are not being released from scrubber wastewater stream.
Mist Eliminator Design	Require periodic PM Testing or installation of Continuous PM Monitor to ensure proper operation of mist eliminators on wet FGD systems.[18]
Fabric Filter Leak Detection	On units controlled by fabric filters require installation of bag leak detection monitors or continuous PM monitors to ensure proper maintainance of PM control device.

Reporting Requirements

All SO_2 Group 2 power boilers should also submit the monthly report as described in Figure 9.1-7.

Figure 9.1-7 Summary of Recommendations to Ensure Ongoing Compliance for SO_2 Group 2 Coal-fired Electric Utility Boilers

AQMP Summary For SO_2 Group 2

Coal-fired Electric Utility Boilers

SO_2 Group 2 Includes:
All coal-fired power boilers serving generators with capacities < 100 MWe.

SO_2 Group 2 Technology Requirement:

The AQMP for Jiangsu Province should require that all SO_2 Group 2 boilers should be limited to using coal with a sulfur content ≤ 1.4% and should be equipped with a de-sulfurization technology that can remove ≥ 98% of the SO_2 in flue gas.

SO_2 Group 2 Monitoring Requirement:

The AQMP for Jiangsu Province should require that all SO_2 Group 2 boilers include continuous emissions monitoring systems (CEMS) and data acquisition and handling systems (DAHS) to demonstrate compliance with the SO_2 standard at midnight each day based on the average of the most recent 720 hours during which any fuel was fired in the boiler.

SO_2 Group 2 Reporting Requirement:

The AQMP for Jiangsu Province should require that all operators of SO_2 Group 2 coal-fired power boilers must submit to Jiangsu Environmental Protection Department a monthly summary report showing the average SO_2 concentrations (at 6% O_2 per GB13223-2011 section 5.2). The monthly report should be submitted electronically within 15 days after the end of the reported month (e.g., the report for January should be submitted by February 15). The report should include the average concentration calculated at the end of each day for the preceding 720 hours including only hours when fuel was fired in the boiler. The report should also include the following information:

1. The maximum sulfur content of any fuel burned during the reporting period.
2. The date of the most recent Relative Accuracy Test Audit (RATA) for the SO_2 CEMS.
3. The days during the month when the SO_2 CEMS was subject to a Cylinder Gas Audit (CGA).
4. The days during the month that the SO_2 CEMS failed a CGA.
5. The corrective actions taken when the SO_2 CEMS failed a CGA.
6. The number of hours required to complete the corrective action(s) before the SO_2 CEMS passed a subsequent CGA. This is the number of "invalid hours" of CEMS data.
7. A certification by the plant manager that no "invalid hours" were included in the compliance calculations during the month and that the submitted emissions calculations are accurate and complete.

Figure 9.1-8 Photo of Modern Coal-fired Power Plant in China[21]

9.1.3 Plan For PM Emissions From Coal-fired Power Boilers

The national standards for PM emissions require that coal-fired power boilers serving generators with electrical outputs greater than 100 MWe achieve an emission rate ≤ 10 mg PM/m^3 at 6 percent O_2. Coal-fired boilers serving generators with < 100 MWe output must achieve an emission rate ≤ 20 mg PM/m^3. Jiangsu Province's plan for PM emissions should be closely related to prior initiatives to reduce SO_2 emissions. U.S. experience indicates that the national emissions standards are achievable by coal-fired power boilers that are equipped with the following air pollution control technologies:

- Electro-static precipitators (that are positioned after the combustion air pre-heater),
- Wet FGD systems, and
- Particulate matter continuous emissions monitoring systems (PM CEMS).

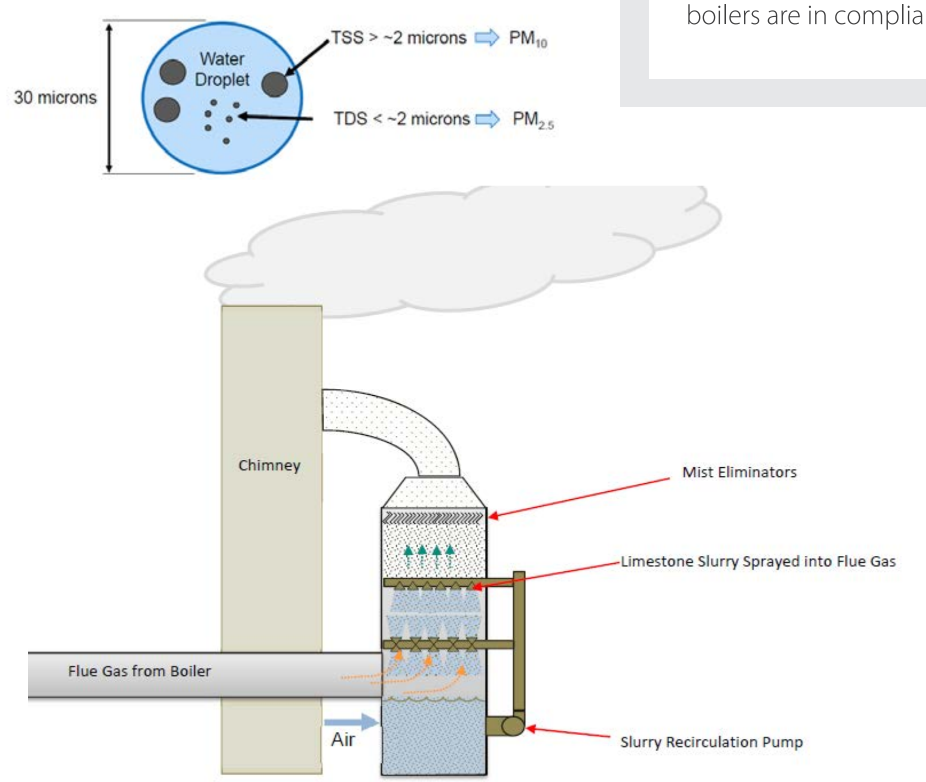
Such control systems can achieve steady emission rates of less than 10 mg/m^3. Similarly, fabric filters and ESPs installed after dry scrubbing systems are capable of complying with the national PM standard. Table 9.1-5 presents a summary of the initiatives planned for ensuring that PM emissions from coal-fired power boilers are in compliance with the national standard:

Table 9.1-5 Jiangsu Province's Initiatives for Ensuring Compliance with National PM Standard for Coal-fired Power Boilers

AFFECTED SOURCES	INITIATIVE	BENEFIT
Sources controlled by wet FGD systems	Require periodic PM stack tests or installation of Continuous PM Monitor (with annual stack tests for PM CEMS validation) to ensure proper operation of mist eliminators.[18]	Proper operation of mist eliminators is necessary to prevent emissions of $PM_{2.5}$ as dissolved solids within entrained droplets of scrubber solution. See Figure 9.1-9.
	When periodic PM stack tests are used, also require monitoring and reporting of total dissolved solids (TDS) and chloride content of wet scrubber liquor. To ensure TDS values remain within range observed during stack tests. Not required for stacks monitored with PM CEMS.	Low concentrations reduce the build-up of residues on mist eliminator surfaces. When residues buid up on mist eliminators water droplets that contain $PM_{2.5}$ as dissolved solids can pass through the mist eliminator.
	• Identify existing units controlled by SCR. • Require stack test for Total PM (tPM) = filterable PM (fPM) + condensible PM (cPM).[22] • For sources where cPM portion causes tPM to exceed national standard, require installation of dry-sorbent, hydrated lime injection systems upstream of wet scrubber to reduce the quantity of cPM being emitted as H_2SO_4.	Reduce H_2SO_4 Emissions (as $PM_{2.5}$ aerosol) from Existing Units with Wet Scrubbers.
Sources controlled by dry FGD systems	On units controlled by fabric filters, require installation of bag leak detection monitors. On units controlled by ESP require continuous PM monitors to ensure proper maintainance of PM control device.	Malfunctions of PM controls can be detected quickly to minimize the duration of excess PM emissions.

The wet FGD systems that have been installed in Jiangsu Province can be effectively operated to achieve steady emission rates ≤ 10 mg/m^3. However, the dissolved solids in scrubber liquor should be closely monitored and mist eliminator systems should be properly designed and maintained to ensure that the PM that is captured by the wet scrubber is not re-emitted. Additionally, the wash-water used to clean the mist eliminators should not contain dissolved solids. Figure 9.1-9 provides a schematic of a typical wet FGD system.

Figure 9.1-9 Schematic of a wet FGD system



9.1.4 Plan For Hg Emissions From Coal-fired Power Boilers

The national standard for Hg emissions under GB 13223-2011 requires that all coal-fired power boilers achieve an emission rate ≤ 0.03 mg Hg/m^3 at 6 percent O_2. Jiangsu Province's plan for PM emissions should be closely related to prior initiatives to reduce SO_2 emissions. U.S. experience on coal-fired power boilers that are equipped with wet FGD systems and continuous Hg monitors (Hg CEMS) indicates that wet FGD scrubbers can achieve steady emission rates of less than 0.03 mg/m^3. Similarly, fabric filters and ESPs installed after dry scrubbing systems are capable of complying with the national Hg standard. Table 9.1-6 presents a summary of the initiatives planned for ensuring that Hg emissions from coal-fired power boilers are in compliance with the national standard:

Table 9.1-6 Jiangsu Province Initiatives for Ensuring Compliance with National Hg Standard for Coal-fired Power Boilers

AFFECTED SOURCES	INITIATIVE	BENEFIT
Sources controlled by wet FGD systems	Require periodic Hg stack tests or installation of Continuous Hg Monitor (with annual stack tests for Hg CEMS validation) to ensure scrubber chemistry remains compatible with Hg removal.[23]	Maintaining Hg in oxidized state ensures Hg is not emitted to atmosphere. See Figure 9.1-10 for typical removal pathways for Hg in Eastern bituminous coal.
	When periodic Hg stack tests are used, also require monitoring and reporting of chloride content and oxydation reduction potential (ORP) of wet scrubber liquor. To ensure ORP and Cl- values remain within range observed during stack tests. Not required for stacks monitored with Hg CEMS.	If monitoring indicates that re-emission is occuring additives can be added to prevent re-emission of Hg to atmosphere.
Sources controlled by dry FGD systems	On units controlled by fabric filters or ESPs, require installation of Hg CEMS. If emissions are above standard require installation of activated carbon injection system.	Hg CEMS in conjunction with activated carbon injection systems allow operators to inject activated content as needed based on the variable Hg content of coals received.

Figure 9.1-10 Typical Hg Removal Profile for a Coal-fired Unit Equipped with SCR, Cold-side ESP and Wet-FGD[24]

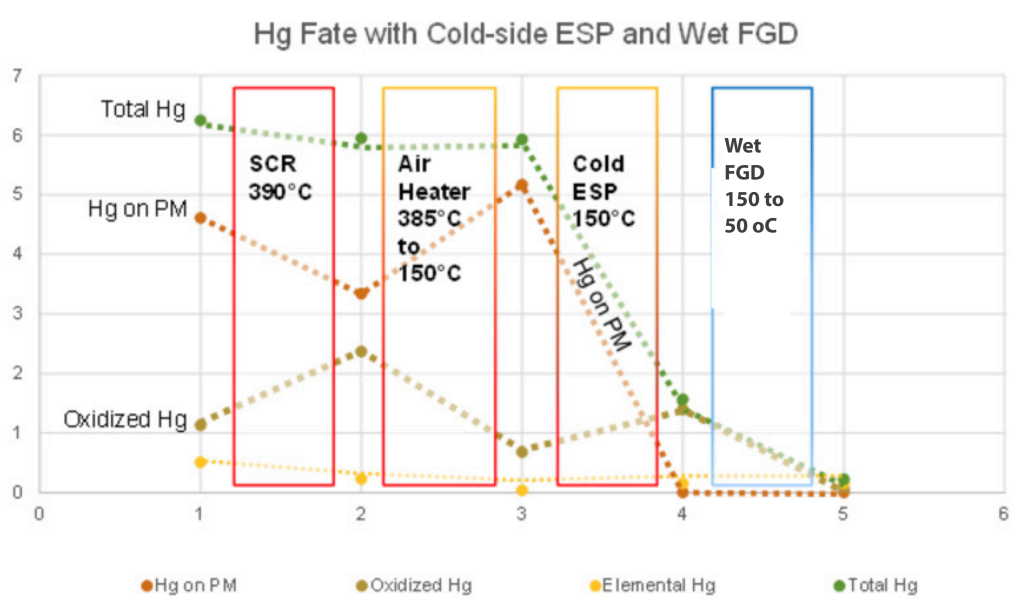


Table 9.1-7 Overview of Air Pollution Control Technologies for Coal-fired Power Boilers

TARGET POLLUTANT	BEST TECHNOLOGIES
Nitrogen Oxides (NO_x)	Low-NO_X Burners (LNB) **and**
	Selective Catalytic Reduction (SCR) **and**
	Economizer By-pass (or Equivalent Measures to Maintain High Flue Gas Temperatures at Low Loads).
Particulate Matter (PM)	Fabric Filter **or**
	Electro-static Precipitator (ESP)
Sulfur Dioxide (SO_2)	Wet Flue Gas Desulfurization with Wet Spray Tower Absorber, High-efficiency Mist Eliminators, and Wastewater Treatment System **or**
	Dry Flue Gas Desulfurization with Circulating Dry Scrubber (no wastewater treatment system required).
Sulfuric Acid Mist (H_2SO_4)	Dry Sorbent Injection System to Supplement Wet FGD (not required with dry FGD systems).
Mercury (Hg)	Activated Carbon Injection (ACI) Upstream of PM Control Device.

Table 9.1-8 Typical Air Quality Operating Permit Limits and Monitoring Technologies for Modern Coal-fired Power Boilers

TARGET POLLUTANT	EMISSIONS LIMIT[25]	AVERAGING PERIOD	MONITORING TECHNOLOGY
Nitrogen Oxides (NO_x)	50 mg/m^3 at 6% O_2	30 Day Rolling Average	NO_X CEMS - Dilution Extractive, Chemiluminescence.
Particulate Matter (PM)	10 mg/m^3 at 6% O_2	24 Hour Block Average	PM CEMS – Forward Light Scatter. Instrument Must Meet USEPA PS-11 and 40 CFR Part 60, Appendix F, Procedure 2 or Comparable QA Specifications.
Sulfur Dioxide (SO_2)	35 mg/m^3 at 6% O_2	30 Day Rolling Average	SO_2 CEMS – Dilution Extractive, UV Fluorescence.
Sulfuric Acid Mist (H_2SO_4)	5 mg/m^3 at 6% O_2	6 Hours	Semi-annual Stack Test Method CTM-013A or Comparable Method. http://www3.epa.gov/ttnemc01/ctm/ctm-013A.pdf
Mercury (Hg)	0.002 mg/m^3 at 6% O_2	12 Month Rolling Average	Hg CEMS – Cold Vapor Atomic Fluorescence or Sorbent Trap Monitoring System

Figure 9.1-11 Typical Footprint of a Wet FGD System Producing High-quality Gypsum

Figure 9.1-12 Typical Analyses of FGD Wastewater[26]

Table 1. FGD Wastewater Characteristics

Parameter	Unit	Typical Influent Range
Suspended Solids (TSS)	mg/L	250 - 20,000
Total Dissolved Solids (TDS)	mg/L	15,000 – 35,000
pH		4 – 6
Chloride (Cl)	mg/L	10,000 – 25,000
COD	mg/L	200 – 500
Ammonia (NH_4)	mg/L	20 – 60
Nitrate (NO_3)	mg/L	30 – 120
Calcium (Ca)	mg/L	300 - 5,000
Magnesium (Mg)	mg/L	50 - 4,000
Sulfate (SO_4)	mg/L	3,000 – 5,000
Fluoride (F)	mg/L	40 – 100
Aluminum (Al)	mg/L	20 – 200
Arsenic (As)	mg/L	0.5 – 0.8
Boron (B)	mg/L	1-10
Cadmium (Cd)	mg/L	0.05 – 0.1

Parameter	Unit	Typical Influent Range
Chromium (Cr)	mg/L	0.3 – 1
Cobalt (Co)	mg/L	0.1 – 0.8
Copper (Cu)	mg/L	0.2 – 0.8
Iron (Fe)	mg/L	80 – 400
Mercury (Hg)	mg/L	0.01 – 0.8
Nickel (Ni)	mg/L	2 – 7
Lead (Pb)	mg/L	0.5 – 1.5
Zinc (Zn)	mg/L	0.5 – 1.0
Manganese (Mn)	mg/L	3-20
Selenium (Se)	mg/L	1-4
Vanadium (V)	mg/L	2-15
$Si0_2$	mg/L	50-300

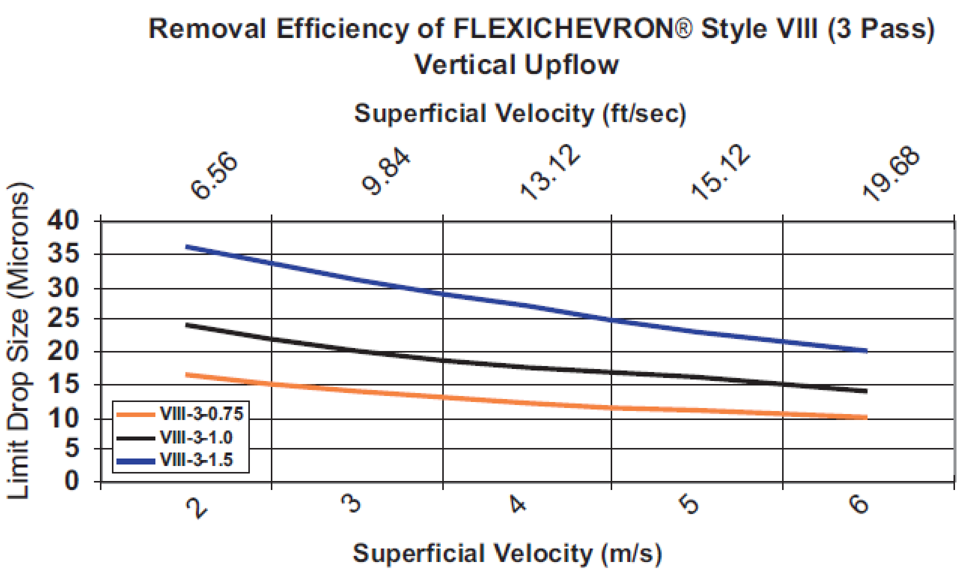
Michael L. Pudvay
Infilco Degremont, Richmond, VA

Mist eliminators require high velocities to remove micron-scale water droplets, and must have proven designs that prevent re-entrainment of captured droplets. If well-designed mist eliminators are not installed at the exit of wet FGD spray towers, the water droplets that escape in the exhaust will carry significant quantities of fine particulate and, upon evaporation of the water droplet, contribute significant PM emissions to ambient air. Figure 9.1-13 presents a photo of a typical mist eliminator system.

Removal efficiency of mist eliminators is a function of superficial velocity. Well-designed mist eliminators can remove more than 99 percent of droplets larger than 10 microns. The coal-fired power boiler's variable load conditions (and associated variable flue-gas velocities) should be considered when designing the mist eliminator system to ensure that the design specification enables removal of water droplets at all operating conditions. Figure 9.1-14 presents mist eliminator removal efficiency for an example design.

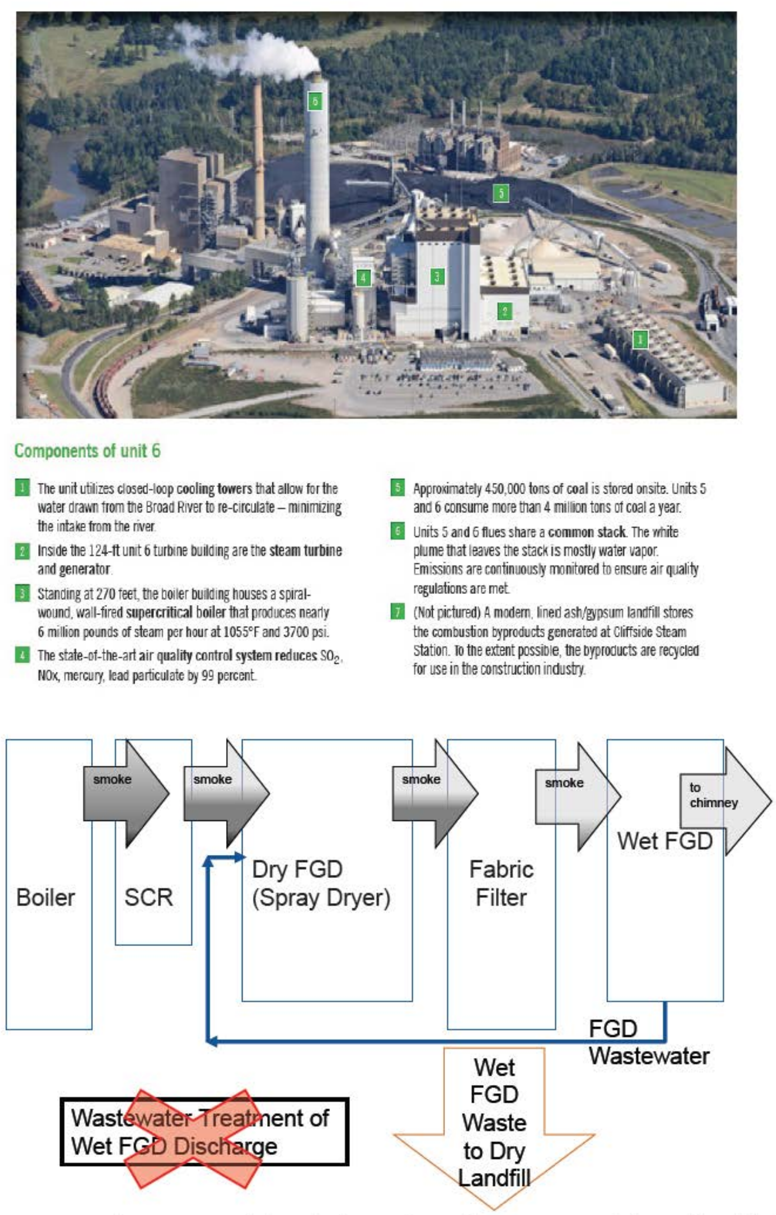
Figure 9.1-13 **Typical Mist Eliminator System**[27]

Figure 9.1-14 **Removal Efficiency of FLEXICHEVRON Style VIII (3 Pass) Vertical Upflow**[28]



The newest coal plant in the U.S. has a dry FGD system followed by a fabric filter and wet FGD system to eliminate the need for a wastewater treatment system and to produce higher quality gypsum. This arrangement also tends to reduce the rate of accumulation of dissolved solids in the scrubber liquor. Figure 9.1-15 provides an illustration of a coal-fired boiler control system configuration used to eliminate wastewater discharge.

Figure 9.1-15 Illustration of Coal-fired Boiler Control System Configuration Used to Eliminate Wastewater Discharge[29]

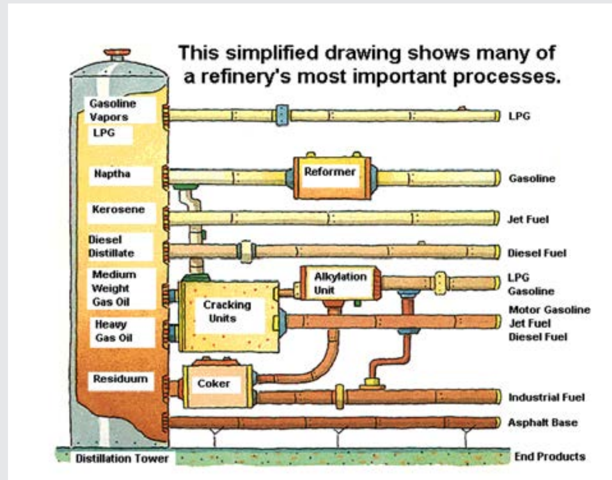


9.2 PETROLEUM REFINERIES

9.2.1 Background

Petroleum refineries are facilities that are engaged in producing liquefied petroleum gases (LPG), motor gasoline, jet fuels, kerosene, distillate fuel oils, residual fuel oils, lubricants, asphalt (bitumen), and other products through distillation of crude oil or through redistillation, cracking, or reforming of unfinished petroleum derivatives. There are three basic types of refineries: "topping," "hydroskimming," and "upgrading" (also referred to as "conversion" or "complex"). Topping refineries have a crude distillation column and produce naphtha and other intermediate products, but not gasoline. Hydroskimming refineries have mild conversion units such as hydrotreating units and/or reforming units to produce finished gasoline products, but they do not upgrade heavier components of the crude oil that exit near the bottom of the crude distillation column. Upgrading/conversion refineries have cracking or coking operations to convert long-chain, high molecular weight hydrocarbons ("heavy distillates") into smaller hydrocarbons that can be used to produce gasoline products ("light distillates") and other higher value products and petrochemical feedstocks. Figure 9.2-1 presents a simplified view of an upgrading refinery and the types of products produced.

Figure 9.2-1 Simplified Schematic of Common Refinery Process Units and Products[30]



Petroleum refineries are large facilities with a variety of different emission sources releasing multiple pollutants, including PM, SO_2, NO_x, VOC, and CO_2. The relative importance of the different sources are dependent on the processes present at a given refinery and the emission control systems used. Key emission sources for each pollutant type are briefly discussed.

9.2.2 Refinery PM Emission Sources And Controls

The fluid catalytic cracking unit (or FCCU) catalyst regenerator, if present, is typically the largest single source of PM emissions at the refinery. The U.S. nationwide contribution of refinery sources to $PM_{2.5}$ emissions is provided in Figure 9.2-2. For refineries that do not have an FCCU, process heaters, boilers, and cooling towers are the dominant sources of PM emissions at the refinery. Coke production and handling, if present, and flares may also contribute to PM emissions from the refinery.

Figure 9.2-2 Contribution of Refinery $PM_{2.5}$ Emissions by Source Type in the U.S.[31]

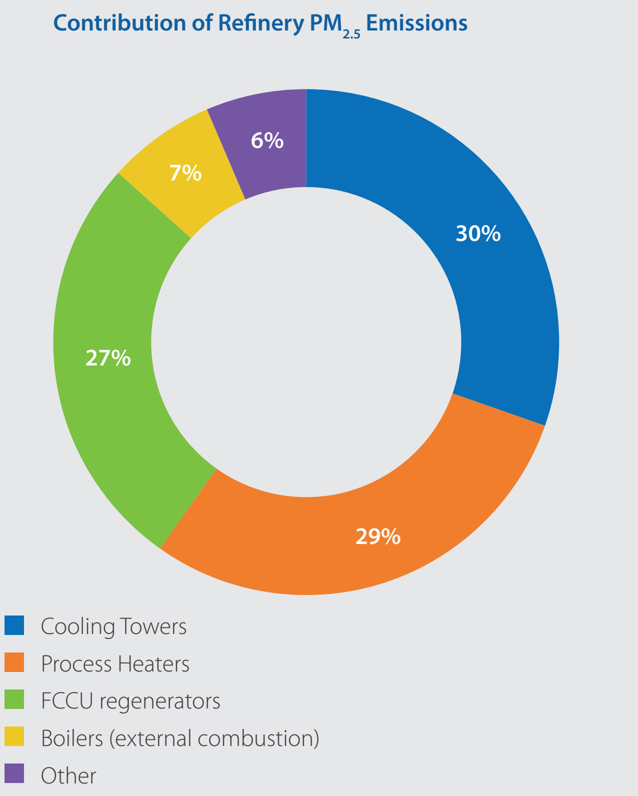


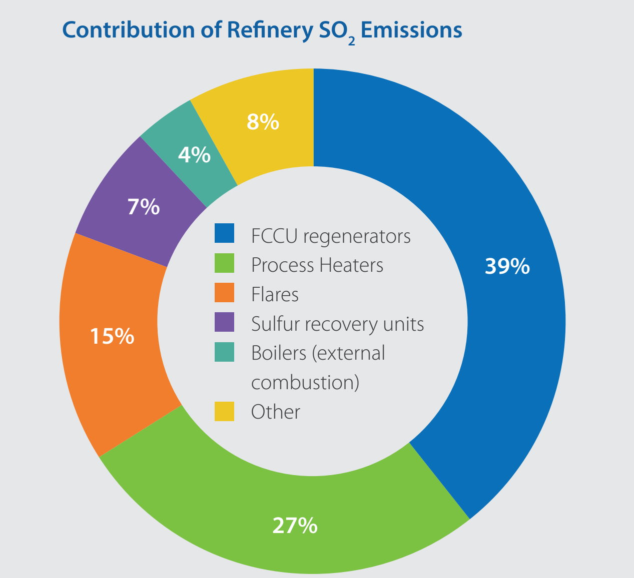
Figure 9.2-3 Photograph of BELCO EDV Wet Scrubber Controlling FCCU Regenerator Emissions[32]

The most common PM control system for FCCU is either an electrostatic precipitator (ESP) or a wet scrubber. Figure 9.2-3 is a photograph of a wet scrubber controlling FCCU regeneration emissions. Use of refinery fuel gas for process heaters or boilers rather than fuel oil can reduce PM emissions from process heaters and boilers. Alternatively, ESP, wet scrubber, or baghouse could be used to control emissions from process heaters or boilers that have high PM emissions (burning coke or heavy fuel oil). Mist eliminators can be used to reduce PM emissions from cooling towers.

9.2.3 Refinery SO_2 Emission Sources And Controls

The FCCU catalyst regenerator, if present, is typically the largest source of SO_2 emissions at the refinery. Heaters and boilers can also be significant sources of SO_2 emissions, particularly if sulfur compounds are not removed from fuel gas prior to the combustion source. Figure 9.2-4 shows the relative contribution of refinery emission sources to the U.S. nationwide refinery SO_2 emissions.

Figure 9.2-4 Contribution of Refinery SO_2 Emissions by Source Type in the U.S.[31]

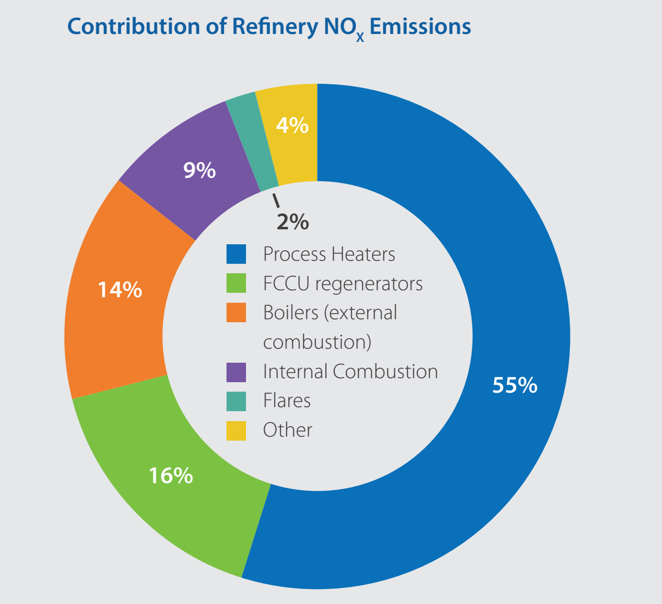


Wet scrubbers used for FCCU PM emission control also get excellent SO_2 emission control. When an FCCU has an ESP for PM emission control, catalyst additives can be used to reduce SO_2 emissions from the FCCU. Use of sweetened refinery fuel (fuel gas for which hydrogen sulfide has been removed via an amine scrubbing system) rather than untreated refinery fuel gas or heavy fuel oils can be used to reduce SO_2 emissions from process heaters and boilers. Adequate sulfur recovery capacity will be needed to recover the sulfur removed from the refinery fuel gas (in order to prevent transferring the SO_2 emissions from process heaters and boilers to sulfur recovery units and/or flares). For process heaters, boilers, and coking units that have high SO_2 emissions, traditional post-combustion controls, such as a wet scrubber, can be used to reduce SO_2 emissions from these sources. Sulfur recovery emissions can be reduced by using a tail gas treatment unit to improve the overall efficiency of the sulfur recovery unit or by using a wet scrubber control.

9.2.4 Refinery NO_x Emission Sources And Controls

Process heaters and boilers are the largest source of NO_x emissions at the refinery. Other combustion sources, such as the FCCU catalyst regenerator, internal combustion engines and flares may also contribute to NO_x emissions. Figure 9.2-5 shows the relative contribution of refinery emission sources to the U.S. nationwide refinery NO_x emissions.

Figure 9.2-5 Contribution of Refinery NO_x Emissions by Source Type in the U.S.[31]



Emission reductions of NO_x can be achieved by improved combustion control systems (controlling excess air amounts) and ultra-low NO_x burner systems. For large combustion sources (large boilers or FCCU catalyst regenerators), selective catalytic reduction (SCR) or, for FCCU equipped with wet scrubbers, LoTox control systems may be used. There are also catalyst additives that may help to reduce NO_x emissions from the FCCU catalyst regenerator.

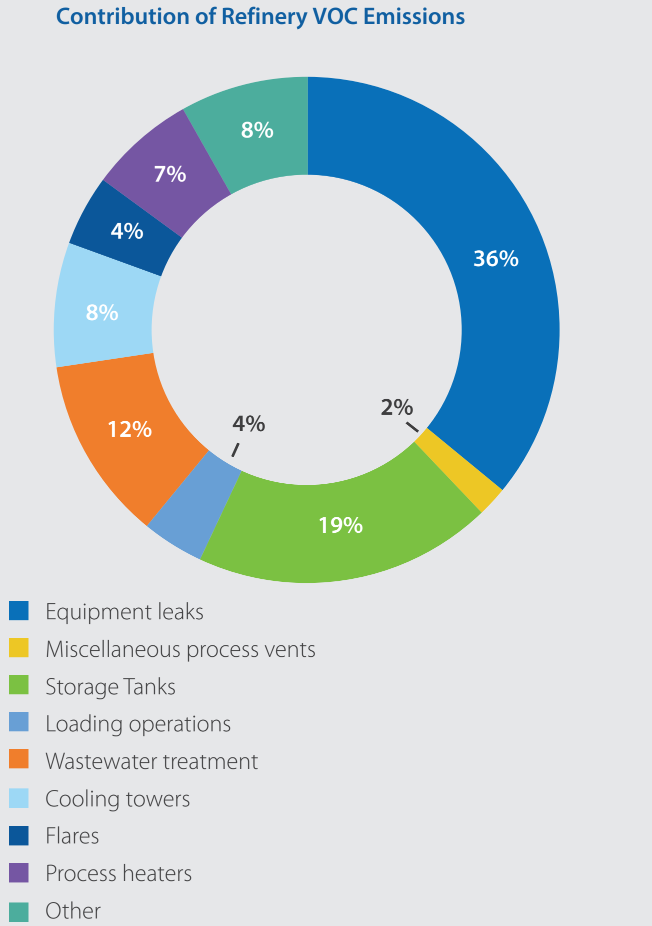
9.2.5 Refinery VOC Emission Sources And Controls

VOC emissions occur from a wide variety of sources at the petroleum refinery including leaking equipment components (leaks around valve stems or pump seals), storage tanks, wastewater collection and treatment, cooling towers, and transfer operations, such as tanker truck loading, railcar loading, and marine vessel loading. Figure 9.2-6 shows the relative importance of various VOC emissions sources at petroleum refineries.

VOC emissions control is dependent on the source type. Typical VOC emission reduction methods are outlined below:

- Equipment leaks: leak detection and repair program
- Storage tanks: internal or external floating roofs or vent to a control device
- Wastewater treatment system: cover and use water seals for collection system, cover tanks until treatment (steam stripping or biological treatment unit)
- Cooling towers: leak detection and repair program
- Loading operations: vapor balancing or vent to a control device
- Process vents: vent to control device
- Process heaters, boilers, flares: operate with adequate combustion (excess air, CO levels less than 500 ppmv)

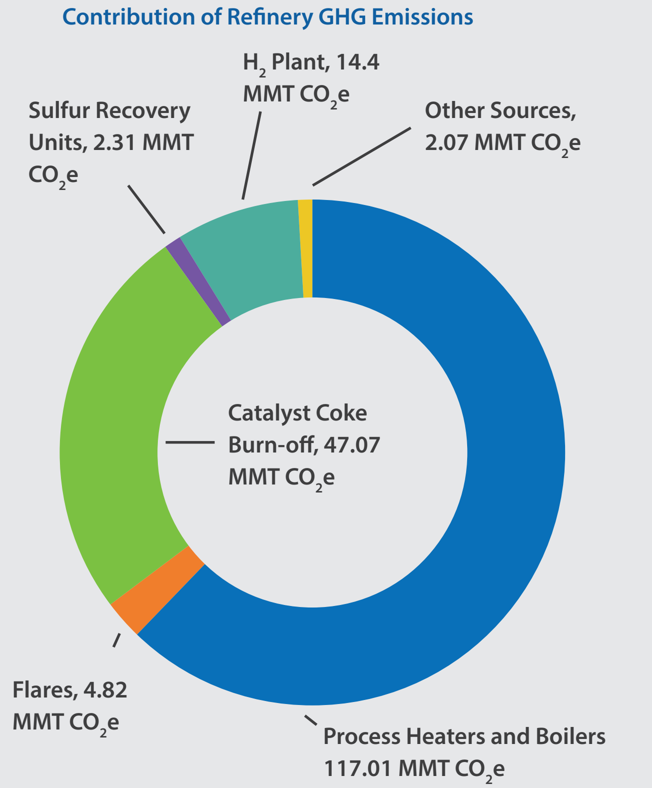
Figure 9.2-6 Contribution of Refinery VOC Emissions by Source Type in the U.S.[31]



9.2.6 Refinery GHG Emission Sources And Controls

Carbon dioxide is the most significant greenhouse gas emitted from petroleum refineries, but some processes also release methane. Most of the CO_2 generated is the result of fuel combustion in process heaters or boilers. For refineries with FCCU, a significant amount of CO_2 is generated during the catalyst regeneration process. Many refinery processes require hydrogen, and hydrogen production is another significant source of CO_2 emissions. Figure 9.2-7 shows the relative importance of various GNG emission sources at petrolium refineries.

Figure 9.2-7 Contribution of Refinery GHG Emissions by Source Type in the U.S.[33]



9.2.7 Refinery Emissions Standards

The U.S. has new source performance standards (NSPS) that regulate emissions of criteria pollutants (CO_2, NO_x, VOC and PM). The primary NSPS for petroleum refineries is 40 CFR part 60 subparts J and Ja. Other NSPS are applicable to specific sources. For example subpart Kb specifies control of VOC from storage tanks, subpart GGG/GGGa specifies LDAR program requirements for controlling VOC emissions from equipment leaks, and subpart Db considers emission controls for industrial boilers. The U.S. also controls toxic chemicals through National Emissions Standards for Hazardous Air Pollutants (NESHAP). The key NESHAP concerning petroleum refinery emission sources is 40 CFR part 63 subparts CC and

UUU. Most of the refinery NESHAP use criteria pollutants as a surrogate for toxic emissions (e.g., PM as a surrogate for toxic metal pollutants).

Table 9.2-1 provides a summary of U.S. regulatory requirements for various refinery emissions sources. Table 9.2-1 also provides the typical controls and monitoring systems used for these emission controls.

Table 9.2-1 Summary of Existing U.S. Regulatory Requirement for Key Refinery Emission Sources[34, 35, 36]

EMISSION SOURCE	POLLUTANT	LIMIT	CONTROLS	MONITORING
FCCU Regenerator	PM	1.0 g/kg coke burn; existing units; 0.5 g/kg new sources	ESP or wet scrubber	Control device parameters
	SO_2	50 ppmv, 7-day ave.; 25 ppmv,365-day ave.	Catalyst additives or wet scrubber	SO_2 CEMS
	NO_X	80 ppmv, 7-day ave.	Combustion controls, SNCR, SCR, LoTox, catalyst additives	NO_X CEMS
	VOC	≤500 ppmv CO	Complete combustion regenerator or post-combustion device (CO boiler)	CO CEMS or temperature and oxygen level operating limits
Process heaters and boilers (gas-fired)	SO_2	20 ppmv, 3-hr ave; 8 ppmv, 365-day ave. Alternatively, H_2S limits in fuel gas of: 162 ppmv, 3-hr ave.; 60 ppmv, 365-day	Amine treatment of fuel gas	SO_2 CEMS in exhaust stack or continuous H_2S monitor for central fuel gas lines
	NO_X	40 ppmv (or 0.040 lbs/MMBtu) for natural draft units; 60 ppmv (or 0.060 lbs/MMBtu) for forced draft units (both on 30-day ave.)	Ultra-low NO_X burners and/or advanced air controls	NO_X CEMS or, for units with heat rate capacity of <100 MMBtu/hr, test and set maximum O_2 exhaust concentration
Process heaters and boilers (liquid-fired)	SO_2	0.20 lb/MMBtu	Wet scrubber; use low sulfur fuels	SO_2 CEMS in exhaust stack or continuous H_2S monitor for central fuel gas lines.
	NO_X	0.10 to 0.20 lb/MMBtu for units distillate fuel oil based on heat release rate; 0.30 to 0.40 lb/MMBtu for residual fuel oil based on heat release rate	Low NO_X burners and/or advanced air controls.	NO_X CEMS or, for units with heat rate capacity of <100 MMBtu/hr, test and set maximum O_2 exhaust concentration

Table 9.2-1 continued

EMISSION SOURCE	POLLUTANT	LIMIT	CONTROLS	MONITORING
Flare	PM	Visible (smoke) emissions cannot exceed 5-minutes in any 2-hr period	Steam assist or air assist	Visible emissions observations (or use of camera)
	SO_2	162 ppmv, 3-hr ave., H_2S limits in flare gas for routine flows; 500 lbs/day SO_2 action level for SSM events	Amine scrubbing; Flare minimization plan, flare gas recovery	Continuous H_2S monitor of flare gas Total reduced sulfur and flow monitoring of flare gas
	VOC	Continuous pilot flame; 270 Btu/scf net heating value in flare combustion zone on 15-minute ave. basis	Continuous pilots; Advance steam controls and supplemental natural gas	Thermocouple or other pilot flame monitor; flare gas and steam flow monitors, continuous calorimeter or GC for flare gas
Cooling Towers	PM		Mist eliminators	
	VOC	6.2 ppmv THC in stripping column exhaust gas (80 ppbw THC in cooling water)	Repair "leaks" identified	Monthly stripping column analysis (can use quarterly analysis if "leak" action level reduced to 3.1 ppmv THC)
Sulfur Recovery Unit	SO_2	250 ppmv (dry, 0% excess air) for units with capacity greater than 20 long tons per day (LTPD) 2,500 ppmv (dry, 0% excess air) for units with capacity of 20 LTPD or less	Claus with tail gas treatment units; Claus with additional stages, LoCat system, or wet scrubber	SO_2 CEMS
Equipment Leaks	VOC	LDAR program focused on valves and pumps with leak defined as 10,000 ppmv for existing sources and 1,000 ppmv for pumps and 500 ppmv for valves at new sources	Repair "leaks" identified	Monitoring monthly using EPA Method 21. Can reduce monitoring frequency to quarterly or semi-annually) for components not leaking for 2 consecutive periods
Storage Tanks	VOC	Equipment standards for floating roofs or vent to control device (95% control efficiency) for vessels over certain size and vapor pressure of contents	Dual seal roofs, gasketed hatches, wipers of ladders and guide poles	Annual inspections.

Table 9.2-1 continued

EMISSION SOURCE	POLLUTANT	LIMIT	CONTROLS	MONITORING
Wastewater collection and treatment	VOC	Control streams with flows exceeding 0.02 liters/min and concentrations of 10 ppmw or greater of benzene (with some exceptions)	Water seals for drains, covered and controlled sumps, junction boxes and tanks prior to treat-ment (either steam stripping or enhanced biological treatment unit)	Quarterly sampling, annual inspections, control device monitoring parameters.
Process vents	VOC	98% control or 20 ppmv concentration for vents with emissions exceeding 72 lbs/day VOC	Combustion controls (process heater, boiler, incinerator or flare)	Initial performance test and temperature monitoring (or flare monitoring - see flares above)
Gasoline loading	VOC	10 mg TOC per liter gasoline loaded	Vapor balancing; vent to control device	Initial performance test and control system parameter monitoring
Marine vessel loading (MVL)	VOC	97 % control efficiency for MVL with potential to emit greater than 10 Mg/yr of any one toxic or 25 Mg of com-bined toxic VOC	Vapor balancing; vent to control device	Initial performance test and control system parameter monitoring

The control devices listed above are available in the U.S. from multiple vendors. Table 9.2-2 lists a few of the U.S. vendors, or vendors with a U.S. presence, and information on some of the control equipment they can provide.

Table 9.2-2 Pollution Control Equipment Vendors

VENDOR	POLLUTANTS AND CONTROL EQUIPMENT
Alstom	PM (ESPs and fabric filters), SO_2 (scrubber), NO_x (SNCR)
ClearSign Technologies	Duplex™ technology for process heater NO_x reduction without longer flame lengths associated with ultra-low NO_x burners
Ducon	Controls for PM, SO_2, volatile organic compounds, NO_x
Durr	Organics (RTO)
DuPont – Belco Technologies Corporation	EDV® wet scrubber for SO_2 and PM control; LoTOx™ pretreatment unit (prior to wet scrubber) to also achieve NO_x control
Hamon Research Cottrell	PM (ESPs and fabric filters), SO_2 (scrubber), NO_x (SNCR)
Grace	FCCU catalyst additives for SO_2 and NO_x control
Johnson Matthey	FCCU catalyst additives for SO_2 and NO_x control
John Zink Hamworthy	Low and ultra-low NO_x burner systems for NO_x control; flares and thermal oxidizers for VOC control; flare gas recovery systems
Merichem Company	Lo-Cat® H_2S removal technology; also have amine scrubber systems
Pall Corporation	Specialized filtration system for FCCU PM control
WorleyParsons	Amine scrubbing systems, sulfur recovery plants, and tail gas treatment units for SO_2 control
Zeeco	Low and ultra-low NO_x burner systems for NO_x control; flares and thermal oxidizers for VOC control; flare gas recovery systems

9.2.6 Recomendations

Table 9.2-3 summarizes the recommendations for Jiangsu Province based on the U.S. experience in the relevant fields.

Table 9.2-3 Summary of U.S. Experiences and Recommendations

U.S EXPERIENCE		RECOMMENDATIONS FOR JIANGSU
THEN	NOW	
Originally, EPA provided separate NSPS SO_2 emissions standards specifically for FCCU using catalyst additives.	EPA requires performance based on best technology (wet scrubbers). Catalyst suppliers were able to improve performance to meet the emissions limit.	**Do not specify the use of a specific technology and do not set different emission limits for different control technologies. Develop emission limits that are readily achievable and allow operators to select the control device or system of control devices that best meet the emissions limit in their specific application.**
Originally, EPA required a single initial performance test and allowed daily parameter monitoring to demonstrate compliance when a CEMS was not being used.	Control device performance can vary non-linearly with a specific operating parameter, and the long averaging period did not ensure controls were always operated efficiently. Revised rule to require either annual or one a permit period performance tests and operating limits based on the results and length of performance test (typically 3 hours).	**When using control device operating parameters, make sure operating limits are tied directly to the performance test and that the averaging periods are short enough to ensure continuous compliance.**
Flare performance indicators were established but few ongoing monitoring requirements were established. Only visible emissions requirement was enforced, which led refineries to use high steam rates and combustion efficiencies were poor.	Revised and updated performance indicators and established continuous monitoring requirements for all of the performance indicators.	**Ensure all of the requirements needed to ensure proper control device operations are covered in the rule (or permit). Focus on only the "easy" or "cheap" monitoring parameters may lead to poor operations.**
Equipment leak and storage vessel monitoring and inspection requirements were done quickly and poorly. The requirements were focused on a checklist to simply do the inspection. Leak detection monitoring and storage vessel inspections were performed, but full methods were not followed, so many leak sources were not properly identified. Enforcement inspections found 3 to 10 times more leaks than reported by the facility.	Revised the requirements to show more detailed log of activities and timing of activities to ensure that monitoring and inspections were performed in a rigorous manner. Use optical gas imaging cameras on inspections to ensure no unusual leaks are present.	**Enforcement inspections are needed to ensure facilities comply with rule requirements. Requiring more recordkeeping and reporting by facilities may help to minimize the need and effort required for inspections, but these cannot eliminate the need for periodic site inspections.**

9.3 IRON AND STEEL

9.3.1 Background

Facilities within the iron and steel industry may be configured in various ways and differ widely in size and potential environmental impact. Integrated iron and steel facilities contain a blast furnace that converts processed iron ore to molten iron. These facilities typically contain a basic oxygen furnace to convert the molten iron to steel, and casting operations. These facilities may include steel refining operations, coke ovens, sinter plants as well as operations such as rolling mills to produce finished products. Coke ovens convert coal to coke (which is used to fuel blast furnaces) and may be operated as stand-alone facilities or as part of an integrated iron and steel facility. Electric arc furnaces are used to recycle scrap iron and steel (which may include post-consumer scrap as well as internally generated scrap). These are typically operated as stand-alone facilities but may also be present at integrated iron and steel facilities. Electric arc furnaces include casting operations and may also include steel refining operations.

9.3.2 Manufacturing Process

9.3.2 (A) Coke Ovens

Coke ovens are chambers in which bituminous coal is heated to drive off volatile components and to produce coke for use in blast furnaces. Multiple ovens are constructed side-by-side making up a coke battery. Individual ovens are operated as batch processes. There are multiple emission points (stack and fugitive) associated with coke ovens.

9.3.2 (B) Sinter Plants

Some integrated steel mills contain sinter plants. Sinter plants convert wastes including ore fines, coke fines, blast furnace dust and mill scale into blast furnace feed. Gaseous fuel (natural gas, coke oven gas, blast furnace gas) is used for ignition but most of the energy required comes from combustion of carbon materials in the feed. Sintering is a continuous process that takes place on a traveling grate. There are multiple emission points (stack and fugitive) associated with sinter plants.

9.3.2 (C) Blast Furnaces

Blast furnaces are located at integrated steel mills and convert iron ore (chiefly iron oxide) to molten iron in a batch process. Iron ore pellets, sinter, coke and limestone (which acts as a flux) are charged to the blast furnace in layers. The coke is used as a reducing agent in the conversion of iron ore to molten iron. Additional blast furnace inputs may include iron and steel scrap, mill scale, and basic oxygen furnace slag. Preheated air is added near the bottom of the furnace. The coke is combusted to provide heat and also reduces the iron oxide in the ore and sinter to iron. Molten iron and slag are tapped from the furnace separately. Blast furnace gas, which is high in carbon monoxide, is produced. Some of this gas is combusted in the blast furnace stoves which are used to preheat the air added to the furnace. The remainder is combusted in other parts of the steel mill. In some cases excess blast furnace gas is flared.

9.3.2 (D) Basic Oxygen Furnaces

Basic oxygen furnaces are located at integrated steel mills. They are used to convert molten iron from the blast furnace to steel, in a batch process, by adding oxygen to combine with carbon dissolved in the iron. Iron and steel scrap (primarily internally generated) is generally added to the basic oxygen furnace which moderates the temperature. Lime or other flux is added. In addition to oxidizing the carbon, silicon and other impurities are also oxidized and transferred to slag formed from the lime. The steel is tapped to a casting operation and the slag is tapped for disposal.

9.3.2 (E) Electric Arc Furnace Steelmaking

Electric arc furnaces (EAFs) are used to melt and effectively recycle steel scrap. They are typically operated as standalone facilities but may be located at integrated steel mills. Scrap and flux are charged to the furnace and carbon electrodes are lowered into the furnace. An electric arc (AC or DC) between the electrodes provides most of the energy required to melt the scrap. For reasons of economy, some of the energy can be supplied by adding natural gas or a powdered coke/oxygen mixture to the furnace. Steel and slag are tapped. Most EAFs are collocated with continuous casting operations. In some cases, ingots are cast. The majority of EAFs operate as batch processes, however some operate continuously which is more energy efficient.

9.3.2 (F) Other Miscellaneous Emission Points

1. Ladle metallurgy, alloying, decarburization

Steel refining and alloying operations are often located at facilities that operate basic oxygen furnaces and electric arc furnace steelmaking. Molten steel from the furnaces is refined in these processes by adding alloying materials and removing carbon and other impurities to meet specifications for particular grades of steel.

2. Boilers

Energy in excess blast furnace and coke oven gases are sometimes combusted to produce process steam or electricity in integrated steel mills.

3. Flares

Excess blast furnace and coke oven gases are sometimes combusted in flares. These are often operated intermittently.

4. Material Handling (coal, coke, ore, scrap, slag, flux, etc.)

Many of the inputs to, and outputs from iron and steel processes are solids which may emit dust when unloaded, conveyed, or transferred. Windblown dust may also be generated from material storage piles.

9.3.3 Emission Sources And Emission Controls

9.3.3 (A) Coke Ovens

Air pollutants are emitted during charging, and from leaking doors, lids and offtakes during the coking cycle. Additional pollutants are emitted during pushing and quenching at the end of a coking cycle and from battery and combustion stacks.

Air pollutants emitted from coke ovens include particulate matter; oxidized, reduced and organic sulfur compounds; volatile organic chemicals; polycyclic organic matter; ammonia; and carbon dioxide. Charging emissions can be captured by using steam aspiration to pull the emissions into the gas collecting main. Leaks from doors, leaks and offtakes are limited through work practices including inspection, maintenance and repair and application of sealants to stop leaks when they are observed. With good work practices these leaks can be eliminated.

Pushing "green" (underprocessed) coke results in excessive pushing emissions and can be caused by overcharging an oven, cold flues due to plugging or poor combustion, non-uniform heating and cold spots on the ends of ovens and inadequate coking time. These can be minimized through good work practices.

Pushing emissions can be captured with a cokeside shed, a moveable hood or a hooded/vented quench car. Captured emissions can be routed to a Venturi scrubber, hot water scrubber or a multiclone. Quenching emissions can be minimized through control of quench water quality (organics and total dissolved solids) and the use of baffles in quench towers. Baffles should be washed daily except in freezing weather.

Battery stack emissions can be treated with a coke oven gas cleaning system which includes an amine scrubber, a hydrogen cyanide destruction unit and a sulfur recovery unit.

9.3.3 (B) Sinter Plants

Air pollutants are emitted from various points in the sinter process including the windbox, the sinter discharge, crushing and screening operations, and the sinter cooler. Particulate matter is emitted from all of these emission points and organics including polycyclic organic matter are emitted at the windbox. Sinter plants also emit NO_X, although NO_X emissions are typically uncontrolled.

Sinter plant emissions are typically controlled by baghouses. Wet scrubbers may also be used to control windbox emissions.

9.3.3 (C) Blast Furnaces

Blast furnace gas (containing particulate matter, organic compounds, sulfur compounds, and carbon monoxide) is collected at the top of the furnace. Wet scrubbers are used to remove particulate matter and organic compounds from blast furnace gas. Carbon monoxide in cleaned blast furnace gas is destroyed during combustion. Treatment of wastewater from wet scrubbers used to clean blast furnace gas can generate emissions of organics, hydrogen cyanide, and sulfur compounds.

Other (primarily particulate matter) emissions are associated with tapping of hot iron and slag, raw material and slag handling, and treatment of scrubber wastewater.

9.3.3 (D) Basic Oxygen Furnaces

Emissions are produced during transfer of hot metal to the furnace, charging, oxygen blowing, slag tapping, and steel tapping. Particulate matter is the major air pollutant emitted during basic oxygen furnace operations. If post-consumer scrap is added to the furnace, additional pollutants (e.g., mercury, lead, dioxins/furans) may be emitted.

Baghouses, electrostatic precipitators, and wet scrubbers are used to control emissions. Particulate matter emissions generated as a result of slag handling and disposal are sometimes controlled with water sprays.

9.3.3 (E) Electric Arc Furnace Steelmaking

Most of the air pollutants are emitted from the top of the furnace, particularly during and immediately after charging. Additional emissions occur during tapping of steel and slag. Particulate matter is the most significant air pollutant from electric arc furnace steelmaking and is primarily generated from the combustion of oil, grease and coatings present on the scrap. Melting post-consumer scrap, particularly automotive scrap, can produce emissions of hazardous metals, including mercury and lead. Dioxins and furans can be formed and emitted when scrap containing plastic is melted.

Particulate emissions are typically captured with a hood above the removable furnace lid, and controlled with fabric filters. Some facilities duct building ventilation air to the same fabric filters and others have secondary baghouses. Emissions from some collocated operations such as casting can be co-controlled by the baghouses for the EAF. Emissions of mercury, lead and dioxins/furans are controlled by removing mercury- and lead-containing materials and plastics from the scrap before it is fed to the furnace. This is most practical to do before scrap is shredded.

9.3.3 (F) Other Miscellaneous Emission Points

1. Ladle metallurgy, alloying, decarburization

These operations have the potential to emit particulate matter and are typically controlled with baghouses. In electric arc furnace steelmaking, decarburization processes (argon-oxygen decarburization and vacuum decarburization) are often co-controlled with the baghouse for the EAF.

2. Boilers

Emissions from boilers may contain sulfur dioxide, and NO_X, and are subject to the same control considerations as other fossil-fuel fired boilers.

3. Flares

Add on control devices are not typically used to control flare emissions. Low NO_X burner systems should be considered depending on the volume of gas combusted.

4. Material Handling (coal, coke, ore, scrap, slag, flux, etc.)

Dust emissions can be limited through the use of dust suppressants, water sprays, covered conveyor belts, enclosed transfer stations, reducing drop distances and telescopic chutes.

9.3.3 (G) Control Devices And Emission Limits

Control devices and practices typically used for air pollution control in the iron and steel industry are listed in Table 9.3-1. Suitable capture equipment (typically exhaust hooding) must be installed to direct emissions to the control device. The effectiveness of control devices should be confirmed though performance testing. In addition, operating parameters should be identified, and maintained at appropriate levels on a continuous basis. In many cases, it is feasible to confirm the effectiveness of capture systems through opacity limits. Fabric filters and wet scrubbers typically have PM control efficiencies greater than 95%.

Table 9.3-1 Typical Control Devices Used at Iron and Steel Facilities

EMISSION SOURCE	POLLUTANTS	CONTROL DEVICE/PRACTICE
Coke battery -- charging emissions	PM, organics, visible emissions	steam aspiration
Coke battery -- Leaking doors, lids and offtakes	PM, organics, visible emissions	maintenance, inspection, sealants
Coke battery -- pushing	PM, organics, visible emissions	Avoid green pushes, venturi scrubber, hot water scrubber, multiclone
Coke battery -- quenching	PM, organics	Control quench water quality, install baffles in quench tower and wash daily
Coke batteries -- stack emissions	sulfur dioxide, hydrogen cyanide	amine scrubber, hydrogen cyanide destruction unit, sulfur recovery unit
Sinter plant -- windbox	PM, organics	fabric filter, wet scrubber
Sinter plant -- discharge	PM	fabric filter
Sinter plant -- crusher	PM	fabric filter
Sinter plant -- hot screen	PM	fabric filter
Sinter plant -- cooler	PM	fabric filter
Sinter plant -- cold screen	PM	fabric filter
Blast furnace -- exhaust gas	PM	cyclone followed by wet scrubber
Blast furnace -- casting	PM	covered runners, fabric filter
Basic oxygen process furnace -- hot metal transfer	PM	fabric filter
Basic oxygen process furnace -- slag skimming	PM	fabric filter

Table 9.3-1 continued

Basic oxygen process furnace -- charging	PM	fabric filter, electrostatic precipitator, wet scrubber
Basic oxygen process furnace -- oxygen blow	PM	electrostatic precipitator, wet scrubber
Basic oxygen process furnace -- slag removal	PM	fabric filter, electrostatic precipitator, wet scrubber
Basic oxygen process furnace -- tapping	PM	fabric filter, electrostatic precipitator, wet scrubber
Basic oxygen process furnace -- ladle metallurgy	PM	fabric filter, wet scrubber
Basic oxygen process furnace -- molten steel transfer	PM	fabric filter
Electric Arc Furnace -- Steelmaking	dioxins/furans, mercury, lead	scrap specifications, remove plastics from scrap, remove mercury and lead from automotive scrap
Electric Arc Furnace -- Steelmaking	PM	fabric filter

Vendors of air pollution control devices suitable for use in the iron and steel industry include those listed in Table 9.3-2. Capital costs for fabric filters used to control emissions from iron and steel emission sources are estimated at $400-$600 per actual cubic meter per minute (2015$). Annual operating costs for these emission control systems are estimated at $100-$600 per actual cubic meter per minute. Capital costs for wet scrubbers are typically less than those for fabric filters of equal capacity, however consideration of water treatment costs may make fabric filters more attractive.

Table 9.3-2 Pollution Control Equipment Vendors

VENDOR	POLLUTANTS AND CONTROL EQUIPMENT
American Air Filter	PM (fabric filters)
B & W/ MEGTEC	PM (fabric filters, ESPs), thermal oxidizers, carbon adsorption
Ducon Environmental Systems	Controls for PM, SO_2, dioxin/furan, mercury, volatile organic compounds
Fisher-Klosterman, Inc.	PM (cyclones, scrubbers, fabric filters)
Met-Pro Environmental	PM (scrubbers, fabric filters, cyclone), thermal and catalytic oxidizers
Mikropul	PM (fabric filters, scrubbers)

Emission limits established for iron and steel emission sources in the United States are listed in Table 9.3-3. Specific conditions under which these limits apply are detailed in the referenced regulations. These conditions include performance test method, testing frequency, test duration and monitoring as a means to ensure continuous compliance. Separate limits and requirements may be appropriate for periods of startup and shutdown.

Table 9.3-3 Emission Limits for the Iron and Steel Industry Based on U. S. Regulations[37]

EMISSION SOURCE	PARAMETER	LIMIT/PRACTICE	REFERENCE
Electric Arc Furnace Steelmaking	dioxins/furans, lead, mercury	Pollution prevention (control of plastics, free liquids, mercury and lead in post-consumer scrap)	40CFR63, subpart YYYYY
Electric Arc Furnace Steelmaking (including argon-oxygen decarburization)	particulate matter	0.0052 grains/ dscf (12 mg/dscm)	40CFR63, subpart YYYYY
Electric Arc Furnace Steelmaking (including argon-oxygen decarburization)	particulate matter, alternate standard for small stainless steel plants	0.8 lb/ton (0.4 kg/MT)	40CFR63, subpart YYYYY
Electric Arc Furnace Steelmaking (including argon-oxygen decarburization)	opacity	6%	40CFR63, subpart YYYYY
Coke plant pushing emissions from cokeside shed	particulate matter	0.01 grains/dscf (23 mg/dscm)	40CFR63, subpart CCCCC
Coke plant pushing emissions from moveable hood ducted to stationary control device	particulate matter	0.02 lb/ton coke (0.01 kg/ MT coke)	40CFR63, subpart CCCCC
Coke plant pushing emissions from mobile scrubber car that does not capture emissions during travel (short battery)	particulate matter	0.03 lb/ton coke (0.015 kg/ MT coke)	40CFR63, subpart CCCCC
Coke plant pushing emissions from mobile scrubber car that does not capture emissions during travel (tall battery)	particulate matter	0.01 lb/ton coke (0.005 kg/ MT coke)	40CFR63, subpart CCCCC
Coke plant pushing emissions from mobile control device that captures emissions during travel	particulate matter	0.04 lb/ton coke (0.02 kg/ MT coke)	40CFR63, subpart CCCCC

Table 9.3-3 continued

EMISSION SOURCE	PARAMETER	LIMIT/PRACTICE	REFERENCE
Coke plant pushing emissions (short battery, vertical flues)	opacity	30 %	40CFR63, subpart CCCCC
Coke plant pushing emissions (tall battery, vertical flues)	opacity	35 %	40CFR63, subpart CCCCC
Coke plant quenching emissions	quench water total dissolved solids	1100 mg/L	40CFR63, subpart CCCCC
Coke plant quenching emissions	work practices	Limit organics in quench water, install and wash baffles	40CFR63, subpart CCCCC
Coke plant battery stacks (normal cycle)	opacity	15 % daily average	40CFR63, subpart CCCCC
Coke plant battery stacks (extended cycle)	opacity	20 % daily average	40CFR63, subpart CCCCC
Sinter plant	VOC	Maintain feed at <0.02 % oil, or limit windbox exhaust to 0.2 lb VOC/ton sinter (0.1 kg/MT sinter	40CFR63, subpart FFFFF
Sinter plant windbox (existing)	particulate matter	0.4 lb/ton sinter (0.2 kg/MT sinter)	40CFR63, subpart FFFFF
Sinter plant windbox (new)	particulate matter	0.3 lb/ton sinter (0.15 kg/MT sinter)	40CFR63, subpart FFFFF
Sinter plant discharge end (existing)	particulate matter	0.02 grains/dscf (46 mg/dscm)	40CFR63, subpart FFFFF
Sinter plant discharge end (existing)	opacity	20 %	40CFR63, subpart FFFFF
Sinter plant discharge end (new)	particulate matter	0.01 grains/dscf (23 mg/dscm)	40CFR63, subpart FFFFF
Sinter plant discharge end (new)	opacity	10 %	40CFR63, subpart FFFFF
Sinter cooler (existing)	opacity	10 %	40CFR63, subpart FFFFF
Sinter cooler (new)	particulate matter	0.01 grains/dscf (23 mg/dscm)	40CFR63, subpart FFFFF

Table 9.3-3 continued

EMISSION SOURCE	PARAMETER	LIMIT/PRACTICE	REFERENCE
Blast furnace cast house (existing)	particulate matter from control device	0.01 grains/dscf (23 mg/dscm)	40CFR63, subpart FFFFF
Blast furnace cast house (existing)	opacity	20 %	40CFR63, subpart FFFFF
Blast furnace cast house (new)	particulate matter from control device	0.003 grains/dscf (7 mg/dscm)	40CFR63, subpart FFFFF
Blast furnace cast house (new)	opacity	15 %	40CFR63, subpart FFFFF
Basic oxygen process furnace (closed hood) during primary blow	particulate matter	0.03 grains/dscf (70 mg/dscm)	40CFR63, subpart FFFFF
Basic oxygen process furnace (open hood) existing	particulate matter	0.02 grains/dscf (46 mg/dscm)	40CFR63, subpart FFFFF
Basic oxygen process furnace (open hood) new	particulate matter	0.01 grains/dscf (23 mg/dscm)	40CFR63, subpart FFFFF
Basic oxygen process furnace secondary emissions control device (existing)	particulate matter	0.01 grains/dscf (23 mg/dscm)	40CFR63, subpart FFFFF
Basic oxygen process furnace secondary emissions control device (new)	particulate matter	0.0052 grains/ dscf (12 mg/dscm)	40CFR63, subpart FFFFF
Hot metal transfer, skimming and desulfurization operations at basic oxygen process furnace emissions from control device (existing)	particulate matter	0.01 grains/dscf (23 mg/dscm)	40CFR63, subpart FFFFF
Hot metal transfer, skimming and desulfurization operations at basic oxygen process furnace emissions from control device (new)	particulate matter	0.003 grains/dscf (7 mg/dscm)	40CFR63, subpart FFFFF
Ladle metallurgy operation at basic oxygen process furnace emissions from control device (existing)	particulate matter	0.01 grains/dscf (23 mg/dscm)	40CFR63, subpart FFFFF
Ladle metallurgy operation at basic oxygen process furnace emissions from control device (new)	particulate matter	0.004 grains/dscf (9 mg/dscm)	40CFR63, subpart FFFFF

Table 9.3-3 continued

EMISSION SOURCE	PARAMETER	LIMIT/PRACTICE	REFERENCE
Basic oxygen process furnace building (existing)	opacity	20 %	40CFR63, subpart FFFFF
Basic oxygen process furnace, bottom blown, building (new)	opacity	10 % (except for one 6 minute period per cycle, 20%)	40CFR63, subpart FFFFF
Basic oxygen process furnace, top blown, building (new)	opacity	10 % (except for one 3 minute period per cycle, 20%)	40CFR63, subpart FFFFF
Byproduct coke batteries, tall (existing)	leaking doors	4 %	40CFR63, subpart L
Byproduct coke batteries, short (existing)	leaking doors	3.3 %	40CFR63, subpart L
Byproduct coke batteries (existing)	leaking lids	0.4 %	40CFR63, subpart L
Byproduct coke batteries (existing)	leaking offtakes	2.5 %	40CFR63, subpart L
Byproduct coke batteries (existing)	visible emissions	12 seconds per charge	40CFR63, subpart L
Byproduct coke batteries, (new)	leaking doors	0 %	40CFR63, subpart L
Byproduct coke batteries, (new)	leaking lids	0 %	40CFR63, subpart L
Byproduct coke batteries, (new)	leaking offtakes	0 %	40CFR63, subpart L
Byproduct coke batteries, (new)	visible emissions	34 seconds per charge	40CFR63, subpart L
Non-recovery coke batteries	leaking doors	0 %	40CFR63, subpart L
Non-recovery coke batteries (new)	leaking lids	0 %	40CFR63, subpart L
Non-recovery coke batteries (new)	leaking offtakes	0 %	40CFR63, subpart L

9.3.4 General Consideration Of GHG Emissions

Carbon dioxide is the most significant greenhouse gas associated with iron and steel processes. Carbon dioxide emissions can be limited by maximizing energy efficiency. Steps to improve energy efficiency include:

- Maximizing energy recovery (and minimizing flaring) of coke oven gas and blast furnace gas: use as fuel in sinter plants, use for coal drying in coke ovens or generate energy in boilers;
- Reducing coke use in blast furnaces by partially substituting pulverized coal and/or natural gas;
- Recovery of energy from basic oxygen furnace gas to produce steam;
- Continuous electric arc furnace processes (e.g., Consteel);
- Preheating scrap fed to electric arc furnaces;
- Direct current electric arc furnaces;
- Improved mechanical efficiency (e.g., variable speed fans; energy efficient motors).

Many other heat recovery and energy efficiency measures are feasible on a site-specific basis.

9.3.5 Recommendations

The integrated iron and steel industry in the United States has been contracting in recent years and no new capacity has been constructed. As a consequence, demand for coke has decreased and little or no new capacity has been added. Related to the decline in the integrated iron and steel industry, electric arc furnace steelmaking (secondary steel) has increased in importance. Table 9.3-4 includes some recommendations for new and retrofit technologies in use worldwide that have the potential to decrease emissions.

Table 9.3-4. Summary of U.S. Experiences and Recommendations

CONTROL		RECOMMENDATIONS FOR JIANGSU PROVINCE
THEN	NOW	
AC EAF Steelmaking	DC EAF Steelmaking	**Use DC technology for new EAFs for improved energy efficiency and reduced emissions.**
Batch EAF Steelmaking	Continuous EAF Steelmaking	**Continuous processes use less energy and offer better emissions capture.**
By-product coke ovens	Heat recovery coke ovens (also referred to as non-recovery coke ovens.	**Heat recovery process offers better emissions capture.**
Wet coke quenching	Dry coke quenching (Japan)	**Dry coke quenching offers better emissions capture.**
Combustion heat recovery from basic oxygen furnaces	Suppressed combustion heat recovery from basic oxygen furnaces	**Suppress combustion recovers more heat and decreases particulate emissions.**
Open sinter processes	Recirculating sinter plant off gas (Netherlands)	**Recirculating sinter gas recovers more heat and decreases emissions.**

9.4 CEMENT MANUFACTURING

9.4.1 Background

Cement along with water and aggregates (sand and rock) are the key ingredients in making concrete. Portland cement is the most common type of cement produced. Cement is manufactured by chemically combining materials containing calcium, silicon, aluminum, iron, and other ingredients. Materials used to make cement include primarily limestone, which is the main ingredient comprising 89 – 90% of the ingredients, along with lesser amounts of shale, clay, sand, iron ore, fly ash, and other ingredients.

9.4.2 Manufacturing Process

In a typical process, limestone and other raw materials are obtained by blasting or mechanical mining from a quarry near the cement plant. Raw materials not obtained from the quarry are brought to the cement plant from offsite. In a series of material handling processes, the raw materials are crushed, ground to a fine powder, mixed to a homogenous state and dried. The resulting mixture is the raw feed that is introduced into a pyroprocessing system where it is subjected to high temperatures and transformed chemically into clinker. The heart of the pyroprocessing system is the kiln.

At the high temperatures of the kiln, the feed is transformed into clinker, a hard rock-like material that is ground and mixed with gypsum to form cement. In Figure 9.4-1 below is a simplified view of the cement manufacturing process.

In its simplest form, the kiln, or rotary kiln, is an inclined, refractory lined steel tube. The raw materials are fed into the upper end of the slowly rotating kiln while the combustion fuels are introduced at the lower end of the kiln. The raw materials move down the kiln countercurrent to the hot gas flow. In its trip through the kiln, the material is dried, calcined (CO_2 driven off) and reacted to form clinker. Kilns of this design are either long wet kilns or long dry kilns. In wet kilns, the raw materials are introduced to the kiln as a slurry and, therefore, require much more energy to produce clinker. In a long dry kiln, the mixed raw materials are dried in a separate dryer before being introduced into the kiln. A diagram of a long kiln is shown in Figure 9.4-2 below. These older long wet and dry kilns are being replaced by more efficient preheater kilns or preheater/precalciner kilns.

Figure 9.4-1 Overview of the Cement Manufacturing Process

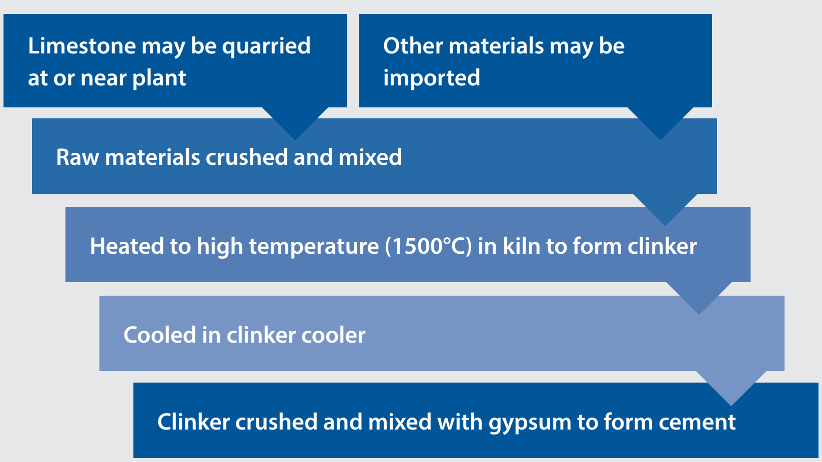
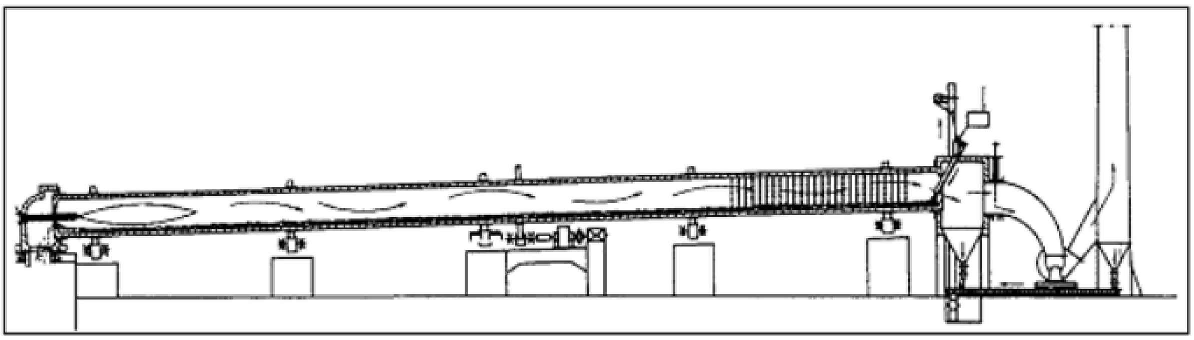
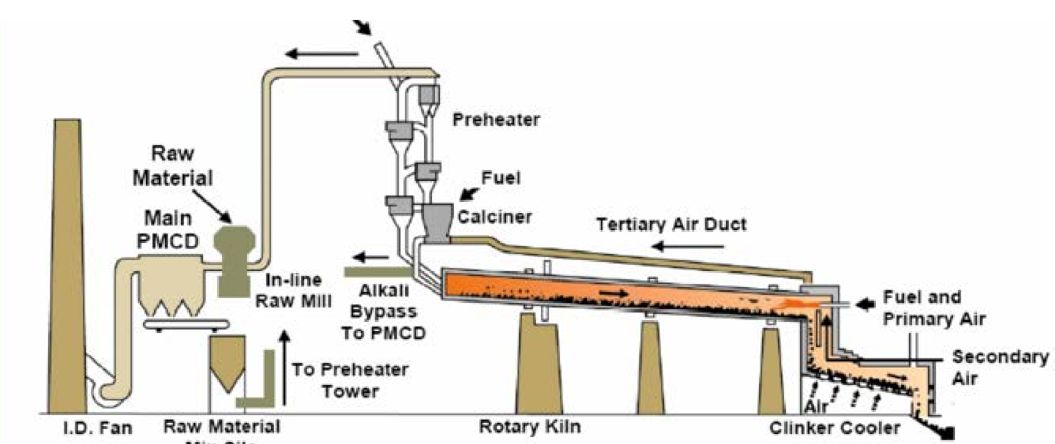


Figure 9.4-2 **Long Dry Rotary Kiln**[38]



In a preheater (PH) kiln system, the raw materials are introduced at the top of the preheater tower, which consists of a series of cyclones and interconnecting ducts. The raw feed travels down the cyclones countercurrent to hot gases from the kiln and is dried and preheated before entering the kiln. This allows for a shorter rotary kiln. In a preheater/precalciner (PH/PC) kiln system, the raw feed moves to a second section at the bottom of the preheater tower, a special furnace called the calciner or precalciner. In this section, CO_2 is calcined from the raw feed. From the precalciner, the feed moves into a rotary kiln to complete the chemical reactions to form clinker. In a PH/PC kiln, fuel is fired in the calciner as well as the discharge end of the rotary kiln. A diagram of a preheater/precalciner kiln system is shown in Figure 9.4-3.

Figure 9.4-3 **Preheater/Precalciner Kiln System**



The design of the PH/PC kiln make it the most efficient of the various types of kilns as can be seen in Table 9.4-1. For many types of pollutants, energy efficient kilns emit fewer pollutants than inefficient kilns.

Table 9.4-1 Heat Input by Kiln Type[38]

KILN TYPE	HEAT INPUT (MMBTU/TON OF CLINKER)	PERCENT INCREASE IN HEAT INPUT COMPARED TO PH/PC HEAT INPUT
Long wet	6.0	45
Long dry	4.5	36
Preheater	3.8	15
Preheater/ precalciner	3.3	—

9.4.3 Emission Sources And Emission Controls

Each step in the cement manufacturing process is a source of emissions. Emissions are generally either fugitive emissions or process emissions. As shown in table 9.4-2, all processes in cement manufacturing emit PM emissions. In addition to PM emissions, the kiln emits other pollutants as a result of combustion and the high-temperature processing of the raw materials.

Table 9.4-2 Emissions by Cement Manufacturing Process

CEMENT MANUFACTURING PROCESS	EMISSIONS
Raw materials processing *Grinding/milling* *Drying* *Mixing* *Storage* *Conveyors and transfer*	PM
Kiln	PM SO_2 NO_x HCl VOC Mercury Dioxin/furans
Clinker cooler	PM
Finishing *Grinding* *Conveyors and transfer* *Storage silos* *Loading* *Bagging*	PM
Fugitive dust *Quarrying operations* *Roads/vehicles* *Exposed storage piles* *Spillage*	PM

Because the kiln is considered to be the most significant source of emissions at a cement manufacturing plant, U.S. regulations focus on reducing emissions from that source. U.S. emission standards distinguish between criteria pollutants, such as PM, NO_X and SO_2, and hazardous air pollutants, such as mercury, HCl and metals. U.S. emission limits for cement kilns are summarized in Table 9.4-3.

Table 9.4-3 U.S. Emission Limits for Cement Kilns[39, 40]

POLLUTANT	EXISTING KILN	NEW KILN
PM (also a surrogate for hazardous metal emissions)	0.07 lb/ton clinker	0.02 lb/ton clinker
NO_X	Not applicable	1.50 lb/ton clinker
SO_2	Not applicable	0.4 lb/ton clinker
Mercury	55 lb/MM tons clinker	21 lb/MM tons clinker
HCl	3 ppm	3 ppm
THC (a surrogate for hazardous organic pollutants)	24 ppmvd	24 ppmvd
Dioxin/furan	0.2 ng/dscm (TEQ)	0.2 ng/dscm (TEQ)

To reduce the emissions of these pollutants and comply with the emission limits, a facility may need to install an air pollution control device. For some pollutants, there may be more than one control device option to choose from. In some cases, a control device may remove more than a single pollutant. For example, an activated carbon injection (ACI) system will reduce mercury emissions as well as THC. And because ACI systems are typically installed after the main kiln baghouse to allow recycling of the cement kiln dust, an ACI system will typically include its own polishing baghouse, which would further reduce PM emissions. But a wet scrubber can also reduce mercury emissions while also controlling emissions of HCl and SO_2. The selection of add-on controls will be a site-specific decision for each cement plant and their particular circumstances. Table 9.4-4 summarizes the types of add-on air pollution control devices that can be used for each pollutant and their removal efficiencies. It should be noted that in addition to these existing add-on control devices, there are other control technologies that are under development by technology companies that will be available to aid the U.S. cement industry in compliance with the emission limits in the U.S. EPA's NSPS and NESHAP for the Portland cement manufacturing industry. For example, the Cement Americas Publication recently reported that the Tri-Mer Corp. has developed a ceramic filter technology that will be effective in removing emissions from cement kilns, including PM, SO_2, HCl, mercury and heavy metals and will effectively destroy NO_X, organic HAP, and dioxins.[41]

Table 9.4-4 U.S. Regulated Pollutants, Appropriate Add-On Control Devices and Removal Efficiency[42]

REGULATED POLLUTANT	CONTROL DEVICE	TYPICAL REMOVAL EFFICIENCY
Mercury	Wet scrubber ACI[43] w/polishing baghouse	80% 90%
THC (surrogate for organic HAP)	ACI w/polishing baghouse RTO[44] (preceded by wet scrubber)	50% 98%
Organic HAP	ACI w/polishing baghouse RTO (preceded by wet scrubber)	80% 98%
HCl	Wet scrubber Dry lime injection	99.9% 75%
PM (surrogate for metal HAP)	Baghouse	99.9%
NO_X	SNCR[45]	50%
SO_2	Wet scrubber Dry lime injection	95% 70%

The control devices listed above are available in the U.S. from multiple vendors. Table 9.4-5 lists a few of the U.S. vendors, or vendors with a U.S. presence, and information on some of the control equipment they can provide.

Table 9.4-5 Pollution Control Equipment Vendors

VENDOR	POLLUTANTS AND CONTROL EQUIPMENT
Alstom	PM (ESPs and fabric filters), SO_2 (scrubber), NO_X (SNCR), controls for mercury
Clarcor Industrial Air	PM (fabric filters)
Ducon	Controls for PM, SO_2, HCl, dioxin/furan, mercury, volatile organic compounds, NO_X
Durr	Organics (RTO)
FL Smidth	PM (fabric filters), NO_X (SNCR), mercury and organics (ACI), multipollutant control devices, process controls
Hamon Research Cottrell	PM (ESPs and fabric filters), SO_2 (scrubber), NO_X (SNCR), PM and mercury (COHPAC™, TOXECON™)

The impacts of the emission limits on U.S. cement plants were estimated for a typical PH/PC kiln that produces 1.2 million tons of clinker per year. Impacts were estimated from a baseline level, that is, the emission levels that existed before the cement industry was required to comply with the emission limits. Baseline emissions were estimated using emission factors obtained from various sources and are summarized in Table 9.4-6.

Table 9.4-6 Baseline Emission Factors[42]

POLLUTANT	BASELINE EMISSION FACTOR	EMISSION UNITS	SOURCE OF EMISSION FACTOR
NO_X	2.5	lb/ton clinker	Stack tests for PH/PC kiln
SO_2	0.3	lb/ton clinker	Stack tests
PM	0.34	lb/ton clinker	EPA's National Emissions Inventory
HCl	12	ppmv	Stack test
THC	21.4	ppmv	Stack test
Mercury	111	lb/MM tons clinker	Mass balance approach

Baseline emissions and emission reductions for a typical PH/PC kiln producing 1.2 million tons of clinker per year are summarized in Table 9.4-7 below. The emission reductions from baseline emissions are based on the estimated control efficiency and the application of controls that were considered state-of-the-art controls at the time the U.S. EPA developed the NSPS and NESHAP for Portland cement manufacturing.

While the controls listed below may represent state-of-the-art controls in the cement industry, the development of new control technologies as well as the variation in operating conditions from kiln to kiln, and especially plant to plant, make it difficult to know how companies in the cement industry have decided to meet the U.S. emission limits for cement manufacturing. The compliance date for the cement rule is September 2015 and no data have been collected that characterizes how the industry will comply with the new emission limits. For example, while some plants may install SNCR in order to comply with the NO_X emission limits, other plants may be able to comply through the use of process controls such as low NO_X burners, staged combustion, feed mix composition, kiln fuel type and other operating practices. It is likely that there will not be a single state-of-the-art facility, but rather a range of state-of-the-art facilities exhibiting a range of add-on control devices as well as advanced systems for monitoring and controlling process and control systems that will help to ensure optimum performance and compliance.

Table 9.4-7 Baseline Emissions and Emission Reductions (1.2 million ton/yr kiln)[42]

POLLUTANT	BASELINE EMISSIONS	CONTROL	REMOVAL EFFICIENCY	EMISSION REDUCTIONS (TPY)
PM	204 tpy	Replace standard fabric filters with PTFE[46] membrane bags	≥99.9%	198 tpy
NO_X	1500 tpy	SNCR	50%	750 tpy
SO_2	200 tpy	Wet Scrubber	95%	190 tpy
Mercury	130 lb/yr	ACI	90%	120 lb/yr
HCl	68 tpy	Wet Scrubber	99.9%	67.9 tpy
THC	185 tpy	ACI	50%	90 tpy
Organic HAP	50 tpy	ACI	80%	40 tpy

Costs of controlling emissions from cement kilns was estimated by the U.S. Environmental Protection Agency as part of development emission standards for the Portland cement manufacturing industry. Estimates of capital and annualized costs for a typical PH/PC kiln capable of producing 1.2 million tons of clinker per year were estimated and included the cost of compliance monitoring using continuous emissions monitoring (CEMS). Costs are summarized below in Table 9.4-8. For the pollutants that are controlled using the same control technology, only the cost of a single control system would be incurred by the cement plant. For example, a plant that installs a wet scrubber on a kiln for the control of HCl emissions at a capital cost of $25.1 million and an annualized cost of $3.6 million, would also control SO_2 emissions. The only additional cost would be the costs for monitoring SO_2 emissions.

Table 9.4-8 Capital and Annualized Cost of Control (1.2 million ton/yr kiln)[42]

POLLUTANT	CONTROL	CAPITAL COST	ANNUALIZED COST
HCl	Wet scrubber	$25.1 million	$3.6 million
THC	ACI	$3.2 million	$1.1 million
Mercury	ACI	$3.2 million	$1.1 million
PM	PTFE membrane bags	$1.8 million	$350,000
NO_x	SNCR	$2.3 million	$1.3 million
SO_2	Wet scrubber	$25.1 million	$3.6 million

9.4.4 GHG Emissions

Carbon dioxide is the most significant greenhouse gas emitted from the cement manufacturing. Unlike other industrial processes, most of the CO_2 generated is not the result of combustion but results from the decomposition of limestone ($CaCO_3$), the main ingredient in the production of clinker. The cement industry has been working globally to reduce CO_2 emissions. Examples of strategies for reducing CO_2 emissions include the following:

- Fuel efficiency improvements from equipment conversions and upgrades
- High impact options
- Electrical/Instrumentation upgrades
- Substituting raw materials or fuels
- Reduction of the clinker cement ratio

These are discussed in detail in a 2009 Portland Cement Association report, "Carbon Dioxide Reduction Technology Effectiveness Assessment – Initial Evaluation," by A. Hollingshead and G. J. Venta, PCA R&D Serial No. SN3125, 2009.

9.4.5 Recommendations

The U.S. EPA published final rules for Portland cement manufacturing in 2013 with the compliance deadline in September 2015. Their multipollutant approach encountered some issues not typically encountered when developing emission standards for a single pollutant. Such an approach can also present challenges for the industry as they strive to comply with the emission standards in a cost-effective manner. Table 9.4-9 includes some recommendations that have the potential to decrease emissions.

Table 9.4-9 Summary of U.S. Experiences and Recommendations

U.S. EXPERIENCE		RECOMMENDATIONS FOR JIANGSU PROVINCE
TYPES	DETAILS	
Emission limit stringency	Depends on statutory basis in Clean Air Act (CAA). For example: Section 111 – Best available control technology that is demonstrated Section 112 – Maximum achievable control technology Section 129 - Cement kilns burning solid or hazardous waste are commercial/ industrial solid waste incinerators (CISWI) and subject to more stringent limits	**Emission standards should reflect best available control technology that is demonstrated.**
	U.S. EPA emission limits account for variability	**Emission limits should account for variability in emissions and reflect what is achievable over a specified period, such as daily or 30 days, for a properly operated and maintained controlled emission source**
Identifying appropriate add-on air pollution controls	Levels of many pollutants (for example, SO_2, organics, mercury) vary by raw material and fuel	**Level of control needed and, therefore, type of control needed, can vary from plant to plant**
	Multipollutant control is complex and one size does not fit all	**Appropriate controls will be site-specific**
	Some controls have adverse environmental consequences (for example, RTO for organic control have increased fuel demand and emit greenhouse gases; ACI for organic and mercury control increase PM loading)	**Consider any potential adverse environmental impacts of available control options**
Long wet and dry kilns	Preheater/precalciner kilns	**Preheater/precalciner kilns are more energy efficient and inherently emit less NO_x**
Periodic demonstration of compliance	Continuous compliance	**Require continuous compliance monitoring (for example, hourly or daily or every 15 minutes)**

9.5 SURFACE COATING PROCESSES

9.5.1 Background

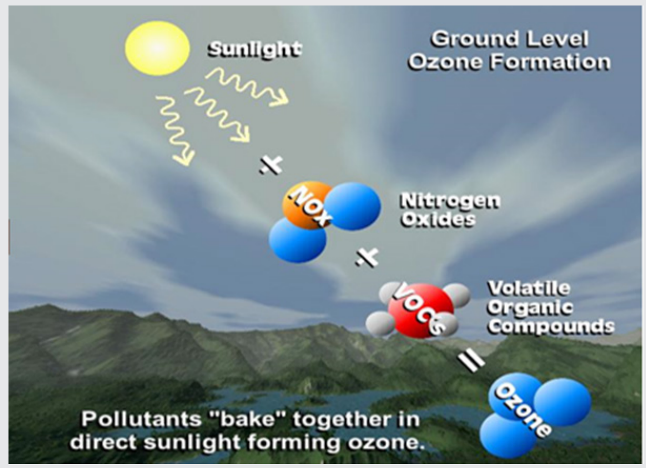
Surface coating is the process of applying paints or coatings to a substrate, such as metal, wood, or plastic, for decorative or protective purposes. In the United States and many other countries, businesses that perform surface coating operations are subject to a variety of state and federal environmental regulations that involve air, water, and solid waste emissions. In many cases, pollution prevention (P2) strategies have been designed to reduce regulatory requirements for surface coaters.

This section discusses general surface coating operations, types of emissions, and different types of control approaches. At the end of this section, tables and figures specific to one important industrial sector, automotive and light-duty truck coating operations, are included as examples. Surface coaters release volatile organic compounds (VOCs), hazardous air pollutants (HAPs), and particulate matter (PM) to the air while preparing surfaces, applying coatings, cleaning equipment, and mixing and storing paints and solvents. In many countries, VOCs, HAPs, and PM are regulated air pollutants.

Volatile Organic Compounds (VOC): Any compound of carbon, excluding carbon monoxide (CO), carbon dioxide (CO_2), carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions.

VOCs are photochemically reactive; they react with nitrogen oxides (NO_X) in sunlight to generate ozone (O_3). There are also "negligibly reactive" carbon compounds which are exempted from the VOC definition. There are approximately 40 compounds that are exempt (mostly chlorofluorocarbons), but the most important exempt compounds are methane and ethane.

Figure 9.5-1 Ground Level Ozone Formation[47]



9.5.2 Surface Coating Processes And Emission Points

Coatings are applied to multiple types of substrates or products to provide aesthetic or durability/performance surfaces for the product. Typical spray coating operations, one in a spray booth and one not in a spray booth, are illustrated in Figures 9.5-2 and 9.5-3. VOC emissions from coating operations include solvents in the coating, thinning solvents, and cleaning solvents. Solvents in coatings are emitted during application to a substrate or product and during drying/curing. There can be multiple solvents in a coating, and each solvent has a different purpose. Some solvents are intended to flash off quickly while others last longer to produce a smooth finish while drying. Sometimes, VOC or HAP are generated as part of curing process (e.g., "cure formaldehyde" from certain phenolic resins).

Figure 9.5-2 Crossdraft Ventilation Spray Booth[48]

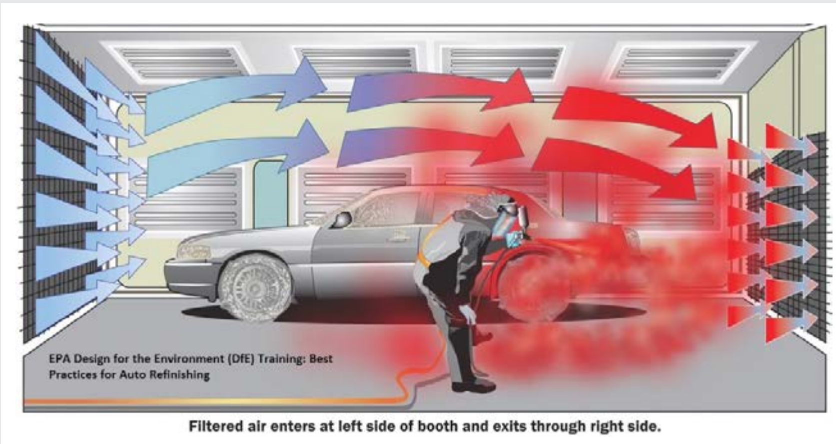


Figure 9.5-3 Spray Coating Operation[49]

Thinning solvents and cleaning materials typically contain VOC and contribute to overall emissions. Thinning solvents are added to adjust the viscosity of the coating. Temperature and humidity affect coatings and how well or easily they are applied. Cleaning solvents are used to clean the application equipment, the spray booth, and in hand wiping equipment.

In general, it is assumed that 100% of solvents in coatings are volatilized. For spray application, most of the solvent is volatilized during spraying operation, typically 60 – 90%, and the balance of the solvent is volatilized during drying/curing operations. For other types of application methods, such as dip coating or curtain coating, less solvent is volatilized during application and more is volatilized during drying steps.

9.5.3 Composition Of Surface Coatings

As shown in Figure 9.5-4, many coatings are made up of solids (which are the non-volatile portion consisting of resins and pigments), VOC solvents, and water. There are many different types of coatings, for example, stains have very low solids content and high solvent content, and primers typically have high solids and low solvent content. Water is considered an exempt solvent.

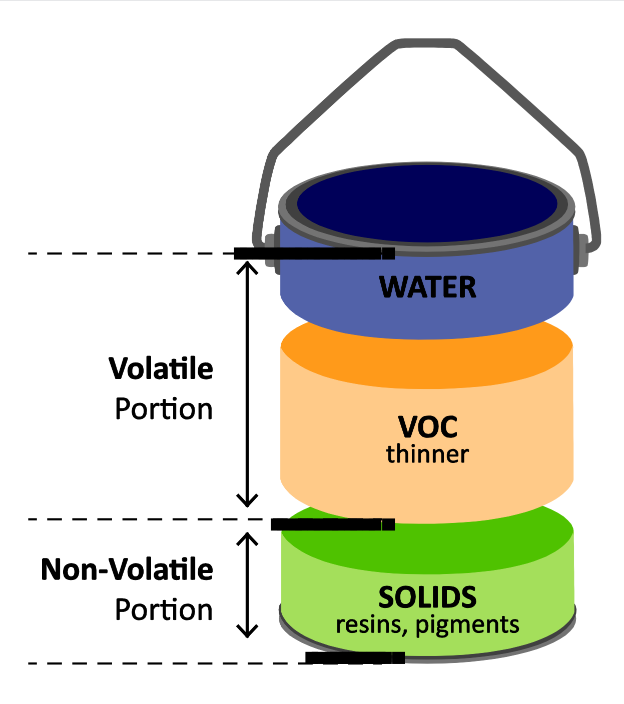
The VOC content of paints and coatings can be expressed in different units:

1. g VOC (less exempt solvent)/ L coating;
2. g VOC (less exempt solvent) / g solids; or
3. g VOC (less exempt solvent) / L solids.

It is important to have a common basis for comparing VOC Contents. In general, the preferred units are based on solid contents for regulatory work and compliance. In the U.S., the U.S EPA tends to use units of g VOC (less exempt solvent)/g solid (item 2), however, the State of California tends to use units of g VOC (less exempt solvent)/L solids (item 3).

Information on the coating contents can be found in Material Safety Data Sheets (MSDS), Certified Product Data Sheet (CPDS), Product Data Sheet (PDS), and Environmental Data Sheet (EDS). In the U.S., an MSDS is required to be provided by the manufacturer for each product. The MSDS sheet includes what the material is, provides the physical and chemical properties of the material, explains how to handle it safely, and how to respond to exposure or spill.

Figure 9.5-4 Coating Composition[50]



A CPDS is documentation furnished by coating suppliers or an outside laboratory that provides the HAP content by percent weight, measured using EPA Method 311, or an equivalent or alternative method approved by EPA; the VOC content and solids content by percent weight, measured using EPA Method 24, or an alternative or equivalent method; and the density, measured by EPA Method 24 or an alternative or equivalent method.

A PDS is not required but is usually available to facilities. A PDS contains information similar to an MSDS but does not necessarily include all of the MSDS information. The PDS tends to be more general. Larger coating manufacturers now develop these for their coating products.

An EDS provides VOC content of the coating or solvent. Facilities must base their VOC calculations and compliance on the VOC information in the EDS. The coating manufacturer develops these, and by following certification guidelines, they self-certify based on the criteria. An EDS is sometimes also called Certified Product Data Sheet.

Many industrial coatings may have 2 or 3 parts and are mixed prior to application; in this instance, a facility needs to know the mix ratio by weight or volume. Similarly, many coatings are thinned (diluted) at the facility where they are used. Thinners may be composed of 100% solvent (zero percent solids) which may be a VOC or HAP. Thus it is important to maintain records (mass or volume) of the actual materials that are applied.

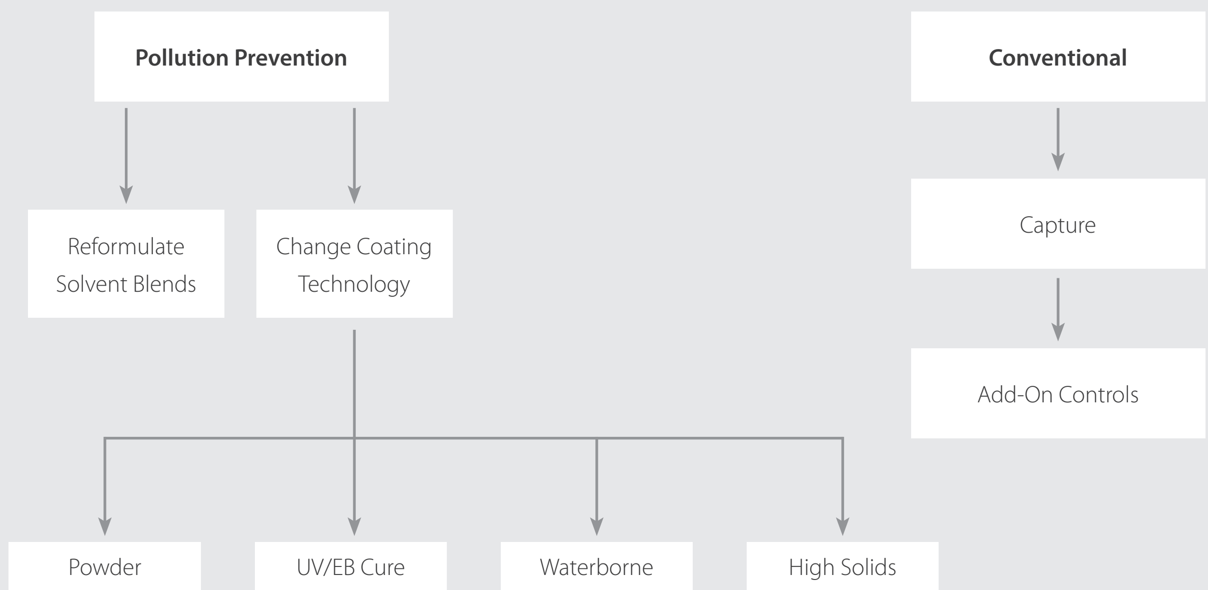
9.5.4 VOC Emissions Control Strategies

There are two general control approaches for reducing VOC emissions from coating operations, as shown in Figure 9.5-5. These are: (1) pollution prevention, and (2) conventional capture and control with add-on air pollution control devices (APCDs).

9.5.4 (A) Pollution Prevention And Waste Minimization

Pollution prevention approaches reduce or eliminate the quantity of VOC introduced in coating processes. Pollution prevention approaches result in emissions reductions from the coating process itself, and also reduce emissions from both thinning and cleanup solvents. Pollution prevention can involve reformulating the solvents used, or changing the coating technology. Alternative coating technologies may include changing to powder coatings, coatings that are cured using ultraviolet or electron beam, waterborne coatings, and high solids coatings. In the U.S., the focus has been on pollution prevention to reduce or eliminate the quantity of VOC introduced in coating processes, rather than use of capture and control.

Figure 9.5-5 Control Approaches for Reducing VOC Emissions from Coatings



Pollution prevention and waste minimization approaches are shown in Table 9.5-1. For example, changes to application techniques can improve the transfer of coatings to the part or substrate, or reduce the amount of VOC used or emitted. One approach mentioned in the table is to change the coating application technique to one that doesn't atomize (or spray) the coating, so that there is a much higher transfer efficiency (increase the amount of coating deposited on the substrate), which uses less coating material and lowers emissions. Application techniques such as dip coating and curtain coating, where the part is placed in or run through the coating, would work for smaller parts such as widgets, bricks, car bodies/frames, etc. There are several popular programs and concepts related to pollution prevention and waste minimization, including DfE (or Design for Environment), and a new concept called "PtD" (or Prevention through Design). Additional pollution prevention and waste minimization information is available through the Design for the Environment Program of the U.S. EPA (http://www2.epa.gov/saferchoice/design-environment-dfe-workplace-best-practices), and the Prevention through Design Program of the U. S. National Institute of Occupational Safety and Health (http://www.cdc.gov/niosh/topics/ptd/pubs.html.

Some examples of emissions reductions that can be achieved using pollution prevention include 1) a change to waterborne coatings, which would achieve up to 100% emission reduction; 2) a change to low vapor pressure cleaning solvents, which could achieve greater than 50% emission reduction; and 3) changing coating technology to powder coatings, which would achieve nearly 100% emission reduction. Pollution prevention is always preferable – especially for a new process because pollution prevention also reduces clean-up and disposal issues.

Table 9.5-1 Pollution Prevention and Waste Minimization

CAN BE APPLIED TO:	EMISSION REDUCTION APPROACH
Coating materials	Use low or non VOC materials; water-based materials; use powder and ultraviolet coatings;
Thinning materials	Use low-VOC materials or water
Cleaning materials	For spray booth cleaning and for hand wipe cleaning, use low or non VOC materials; use low vapor pressure cleaners; work practice to use only as much as is needed and no more;
Coating application techniques	Changing equipment and nozzles to reduce coating overspray by: • Improving transfer efficiency, • Changing to low flow nozzle to reduce overspray, • Using electro-deposition of coating to reduce overspray, or • Changing to curtain coating or dip coating.
Coating, thinning, cleaning	Coating process SOPs written to limit the amount of coatings, thinning solvents and cleaning solvents; Keep containers close to the greatest extent possible; Keep solvent laden rags in closed containers.

In changing a coating process to use of low VOC, non-VOC or VOC-exempt coatings, a facility must consider the impacts of this change to the process. Impacts to the process and the product may include the need for different storage, application, and drying equipment, how much drying time and drying air is required with the new coating, performance of the coating, ease of application, and durability issues for the final product. Sometimes facilities are able to switch coatings for some products but not for others. In those instances, the facility may have both the equipment for applying and drying solvent borne coatings, and equipment for applying and drying waterborne coatings. In addition, the move from solvent borne to waterborne is not a "no-cost" change. Water can cause rust and other issues for metal equipment, so switching to waterborne may involve upgrading to stainless steel application equipment and upgrading drying and air heating equipment.

The largest coating companies in the U.S., and among the largest worldwide, include PPG Industries, Sherwin Williams, DuPont, and Valspar.

9.5.4 (B) Add-On Air Pollution Control Devices

Use of conventional add-on air pollution control devices (APCDs) involves capturing the VOC emission stream and routing it to a control device. Typical VOC APCDs include those listed in Table 9.5-2. Although capture systems and add-on control devices are available for the control of VOC emissions from surface coating processes, the selection of add-on controls is highly dependent on the composition of the coating applied and the product being coated. The VOC emissions often occur in spray booths and typically exhaust a high volume of air with a low concentration of VOC, which would result in a high cost of control.

Table 9.5-2 Add-on Air Pollution Control Devices for VOCs[51]

AIR POLLUTION CONTROL DEVICE	EXPECTED CONTROL EFFICIENCY
Thermal Incinerators, Thermal Oxidizer, Afterburners,	98%
Catalytic Oxidizers	95%
Concentrators	Approximately 90% (for concentrator plus thermal incinerator)
Vapor Incinerators, Afterburners, Flares	98% for properly operated flare and with heat content >11 MJ/sm^3.
Carbon Adsorbers	95 to 98%
Condensers	50 to 99%
Water Curtains	Varies, depends on solubility of the specific VOC
Water Scrubbers	Varies, depends on solubility of the specific VOC

9.5.5 Calculating VOC Emissions (Facilities Without APCDs)

To show compliance with an air emission limit, surface coaters must calculate and track air emissions using one of three approaches:

1. Surface coaters may determine their annual air emissions by obtaining ongoing VOC/HAP data (or reports) from their paint or solvent suppliers or manufacturers. VOC/HAP reports can be used to demonstrate compliance with emission limits or permit requirements because these reports include information on the type and quantity of products used at the facility, the VOC and HAP content of each product, and the total amount of VOC and HAPs emitted by the facility each year.
2. Surface coaters may choose (or may be required) to perform their own air emission calculations on a monthly or daily basis. These surface coaters often use electronic spreadsheets to track product purchase information and product chemical information (included on MSDS or CPDS) and to perform air emission calculations.
3. Auto body shops and surface coaters of metal parts and products may take advantage of streamlined procedures for calculating, tracking, and reporting air emissions.

In the U.S., a facility's air permit will specify the type and frequency of its VOC and HAPs calculations and recordkeeping requirements.

9.5.6 Regulations For VOC Emissions From Coating Processes

U.S. EPA has developed surface coating regulations for several different industries, see Table 9.5-3. Some regulations apply to new sources, some to existing sources, and some only to those facilities that are located in nonattainment areas for ozone (O_3). Some air regulations require select businesses to reduce VOC emissions using Reasonably Available Control Technology (RACT). These requirements may include using low VOC or high performance coatings, High Volume Low Pressure (HVLP) spray guns, or other technologies that will achieve a high degree of emission control for coating operations. The U.S. EPA has developed control techniques guidelines for some industrial emission sources to assist states in determining RACT for VOC sources. Table 9.5-3 lists the industries that perform surface coating for which control techniques guidelines have been developed.

The following websites provide more details for each industry source: www.epa.gov/ttn/atw/coat/common/coatingsdisc.html and http://www3.epa.gov/ozonepollution/SIPToolkit/.

Table 9.5-3 Industries Subject to U.S. EPA Surface Coating Regulations

NEW SOURCE PERFORMANCE STANDARDS (NSPS) AND NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS (NESHAP)	CONTROL TECHNIQUES GUIDELINES (CTGS)
Architectural and Industrial Maintenance (AIM)	Pressure Sensitive Tape and Labels
Automobile & Light Duty Truck	Offset Lithography
Fabric Printing, Coating, & Dyeing	Paper, Film, and Foil Coatings
Large Appliances	Large Appliances
Metal Can	Metal Can
Metal Furniture	Metal Coil
Paper & Other Web	Metal Furniture
Wood Building Products	Industrial Adhesives
Aerospace	Wood Building Products
Shipbuilding	Aerospace
Metal Coil	Shipbuilding
Misc. Metal Parts	Automobile Refinishing
Plastic Parts	Fiberglass Boat Manufacturing
Wood Furniture	Plastic Parts
	Wood Furniture
	Flatwood Paneling

9.5.7 Typical Compliance Options For Surface Coating Regulations

In the U.S., coating facilities typically have three options for meeting and demonstrating compliance with VOC emission limits:

1. Use of Compliant Material* – no reporting required
   - as purchased
   - as applied
2. Meet an Emission Rate - without Add-On Controls
   - Example: 200 g VOC/L × 5,000 L/yr = 1,000 kg VOC/yr
3. Emission Rate - with Add-On Controls

** Expressed in units of:*

$$\frac{\text{g VOC (less exempt solvent)}}{\text{g (or liter) of solids applied}}$$

For both items 2 and 3 above, facilities must keep records showing their emission calculations and report the data.

9.5.8 Automotive Painting

Because of the large number of industries that have surface coating operations, the new car (assembly plant) automotive industry was selected to illustrate VOC emission controls and related aspects associated with surface coating processes.

The 2004 NESHAP for automobile and light-duty truck assembly coating operations imposed organic HAP emission limitations calculated on a monthly basis for existing sources. More stringent limits apply to new sources. The limits for automobile and light-duty truck assembly coating for existing and new sources are summarized in Table 9.5-4 below.

Table 9.5-4 U.S. Emission Limits for Automotive and Light Duty-Truck Painting Operations[52]

ASSEMBLY COATING PROCESS	EXISTING SOURCES	NEW OR RECONSTRUCTED SOURCES
Combined primer-surfacer, topcoat, final repair, glass bonding primer, and glass bonding adhesive operation plus all coatings and thinners, except for deadener materials and for adhesives and sealer materials that are not components of glass bonding systems, used in coating operations added to the affected source.	0.132 kg organic HAP/liter of solids deposited	0.060 kg organic HAP/ liter of solids deposited
Combined electrodeposition primer, primer-surfacer, topcoat, final repair, glass bonding primer, and glass bonding adhesive operation plus all coatings and thinners, except for deadener materials and for adhesives and sealer materials that are not components of glass bonding systems, used in coating operations added to the affected source.	0.072 kg organic HAP/liter of solids deposited	0.036 kg organic HAP/liter of solids deposited

Jiangsu has established provincial VOC emission standards for surface coating of various categories of new vehicles.[53] These standards are based on mass of VOC emitted per surface area coated. The standard for passenger cars (seating capacity <9) is 35g VOC/m2. These standards are based on total surface area available for electrodeposition primer. As primer-surfacer and topcoat are applied only to the outward facing surfaces of body panels, an alternate standard for these materials based on mass of VOC emitted/volume of deposited coating solids has been included in Table 9.5-5. A summary of recommended VOC emission limits for automobile and light duty truck surface coating for these and other coating operations is provided in Tables 9.5-5 and 9.5-6 below:

Table 9.5-5 Recommended VOC Emission Limits for Automobile and Light-Duty Truck Assembly Coatings[54]

ASSEMBLY COATING PROCESS	RECOMMENDED VOC EMISSION LIMIT		
Electrodeposition primer (EDP) operations (including application area, spray/rinse stations, and curing oven)	When solids turnover ratio (R_T)>0.16:	When $0.040<R_T<0.160$:	When $R_T<0.040$:
	0.084 kg VOC/liter coating solids applied	$0.084 \times 350^{0.160-R_T}$ kg VOC/liter coating solids applied.	No VOC emission limit
Primer-surfacer operations (including application area, flash-off area, and oven)	1.44 kg VOC/liter of deposited solids on a daily weighted average basis		
Topcoat operations (including application area, flash-off area, and oven)	1.44 kg VOC/liter of deposited solids on a daily weighted average basis		
Final repair operations	0.58 kg VOC/liter of deposited solids on a daily weighted average basis		
Combined primer-surfacer and topcoat operations	1.44 kg VOC/liter of deposited solids on a daily weighted average basis		

Table 9.5-6 Recommended VOC Emission Limits for Miscellaneous Materials Used at Automobile and Light-Duty Truck Assembly Coating Facilities[54]

MATERIAL	RECOMMENDED VOC EMISSION LIMIT*
Glass bonding primer	900 g VOC/liter
Adhesive	250 g VOC/liter
Cavity wax	650 g VOC/liter
Sealer	650 g VOC/liter
Deadener	650 g VOC/liter
Gasket/gasket sealing material	200 g VOC/liter
Underbody coating	650 g VOC/liter
Trunk interior coating	650 g VOC/liter
Bedliner	200 g VOC/liter
Weatherstrip adhesive	750 g VOC/liter
Lubricating wax/compound	750 g VOC/liter

*Grams of VOC per liter of coating excluding water and exempt compounds, as applied.

9.5.9 Maximum Incremental Reactivity

Although VOCs are considered photochemically reactive, they do not all have the same degree of reactivity. The California Air Resources Board (CARB) has adopted regulations for VOC based on their relative ground-level ozone impacts. These impacts are quantified using the Maximum Incremental Reactivity (MIR) scale. An MIR value is assigned to each VOC compound that is a measure of the compound's potential to react in the atmosphere to form O_3. The MIR units are in grams of O_3 formed per gram of VOC (g O_3 formed/g VOC). MIR values equal to or less than the MIR for ethane (0.28) are considered negligibly reactive. MIR values have been developed for 1,140 compounds and mixtures. Table 9.5-7 contains MIR values for selected VOC compounds. The higher the MIR value for a given solvent, the more ozone is generated when it is emitted to the atmosphere.

Table 9.5-7 MIR Values for Selected Compounds[55]

VOC	MIR (g O_3 / g VOC)
Ethane	0.28
Methanol	0.67
Benzene	0.72
Isobutane	1.23
n-Butane	1.15
Styrene	1.73
Ethyl Benzene	3.04
Toluene	4.00
m-Xylene	9.75
o-Xylene	7.64
p-Xylene	5.84
Isobutene	6.29
Ethene	9.00
Formaldehyde	9.46
Methyl methacrylate	15.61
Methacrylic acid	18.78

Advantages to the MIR approach include the following:

- Discourages use of high-reactivity solvents and encourages use of low-reactivity solvents,
- Encourages reformulating the coating to use a lower reactive solvent, and
- Provides information on the impact of various VOCs on O_3 formation.

Disadvantages to the MIR approach include the following:

- Imposes more recordkeeping and reporting burden on the paint and solvent manufacturers,
- May reveal formulations that are considered trade secrets by some manufacturers, and
- Because of differences in solvency characteristics, replacing a high MIR solvent with a lower MIR solvent can have impacts on the coating process, the coating application equipment, drying process and on product quality.

9.5.10 Baseline Emissions And Emission Reductions

The EPA's estimated reduction in nationwide emission reductions of hazardous air pollutants (HAP) as well as VOC as a result of the EPA's NESHAP are shown in Table 9.5-8.

Table 9.5-8 Nationwide Emission Reductions for (U.S. Automobile and Light-Duty Truck Surface Coating Facilities)[56]

POLLUTANT	BASELINE EMISSIONS	CONTROL	REMOVAL EFFICIENCY	EMISSION REDUCTIONS
HAP	10,000 tons per year	Combination of add-on controls for exhaust streams and replacement coatings	60%	4,000 tons per year
VOC	25,000 tons per year		50%	12,500 tons per year

9.5.11 Control Costs

There are several (process) steps in automobile and light-duty truck surface coating operations. In complying with U.S. EPA emission limitations, there are specific process areas or steps where facilities typically have to make changes. The cost per ton of HAP controlled for each step is presented in Table 9.5-9.

Table 9.5-9 Emissions and Control Costs for Automobile and Light-Duty Truck Surface Coating Operations[56]

SURFACE COATING PROCESS	CONTROL APPROACH	COST
Electrodeposition Primer with Oven Curing	Thermal oxidizer for oven exhaust	$8,200/ton of HAP controlled
Primer-Surfacer and Topcoat	Reformulation (reduce HAP-to-VOC ratio)	$540/ton of HAP controlled
Primer-Surfacer and Topcoat	Thermal oxidizer for spray booth exhaust	$40,000/ton of HAP controlled
All Steps Combined (Average)	—	$25,000/ton of HAP controlled

Costs of controlling emissions from automotive and light-duty truck surface coating facilities were estimated by the U.S. Environmental Protection Agency as part of development of emission standards for the U.S. automotive manufacturing industry. Estimates of capital and annualized costs for the overall U.S. automotive painting industry were estimated and included the cost of compliance monitoring using continuous emissions monitoring (CEMS). The estimated total capital costs are $670 million resulting in an additional annualized capital cost of $75 million. Total annual costs including capital recovery, operating costs, monitoring, and recordkeeping and reporting are $154 million per year.[56]

9.5.12 U.S. State-Of-The-Art Facility

There are many coating facilities that, using different technologies, would be considered state-of-the-art facilities. Nissan's Tennessee facility is an example of a facility using state-of-the-art coating systems. This facility implemented a new coating system with a "three-wet" paint process, where all 3 coats are applied while wet, with no drying step between the coating layers. The VOC emissions were reduced by 70%. This coating system also reduced energy consumption by 30% as a result of fewer drying steps and because there is less process time from beginning to end, the process has increased efficiency. [57]

9.5.13 Greenhouse Gas Considerations

Carbon dioxide is the most significant greenhouse gas associated with coating systems. Efforts to reduce CO_2 emissions generally focus on increasing efficiencies and reducing energy use. Examples of efficiency measures include:

- The use of wet paint processes where multiple layers of paint are applied while each layer is still wet eliminates stand-alone paint applications and dedicated ovens required in conventional painting processes.
- The reduced use of blowers to reduce the amount of natural gas needed to heat the air and ovens.
- Recovering the heat from paint spray booth stacks using heat pump technology.

9.5.14 Recommendations

Table 9.5-10 summarizes the recommendations for Jiangsu Province based on the U.S. experience in the relevant fields.

Table 9.5-10 **Summary of U.S. Experiences and Recommendations**

U.S EXPERIENCE		RECOMMENDATIONS FOR JIANGSU
THEN	NOW	
All VOC compounds treated equally, no distinction based on photochemical reactivity to form O_3 (no MIR approach)	Certain States now evaluate VOC compounds based on MIR and account for/ encourage those VOC with lower MIR vs. higher MIR	**Evaluate MIR approach**
Conventional capture and control, i.e., capture of VOC emission streams from coating application process and venting to an add-on Air Pollution Control Device (APCD)	Reduce or eliminate VOC introduced into the coating process, thinning solvents, and cleanup solvents, by reformulating solvents or changing coating technology	**Pollution prevention programs**
VOC solvent selection focused on process technical impact and coating performance only (storage, application, and drying equipment; drying time and energy requirements; and coating performance, ease of application, and durability of final product)	VOC solvent selection considers process technical impact, coating performance, and environmental/VOC emission impacts	**Alternate materials - reformulation**
Conventional air atomized spray	High volume, low pressure (HVLP) spray, electrostatic assist, improved operator training, automated spray equipment	**Improved transfer efficiency – spray equipment / automation**
Emission limits based on percent control	Emission limits based on mass VOC emitted per mass solids applied, or mass VOC emitted/surface area	**Encourage waterborne materials**
Solvent borne coating	Waterborne, powder, ultraviolet cure	**Eliminate organic emissions and minimize waste coating**

9.6 MOBILE SOURCES AND FUELS

9.6.1 Background

Mobile sources emit CO, CO_2, NO_X, VOCs, PM (including black carbon), and air toxics, and are an important contributor to urban- and regional-scale emissions inventories. For urbanized areas in developed nations, mobile source emissions are typically responsible for about half or more of the urban air pollution problem, and contribute overwhelmingly to some pollutants such as CO and air toxics. In the Los Angeles area, for example, mobile source-dominated emissions of diesel particulate matter (DPM), benzene, and 1,3-butadiene, are estimated to represent over 80% of region wide cancer risk associated with air pollution (Figure 9.6-1). In addition, mobile sources create pollution "hot-spots" (areas of high pollutant concentrations) near heavily traveled roads, and studies show that populations close to major roads are at greater risk for adverse health effects.

Currently, vehicle use in China is at exceptionally low levels per capita compared to western developed countries. (Figure 9.6-2).

Figure 9.6-1 Sources of Los Angeles Area Air Toxics with Excess Cancer Risk[58]

Basinwide Risk: 418 per million
Based on Average of 10 Fixed Monitoring sites

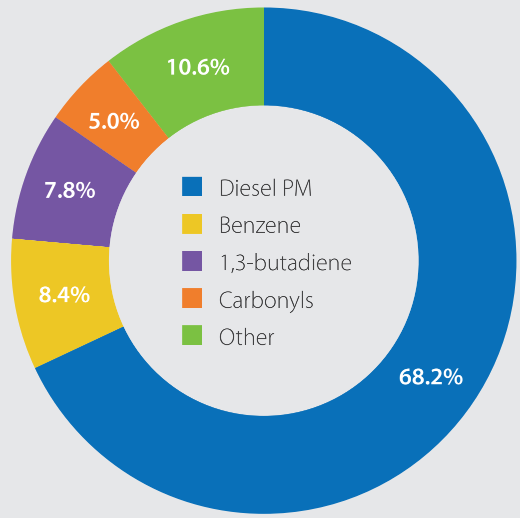


Figure 9.6-2 Per Capita Travel Activity (Vehicle Kilometers Traveled, VKT) Compared to Gross Domestic Product (GDP) in 2008[59]

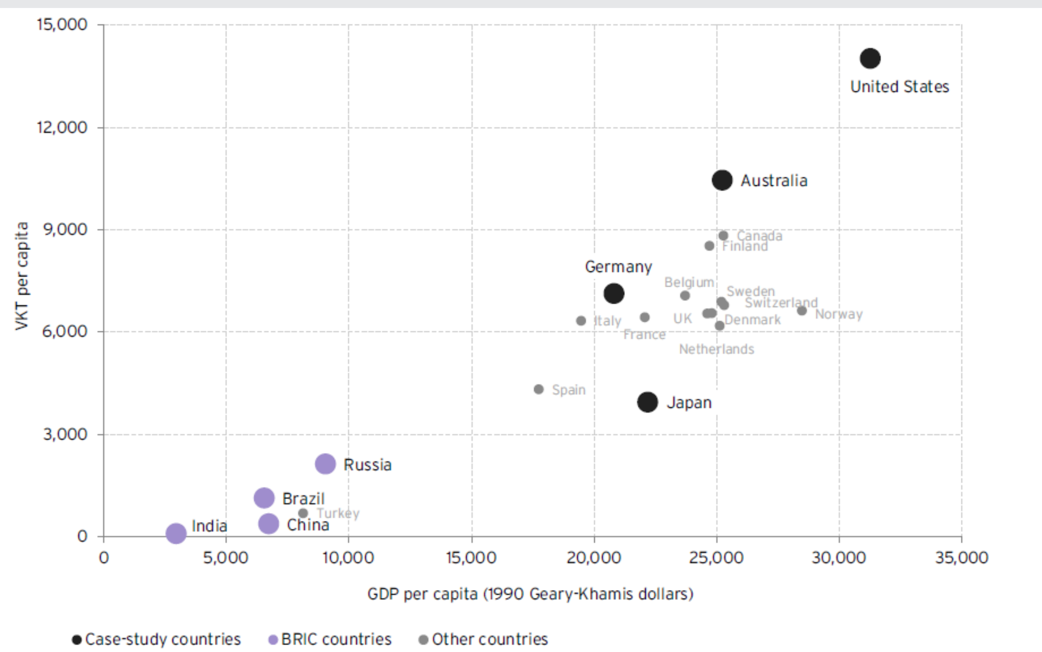
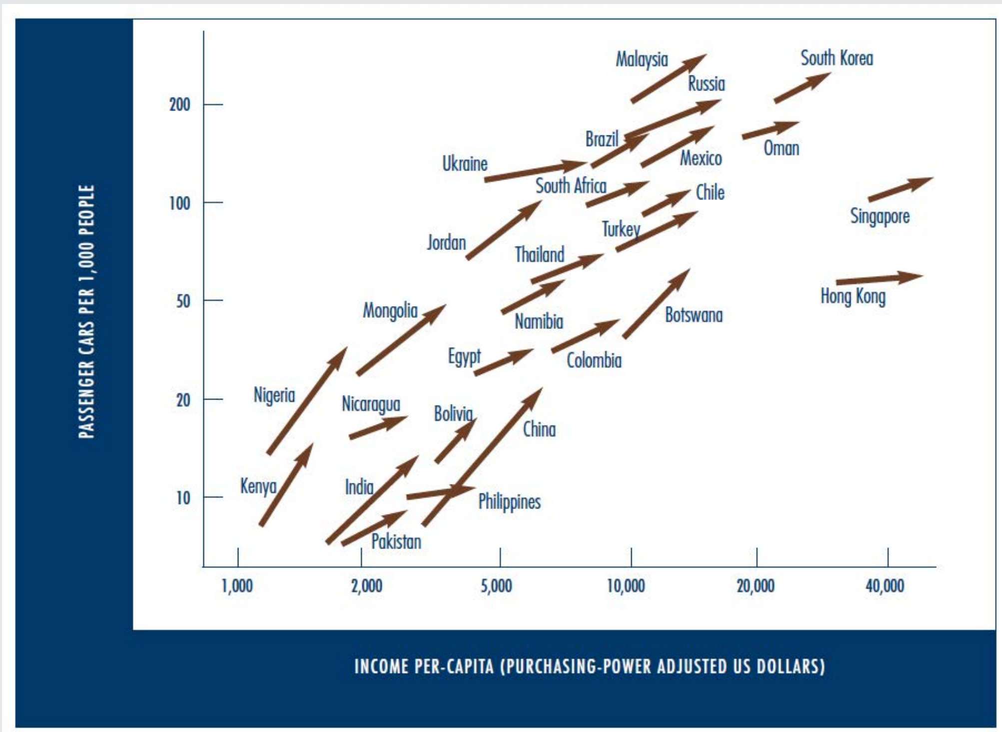
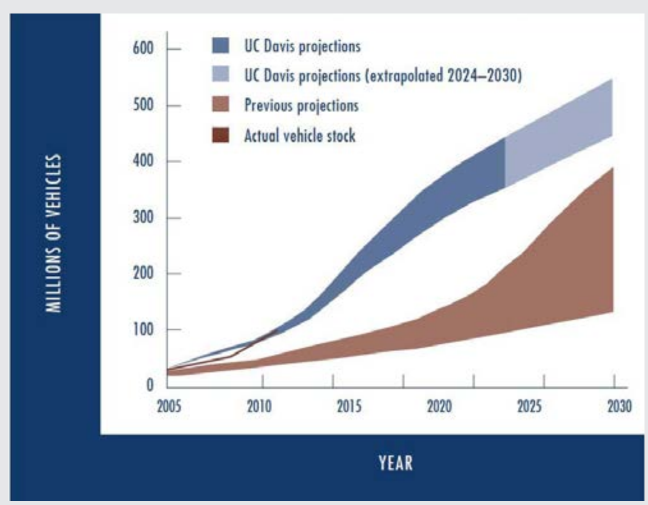


Figure 9.6-3 Motorization and Economic Growth in Developing Countries, 2002-2007 (Logarithmic Scale)[62]



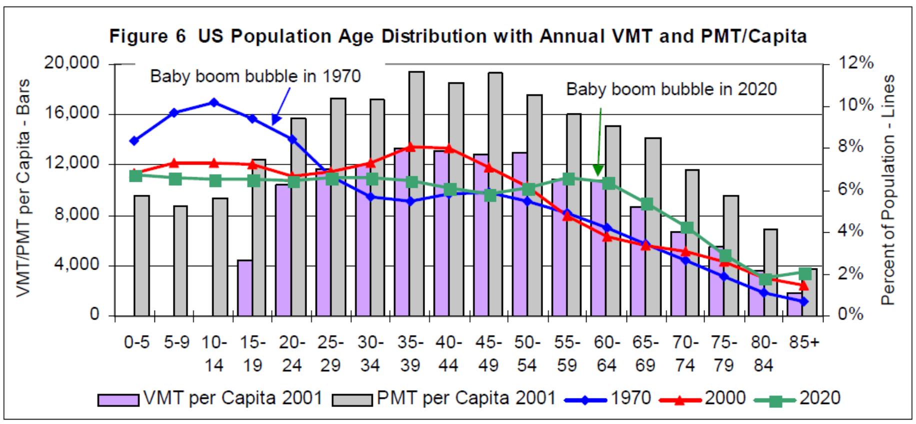
Given the comparatively low per-capita use of vehicles in China, there are many urbanized areas in China where air pollution problems are currently dominated by heavy industry. Studies indicate that in Jiangsu Province, for example, stationary sources have historically been the major contributors to air pollution.[60, 61] However, the expectation is that motor vehicles are, and will continue to be, a rapidly growing source of urban-area air pollution in China, due to several factors including population growth and rising per capita income, and the very low starting point of per-capita vehicle use. Studies show, for example, that as income rises, so does the population of vehicles per capita, and data from China are consistent with these findings (Figure 9.6-3). As a consequence, China is experiencing a high rate of growth in motor vehicle use—forecasts indicate these annual growth levels may be as high as 13-17% in coming years (Figure 9.6-4).

Figure 9.6-4 The Population of Chinese Motor Vehicles is Projected to Increase Substantially[63]



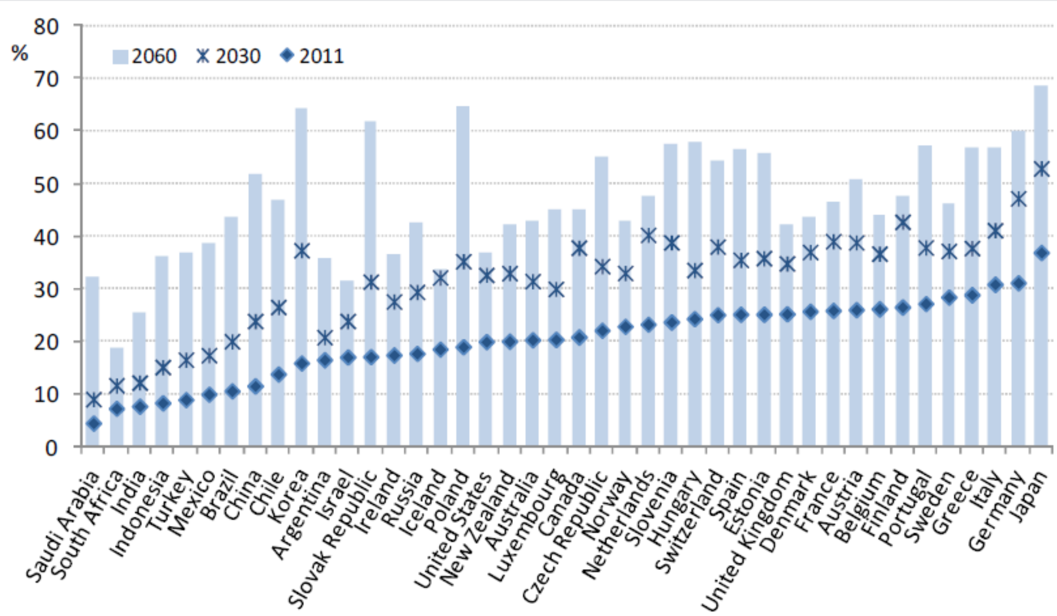
One factor that may dampen future growth rates in vehicle use is the shift in population age that is occurring in China as well as other nations. Data show that (a) as people age, they tend to drive less (Figure 9.6-5), and (b) the fraction of China's population that is older than 65 is growing over time (Figure 9.6-6). However, forecasted demographic shifts in population age are expected to materialize more fully by mid-century; until then, as shown in Figure 9.6-3, substantial vehicle growth is projected for China.

Figure 9.6-5 **U.S. Data Illustrates Reduced Driving with Increasing Driver Age**[64]



Source: CUTR analysis of NHTS/NPTS and Census data.

Figure 9.6-6 **Populations in China and Other Nations are Aging**[65]



9.6.2 Motor Vehicle Related Challenges

Some brief principles describe the key challenges to be addressed when reducing motor vehicle related air pollution.

1. Most urban areas experience continuous growth in vehicle use. Over time, in most countries, average per-vehicle emissions rates have declined due to technological advances in vehicles and fuels; however, increased numbers of vehicles and total vehicle kilometers traveled (VKT) have offset emissions reductions.

2. To improve existing and near-term air quality, it is important that control programs address the "in-use" fleet of vehicles, meaning those already on the road or, in the case of off-road vehicles such as construction equipment, boats, trains, and airplanes, those already in the field. Within the in-use fleet, there are two important sub-challenges to address.

    a. First, "middle-aged" vehicles, those roughly 10 to 20 years old, contribute disproportionately to emissions. The oldest vehicles on the road tend to be the highest emitters on an individual car basis. However, as vehicles age and are removed from the fleet, there tend to be few very old cars remaining, and those that survive over time tend to not be driven as much each year compared to middle-aged or newer vehicles. New vehicles have had to meet more stringent emissions standards, have not deteriorated much, and are under warranty; they contribute modestly to overall emissions. In contrast, middle-aged vehicles are no longer under warranty, have often had time to deteriorate, are still relatively plentiful, and are driven more per year than the oldest cars. The result is that they are the most important portion of the fleet in terms of emissions.

    b. Second, numerous studies of cars, trucks, ships and other sources indicate that regardless of model year, a small fraction (~10%) of the fleet is responsible for a large fraction (50% or more) of fleet emissions. Therefore, a key challenge is the need to identify and control these high emitters, often referred to as "gross polluting vehicles." Since gross polluters have been found within virtually all model years, it is difficult to predict which vehicles within a model year group will be gross polluters, unless steps are taken to require routine vehicle inspections or to deploy on-road emissions measurement equipment such as remote sensing devices (RSD).

3. To ensure future air quality improvements, experience shows that control programs need to address newly manufactured vehicles that will, over time, replace the in-use fleet.

Approaches to address these challenges fall into two broad groups: technology-based efforts to reduce vehicle emission rates (in other words, to reduce the amount of pollutants emitted from the exhaust stream), and behavior-based efforts to curb vehicle use. Historically, technology-based controls have been far more effective over time than behavior-based methods since, fundamentally, it is difficult to get people to change their behavior.

9.6.3 Program Approaches To Address Challenges

Mobile source emission levels are a function of several parameters, including the vehicle fleet mix (types and ages of vehicles), fuels characteristics, traffic volumes, vehicle maintenance, travel speeds and congestion levels, and the number of vehicles in use and the miles they are driven. Strategies for controlling mobile source emissions can be implemented at the international, national, provincial, or local scale, depending on the type of mitigation being considered. In general, mitigation approaches fall into six categories:

1. New-vehicle emissions standards – primarily at the national level, emissions standards for new vehicles (e.g., Euro 5, U.S. Tier 3) are used to reduce emissions as lower-emitting vehicles penetrate the fleet over time. In the U.S., California provides a less common example of a sub-national state granted authority to govern new-vehicle emissions. California's authority stems from

the unique severity of its air quality problems, its large population, and the dominant role it plays in the U.S. automotive market. New-vehicle standards are often cited as the single most effective long-term measure used to improve air quality in the cities of developed nations. This approach is technology based and relatively easy to enforce since the sources selected are high-volume manufacturers. Implementation is slow; it can take many years, 10 to 15 for example, for new vehicles to fully penetrate the fleet and replace older, higher-emitters. Per-vehicle emissions reductions of 90% and greater are frequently achieved over the long term.

2. Fuel property changes – specifications on fuel properties can be implemented at the national or provincial scale to reduce emissions; for example, Jiangsu Province is currently on an accelerated schedule for implementing low sulfur fuels that will reduce particulate emissions. Other examples of fuel-based controls include the addition of oxygenates to gasoline to reduce CO and reactive VOC emissions, limits on the benzene content of gasoline to reduce air toxics emissions, and Reid vapor pressure (RVP) standards to reduce evaporative VOC emissions. This approach is technology based and relatively easy to enforce. Implementation can be relatively quick (e.g., 3 to 5 years), and the fuel change will affect the entire fleet (in-use as well as new vehicles). Public education is essential; some fuel reformulation efforts that unexpectedly changed fuel odors or raised fuel prices have triggered adverse public responses when the public was inadequately informed about upcoming program implementation. Per-vehicle emissions reductions of 10% and greater are frequently achieved.

3. Retrofits and replacement of high-emitting vehicles – For existing vehicles, after-market control devices such as diesel particulate filters can be installed to reduce emissions, and incentive programs can be implemented to accelerate the replacement of older vehicles with newer, cleaner models. This approach is technology based, but relies on the participation (voluntary or mandated) of owners of individual vehicles and vehicle fleets. Enforcement is relatively easy if programs are voluntary, though more complex in mandatory programs involving large fractions of the driving public. Implementation can be relatively quick (e.g., 3 to 5 years), but may depend on the availability of public money to fund or subsidize retrofits and replacements. As shown by recent truck replacement programs at U.S. ports, truck retirement programs can accelerate fleet turnover. For example, retirement programs accelerated fleet turnover by a decade for trucks servicing the Port of Oakland, California, and reduced individual vehicle emissions 50-75%.[66] However, regional emissions reductions are typically small. From 1999 through 2003, California's landmark voluntary truck retrofit and replacement program (the "Carl Moyer Program") spent $25 million and reduced on-road truck NO_X emissions by about 2%.[67]

4. Inspection and maintenance (I/M) programs to identify and repair high-emitters – Periodic inspections of in-use vehicles can identify higher-emitting vehicles and encourage their repair or retirement. This approach is technology based, but relies on successful behavioral participation of vehicle owners and inspection and repair facilities. Designing optimal I/M programs has proven politically and technically difficult. Program design must be connected to vehicle technology. The most advanced U.S. programs now rely entirely on on-board diagnostic (hand-held computer readout) systems instead of exhaust emissions test programs. However, where the vehicle fleet is still comprised of older-technology vehicles, exhaust testing is an essential component of I/M programs. Centralized test programs that separate testing from repair work have proven more effective than decentralized programs, but are less acceptable to the public. Enforcement has proven difficult over time, with many I/M programs yielding less-than-expected emissions reductions. U.S. experience indicates fleet-wide emissions reductions of 10% to 15% are possible depending on program design features[68]. Implementation can be relatively quick (e.g., 3 to 5 years); however, substantial public and repair industry education is needed to support implementation success.

5. Transportation Systems Management (TSM) – At the traffic corridor level, cities can take action to smooth traffic flow and reduce emissions associated with stop-and-go and reduced-speed travel. Examples include traffic signal light timing synchronization, bus pullouts, turn lanes, and accident alerts that allow for traffic rerouting. Many of these strategies are packaged at the regional level into intelligent transportation systems (ITS) and are complemented by roadway capacity expansions to improve regional travel. This approach is technology based, with limited enforcement needs. Since TSM programs work at optimizing existing infrastructure, impacts are incremental and relatively small when calculated at the regional level (e.g., regional emissions reductions of 1-3% or less). Implementation can be relatively quick (e.g., 1 to 3 years).

6. Travel Demand Management – at provincial and local levels, government agencies can take measures to reduce VKT and encourage the use of less polluting modes of transportation through the addition of bicycling and walking paths, freeway travel lanes dedicated to high-occupancy vehicles, van and carpool support programs, increased public transit, and other services. These measures are designed to impact driver behavior, either through voluntary or mandatory programs. Examples of voluntary approaches include "Spare the Air" notification programs on days when carpooling and public transit use are encouraged; mandatory programs have included alternate day vehicle restrictions (such as was done during the 2008 Olympics in Beijing) and fees for accessing a city center, such as was implemented in Stockholm, Sweden and London, England. In addition, land use planning can include "smart growth" strategies to encourage dense, mixed-use development to reduce suburban sprawl and vehicle activity. Research has long showed that populations in dense urban areas well served by transit have reduced per capita vehicle use.[69] Many cities in China and other parts of Asia are at density levels that exceed cities in Europe and the U.S., and transit systems have worked to help reduce historic vehicle use in Asian cities. Overall, efforts to encourage travel behavior change have had widely varying results, depending in part on whether travel restrictions were mandatory (Beijing Olympics, 30-50% vehicle emissions reductions over a limited time), whether pricing strategies were used (Stockholm and London, 20-30% travel reductions achieved in affected central city locations), or whether communities were more dense and mixed use.[70] The U.S. has estimated that efforts to encourage mixed use development may result in ~5% (<1% to 11%) vehicle emissions reductions at the regional scale.[71] Mandatory travel reduction programs can be difficult to enforce over the long-term and can have unintended consequences, as has been demonstrated in areas such as Athens Greece, where some drivers purchased higher-polluting second vehicles to escape alternate-day license-plate-based driving restrictions.[72]

9.7 OTHER

Other air pollutant emission sources of concern in Jiangsu Province, and in the three cities include the following:

- Industrial boilers
- Biomass burning
- Electronics manufacturing
- Biopharmaceutical manufacturing
- Fugitive dust (including dust from construction sites)
- Restaurants/cooking
- Fertilizer application

While emissions from these sources are not addressed directly within the scope of this report, developing emission estimates for these sources will improve the overall quality of the emission inventory. In addition, obtaining emission reductions from these sources will contribute to the attainment and maintenance of air quality goals for Jiangsu Province, and for the three cities, individually.

Guidance on estimating emissions from many of these sources is available from the U.S. EPA's Technology Transfer

Network (TTN), Clearinghouse for Inventories and Emission Factors (CHIEF).[73] The emission inventory resources available on CHIEF include training modules, emission factor resources, and links to inventory-related software and tools.

Tools specific to $PM_{2.5}$ emission estimation are available from the U.S. EPA's $PM_{2.5}$ Inventory Resource Center.[74] The $PM_{2.5}$ Resource Center includes guidance on $PM_{2.5}$ inventory preparation, emission estimation tools, quality control, and information on ongoing $PM_{2.5}$ research projects.

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2. Emission limits are based on standard cubic meters at 273K and 101.325 kPa.
3. The Ministry of Environmental Protection (MEP) issued GB 13223-2011 in December of 2011, National Development and Reform Commission (NDRC), and Ministry of Finance jointly issued the 12th Five-Year Plan on Air Pollution Prevention and Control in Key Regions. The plan was approved by the China's State Council in September 2012. http://en.cleanairchina.org/product/6285.html.
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5. The economizer is a heat-exchanger located where the flue gas exits the boiler. The economizer transfers heat from the flue gas to feed water entering the boiler. At low operating loads the velocity of flue gas is much slower and the economizer absorbs significantly more heat from the flue gas. During these low-load operating conditions, the flue gas becomes too cold to support the chemical reactions in the SCR that reduce the oxidation state of NO_X to form N_2 and H_2O.
6. This profile reflects operation of a unit that does not have an economizer by-pass or other accommodations to maintain high flue gas temperatures when the unit is operating at low loads.
7. Measures may include partial economizer bypass ducts or equivalent measures for maintaining flue gas temperatures in the range necessary for NO_X reduction by the specified catalyst material.
8. Article 15 of the Environmental Protection Law of the People's Republic of China (4/24/2014) authorizes provinces to set standards which are more stringent than the national standards. http://www.china.org.cn/english/government/207462.htm.
9. The post combustion classification is based on the expected concentration of NO_X exiting the furnace after installation of only state-of-the-art low-NO_X burners and combustion air systems.
10. Yuan Xu, R.H. Williams, and R. Socolow, "China's rapid deployment of SO_2 scrubbers," Energy & Environmental Sciences, vol. 2, pp. 459-465, 2009.
11. By-pass ducts on desulfurization equipment for coal-fired boilers.
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13. Dry scrubbers on a new unit can be used to reduce the water quality impacts of wet scrubbers installed on existing units. See https://www.duke-energy.com/pdfs/NG-Cliffside-Modernization-Brochure.pdf.
14. The standard for utility boilers with ≥ 100MWe capacity is 35mg SO_2/m^3 at 6 percent O_2.
15. A cold-side ESP is installed prior to the combustion air preheater and typically operates at temperatures < 150°C.
16. A hot-side ESP is installed after the combustion air preheater and typically operates at temperatures > 350°C.
17. In the USA at the Cliffside Coal Plant in Charlotte, NC, a dry scrubber is used to evaporate wastewater generated by two wet FGD systems at the same power plant.

18. The performance of mist eliminators on wet scrubbers must be monitored or significant $PM_{2.5}$ emissions can occur when slurry droplets with high dissolved solids are entrained in flue gas exiting the scrubber.
19. http://cornerstonemag.net/water-saving-fgd-technologies/
20. The standard for power boilers serving generators < 100MW is 50mg SO_2/m^3 at 6 percent O_2.
21. Shubert Ciencia, CC-BY-2.0 (http://creativecommons.org/licenses/by/2.0), via Wikimedia Commons.
22. On wet scrubbers USEPA Reference Method 5B should be used to quantify filterable PM (fPM) and USEPA Reference Method 202 (Dry Impinger Method) should be used to quantify condensable PM (cPM).
23. Wet scrubbers are capable of removing oxidized forms of Hg. If the scrubber chemistry changes due to high levels of chlorides in scrubber liquor, oxidized Hg can be converted to elemental Hg and exit the scrubber.
24. Emission rates are presented as lbs of Hg per trillion Btu of heat input from coal.
25. To determine compliance with the listed limits, actual concentration measurements should be adjusted from the measured O_2 concentration in the flue gas to 6% O_2 using the following equation:

    $$C_{adj}=C_{measured}\ \frac{20.9-6}{20.9-O_{2\ measured}}\ ;$$

    See Section 7 of Appendix A-7 to 40 CFR Part 60.
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10

Assessment of Air Quality Improvement, Costs and Benefits for Future Control Strategy Scenarios

OVERVIEW

U.S. best practices for assessing air quality improvement, costs, and health benefits for a proposed emission reduction strategy would involve a comparison between the base case and the future case emissions inventories, using a platform such as Air Benefit and Cost and Attainment Assessment System (ABaCAS). Without a complete air emission inventory and emissions modeling, we cannot predict the magnitude of ambient air quality improvement that will be achieved with the application of the proposed control technologies. Consequently, this chapter provides information on achievable emission reductions and air quality improvements, based on U.S. experience with the application of these technologies.

The sections which follow describe emission reductions, ambient air quality improvement, control costs, health and economic benefits, and other impacts associated with implementation of the proposed control strategies in the U.S. at the facility level, and in some cases, at the national level. In the future, the U.S.-based facility-level information on emissions reductions presented in Chapter 9 and cost estimates summarized here can be used, along with the baseline emissions inventory in Jiangsu, to develop future case emissions inventories that include a range of potential control options for industrial facilities in Jiangsu. Using the ABaCAS model, Jiangsu could estimate the ambient air quality levels that would result after implementation of the selected control options. If the selected control options do not show enough improvement, then more stringent options can be modeled until the desired outcome is predicted from the model. The model also includes estimated costs and health benefits which must also be considered when determining which control requirements will be implemented. It is expected that Jiangsu would review a series of different options of varying levels of stringency, and select the options based on the future case emissions inventory that provided the best balance between air quality improvements, costs and health benefits.

The predicted ambient air quality level resulting from the emissions modeling will depend on the quality of the base case and future case emissions inventories. The impacts of pollution from neighboring cities and provinces will also impact the actual ambient air quality levels achieved, and these impacts can be difficult to estimate. As noted in a previous section, in preparation for the Nanjing Youth Olympics in 2014, Jiangsu did a study where they analyzed data from the ambient air quality monitoring stations during periods where specific industrial activities were halted. The data from this study provided real-time data that showed significant improvements in air quality when the industry sectors were shut down. This study helped to focus this Air Quality Management Planning Framework on industrial sectors, as noted previously. The study results will also be very useful in developing any future modeling scenarios, and determining background levels of pollutants and contributions from neighboring cities and provinces.

10.1 EMISSION REDUCTIONS

Emission reductions realized for the industrial sectors discussed in Chapter 9 are summarized in Table 10-1. Emission reductions from petroleum refining are presented as the percentage reductions in criteria pollutants and HAP from the period 1990-2010. In the iron and steel manufacturing sector, the application of fabric filters or other PM control devices are estimated to reduce PM emissions and metal HAP emissions by 1,500 tons/yr and 13 tons/yr, respectively. Total emission reductions for PM and SO2 for all existing cement kilns are summarized below. In Chapter 9, emission reductions for HAP and non-HAP are presented for a typical modern kiln with a production capacity of 1.2 million tons of clinker/yr. Reductions in SO2 emissions are the result of emission controls for HAP as well as emission control for SO2. As the emissions standard for NOX only applies to new sources, the estimated emission reduction occurs in the 5th year after promulgation of the standard for Portland cement. Emission reductions of HAP and VOC from the automobile and light-duty truck surface coating facilities are summarized below, as an example of the emission reductions achievable from surface coating operations. Emission reductions achievable from surface coating facilities are described in more detail in Chapter 9.

Table 10-1 Emission Reductions for Industrial Sectors

INDUSTRIAL SECTOR	EMISSION REDUCTIONS
Petroleum refining[1]	
Criteria air pollutants	80% from 1990-2010
HAP	70% from 1990-2010
Iron and steel	
Metal HAP	13 tons/yr
PM	1,500 tons/yr
Cement manufacturing	
PM	9,500 tons/yr
NO_X	6,600 tons/yr
SO_2	95,500 tons/yr
Surface coating	
HAP	6,000 tons/yr
VOC	12,000 tons/yr

10.2 AMBIENT AIR QUALITY IMPROVEMENT

Following implementation of the selected control options in Jiangsu, the ambient air quality should improve, assuming that these controls are properly operated and maintained and that pollution from neighboring provinces and cities impacting Jiangsu does not increase. Predicted levels of air quality improvement from modeling are continuously compared to the actual ambient air quality levels as measured from monitoring stations, and adjustments to air quality plans are made to ensure that the required levels are met. The U.S. EPA tracks air quality trends in the U.S. using measurements from ambient air quality monitors located across the country. Table 10-2 shows that U.S. air quality, based on common pollutants, has improved significantly since 1980.

The EPA also tracks nationwide emissions of air pollutants and the pollutants they are formed from (their precursors). These estimates are based on actual monitored readings or engineering calculations of the amounts and types of pollutants emitted by factories, vehicles, and other sources. Table 10-3 shows that the emissions of common air pollutants and their precursors have been reduced substantially since 1980.

Table 10-2 Percent Change in Ambient Air Quality for Common Pollutants in the U.S.[2]

POLLUTANT	1980 VS 2014	1990 VS 2014	2000 VS 2014
Carbon Monoxide (CO)	-85%	-77%	-60%
Ozone (O_3) (8-hr)	-33%	-23%	-18%
Lead (Pb)	-98%	-97%	-87%
Nitrogen Dioxide (NO_2) (annual)	-60%	-52%	-43%
Nitrogen Dioxide (NO_2) (1-hour)	-57%	-45%	-29%
PM_{10} (24-hr)	—	-36%	-30%
$PM_{2.5}$ (annual)	—	—	-35%
$PM_{2.5}$ (24-hr)	—	—	-36%
Sulfur Dioxide (SO_2) (1-hour)	-80%	-76%	-62%

Table 10-3 Percent Change in Common Air Pollutant Emissions in the U.S.[3]

POLLUTANT	1980 VS 2014	1990 VS 2014	2000 VS 2014
Carbon Monoxide (CO)	-69%	-62%	-46%
Lead (Pb)	-99%	-80%	-50%
Nitrogen Oxides (NO_X)	-55%	-51%	-45%
Volatile Organic Compounds (VOC)	-53%	-38%	-16%
Direct PM_{10}	-58%	-19%	-16%
Direct $PM_{2.5}$	—	-25%	-33%
Sulfur Dioxide (SO_2)	-81%	-79%	-70%

10.3 CONTROL COSTS

Costs for recommended emission controls (discussed in Chapter 9) for the iron and steel, cement manufacturing, and surface coating industrial sectors are summarized in Table 10-4. For the iron and steel sector, add-on controls are primarily for the control of PM, with fabric filters being the most cost effective control for most emission sources. In the cement manufacturing sector, annualized costs were estimated for a typical kiln having a production capacity of 1.2 million tons of clinker/yr equipped with a wet scrubbers for SO_2 and HCl control ($3.6 million), SNCR for NO_X control ($1.3 million) and upgrading baghouses by replacing standard cloth bags with PTFE membrane bags for PM control ($0.35 million). In surface coating operations for automobiles, costs range from $540/ton of HAP controlled to $40,000/ton depending on the surface coating step and control approach, with an average cost of $25,000/ton of HAP controlled. Because of the complexity of refineries and the number and types of emissions sources, control costs for refineries are summarized separately in Table 10-5.

Table 10-4 Cost of Controls to Reduce Emissions from Industrial Sectors

INDUSTRIAL SECTOR	CONTROL MEASURE	ANNUALIZED COST
Iron and Steel[4]	Fabric filter	$100-600/acm/min
Cement Manufacturing[5]	Scrubber, SNCR, PTFE bags	$0.35-3.6 million
Surface Coating[6]	Thermal oxidizer, reformulation	$25,000/ton of organic HAP controlled

Table 10-5 Petroleum Refinery Emissions Control Costs [7, 8, 9]

EMISSION SOURCE	POLLUTANT	CONTROLS	ANNUALIZED COSTS ($/YR)	COMMENT/NOTES
FCCU	PM	ESP	$1.7 to $4-million	40 to 100K bbl/d throughput retrofit project
	SO_2	Catalyst additives	$700/ton SO_2 reduced. Can vary from $1 to $10-million depending on size of unit and uncontrolled SO_2 concentration	40 to 100K bbl/d throughput; uncontrolled SO_2 concentrations ranging from 200 to 1,000 ppmv.
	NO_X	SCR	$1 to $3-million	40 to 100K bbl/d throughput retrofit project
	PM, SO_2, and NO_X	Co-control using wet scrubber with LoTox system	$3 to $10-million	40 to 100K bbl/d throughput retrofit project
Process heaters and boilers (gas-fired)	NO_X	Ultra-low NO_X burners and/or advanced air controls.	$50,000 to $140,000 per process heater	40 to 400 MMBtu/hr process heaters, retrofit
Flare	VOC	Flare gas recovery system	$0.5 to $2.0 million with recovery credits of $0.6 to $4.0 million (so net cost savings of $0.1 to $2.0 million if can use recovered gas to off-set natural gas purchases)	Recovery systems ranging from 4,500 scf/hr to 80,000 scf/hr
Cooling Towers	VOC	Repair "leaks" identified	Quarterly monitoring costs $4,000/yr per cooling tower; recovery credits of $1,000 to $20,000/yr; average net savings of $1,000/yr per cooling tower.	Water circulation rates of 5,000 to 100,000 gpm
Sulfur Recovery Unit	SO_2	Claus (desulfurizing process) with tail gas treatment units	$1.5 to $5-million/yr considering sulfur recovery credits	Claus plant with tail gas treatment unit, sulfur recovery capacities ranging from 5 to 100 long tons/day
Equipment Leaks	VOC	Repair "leaks" identified	$400/ton VOC reduced	Average for original 40 CFR 63 subpart CC
Storage Tanks	VOC	Dual seal roofs, gasketed hatches, wipers for ladders and guide poles	$380/ton VOC reduced	Average for original 40 CFR 63 subpart CC

10.4 HEALTH AND ECONOMIC BENEFITS

According to an estimate released by the World Health Organization, there were 7 million premature deaths as a result of air pollution exposure around the world in 2012.[10] Various studies by the MEP and the China Academy of Sciences have also estimated the economic impacts of all environmental degradation (not just air pollution) as a percentage of the China GDP, ranging from 3 percent to 13.5 percent, depending on the methodology.[11]

Health effects for various criteria and hazardous air pollutants are summarized in Table 10-6. For several pollutants, the health effects vary according to the dosage, which are often related to the length of exposure, that is, acute or chronic. Some of the HAP, for example dioxins/furans and lead, have also been determined by EPA to be probable or known human carcinogens.

Table 10-6 Health Effects for Various Criteria and Hazardous Air Pollutants

POLLUTANT	INDUSTRY SECTOR	HEALTH EFFECT	NON HEALTH EFFECTS
Dioxin/ Furan	Portland cement, Iron and steel	Chloracne (a skin disease resembling severe acne, caused by exposure to chlorinated chemicals) Drowsiness, dizziness, headaches, eye/skin/respiratory tract irritation with acute inhalation exposure Blood disorders, reproductive effects from chronic exposure Classified by EPA as a Group B2 probable human carcinogen	Adverse effects on fish and wildlife
HCl, Cl	Portland cement, Refineries	Irritation of the mucous membranes of the nose, throat and respiratory tract Exposure to high concentrations can lead to swelling and spasm of the throat and suffocation Exposure can lead to RADS, a chemically- or irritant-induced type of asthma. Children more vulnerable	Corrosive
Lead	Iron and steel, Refineries	Brain damage, kidney damage, gastrointestinal distress Central nervous system effects Blood pressure effects Kidney effects Slowed cognitive development, reduced growth in children Reproductive effects Low birth weight and slowed postnatal neurobehavioral development in fetus from maternal lead exposure Classified by EPA as a Group B2, probable human carcinogen	Adverse effects on fish and wildlife
Metal HAP (PM usually a surrogate, excludes mercury)	Portland cement, Iron and steel, Refineries, Surface coating	Central nervous system (visual reaction time, hand steadiness, eye-hand coordination, weakness, lethargy, tremors, mask-like face, and psychological disturbances, impotence, loss of libido)	Adverse effects on fish and wildlife

Table 10-6 continued

POLLUTANT	INDUSTRY SECTOR	HEALTH EFFECT	NON HEALTH EFFECTS
Mercury	Portland cement	Consumption of MeHg (in fish) can cause neurodevelopmental effects, including ability of children to learn and succeed in school. Appears to affect cardiovascular system. MeHg classified as possible human carcinogen by IARC and EPA	Accumulates in food chain
NO_x	Portland cement, Refineries	Adverse respiratory effects, especially in people with asthma Emphysema and bronchitis Aggravation of existing heart disease	Reacts with VOC in sunlight to form ground level ozone
Organic HAP (THC usually a surrogate)	Portland cement, Iron and steel, Refineries, Surface coating	Central nervous system (fatigue, nausea, tremors, lack of coordination) Liver, kidney, and blood effects Respiratory effects Developmental effects Reproductive system effects Leukemia in benzene-exposed humans; benzene is classified by EPA as a Group A, known human carcinogen	Can contribute to ground level ozone formation
PM	Portland cement, Iron and steel, Refineries, Surface coating	Aggravation of existing respiratory and cardiovascular disease and increased risk of premature death	Increased light extinction (affects visibility)
$PM_{2.5}$	Portland cement, Iron and steel, Refineries	Cardiovascular disease (heart attacks) Respiratory disease (asthma attacks, acute and chronic bronchitis, other respiratory symptoms) Adverse effects on birth weight, pre-term births, pulmonary function and other cardiovascular and respiratory effects Premature mortality for adults and infants	Increased light extinction (affects visibility)
SO_2	Portland cement, Iron and steel, Refineries	Adverse respiratory effects including bronchoconstriction and increased asthma symptoms Emphysema and bronchitis Aggravation of existing heart disease	Lead to acid rain formation
VOC	Portland cement, Iron and steel, Refineries, Surface coating	Adverse respiratory effects, especially in people with asthma Emphysema and bronchitis Aggravation of existing heart disease	Reacts with nitrous oxides in sunlight to form ground level ozone

Benefits of emission standards are typically expressed in terms of the amount of emission reductions of regulated pollutants. For HAP emission reductions, the benefits also include recognition that exposure to substances that can cause chronic and acute disorders in humans, as those listed in Table 10-6, will be reduced. These benefits are typically not quantified, only discussed in a qualitative manner.

However, the US EPA recently estimated the human health benefits of the Portland cement emission standards promulgated in 2010 that went into effect in 2013. A summary of those estimated benefits is presented in Table 10-7. The EPA estimated the benefits that would accrue as a result of standards that reduce exposure to fine PM ($PM_{2.5}$). The estimated PM reductions result from emission limits on PM as well as emission limits on other pollutants, including HAP and criteria pollutants, although the EPA was not able to quantify the health or ecosystem benefits of reducing HAP emissions. The reductions in $PM_{2.5}$ result from emission standards that reduce emissions of PM as well as emissions of SO_2 from Portland cement manufacturing. The emission reductions in SO_2 are the result of the SO_2 emission standards as well as the HCl emission standards. These estimated benefits do not include energy disbenefits of $210 to $470 million.

Table 10-7 Summary of Avoided Health Incidences and Monetized $PM_{2.5}$ Benefits Estimates for the Final 2010 Portland Cement NESHAP and NSPS[12]

FACTOR	AVOIDED HEALTH INCIDENCES	MONETIZED BENEFITS (MILLIONS OF 2005$, 3% DISCOUNT RATE)	MONETIZED BENEFITS (MILLIONS OF 2005$, 7% DISCOUNT RATE)
Avoided Premature Mortality	960 to 2,500	$7,600 to $19,000	$6,900 to $17,000
Avoided Morbidity:			
Chronic Bronchitis	650	$19	$19
Acute Myocardial Infarction	1,500	$11	$11
Hospital Admissions, Respiratory	240	$0.2	$0.2
Hospital Admissions, Cardiovascular	500	$0.9	$0.9
Emergency Room Visits, Respiratory	1,000	$0.03	$0.03
Acute Bronchitis	1,500	$0.01	$0.01
Work Loss Days	130,000	$1.2	$1.2
Asthma Exacerbation	17,000	$0.06	$0.06
Minor Restricted Activity Days	750,000	$3.0	$3.0
Lower Respiratory Symptoms	18,000	$0.02	$0.02
Upper Respiratory Symptoms	14,000	$0.03	$0.03

10.5 OTHER IMPACTS

In the U.S. , the publication of proposed and final EPA emission standards in the Federal Register usually discuss the secondary impacts in terms of solid waste and water impacts as well as energy impacts. Depending on the control measures implemented, these secondary impacts may include the generation of additional solid waste and wastewater. Increased use of fabric filters for example may increase the amount of solid waste generated, unless the waste can be recycled back to the process or used as a raw material in another industrial process. The increased use of wet scrubbers can also increase the quantity of wastewater and solid waste generated that must be disposed of, as well as increase the consumption of water. In some cases, for example in the cement industry, the wastewater from a scrubber can be dewatered, dried and used as gypsum and mixed with the ground clinker to make cement. The increased use of air pollution control devices can also increase energy demands including the increased consumption of electricity necessary to operate blowers and other equipment and, in the case of thermal oxidizers, can increase the consumption of natural gas or other fuels used for combustion. In these instances, increased CO_2 emissions may occur and may influence the choice of emission control equipment.

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11

Implementation and Ongoing Assessment

OVERVIEW

An effective implementation and ongoing assessment program includes the following components: schedule for implementation and compliance; measures specific to stationary sources (pre-construction permits; operating permits; monitoring, recordkeeping and reporting requirements; compliance monitoring; enforcement program); measures specific to mobile sources (inspection and maintenance program; periodic fuels testing); emergency episode program; and tracking. The implementation of these components in the U.S. is discussed in the sections which follow.

11.1 IMPLEMENTATION/COMPLIANCE SCHEDULE

As specified in the 2013 Air Pollution Control Action Plan, the current ambient air quality improvement goal for Jiangsu Province is to achieve a 20% reduction in annual $PM_{2.5}$ concentrations (from 2012 levels) by 2017. The 2013 Action Plan also includes longer term goals for meeting the current China $PM_{2.5}$ ambient standards by 2030. By keeping these longer term air quality goals in mind, city and provincial officials can ensure that emission reduction strategies aimed at meeting the 2017 interim goals will be compatible with meeting the longer term 2030 air quality goals.

11.2 STATIONARY SOURCES

In the U.S., the stationary source implementation program includes the following elements: pre-construction permits; operating permits; monitoring, recordkeeping, and reporting requirements; compliance monitoring, and an enforcement program. Each of these elements is an important component of any air quality implementation program.

11.2.1 Pre-construction Permits

In the U.S., New Source Review (NSR) requires stationary sources of air pollution to get permits before construction starts. New Source Review permitting protects air quality when factories, industrial boilers and power plants are newly built or modified. NSR also assures that new or modified industries are as clean as possible. In addition, the program assures that advances in air pollution control occur concurrently with industrial growth.[1] NSR permits specify what construction is allowed, emission limits, and often how the source must be operated.

In the U.S., most NSR permits are issued by state or local air pollution control agencies. EPA issues permits in some cases. EPA establishes the basic requirements for an NSR program in its federal regulations. States may develop unique NSR requirements and procedures tailored for their air quality needs as long as the program is at least as stringent as EPA's requirements. EPA must approve these programs in the State Implementation Plan (SIP). Other states may be delegated the authority to issue permits on behalf of EPA and are often referred to as "delegated states."

There are three types of NSR permitting requirements. A source may have to meet one or more of these permitting requirements.[2]

1. Prevention of Significant Deterioration (PSD) permits are required for new major sources or a major source making a major modification in areas that meet the National Ambient Air Quality Standards;
2. Nonattainment NSR permits which are required for new major sources or major sources making a major modification in areas that do not meet one or more of the National Ambient Air Quality Standards; and
3. Minor source permits.

PSD[3]

Prevention of Significant Deterioration (PSD) applies to new major sources or major modifications at existing sources for pollutants where the area the source is located is in attainment or unclassifiable with the National Ambient Air Quality Standards (NAAQS). PSD does not prevent sources from increasing emissions. Instead, PSD is designed to:

1. protect public health and welfare;
2. preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, scenic, or historic value;
3. ensure that economic growth will occur in a manner consistent with the preservation of existing clean air resources; and
4. assure that any decision to permit increased air pollution in any area to which NSR applies is made only after careful evaluation of all the consequences of such a decision and after adequate procedural opportunities for informed public participation in the decision making process.

PSD requires the following:

1. installation of the "Best Available Control Technology" (BACT);
2. an air quality analysis;
3. an additional impacts analysis; and
4. public involvement.

BACT is an emissions limitation which is based on the maximum degree of control that can be achieved. It is a case-by-case decision that considers energy, environmental, and economic impacts. BACT can be add-on control equipment or modification of the production processes or methods. This includes fuel cleaning or treatment and innovative fuel combustion techniques. BACT may be a design, equipment, work practice, or operational standard if imposition of an emissions standard is infeasible.

The primary purpose of the air quality analysis is to demonstrate that new emissions emitted from a proposed major stationary source or major modification, in conjunction with other applicable emissions increases and decreases from existing sources, will not cause or contribute to a violation of any applicable NAAQS or PSD increment.

Generally, the analysis will involve (1) an assessment of existing air quality, which may include ambient monitoring data and air quality dispersion modeling results, and (2) predictions, using dispersion modeling, of ambient concentrations that will result from the applicant's proposed project and future growth associated with the project.

Class I areas are areas of special national or regional natural, scenic, recreational, or historic value for which the PSD regulations provide special protection. The Federal Land Manager (FLM), including the State governing body, where applicable, is responsible for defining specific Air Quality Related Values (AQRV's) for an area and for establishing the criteria to determine an adverse impact on the AQRV's. If a FLM determines that a source will adversely impact AQRV's in a Class I area, the FLM may recommend that the permitting agency deny issuance of the permit, even in cases where no applicable increments would be exceeded. However, the permitting authority makes the final decision to issue or deny the permit.

PSD increment is the amount of pollution an area is allowed to increase. PSD increments prevent the air quality in clean areas from deteriorating to the level set by the NAAQS. The NAAQS is a maximum allowable concentration "ceiling." A PSD increment, on the other hand, is the maximum allowable increase in concentration that is allowed to occur above a baseline concentration for a pollutant. The baseline concentration is defined for each pollutant and, in general, is the ambient concentration existing at the time that the first complete PSD permit application affecting the area is submitted. Significant deterioration is said to occur when the amount of new pollution would exceed the applicable PSD increment. It is important to note, however, that the air quality cannot deteriorate beyond the concentration allowed by the applicable NAAQS, even if not all of the PSD increment is consumed.

The additional impacts analysis assesses the impacts of air, ground and water pollution on soils, vegetation, and visibility caused by any increase in emissions of any regulated pollutant from the source or modification under review, and from associated growth. Associated growth is industrial, commercial, and residential growth that will occur in the area due to the source.

Nonattainment NSR[4]

Nonattainment NSR applies to new major sources or major modifications at existing sources for pollutants where the area the source is located is not in attainment with the National Ambient Air Quality Standards (NAAQS). Nonattainment NSR requirements are customized for the nonattainment area. All nonattainment NSR programs have to require (1) the installation of the lowest achievable emission rate (LAER), (2) emission offsets, and (3) opportunity for public involvement.

LAER is the most stringent emission limitation derived from either of the following:

- the most stringent emission limitation contained in the implementation plan of any State for such class or category of source; or
- the most stringent emission limitation achieved in practice by such class or category of source.

The emissions rate may result from a combination of emissions-limiting measures such as (1) a change in the raw material processed, (2) a process modification, and (3) add-on controls.

Offsets are emission reductions, generally obtained from existing sources located in the vicinity of a proposed source which must (1) offset the emissions increase from the new source or modification and (2) provide a net air quality benefit. The obvious purpose for requiring offsetting emissions decreases is to allow an area to move towards attainment of the NAAQS while still allowing some industrial growth.

Minor NSR[5]

Minor NSR is for pollutants from stationary sources that do not require PSD or nonattainment NSR permits. The purpose of minor NSR permits is to prevent the construction of sources that would interfere with attainment or maintenance of a NAAQS or violate the control strategy in nonattainment areas. Also, minor NSR permits often contain permit conditions to limit the source's emissions to avoid PSD or nonattainment NSR.

States are able to customize the requirements of the minor NSR program as long as their program meets minimum requirements. The permit agency's minor NSR program is part of the State Implementation Plan (SIP).

11.2.2 Operating Permits

An Operating Permit Program ensures that air quality control requirements are in place and met. In the U.S., Title V of the Clean Air Act requires major sources of air pollutants, and certain other sources, to obtain and operate in compliance with an operating permit. Sources with these "title V permits" are required by the Act to certify compliance with the applicable requirements of their permits at least annually.[6]

Operating permits are:[7]

- Legally-enforceable documents designed to improve compliance by clarifying what facilities (sources) must do to control air pollution.
- Required by national legislation (Title V of the Clean Air Act).
- Issued to all large sources ("major" sources) and a limited number of smaller sources (called "area" sources, "minor" sources, or "non-major" sources).
- Most are issued by State or local agencies ("part 70" permits); a small number are issued by EPA ("part 71" permits).
- Permits include pollution-control requirements from federal or state regulations that apply to a source.
- Other air permits may be required (e.g., "Pre-construction" permits, "PSD" permits, or "NSR" permits).

The operating permit program streamlines the way federal, state, and local authorities regulate air pollution by consolidating all air pollution control requirements into a single, comprehensive "operating permit" that covers all aspects of a source's year-to-year air pollution activities. The program is designed to make it easier for sources to understand and comply with emission control requirements, and results in improved air quality.[8]

Congress created the U.S. operating permit program to ensure better compliance and to allow for more thorough air pollution control. With Title V of the 1990 Clean Air Act Amendments, Congress adopted measures that require all states to develop and implement operating permit programs. In doing so, Congress hoped to eliminate any potential confusion associated with the various air pollution emission reduction programs required by the federal Clean Air Act and different state and local regulations. Under Title V, EPA must establish minimum elements to be included in all state and local operating permit programs, and then assist the state and local governments in developing their programs.

The goals of the operating permit program include:

- Develop a comprehensive permit system that identifies and implements the Clean Air Act requirements for air pollution sources.
- Provide an opportunity for citizens to be involved in the permit review process.
- Improve compliance with emissions control requirements.

Other key provisions of the operating permit program are as follows:

- Sources are required to provide emissions reports to their permitting authorities at least semiannually and must certify their compliance status annually.
- Sources must periodically renew their operating permit, generally every 5 years.
- To fund their programs, permitting authorities are required to collect permit fees from sources subject to the operating permit program. Fees are most frequently based on the amount of air pollutants that a source may emit.
- Public notification and opportunity for comment must be provided during the permit review process for every new permit and when permits are renewed or significantly revised.
- EPA is responsible for overseeing the implementation of permit programs and may object to a permit that fails to comply with program requirements.
- EPA is also required to establish a federal permit program in any area where the permitting authority fails to develop and maintain an adequate program of its own.

It is also important to note that state and local governments can and do implement separate requirements that are appropriate for their unique local conditions.

In the U.S., state and local permitting authorities have primary responsibility for running operating permit programs, including reviewing permit applications and issuing permits. EPA Regional Offices have oversight responsibilities over State programs, including:[9]

- Review of State program submittals and revisions to State programs,
- Periodic review of State programs,
- Review and comment on draft State permits, and
- Review of monitoring or other reports required by the permit.

The EPA also performs other functions (often in concert with EPA Regions), including:

- Review of public petitions asking EPA to object to State-issued operating permits,
- National rulemakings, policy or guidance for the operating permit program, and
- Response to Congressional/Executive Branch requests for Information.

11.2.3 Monitoring, Recordkeeping And Reporting Requirements

Stationary sources should have requirements for monitoring emissions from the source, using continuous emissions monitoring techniques if possible. Where continuous monitoring is not possible (or practical), specific test methods and requirements for periodic tests should be required. The operating permit should also include requirements for periodic inspections, recordkeeping, and self-reporting, using electronic methods, standard formats, and common protocols where possible.

Monitoring

Operating permits document how air pollution sources will monitor, either periodically or continuously, their compliance with emission limits and all other applicable requirements on an on-going basis. Thus, monitoring requirements are a very important aspect of the operating permit because:[10]

1. Monitoring provides facility owners/operators with information they can use to: (a) self-assess their performance relative to meeting air pollution requirements, and (b) assist them in determining the proper corrective actions, when necessary, and
2. Monitoring provides the basis for most on-going compliance demonstrations and provides documentation to support the compliance certification required of the source owners/operators.

In short, the role of monitoring is to assure compliance with the operating permit conditions and air pollution regulations.

In the U.S., Part 70 identifies the standard monitoring requirements that each permit shall include. The monitoring and related recordkeeping and reporting requirements states, in part, that "each permit shall contain the following requirements with respect to monitoring:

A. All monitoring and analysis procedures or test methods required under applicable monitoring and testing requirements . . .

B. Where the applicable requirement does not require periodic testing or instrumental or noninstrumental monitoring (which may consist of recordkeeping designed to serve as monitoring), periodic monitoring sufficient to yield reliable data from the relevant time period that are representative of the source's compliance with the permit..." [70.6(a)(3)(A) and (B)]

Furthermore, the compliance requirements state, in part that: "all [operating] permits shall contain ... compliance certification, testing, monitoring, and reporting requirements sufficient to assure compliance with the terms and conditions of the permit..." [70.6(c)(1)]

In 1997, the EPA promulgated regulations for Compliance Assurance Monitoring (CAM). The CAM rule applies to major sources required to have a title V permit. It applies specifically to major emission units at the source that rely on add-on air pollution control devices to achieve compliance. The CAM rule requires owners/operators to submit specific information on how monitoring will be conducted (sometimes referred to as the "CAM Plan"), including a justification for the proposed monitoring. The CAM rule also identifies the required permit conditions, including:

1. the approved monitoring approach, including the indicator(s) of performance to be monitored;
2. the indicator range such that operation within the range provides a reasonable assurance of compliance;
3. specifications for the monitoring system and monitoring location to assure data representativeness;
4. quality assurance and quality control practices to ensure continuing validity of the data; and
5. the frequency of monitoring, and, if applicable, the data averaging period.

Recordkeeping

In the U.S., Part 70 identifies the standard recordkeeping requirements that each permit shall include. The monitoring and related recordkeeping and reporting requirements states, in part, that "With respect to recordkeeping, the permit shall incorporate all applicable recordkeeping requirements and require, where applicable, the following:

(A) Records of required monitoring information that include the following:

(1) The date, place as defined in the permit, and time of sampling or measurements;

(2) The date(s) analyses were performed;

(3) The company or entity that performed the analyses;

(4) The analytical techniques or methods used;

(5) The results of such analyses; and

(6) The operating conditions as existing at the time of sampling or measurement; …" [70.6(a)(3)(C)(ii)(A)]

Furthermore, the recordkeeping requirements state that permits should require, where applicable, "Retention of records of all required monitoring data and support information for a period of at least 5 years from the date of the monitoring sample, measurement, report, or application. Support information includes all calibration and maintenance records and all original strip-chart recordings for continuous monitoring instrumentation, and copies of all reports required by the permit." [70.6(a)(3)(c)(ii)(B)]

Reporting

Each operating permit should include a requirement that the permittee submit to the permitting authority, no less often than every 6 months (semi-annually), the results of any required monitoring, and such other conditions as are necessary to assure compliance with applicable requirements, including the requirements of the applicable implementation plan. Each operating permit should set forth reporting requirements to assure compliance with the permit terms and conditions.

Any report required to be submitted by an operating permit should be signed by a responsible corporate official, who will certify its accuracy.

11.2.4 Compliance Monitoring

Compliance monitoring is one of the key components EPA uses to ensure that the regulated community obeys environmental laws and regulations. It encompasses all regulatory agency activities performed to determine whether a facility (or group of facilities, such as plants related geographically, by sector, or corporate structure) is in compliance with applicable law. Compliance monitoring includes: [11]

- formulation and implementation of compliance monitoring strategies
- on-site compliance monitoring: compliance inspections, evaluations, and investigations (including review of permits, data, and other documentation)
- off-site compliance monitoring: data collection, review, reporting, program coordination, oversight, and support
- inspector training, credentialing and support

EPA provides compliance incentives and auditing to encourage facilities to find and disclose violations to the Agency. Violations may also be discovered from tips/complaints received by the Agency from the public. Violations discovered as a result of any of these activities may lead to civil or criminal enforcement.

Next Generation Compliance

Today's pollution challenges require a modern approach to compliance, taking advantage of new tools and approaches while strengthening vigorous enforcement of environmental laws. Next Generation Compliance is EPA's integrated strategy to do that, designed to bring together the best thinking from inside and outside EPA. [12]

Next Generation Compliance consists of five interconnected components, each designed to improve the effectiveness of the compliance program:

- Design regulations and permits that are easier to implement, with a goal of improved compliance and environmental outcomes.
- Use and promote advanced emissions/pollutant detection technology so that regulated entities, the government, and the public can more easily see pollutant discharges, environmental conditions, and noncompliance.
- Shift toward electronic reporting to help make environmental reporting more accurate, complete, and efficient

while helping EPA and co-regulators better manage information, improve effectiveness and transparency.

- Expand transparency by making information more accessible to the public.
- Develop and use innovative enforcement approaches (e.g., data analytics and targeting) to achieve more widespread compliance.

It is recommended that Jiangsu Province adopt these Next Generation Compliance strategies.

11.2.5 Enforcement Program

The emission reductions in the AQMP need to be based on regulations and other requirements that can be properly enforced by the appropriate authority (e.g., city EPB, provincial provincial EPD, MEP). China's 2014 Environmental Protection law and the 2015 Clean Air law both have strengthened enforcement provisions. Experience in the U.S. has shown that key features of an effective enforcement program include: the cost of violating must be greater than cost of complying; the penalty should recover the economic benefit of violating; enforcement must be fair, consistent and applied evenly; and a strong national and provincial presence should help foster responsible local action. Compliance is also improved when effective outreach, technical assistance programs, and training in how to comply with specific regulations are provided to regulated companies and enterprises.

Enforcing environmental laws is a central part of EPA's Strategic Plan to protect human health and the environment. EPA works to ensure compliance with environmental requirements. When warranted, EPA will take civil or criminal enforcement action against violators of environmental laws.[13]

Types Of Enforcement Actions

Civil Administrative Actions are non-judicial enforcement actions taken by EPA or a state under its own authority. These actions do not involve a judicial court process. An administrative action by EPA or a state agency may be in the form of:

- a notice of violation or a site clean-up (Superfund) notice letter, or
- an order (either with or without penalties) directing an individual, a business, or other entity to take action to come into compliance, or to clean up a site.

Civil Judicial Actions are formal lawsuits. They are filed in court, against persons or entities that have failed to:

- comply with statutory or regulatory requirements,
- comply with an administrative order,
- pay EPA the costs for cleaning up a Superfund site or commit to doing the cleanup work.

These cases are filed by the U.S. Department of Justice on behalf of EPA. In regulatory cases they may be filed by the State's Attorneys General on behalf of the states.

Criminal Actions can occur when EPA or a state enforce against a company or person through a criminal action. Criminal actions are usually reserved for the most serious violations, those that are willful, or knowingly committed. A court conviction can result in fines or imprisonment.

Types Of Enforcement Results

Civil Enforcement

- *Settlements* are generally agreed-upon resolutions to an enforcement case.
  - Settlements in administrative actions are often in the form of consent agreements/final orders (CA/FOs) or administrative orders on consent (AOCs).
  - Settlements in judicial actions are in the form of consent decrees signed by all parties to the action and filed in the appropriate court.
- *Civil Penalties* are monetary assessments paid by a

person or regulated entity due to a violation or noncompliance. Penalties act as an incentive for coming into compliance and staying in compliance with the environmental statutes and regulations. Penalties are designed to recover the economic benefit of noncompliance and to compensate for the seriousness of the violation.

- *Injunctive Relief* requires a regulated entity to perform, or refrain from performing, some designated action. It also brings the entity into compliance with environmental laws.
- *Supplemental Environmental Projects (SEPs)* can be part of an enforcement settlement. SEPs are environmental improvement projects that a violator voluntarily agrees to perform. These projects are in addition to actions required to correct the violations specified in the settlement.

Criminal Enforcement

- *Criminal Penalties* are federal, state, or local fines imposed by a Judge at the sentencing. In addition to criminal penalties, the defendant may be ordered to pay restitution to those affected by the violation. For example, a defendant may be ordered to pay a local fire department the cost of responding to and containing a hazardous waste spill.
- *Incarceration* refers to "prison time" for an individual defendant.

11.3 MOBILE SOURCES

When implementing mobile source control strategies, inspection and maintenance programs are important for checking vehicle compliance with emissions standards. In addition, periodic testing of fuels as they pass through the supply chain is essential.

11.3.1 Inspection And Maintenance (I/M) Program

Compliance with the vehicle and engine emissions standards is the responsibility of the vehicle or engine manufacturer. Vehicles and engines used in the U.S. must be manufactured under the terms of an emissions certificate of conformity issued by EPA. Imported vehicles and engines must be EPA-certified, with certain very limited exceptions. The removal or disabling of vehicle or engine emission controls by any person is prohibited.[14]

EPA reviews applications for emissions certificates from vehicle and engine manufacturers, and conducts emissions testing of vehicles and engines on the production line and in-use following introduction into commerce. EPA works in conjunction with the U.S. Customs and Border Protection to ensure that imported vehicles and engines are certified. In addition, light-duty vehicle emissions are checked periodically through state-implemented "inspection and maintenance" programs in most ozone nonattainment areas. EPA conducts inspections of:

- vehicle and engine manufacturing facilities,
- emission laboratories,
- dealers of vehicles and mobile engines and
- suppliers and installers of vehicle and engine parts.

Periodic inspections of in-use vehicles can identify higher-emitting vehicles and encourage their repair or retirement. This approach is technology based, but relies on successful behavioral participation of vehicle owners and inspection and repair facilities. Designing optimal I/M programs has proven difficult. Program design must be connected to vehicle technology. The most advanced U.S. programs now rely entirely on on-board diagnostic (hand-held computer readout) systems instead of exhaust emissions test programs. However, where the vehicle fleet is still comprised of older-technology vehicles, exhaust testing is an essential component of I/M programs. Centralized test programs that separate testing from repair work have proven more effective than decentralized programs, but are less acceptable to the public. Enforcement has proven difficult over time, with many I/M programs yielding less-than-expected emissions reductions. U.S. experience indicates fleet-wide emissions reductions of 10% to 15% are possible depending on program design features[15]. Implementation can be relatively quick (e.g., 3 to 5 years); however, substantial public and repair industry education is needed to support implementation success.

11.3.2 Periodic Fuels Testing

Refiners and fuel importers have the primary responsibility of compliance with the motor vehicle fuels standards. Parties in the fuel distribution system are responsible for ensuring that motor vehicle fuel is not contaminated and is used in the proper locations and times. For example, in the U.S., more stringent gasoline standards apply during the summer high ozone season and to reformulated gasoline used in certain ozone nonattainment areas. Vehicles and equipment may only use fuels designated and registered for that type of vehicle or equipment.[16]

EPA conducts fuels inspections primarily at:

- retail outlets
- terminals
- refiners
- importers
- fuels testing laboratories

Refiners and importers are required to test all their gasoline and submit reports to EPA. In addition, refiners and importers are required to use independent laboratories to conduct quality assurance testing of reformulated gasoline when it is produced and quality surveys of reformulated gasoline when it is sold at retail outlets, and to submit reports to EPA of this testing.

11.3.3 Key Lessons

Key lessons and observations about the control of motor vehicle emissions are summarized below.

- Six approaches are available to reduce emissions. Overall, technology based approaches have proven far more successful and cost-effective than behavior-based controls, although it takes many years to realize the full benefits of the most important of these approaches, the use of new-vehicle emissions standards. As a consequence, it is important to package technology and behavior-based measures that will achieve short, medium, and long-term emissions reductions.
- Given the difficulties involved with behavior-based controls, it is helpful to remember:
    - An inherent challenge with behavior-based controls is that many of them focus on improving transit service that is best geared to service work trip commutes. However, in many urban environments, work trips are a small fraction of on-road vehicle use. In the U.S., for example, work trips make up about 25% of total vehicle travel. Thus, behavior-based programs geared toward public transit address only a small fraction of the overall travel that contributes to urban air quality problems. The implication is that air quality planners need to fully assess the major mobile source contributors to emissions, and understand what parts of that problem are addressed by individual control measures.
    - Some behavior-based approaches have proven to be more effective and accepted by the public in the short-term than the long-term, such as alternate day driving restrictions. The implication is that some behavior-based approaches can be used to address near-term problems while more effective longer-term solutions are developed.
    - Over the long-term, the most effective behavior-based controls are those that increase travel costs. Successful programs, such as the road pricing programs used in

London and Stockholm, have paired fees to discourage vehicle use with increased transit service. These programs have been self-reinforcing: fees generated in price-controlled zones have funded increased transit. In many cases however, especially in the U.S., it is not feasible to implement charges (e.g., tolls, fuel taxes, price-restricted driving zones, peak-period travel costs) that substantially reduce vehicle use on existing infrastructure. U.S. planners have had more support when implementing pricing policies on new roads. An important implication is that, when possible, planners should consider implementing pricing strategies wherever they are feasible and in particular whenever new roadway capacity is being considered.

- Public education supports both technology and behavior-based controls. When vehicle users fail to understand the need for control programs and their expected outcomes, resulting implementation problems can delay (best case) or cancel (worst case) program implementation. The implication is that implementation time needs to account for educational processes.
- Long-term U.S. experience led to a realization that the transportation and air quality planning communities can work at cross-purposes. The U.S. Clean Air Act Amendments [1990] resolved that challenge by establishing a "transportation conformity" policy that mandated interagency consultation, use of common planning assumptions, and periodic comparisons between transportation and air quality plans. The implication is that other countries need to identify and address any multi-agency planning conflicts that can slow air quality improvement.
- Off-road mobile sources, such as construction equipment, are more difficult to control due to the diversity of the types of sources and, for those that are diesel-powered, their relatively long useful life. Some off-road motor vehicles, such as container ships and airplanes, are difficult to control at the local, regional, or even national level. International agreements are needed. The implication is that more emissions reductions are likely possible from the on-road fleet, at least in the short to medium term, compared to the off-road fleet.
- In both the on- and off-road settings, diesel vehicles are typically the most important vehicle type to control. Among mobile sources, diesel emissions contribute disproportionately to NO_X, coarse and fine particles, visibility, and air toxics. In addition, control of diesel vehicles can progress more slowly than control of the gasoline-powered fleet since diesel engines are longer-lived and fleet turnover is accomplished more slowly. Because of the unique challenges posed by diesel fleets, control programs have strategically targeted those portions of the diesel fleet that are the highest emitting. In California, for example, efforts to accelerate truck retirements or retrofits often focus on short-haul ("drayage") trucks, since they are among the oldest and dirtiest vehicles in the heavy-duty fleet. The implication is that many strategies are needed to address diesel vehicles regionally, although short-term progress can be made with targeted programs at locations involving substantial truck activity such as ports, rail yards, and goods movement distribution centers.
- Control strategies developed to improve air quality tend to include two biases that undermine their success: they under-predict emissions and over-predict control program benefits. These biases have been widely observed, as illustrated by examples from the U.S., Europe, and China. For example, U.S. regulators used emissions modeling tools that for many years' under-predicted on-road mobile source emissions; U.S. regulators also over-predicted the benefits of I/M programs. Beijing officials over-predicted the implementation success of retrofitting gasoline-powered private vehicles with catalytic converters, and with retrofitting taxis to enable their use of liquefied petroleum gas (LPG) fuel. Greek regulators over-predicted the benefits of vehicle use restrictions in Athens. The implication from these biases is that constant tracking is needed to adjust emissions inventories

and modeling tools, and to modify required controls. In addition, contingency planning is important.

Finally, it is important to remember that there is no "silver bullet" that will rapidly and effectively reduce vehicle emissions. Experience has shown that it is important to package controls to include short, medium, and longer-term strategies, as well as behavior and technology-based approaches. The package design will vary depending on the severity and geographic scale of the problems to be addressed.

11.4 EMERGENCY EPISODE PROGRAM

Emergency episode programs for taking action when air pollution levels exceed certain thresholds are essential for the protection of public health. Such episodes may occur under stagnant atmospheric conditions and/or in areas with a dense population of industrial sources and automobiles. Key elements of an emergency episode system include:

- Air quality monitoring network and data management system for collecting and summarizing data, such as AirNow-International.
- Air Quality Index for converting pollutant concentrations to more easily-understood health information.
- An air pollution forecast capability based on air quality modeling tools.
- A public alert system using newspapers, television, Internet and social media(e.g., AirNow-International special message or webpage, smartphone alerts).
- Provincial and city environmental departments take the lead in providing information and appropriate responses.

A typical emergency plan contains four key elements: 1) trigger levels for each pollutant based on ambient data; 2) requirements for each stage that escalate with higher pollutant levels; 3) actions that correlate to what sources and pollutants contribute to emissions; and 4) requirements for large industrial sources to submit emergency plans, and to have such plans reviewed and approved by an air quality agency. A plan may be put into effect based on peak concentrations observed at one or more monitors. A typical plan may have three stages, with actions escalating in proportion to the severity of the level of pollution:

- Stage 1: notice to public, schools, hospitals. Voluntary actions
- Stage 2: some mandatory actions plus cessation of outdoor sports activities
- Stage 3: driving bans, suspension of industrial activities, cessation of indoor and outdoor sports

Effective programs include early notification of the public, close cooperation with other governmental agencies, and responsibility for industry and businesses to take action to reduce pollution. As ambient standards are revised based on health information, emergency episode programs will need to adjust the pollution level stages at which various actions are required.

11.5 TRACKING PROGRESS

Three basic ways for tracking the progress and effectiveness of an air quality management plan are to track: a) the implementation of regulations and programs; b) emissions reductions; and c) air quality improvement.

The implementation of regulations and programs can be tracked by various metrics, such as the number of new regulations finalized; the number of companies or enterprises that have finalized process changes or installed new emissions control technologies; or the number of permits issued.

Progress in terms of emission reductions can be assessed most easily for sources with CEMs, such as many power plants. However, to comprehensively review progress in emissions changes throughout an entire city or province for a particular year typically will take a year or more to estimate and quality-assure activity and emissions data from numerous emissions sources.

Air quality monitoring data provides the most immediate way to track progress. It provides an integrated way to measure the combined effects of emission reduction programs, energy planning, population growth, and other factors.

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12
Energy Planning

12.1 INTRODUCTION

Policymakers and government departments in China responsible for air quality management (AQM) have an important role to play in building meaningful, effective, and well-integrated power sector and environmental planning processes. In other countries, coordinating AQM with existing power sector planning processes has been a challenge; in China, big opportunities exist to coordinate these disciplines as structures for both power sector planning and environmental planning are still at early stages of development or undergoing reform. Ideally, power sector and environmental planning will be developed into a unified structure.

Electricity planning will be increasingly important for meeting the country's air quality and CO_2 reduction goals.[1]

China's rapid economic growth has occurred during a period when the science and health information related to air pollution and other environmental problems has been made much more certain. At the same time, technologies and processes to reduce the harmful effects of pollution have also rapidly advanced. As a result, China's air quality planning can tackle several pollutants at the same time, which is more cost-effective, and also include processes and techniques that use energy more efficiently.

The Air Pollution Control Action Plan 2013 has kicked off provincial AQM planning. So far, these have focused on end-of-pipe and coal-plant efficiency measures. Energy planning can unlock other opportunities, including regional planning that identifies cost-effective renewable generation and transmission projects.

12.2 DESCRIPTION OF CHINA SITUATION

In China, environmental planning and power sector planning are both undergoing development and reform. The 13th Five-Year Plan (2016-2020), currently under development, is an important focus for these changes. The March 2015 announcements made as part of the National People's Congress underscore the seriousness with which China intends to address air pollution. Aided by a new environmental protection law, a two-year crackdown on violators was announced, and new targets were set to decrease the intensity of energy used and to further increase the share of energy provided by renewable sources.

Power Sector Planning

In China, energy planning bears little resemblance to common practice in much of the rest of the world. Over the past decade, China has seen major challenges with energy planning and coordinating investments across different types of resources.[2, 3]

Despite these challenges, China's power sector still managed to deliver impressive growth and reliable service. For example, from 2010 to 2013, China added more than 80 gigawatts (GW) of new generation capacity annually, and capacity continues to grow rapidly.

However, lack of coordinated power sector planning and investment approval has resulted in major consequences, including:

- Significant curtailment of renewables production (that is, "wasted" renewable energy, chiefly wind and hydro). This has been partly because of mismatches of generation investments with the grid, including poor geographic dispersal of investments in wind, and also due to growing numbers of inflexible combined heat and power plants.
- Overinvestment in coal-fired capacity and underinvestment in flexible resources and peaking capacity.
- Missed opportunities to reduce emissions in a low-cost fashion, such as through investments in end-use energy efficiency and distributed renewables.

Like environmental planning, power sector planning is going through its own process of reform. The "Power Sector Reform" guidance issued in March 2015 recognizes the need for a major revamp of power sector planning, and official announcements indicate that the 13th Five-Year Plan is taking up the task.[4] This will be very important for reaching the Chinese government's goals for the power sector—including goals for emissions reduction—at reasonable cost.

12.3 ENERGY PLANNING PRINCIPLES, DRAWN FROM US AND INTERNATIONAL EXPERIENCE

12.3.1 Introduction

Around the world, power sector regulators and their counterparts in air quality regulatory agencies are grappling with the question of how to mobilize adequate low-emissions resources as well as sufficient flexibility to support variable renewables.

Long before energy efficiency, the environment, or risk were considerations for power sector planners, the primary goal of planning was merely to find the optimal mix of different types of generation resources. Today, the principle is similar – the goal is to find a lowest-cost mix of resources. But there are very important innovations: resources now include demand-side resources as well as supply-side. In addition, costs are not just direct capital and fuel costs, but also include the social costs of emissions (and other environmental costs) and benefits of resource characteristics, such as flexibility are also considered by power sector planners.

As discussed in RAP (2014)[5], the power sectors in the United States, EU, and Brazil all feature some kind of planning to identify resources that will meet reliability, environmental, emissions, and other important goals, while minimizing cost and containing risk. However, there are big differences in the comprehensiveness of these planning processes. There are some examples of power sector plans that consider a full range of available resources and a full range of costs and benefits, including the social ("external") costs of emissions, but many national and subnational planning processes still fall short in this regard.

A particularly important issue – that is handled with varying degrees of sophistication in these countries – is consideration in planning of end-use energy efficiency (EE). EE is typically a plentiful and cost-effective resource that can greatly contribute to achieving emissions-reduction goals and significantly reduce consumer electricity bills.

Internationally, electricity system planning takes different forms. There are different industry structures and country contexts. However, some common "best practice" themes are outlined here. Broadly speaking, power sector policy should have two interlocking components: (1) preparation and regular updating of a comprehensive power sector plan to meet reliability, environmental, and other important goals; and (2) design and periodic adjustment of a mechanism, which may be competitive, to deliver the resources identified in the plan.

Good power sector planning usually includes the following 'tracks':

a. resource adequacy planning, which attempts to ensure that supply-side and demand-side resources will together be adequate to reliably meet expected demand;

b. transmission reliability planning, which attempts to ensure that the transmission system evaluates new projects on the basis of their incremental reliability, economic and environmental benefits to reliably and cost-effectively deliver power to consumers;

c. environmental planning to ensure that environmental goals are considered and met.

Ideally, these three components are well integrated, although even the best examples have shortcomings and need to continue to work toward that ideal. Together, these ideally form an integrated process and includes short, medium and long-term view (10 years or more).

12.3.2 Power Sector Planning In The United States

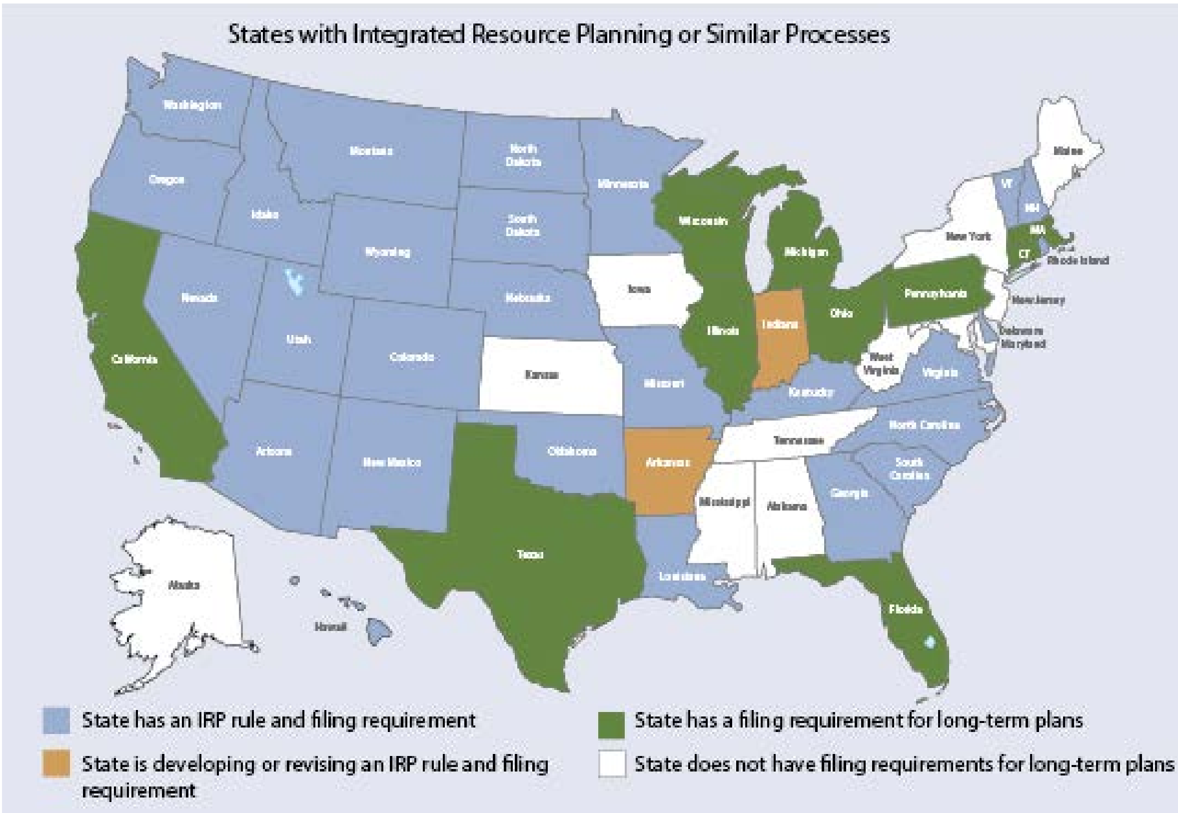
A central theme in the United States has been "integrated resource planning" (IRP), as shown in Figure 12-1. Most states now practice IRP, but in various forms and with varying degrees of success. In brief, a typical IRP process requires utilities to engage in a public process, overseen by regulatory agencies, in which all available supply-side and demand-side resources are evaluated on equal bases, in order to prepare a plan for meeting customer demand at lowest total societal cost.

Inclusion of demand-side resources — particularly end-use energy efficiency — into the power sector planning process has led to increased investment in end-use efficiency, as energy efficiency is typically a less expensive and cleaner alternative to new power plants.

Some states (such as California) have gone as far as to declare energy efficiency the "priority resource" and require that power sector plans include "all cost-effective energy efficiency." The European Union announced policies in the spring of 2015 to advance "energy efficiency first" and formed an Energy Union that will coordinate energy policy among 30 different countries. The EU announcement recognizes the past tendency to promote supply resources over those from the demand side, and emphasizes energy efficiency as a highly cost-effective way to provide reliable resources.[6]

However, even in the leading states and countries, there is still much work to be done to fully integrate emissions externalities into the planning process and to identify and exploit all cost-effective energy efficiency. In this way, energy efficiency investments are considered in the planning process as means to potentially displace alternate investments in conventional power plants and even displace transmission and distribution investments. The low-cost and low-emissions nature of energy-efficiency investments have made this a very successful strategy in many regions.

Figure 12-1 **Integrated Resource Planning in the United States**[7]



There is significant variation across states in terms of regulation and carbon emissions-reduction policies. In particular, states vary in the degree to which they have "restructured" the electricity industry by breaking up vertically integrated utilities and introducing competitive wholesale and retail markets.[8] However, good power sector planning is important in all states – regardless of market model – because decision-makers need to be sure that their policies achieve objectives as intended and at the lowest possible overall cost for society as a whole.

Well-designed IRP typically will include efforts to identify and minimize risks. These risks typically include economic (e.g. fuel price fluctuations) and environmental (e.g. tightened environmental regulations imposed in the future might create 'stranded' or wasted investments).

12.3.3 Summary

To summarize, the 'best practice' themes from international power sector planning are:

- Integrate end-use energy efficiency into power sector planning: Recognize energy efficiency as a cost-effective resource to meet demand for energy services.
- Complete a careful economic analysis of resource options. Equally treat supply-side and demand-side resources. Quantify and include the environmental and public health costs and benefits associated with the resources being evaluated.
- Integrate transmission and distribution planning with other aspects of power sector planning. Use the transmission planners' analytical tools to calculate the economic trade-off between, on the one hand, low-cost but remote generation that requires more transmission investment and, on the other hand, more costly generation closer to load centers requiring less transmission investment. Transmission planners can also analyze how transmission investment can be shaped to meet not only reliability requirements but other public policy objectives as well (e.g., a coal consumption cap, local air quality goals, and renewable energy targets), and
- Identify and minimize economic, business, and environmental risk.[9]

12.4 ENERGY PLANNING EXAMPLES AND BEST PRACTICES

The co-benefits from clearly linking energy and environmental policy are well understood. California has maintained essentially flat per capita energy consumption since the 1970s, and is aware that by so doing, it has avoided the construction and expense of building many power plants, along with their associated emissions. However, while legal structures have not prohibited integration of energy and environmental disciplines, the often siloed nature of environmental and energy laws has not explicitly encouraged their linkage. Since the late 1990s, states have initiated pilot projects that have convened environmental and energy regulators. These examples have grown and deepened to provide a diverse menu of best practices that can be adopted by others. Every state or province has different characteristics; policies that were successful in Maryland or California may not be applicable to Jiangsu. This section emphasizes the important principles associated with the examples of best practices that are mentioned. The next section then describes the process steps that Jiangsu air regulators could take to adapt the best practices into their provincial air quality management plans.

12.4.1 Federal Level Experience

The EPA Clean Power Plan (CPP), finalized August 3, 2015, focuses on a best system of emissions performance for the power sector. Emission reductions can be obtained through three key building blocks, and states have the flexibility to develop their own plan based on local characteristics. EPA's CPP recognizes that electricity can come from any number of power plants, and that emission reductions can be obtained through on-site and off-site techniques and processes. These include:

- Heat rate improvements for the boiler. Using less fuel to produce electricity reduces greenhouse gas and criteria pollutant emissions and fuel costs. EPA estimates up to 6% improvement can be achieved on existing boilers.
- Increase natural gas dispatch. Many natural gas power plants have the potential to increase their capacity factors, and displace higher emitting coal-fired plants.
- Increased use of renewable energy generation. EPA set targets for each state based on regional characteristics and existing state policies.
- EPA anticipates that many state compliance plans will rely on their energy efficiency (EE) programs to help meet the required CO_2 reduction target.

While EPA's CPP focuses on greenhouse gas emissions, the techniques and processes to achieve GHG reductions will also help states to reduce NO_X, SO_2, PM and mercury emissions. EPA has issued draft guidance to help states to evaluate, measure and verify the energy and emissions savings achieved through energy efficiency programs.[10]

12.4.2 US State Level Experience

The US Clean Air Act places primary responsibility on the states to develop air quality plans. Energy planning is also primarily a state activity. Clean energy policies or a need to continue to improve air quality have led to several states implementing programs whose success is driven by energy and environmental planners working together:

Renewable Energy Zones (REZ)

Several Western states have established REZ to take advantage of and to expedite the siting process to locate new solar and wind energy resources. The Texas Public Utilities Commission established a competitive process to build nearly $5 billion in new transmission lines to transmit the wind and solar generation from the west mostly rural areas to the densely populated eastern portion of the state. Eastern Texas has had high air pollution levels for many decades (Houston historically has been ranked with Los Angeles as having the most severe pollution in the US). The REZ will result in over 18 GW of non-fossil generation to be built in western Texas, and has avoided the construction of new fossil fired generation whose emissions would have further exacerbated air pollution in eastern Texas. [11]

Building EE/RE Into Air Quality Models

As part of an effort to evaluate air pollution control measures, Maryland conducted air quality modeling to determine the influence of EE and renewable energy (RE) upon upon ambient concentrations of ozone and fine particles ($PM_{2.5}$). [12]

Modeling results reflect that even modest levels of EE and RE can reduce ozone concentrations by 0.50 or more parts per billion, and $PM_{2.5}$ concentrations by 0.10 $\mu g/m^3$. Maryland also used BenMAP to estimate the public health benefits from these clean energy programs. [13]

California Transmission Planning

California has historically imported much of its electricity from coal-fired power plants located in other states, and the NO_X, SO_2, and PM emissions from these plants has contributed to regional haze and air pollution in many Western states, including the Grand Canyon National Park. Every year the California Independent System Operator (CAISO) produces a plan that identifies new transmission needed to meet California's reliability and policy mandates. California's renewable energy goal (33 percent by 2020)[14] has become the principal driver of transmission planning and investment.

Key components of the transmission plan include:

- Identification of transmission investments needed to support meeting the renewable energy goal. Planners vary assumptions and prepare a range of forecasts of new renewable resource portfolios over a ten-year planning horizon, including type and location.
- Analysis of transmission needs for a range of these possible renewable resource portfolios.
- Identification of transmission upgrades and additions needed to reliably operate the network.
- Economic analysis of transmission upgrades or additions to determine whether they provide additional ratepayer benefits, beyond mere reliability.

CAISO has also taken steps to better integrate generation interconnection procedures into the transmission planning process. The principal changes aim to ensure that the addition of new generation is better coordinated with new transmission needed to integrate the capacity with the system.

Air Quality And Regional Haze Drive Renewable Energy Development

The Grand Canyon and other national parks attract visitors globally for tourism to experience vistas that can extend for over 160 kilometers. Regional urban pollution combined with that from local fossil fuel power plants impaired visibility and had negative economic consequences on regional tourism. EPA published its regional haze rule in 1999; a group of Western states then formed the Western Regional Air Partnership (WRAP) to evaluate policies to reduce haze and improve air quality. A WRAP 2003 summary report reflects that a package of a 20% renewable energy target coupled with increased energy efficiency measures would save consumers $700 million over business as usual and reduce NO_x emissions. This report helped to further drive RE development in Arizona and Nevada. [15]

Utility Level Integrated Resource Plans

Pacificorp is a utility that serves customers in six Western states. The utility prepares what is essentially a regional IRP every two years, with input from regulators, the public and advocacy groups.[16] Existing and expected new environmental requirements are evaluated. The final IRP is provided to energy regulators for review and approval in the six applicable states.

Energy Planning For Jurisdictions With Little To No Previous Experience

Not all states require IRPs to be developed and submitted. And, even in states with IRP requirements, IRPs prepared today are more rigorous than those developed decades ago. As China does not today have IRP requirements, Wisconsin's process could serve as a possible starting point. That state requires a "strategy energy assessment" to be prepared every two years by a utility for submission and review by state regulators. The report is required to evaluate Wisconsin's energy supply, including a forecast of future expected supply and demand. Energy efficiency and renewable energy programs are also included in the assessment.[17]

12.4.3 Examples From Europe And Other Regions

European Union Transmission Planning

Increased renewable energy generation has driven down prices for solar and wind technologies, but has also presented challenges to transmission system operators (TSO) to integrate such resources. The EU's energy and environmental goals forecast continued strong renewable energy deployment, and battery storage technologies offer opportunities to balance generation and demand while also decreasing fossil-fueled generation in order to meet air quality and greenhouse gas goals. TSOs have to prepare ten-year plans that include adequacy assessments, and have a coordinated process that collects and reviews data from all member states. Like other regions, areas of significant renewable energy potential in Europe are not always close to population centers and concentrations of significant energy demand. The EU's TSO's have initiated regional planning to help to better synchronize and balance renewable generation with demand. Transmission infrastructure upgrades are being planned and implemented, even in cases where transmission lines cross national boundaries.[18]

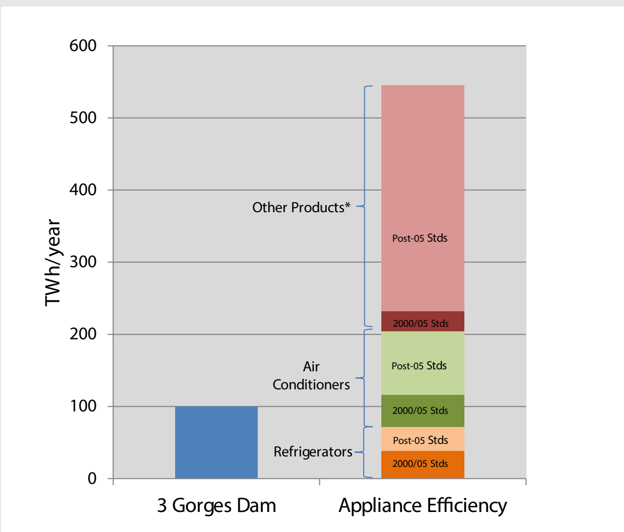
South Africa's Renewable Energy Procurement Process

South Africa experienced severe power outages in 2007-08 that affected all customers, including requiring industrial processes to be closed. South Africa has also set 2025, 2035 and 2050 goals to reduce greenhouse gas emissions.[19] South Africa's electricity generation previous to 2010 was dominated by a single state-owned company and its capacity was 90% coal-fired. To provide increased electricity reliability, to diversify energy sources and to meet the country's environmental goals, South Africa's Department of Energy initiated an open and public process to seek investments in renewable energy sources. Since 2011, three rounds of competitive bidding have attracted over $10 billion in investments for 4,000 MW of new renewable energy generation. South Africa expects that over 40% of new generation added by 2028, or over 20,000 MW, will be from renewable energy sources.[20]

China EE Appliance Standards

China energy intensity and appliance standards help support the case for stronger integration of sound energy policies into air quality plans. China's energy standards have already saved millions of tons of coal and avoided further increases in air pollution.[21] Figure 12-2 below reflects that by 2020, energy efficiency standards will save a quantity of energy five times that of the output from China's largest power source, Three Gorges Dam, or more than one billion tons of coal.[22]

Figure 12-2 Energy Saved by China's Appliance Standards[23]



Jiangsu DSM Experience

Jiangsu has been one of the leading provinces in the area of DSM, with an early focus on DSM during the periods of "tight" power supply in the early 2000s[24]. In the second half of that decade, the State Grid Corporation DSM Instruction Center began designing and constructing efficiency power plants (EPPs) in Jiangsu, as a pilot for the EPP concept. Several hundred MWs of EPPs were constructed under this pilot program, with costs much lower than that of building conventional coal-fired power plant of equivalent capacity.[25] The Jiangsu subsidiary of State Grid has continued to expand energy savings DSM efforts under the 2011 national "DSM Measures" issued by NDRC. The NDRC has evaluated Jiangsu's 2013 and 2014 gridco DSM efforts as "excellent".[26]

12.5 IMPORTANCE OF ENERGY PLANNING FOR AIR REGULATORS

12.5.1 Introduction

Environmental protection and improved air quality are high priorities in China, particularly in light of the severe and large geographic scope of the air pollution events that have occurred since early 2013. According to an estimate released by the World Health Organization, there were 7 million premature deaths as a result of air pollution exposure around the world in 2012.[27] In 2007, the World Bank calculated that the health costs of air and water pollution amount to about 4.3 percent of China's gross domestic product (GDP).[28] A more recent report calculates that the air pollution costs alone could be as high as 13% of GDP.[29] $PM_{2.5}$ from coal-fired power plants has adverse health impacts on people of all ages, but it especially affects the health of children, with long-term effects on cognitive functions. Addressing the air pollution problem requires a nationwide effort in every sector of the economy, but especially from the power sector, which accounts for about half of China's annual coal consumption. Power sector planning will play a key part in the national efforts to improve the environment.

Making emissions a critical consideration in the planning process will allow China to make well-informed power sector decisions. It will require planners to identify and address costs associated with expected environmental policies over the lives of the resource options. In recent years, the Chinese government has issued important new air quality management policies, including the NO_X and SO_2 emission reduction targets and requirements for 113 cities to develop initial air quality management plans by 2015. History from the US and Europe illustrate that ambient air quality standards are likely to be revised and updated, and that initial plans developed by air quality agencies are also periodically revised to incorporate new ambient and regulatory standards.

12.5.2 Promote Integrated Resource Planning (IRP)

Most IRP involve a process that assesses what supply and demand side resources will be needed over some future time frame, typically 5-15 years, and their costs and risks. Good integrated resource plans also evaluate the influences of various energy choices on other variables, such as meeting environmental requirements. The analogous process in air quality planning is the modeling that air regulators conduct to evaluate the efficacy of proposed control measures. The following are among the key energy and economic variables that influence the quantity, timing and costs of energy resources that a utility forecasts that it will need to meet future electricity demand:

- Electricity growth;
- Path of fuel prices (natural gas, coal);
- Resource costs (supply-side, demand-side, grid) for thermal and renewable energy technologies, including escalation rates or cost deflators;
- Expected capacity factors (expected hours per year the generating units will operate, at what load conditions, and what time periods – e.g., peaking vs. baseload);
- Current and expected future electricity prices;
- Transmission constraints or local areas of congestion (analogous to a highway that is at or over capacity during rush hour); and
- Consideration and treatment of renewable energy and energy efficiency

Power system planners routinely complete forecasts of future resource needs and expected costs in the face of risks and uncertainties. Good energy plans also evaluate key non-energy variables that can affect the quantity and costs of resources needed. Key non-energy variables are:

- Capital costs and operation of emissions control equipment to reduce NO_X, SO_2, PM and mercury emissions;
- The potential to regulate GHG emissions in the future and the assumed price of carbon; and
- Inclusion of public health costs from existing air pollution, and the benefits to reduce public health effects over time.

For capital costs, "Best Available Control Technology" (BACT) should be assumed. BACT equates to removal of 90% or greater of NO_X emissions, 95-98% or greater of SO_2 emissions, and 90% or greater for PM and mercury emissions. Standard capital and operating cost data are available from equipment manufacturers and from power companies, based on their installation and operating experiences.

For GHG regulation, China has already launched GHG pilots in several cities and provinces, and Presidents Xi Jinping and Barack Obama signed an agreement to limit and then reduce GHG emissions in each country. Therefore, in any planning exercise, the assumed carbon price should not be zero. Typically low, medium and high carbon prices are assumed to bound the potential influence of GHG reductions on the power sector.

Finally, several recent studies conclude that health effects from air pollution in China are significant and expensive.[28] A China version of BenMAP has also been prepared by the US EPA and Tsinghua University.[30] China specific cost and benefit data can be included in power system planning exercises.

Power system plans that include the above three key factors will more accurately account for the energy and non-energy costs and benefits of supply-side and demand-side resources that are being evaluated. This approach will lead to a more balanced approach to adding new generating capacity and providing reliable electricity. But, perhaps more importantly, it will reduce the total cost of compliance with environmental regulations by encouraging investments in control equipment at the time of power plant construction rather than through more expensive retrofits later.

The planning process will also reveal the total costs and emissions of different resource scenarios. This information will allow power sector, environmental, and other policymakers to see the real tradeoffs between cost and improved air quality.

Implementing a consistent integrated resource planning process would address these topics:

- avoid the recent overbuilding of coal capacity in China;
- integrate wind resources in northern and western China whose generating output has been curtailed due to the inability to access transmission;
- assess the potential for significant additional demand side resources to provide electricity reliability; and
- consider how to integrate electric vehicles

Normally, power sector plans are updated every 2-5 years to account for changes in economic, energy and environmental factors, i.e., changes in economic growth, population growth rates, fuel and technology costs, and new environmental standards. A power sector plan should be amended when new air quality standards are adopted and when significant changes occur that influence the premises upon which energy or economic assumptions were based. In China, an initial plan may need to be updated every two years initially, then as energy, environmental and economic conditions stabilize, subsequent plans could be amended less frequently.

12.5.3 Importance Of Air Regulators In Power Sector Planning

Coordination between air quality and energy planners can help to achieve mutual goals. It can also help to avoid environmental damages and costs. A greater and more consistent role for air quality regulators in power sector planning would have several positive effects:

- **Capture benefits, minimize damages:** There are many low-cost opportunities to reduce emissions that are currently not being taken advantage of. These include low-cost or negative cost measures in the areas of re-dispatching and demand-side management. Environmental damages from pollution equaled 4.3% of China's GDP in 2007.[28]
- **Provide multi-pollutant benefits:** Integration of air quality and energy planning can jointly reduce $PM_{2.5}$, ozone, toxics and greenhouse gases.
- **Consider demand and supply side as equal resources to meet energy and environmental goals:** Policies that include energy efficiency, renewable energy and combined heat and power (CHP) can meet the same environmental goals at lower costs than policies that select only end of pipe emission controls.[31]
- **Avoid unintended consequences:** Head off uneconomic investment decisions that threaten to 'lock in' negative air quality consequences for decades.
- **Influence the goals included in the 13th (and subsequent) Five Year Plans:** Promote "clean first" dispatch of generation resources. Encourage economic dispatch of generation, considering health costs and environmental benefits.
- **Effectively use agency resources:** Analysis of benefits can be jointly applied to fine particle, ozone, mercury and GHG plans.

12.6 PROCESS STEPS FOR AIR REGULATORS

This chapter has emphasized the benefits of having energy efficiency and renewable energy measures considered equally with other measures that air regulators evaluate to meet ambient air quality standards. To capture these benefits, it is essential for air and energy regulators to work together. Each discipline speaks a slightly different language. Energy regulators focus on "keeping the lights on", and doing so at reasonable cost. Air regulators focus on removing pollution and improving public health. Absent recognition that energy regulators have a role in reducing pollution, energy planners would simply continue to allow fossil-fuel fired power plants to be built, with the consequences of increased air pollution. Likewise, if air regulators do not recognize their role to help to maintain electricity reliability and reasonable costs, air planners would not consider the air quality benefits from energy efficiency and renewable energy generation, which would increase the costs of producing electricity and industrial commodities.

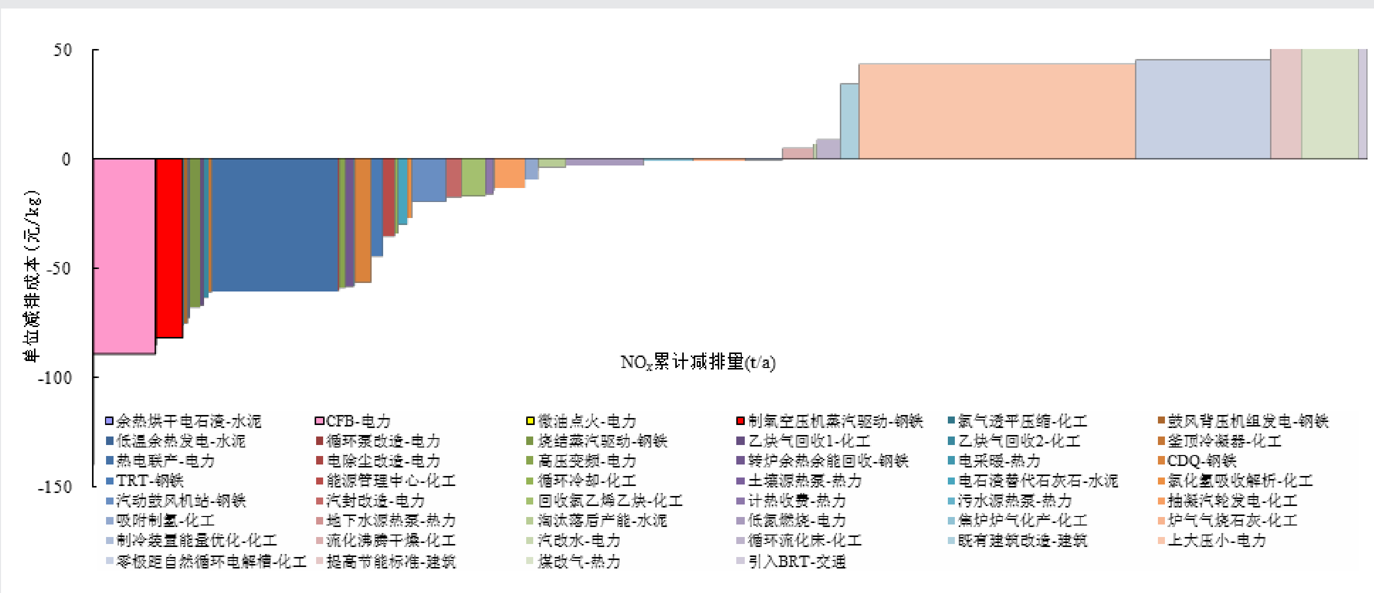
But what steps are needed to ensure that air regulators accurately assess the environmental values associated with clean energy policies, and also ensures that energy regulators appreciate the contributions that air regulators can make to an energy planning process? The traditional air quality planning process emphasizes end-of-pipe emission controls and effective monitoring systems to ensure compliance with emission standards. This model has served air regulators well, but as we increasingly understand the benefits from a multi-pollutant approach and the unintended consequences that can occur from not considering how choices for environmental controls can have energy and economic impacts, air regulators need to consider new approaches or revisions to their existing processes. Making any transition to a multi-pollutant approach more difficult is the relative absence of examples and process steps that air regulators could follow.

Fortunately, recent work in China provides a path for which air regulators can better consider and evaluate all control measures, including energy efficiency and renewable energy programs.

Called co-control, this process model approaches air quality management from a perspective of "top-down" tons. The top-down ton analysis determines the quantity of tons that must be removed from an airshed in order to reach an ambient standard or public health objective. The process then evaluates what control measures are available to be implemented to reduce pollution and rank orders them by efficacy of emissions controlled and their cost.

In the example shown in Figure 12-3 below, this city determined that 41,404 tons per year of NO_x needed to be removed from the airshed in order to meet their air quality goal.[32] The x-axis shows each of the more than 20 control measures that were evaluated and their abatement potential. The y-axis shows the cost per ton for each control measure.

Figure 12-3 NO_x **Abatement Potential vs. Cost for Various Technologies and Processes**



Another example of how air regulators can account for energy system affects and benefits comes from the United States. Taking the best examples from both air quality and energy planning, a process referred to as IMPEAQ, Integrated, Multi-Pollutant Planning for Energy and Air Quality, shows how air quality and energy planners could jointly work together to timely achieve their respective goals.[33] The basic IMPEAQ process steps are summarized in Table 12-1.

Table 12-1 The IMPEAQ Process - Integrated, Multi-Pollutant Planning for Energy and Air Quality

STEP	RESPONSIBLE PARTY	PROCESS STEP DESCRIPTION
1	Air quality planners (either at the national, provincial, regional or city level.)	Determine current air quality levels, including hot spots, from a review of the ambient monitoring network.
2	Air quality planners lead, but elicit input on assumptions from energy and transport planners.	Use air quality models to calculate the tons of emissions to be removed to reach desired ambient concentrations for each pollutant of concern (e.g., current or future ambient air quality standards).
3	Air quality planners lead, but involve energy and transport planners on assumptions.	Run optimization modeling against a multi-pollutant database of emission reduction options – or if unavailable, collaborate with energy regulators – to determine energy savings (and co-benefits) achievable through cost-effective energy efficiency (EE), distributed resource (DR), and renewable energy (RE) measures.
4	Energy savings data need to come from energy planners. Both energy and air planners need to agree on the relevant avoided emissions factors (which will vary by the state and energy market).	Translate EE, DR, and RE energy savings into emission reductions.
5	Air quality planners.	Sum emissions reductions achieved by EE, DR, and RE; repeat from Step 3 until sums reach tonnage targets established in Step 2.
6	Air quality planners, who would consult with/elicit input from energy (and other planners and the public) as in any normal regulatory process.	Conduct regulatory processes necessary to adopt and implement the measures identified in Step 3.

12.7 RECOMMENDATIONS FOR JIANGSU

Air quality and energy planning processes are iterative and attempt to predict what policies will be necessary based on forecasts of expected future outcomes. Forecasts of what will occur 10-15 years from the time the forecast is made will almost certainly be inaccurate, as the results are dependent upon variables that can change each year, and whose influence upon a result can also change. For this reason, both air quality and energy plans tend to be periodically revised and updated, sometimes each year, but frequently every 2-3 years.

The jurisdictions that were the focus of principles and best practices reflected in this chapter have revised and improved their energy planning processes over time. They too had to start from a very basic level, recognize that their initial effort was not perfect, and then improve upon that initial effort as subsequent plans were prepared. It is important to note that lost opportunities and unintended consequences occur when air quality planners do not take energy policies into account, or when air plans do not explicitly consider how the benefits of good energy policies can be analyzed and included as part of an air quality plan.

Jiangsu Province has many challenges to face as it develops and implements plans to improve air quality. The recommendations here recognize that it is not likely that Jiangsu will be able to implement all of them at once, and may have to defer some suggestions to the next revision of the air quality plan. It's critical though for Jiangsu to initiate the process towards better integration of air quality and energy policy. The majority of air pollution in Jiangsu is related to energy consumption, and the better that energy and air policies can be aligned, the more likely that the goals of both disciplines will be met, and met more sooner and cost-effectively.

Initiate a power sector planning process. Work with the local Developmental Research Center (DRC) and National Energy Administration (NEA) to establish a meaningful power sector planning process for Jiangsu. Recommend that Jiangsu be selected as a power sector planning/AQM pilot. The power sector planning process could start with simple resource plan that includes renewable energy (RE) and energy efficiency (EE).

Link the addition of new energy resources to meeting provincial air quality goals. Pollution levels in Jiangsu Province are higher than China's national ambient air quality standards. Any new fossil-fueled plant (coal or gas) will add to that pollution, while new renewable energy resources (wind and solar) and energy efficiency can avoid such increases, and even decrease them if developed in significant quantities. These factors should be considered by energy planners when new resources are approved or selected.

Establish a maximum capacity use factor (CUF) for coal plants. China has invested heavily to expand its wind and solar resources. However, new coal plants continue to be built, and existing ones are causing wind resources to be curtailed in some areas. A CUF for coal plants would send signals to investors and project developers that China's renewable energy development is not temporary and that coal will not be profitable in the future.

Establish a process for air and energy regulators to collaborate on their respective plans. Starting out informally at first and then making such collaboration routine as future air and energy plans are developed or revised. Some initial questions that such a group could discuss are:

i. What is the future expected electricity demand growth and what resources will be needed?
ii. What is renewable energy share of Jiangsu provincial, city-level electricity production? What percentage is imported? What percentage is generated within the province?
iii. Where can additional energy savings projects be conducted?

Determine the environmental benefits of Jiangsu's clean energy policies. Include EE, RE, and sound energy principles in the menu of control measures in the Jiangsu provincial and city-level air quality plans.

Utilize the Environmental Impact Assessment (EIA) process to encourage air and energy policy integration. Use EIA process (and any future versions of a construction and operating permit program) to ensure that new/modified sources have high thermal efficiency, and use standard processes to improve coal quality.

12.8 CONCLUSION

Completing an air quality management plan is a challenging task, even more so in the face of China's rapid economic growth. Agencies have resource constraints, and public demands for quick action, and there are gaps in the quantity and quality of information about how to precisely and effectively adopt control measures to improve air quality. The apparent daunting situation faced today by Jiangsu Province was also faced in the 1950s and 1960s by air quality agencies in Los Angeles and London, and in their cases, even the exact causes of pollution were not known[34], much less the efficacy of control measures that these respective agencies adopted.

Today we can continuously monitor pollution in the ambient atmosphere and in individual industrial and power sector stacks. We also know that humans, flora, fauna and the built environment experience the cumulative and combined influence of all pollutants in the atmosphere. Results from several jurisdictions in the US and Europe conclude that the most cost-effective and expeditious ways to improve air quality are through the implementation of policies and control measures that jointly and simultaneously reduce many pollutants and which capture the benefits of clean energy policies.

Jiangsu Province and its key cities can include the steps recommended in this chapter in their air quality management plans. Not all steps need to be included in the first air quality plan. The key is to establish a process and framework, to consider and evaluate those actions which today are consistent with the capacity and understanding of Jiangsu's air quality and energy planning agencies. Jiangsu Province has good experience already that can be built upon: the DSM pilot and municipal level coal consumption caps. The results of these programs should be evaluated, for how they could be expanded more broadly, and for how the existing programs might be deepened to reveal additional air quality and energy benefits.

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13
Challenges

OVERVIEW

This chapter summarizes challenges that have been noted throughout this report regarding various aspects of air quality planning. Overarching challenges are presented first, followed by summaries of more specific technical challenges, grouped by general topic area.

13.1 GENERAL

- Limited resources. The provincial-level and city-level environmental agencies are relatively small, as compared with U.S. state environmental agencies. As a result, staff cannot specialize in specific areas of air quality management. Instead, staff must cover a wide range of issues and media (air, water, solid waste). Therefore, developing internal experts in specific areas of air quality management is difficult. To exacerbate the problem, there is a significant difference in the role of the environmental agency versus regulated entities as compared with the U.S.

- Rapid growth. With significant new construction, and accelerated shutdown of older, less-efficient facilities, the population of industrial facilities is constantly changing, making it difficult to track even basic information, such as a complete listing of industrial facilities in the province, or within a city jurisdiction. Related to this rapid growth, the many active construction sites and industrial facilities are spread over large areas, making data collection, inspection, and enforcement difficult. In addition, the mobile source inventory in the province has grown 406 percent in ten years, with an annual growth at 20 percent.

- Authority. In some cases, the city does not have the authority to make regulations and laws on environmental issues. More regulations are needed, and are coming, at the national level. It will also be important for cities to collaborate with the Provincial EPD to have them suggest new regulations to the national government, or to establish new regulations at the provincial level.

- Intense pressure to improve air quality. Fast-growing, industrial cities place great pressure on environmental protection.

13.2 EMISSIONS INVENTORY

- Need for China-specific air emission factors. There is a need to develop China-specific air emission factors to assist with improving air emissions inventories. Best practices in the U.S. include conducting air emissions testing on selected process and emission control device combinations, then developing air emission factors that can be applied to similar sources without the need for additional testing. Other provinces and cities with similar industrial operations would then be able to use those emission factors for their own air emissions inventories, and likewise share any air emission factors developed in their province or city.

- Inexperienced EPB staff. Emission inventories are relatively new to many agency staff; some staff have been working on air emission inventories for only a few years. Additional experience is needed in all areas of air quality management, including basic technical foundation for the future.

- Inexperienced industry environmental staff. In addition to EPB staff, the staff at the industrial facilities being asked to report air emission data are also relatively new to emission inventory reporting. These staff also require training and guidance in order to be equipped to provide complete and accurate air emission data for their respective facilities and operations.

- Air emission inventory training. A common topic from many of our discussions was the need for additional training on VOC emission estimation and measurement techniques. Emission estimation techniques are also needed for the petrochemical, cement, power, and iron and steel industries. Other training may include the use of statistical sampling and models for estimating emissions from mobile and area sources.

- Equipment training. The EPB's, monitoring centers, laboratories, and universities often have state-of-the-art equipment. Assistance is needed with ways to use these equipment more effectively as part of the air quality monitoring program and air emission inventory development and verification. Training is needed in areas such as source apportionment (e.g., positive matrix formation [PMF]).

- Data quality training. EPB staff have to deal with data quality issues. Data from power plants is not always reliable. Verifying data for facilities without CEMs can be challenging. Training is needed on best practices for quality assurance/quality control and verification techniques (e.g., statistical analyses) for the underlying data used to develop accurate air emission inventories.

- Other training. Other training needs related to emission inventory development have been expressed or identified, including: data collection and reporting techniques (including CEMS data reporting); air emission estimation techniques for specific pollutants; alternative emission measurement methods (to CEMS) for small entities; fugitive dust emissions estimating techniques (e.g., construction site dust); air emission estimates for small, ubiquitous sources (e.g., restaurants, street cooking, outdoor burning, fireworks, auto repair garages, and use of organic solvents); and documentation of emissions inventory processes for future reproducibility and understanding (methods, data sources, assumptions, calculations).

13.3 EMISSION REDUCTION STRATEGIES

- Short-term strategies. Focusing primarily on short-term emission reduction strategies may not fully address long-term air quality issues. Other effective measures beyond add-on air emission controls (e.g., pollution prevention) should be incorporated in the overall air quality management program.

- Air emission control strategies training. Additional training is needed on relevant control strategies for ozone and VOCs and their effectiveness. There is a need for cost-effective, practical air emission controls and corresponding emission measurement methods. Training should emphasize multi-pollutant emission controls, and the pursuit of "win-win" approaches that will both protect the environment and save money for the company.

- Costs of air emission controls. Information on costs of emission controls for point sources in China has been more challenging to compile due to the dynamic nature of the economy and changing policy landscape. This information continues to improve each year and will be very important for making future regulatory decisions.

13.4 AIR QUALITY MODELING

- Quality-assured model inputs. Quality-assured model inputs, including source data, emission data, terrain data, and meteorological data are critical to obtaining useful model output. There is also a need for development of spatial surrogate data for modeling applications, where there are gaps in data sets.

- Speciation profiles. Accurate, up-to-date source profiles are necessary for use in CMB and for interpreting PMF results. Many source types lack updated profiles. EPA's Speciate, a repository for emissions profiles, has not been updated in a very long time and many profiles may not be applicable to provincial sources. In addition, it is preferable to have source profiles based on measurements using the same type of analytical techniques as the ambient measurements. Source profiles are costly to develop.

- Source apportionment. It is important to be able to apportion secondarily-formed particles/components. However, it is considerably more difficult to relate ambient concentrations of secondary species (sulfate, nitrate, some of the organic carbon) to sources of precursor emissions than it is to identify the sources of primarily emitted particles (black carbon, metals).

- Data set preparation. It is challenging to obtain or develop realistic uncertainties for source and receptor values. Uncertainty is used to weigh the relative importance of input data to model solutions and to estimate uncertainty of the source contributions.

- Experience. Training on source apportionment methods, data preparation, and data interpretation is needed. While there are many journal articles available, learning directly from experienced practitioners is ideal.

13.5 AIR QUALITY MONITORING

- Develop quality assurance program plans and standard operating procedures, and ensure these plans and procedures are followed to ensure high data quality.

- Perform periodic monitoring network assessments to evaluate whether the appropriate air quality and meteorological measurements are being made in the most beneficial locations.

- Perform periodic review of data quality and data usefulness. There may be instruments or measurements that are unnecessary or of poor quality and these could potentially be eliminated to help with cost control.

13.6 MOBILE SOURCES

- Most urban areas experience continuous growth in vehicle use. Over time, in most countries, average per-vehicle emissions rates have declined due to technological advances in vehicles and fuels; however, increased numbers of vehicles and total vehicle miles traveled (VMT) have offset emissions reductions.

- "Middle-aged" vehicles, those roughly 10 to 20 years old, contribute disproportionately to emissions. These vehicles are no longer under warranty, have often had time to deteriorate, are still relatively plentiful, and are driven more per year than the oldest cars. The result is that they are the most important portion of the fleet in terms of emissions.

- Numerous studies of cars, trucks, ships and other sources indicate that regardless of model year, a small fraction (~10%) of the fleet is responsible for a large fraction (50% or more) of fleet emissions. Therefore, a key challenge is the need to identify and control these high emitters, often referred to as "gross polluting vehicles."

- To ensure future air quality improvements, experience shows that control programs need to address newly manufactured vehicles that will, over time, replace the in-use fleet.
- Long-term U.S. experience led to a realization that the transportation and air quality planning communities can work at cross-purposes. The U.S. Clean Air Act Amendments [1990] resolved that challenge by establishing a "transportation conformity" policy that mandated inter-agency consultation, use of common planning assumptions, and periodic comparisons between transportation and air quality plans.

14

Key Recommendations

OVERVIEW

This chapter summarizes key recommendations made throughout this report regarding the many elements of the air quality planning process. The recently amended China Air Pollution Prevention and Control Law (APPCL), effective January 1, 2016, includes a number of important provisions that will help strengthen the framework for air quality management in Jiangsu Province. Detailed implementing regulations will provide crucial guidance and direction for Jiangsu Province in coming years. The following recommendations for Jiangsu EPD and city EPBs are grouped by major topic area, and are made in light of the coming implementation of the national clean air law.

14.1 GENERAL

- Seek opportunities to increase the level of EPB staffing and budgets to address the significant public health challenges presented by air pollution in Jiangsu Province. Current staffing and budget levels do not appear to be adequate to implement numerous new air pollution programs and requirements in Jiangsu Province today.
- Promote opportunities to enhance regional air quality planning among multiple provinces to enable air quality professionals to learn from each other, to develop potential emission reduction strategies, and to identify potential policy solutions.
- Coordinate interagency planning and data sharing to integrate air quality, energy, and transportation planning processes.

14.2 AIR QUALITY GOALS

- Establish clear and specific metrics for determining achievement of national air quality improvement goals. For example, the AQMP for Jiangsu Province should clarify that a 20% reduction in ambient $PM_{2.5}$ concentrations by 2017 will be assessed by calculating the average of all monitors across the province.
- Develop an effective approach for communicating to the general public about progress being made toward the 2017 air quality goals and future goals. Also publicize real-time and historic emissions and air quality data and make them readily available to the general public.

14.3 EMISSIONS INVENTORY

- Develop a high quality emissions inventory for stationary, area, and mobile sources for a base year (such as 2012) and an appropriate future year (such as 2017).
  - The inventory should follow a common data structure for emissions reporting consistent with national guidance aimed at development of a nationally consistent emissions inventory. Efforts made now to develop a nationally consistent inventory will be beneficial to future efforts in Jiangsu to develop plans addressing regional air quality issues and GHG reduction strategies.
  - The inventory at a minimum should include emissions data for the following pollutants: direct $PM_{2.5}$ (including condensable $PM_{2.5}$ emissions), SO_2, NO_X, VOC, ammonia, CO, CO_2, black carbon, and methane.
- Follow guidelines for using the best available data and China-specific emission factors
  - Tier 1: Use CEMS data when available
  - Tier 2: Use facility-specific emissions source test data
  - Tier 3: Use default emission factors from accepted guidance
- Develop activity levels and growth factors for future year emissions projections using data from government agencies, trade associations, market research firms, or other groups that have specific knowledge of future levels of emissions activity. Focus the development of growth factors on those sources and source categories that comprise a large percentage of pollutant emissions and/or for which emissions are expected to change dramatically.
- Require point source facilities exceeding a "major source" size threshold to report their emissions annually using specific national (or provincial) emission estimation guidelines and reporting forms. Forms should include fields for reporting data for each emission unit at the source, including:
  - quantity of emissions by pollutant;
  - emission unit release parameters (i.e., location or GIS coordinates, stack height, stack diameter, release temperature and velocity);
  - annual hours of operation for the unit;
  - the type of pollution control equipment in place;
  - the annual operating hours for the control equipment; and
  - source monitoring technique used.
- Review available emission factors to identify the most representative factors for area sources (agriculture, open-burning, etc.) in Jiangsu Province, with priority given to updating emission factors for source sectors comprising a more significant portion of the overall inventory.
- For estimating emissions from on-road mobile sources, collect information using data sources such as travel demand models, traffic counts, and vehicle registration data.
- For estimating emissions from non-road mobile sources, use a top-down approach using available data on fuel consumption, vessel calls (number of vessels visiting a

port), aircraft activity, and equipment populations.

- For biogenic sources, estimate emissions using models such as the Biogenic Emission Inventory System (BEIS) or the Model of Emissions of Gases and Aerosols from Nature (MEGAN).
- Provide resources for provincial and city-level staff to be trained in national and provincial emission inventory procedures and best practices, including development of area source and mobile source inventories.
- Establish legal mechanisms and procedures to obtain updated emissions data from regulated entities so that the province can comprehensively update the emission inventory according to a regular schedule (such as every 3 years).
- Compare air quality monitoring data and source apportionment results with emission inventory data to identify adjustments needed in the emission inventory.

14.4 EMISSION STANDARDS AND EMISSION REDUCTION STRATEGIES

Overarching recommendations are summarized here. Specific emission reduction strategies for key industry sectors are presented in Chapter 9.

- Develop emission standards that are reflective of the best available control technology (BACT) that is demonstrated and cost-effective.
  - Where possible, establish numeric emissions values with a specified averaging time appropriate for the source. Numerical emission limits allow facility operators to select the control device or system of control devices that best meet the emission limit in their specific application.
  - Consider multi-pollutant and multi-media control strategies, effects on energy-use, and any potential adverse environmental impacts when evaluating appropriate emission limits.
  - Encourage pollution prevention measures, such as substitution of fuels, feedstocks, or alternative equipment that may eliminate the need for add-on emission controls.
  - Implement standards for VOC content of paints and coatings.
- Include the following elements in emission standards:
  - emissions limit representing BACT, with a specified averaging time;
  - requirements for monitoring emissions from the source, using CEMS if possible, or control device operating parameters;
  - when control device operating parameters are used, ensure operating limits are tied directly to the performance test and that the averaging periods are short enough to ensure continuous compliance;
  - requirements for periodic source tests (when CEMS are not used) to measure emissions; and
  - requirements for periodic inspections, recordkeeping and self-reporting, use of electronic methods, standard formats, and common protocols.
- Engage stakeholders who will be responsible for actions needed to improve air quality under the plan early in the process.
- Maintain and update a data base including case-specific information on “best available” stationary source air pollution control technologies and other emission reduction methods. Provincial EPD and city-level EPBs should be required to provide relevant information to this database after air pollution permits are approved for new or modified sources. Similar information from provinces outside of Jiangsu can be integrated into a larger national database in the future. Such control technology databases will support efforts to require best available control technology on sources in cities and provinces that are not meeting current air quality goals.

- Expand requirements for using continuous emissions monitoring systems (CEMS) or other continuous monitoring techniques for power plants and other large facilities. CEMS data provide reliable and temporally resolved emissions estimates. These data will be useful for regulatory and compliance purposes.
- Review and update emission standards (e.g., every 10 years) in accordance with mechanisms established pursuant to the APPCL.

14.5 ENERGY PLANNING

- Establish an integrated planning process for air, energy, and economic regulators to share data and forecasts and collaborate on their respective plans.
- The power sector planning process could start with resource planning procedures that:
  - Consider central and distributed renewable energy (RE) and end-use energy efficiency (EE) measures as cost-effective alternatives to conventional generation in meeting demand for energy services while reducing pollution emissions.
  - Integrate transmission and distribution planning with other aspects of power sector planning.
  - Quantify the environmental and public health costs and benefits associated with the resources being evaluated.
  - Identify and minimize economic, business, and environmental risk.
- Utilize the Environmental Impact Assessment (EIA) process to encourage air and energy policy integration. Use the EIA process (and any future versions of a construction and operating permit program) to ensure that new/modified sources have high thermal efficiency, use standard processes to improve coal quality, and have forecasted emissions that are consistent with air quality goals, both within jurisdictions and in areas downwind.
- Consider establishing a maximum capacity use factor (CUF) for coal plants. This will send signals to investors and project developers that China's renewable energy development is not temporary.
- Build on Jiangsu Province's strong track record in the area of demand-side management (DSM) to reduce energy demand during periods of supply constraint.
- Continue to support efforts to improve energy efficiency, including appliance standards, building standards and other energy efficiency standards, which have already saved millions of tons of coal and avoided further increases in air pollution.
- Determine the economic and environmental benefits of Jiangsu's current clean energy policies as well as future policy options.

14.6 AIR QUALITY MODELING

- Estimate the projected emission reductions associated with existing national policies, existing provincial emission reduction measures, and emission reductions expected in "upwind" provinces. Account for energy demand projections when developing these emissions estimates. Conduct air quality modeling to estimate air quality in the relevant future year.
  - Regional coordination with other nearby provinces is important for determining expected future emissions reductions that could help improve air quality in Jiangsu Province.
  - If the air quality goal cannot be met with only existing measures, then Jiangsu Province and city EPBs should identify additional emission reduction measures that can be adopted in the area.
  - Conduct a new air quality modeling analysis to determine whether the additional emission reduction measures will ensure that air quality goals will be met in the target year.

- Use $PM_{2.5}$ composition data for identifying key sectors for control measures.
- Consider using the ABaCAS system for air quality planning in Jiangsu Province to identify potential control measures to meet the air quality goal, and to estimate health benefits and costs of such measures.

14.7 AIR QUALITY MONITORING

- Continue to operate and if possible expand the existing $PM_{2.5}$ monitoring network in Jiangsu Province. $PM_{2.5}$ speciation monitoring is very useful for identifying contributing source sectors through source apportionment analyses. The recommended minimum suite of pollutants required for effective apportionment analyses include: organic carbon, elemental carbon, ammonium sulfate, ammonium nitrate, and trace elements such as aluminum, silica, calcium, iron, potassium, and titanium. Jiangsu Province makes many of these measurements on an hourly basis, providing much statistical power to source apportionment findings.
- Refine standardized procedures for air quality monitoring, data analysis, and reporting in order to improve data quality and consistency. The standard procedures should include appropriate QA/QC programs to ensure that air quality monitoring data are reliable and provide a sound basis for policy-making.
- Coordinate ambient monitors operated by different entities (e.g., national, provincial, and city) to minimize costs and maximize data collection.
- Collocate meteorological measurement stations with air quality monitoring stations to enhance data validation and interpretation.
- Review ambient monitoring data frequently to identify monitoring errors early and to increase data completeness.
- Perform periodic review of ambient air quality monitoring objectives and procedures to ensure the monitoring network is appropriate as goals and priorities change.

14.8 TRACK PROGRESS

- Track the progress and effectiveness of the air quality management plan with requirements to regularly and routinely:
    - Track the implementation of specific regulations and programs by EPBs and affected facilities. Determine whether implementation milestones and compliance dates are being met on time.
    - Assess the level of air quality improvements at monitoring stations.
    - Quantify the emissions reductions achieved in subsequent emission inventories.
    - Publicize results and modify emission reduction strategies as a result of findings.

14.9 EMERGENCY EPISODES

- Update and implement emergency episode programs for taking action when air pollution levels exceed certain thresholds. The program should include:
    - Timely air quality forecasts and communication of real-time air quality data to the public. Provide the public with information about actions they can take to reduce pollutant emissions and limiting their exposure.
    - A phased set of required actions to be implemented by governments and sources of emissions as air pollution levels increase above specific thresholds on high pollution days.
    - Early notification of the public to communicate information about air pollution levels, actions they can take to reduce pollutant emissions, and recommendations for limiting their exposure.

- Facility-level Risk Management Plans for facilities in key sectors. Facilities should have emergency preparedness plans in place that require implementation of mitigation measures and other actions in the event of high pollution events or sudden, accidental releases of emissions at the facility.

14.10 COMPLIANCE AND ENFORCEMENT

- Develop a strong enforcement program with national and provincial oversight.
  - Enforcement must be fair, consistent and applied evenly across regulated facilities.
  - The cost of violating the standards must be greater than cost of complying.
  - The penalty should recover the economic benefit of the emissions that should have been avoided. Penalties assessed to facilities can be used to pay for the enforcement staff and inspections.
- Coordinate with staff responsible for enforcement to establish regulations, monitoring, and permit requirements that are clear and easily enforced with a goal of improved compliance and environmental outcomes.
- Provide outreach, technical assistance programs, and training to regulated companies and enterprises on how to comply with specific regulations.
- Conduct enforcement inspections to ensure facilities comply with rule requirements. Requiring more recordkeeping and reporting by facilities may help to minimize the need and effort required for inspections, but these cannot eliminate the need for periodic site inspections.
- Use and promote advanced emissions/pollutant monitoring techniques so that regulated entities, the government, and the public can more easily recognize pollutant discharges, environmental conditions, and noncompliance.
- Use electronic reporting to help make environmental reporting more accurate, complete, and efficient while helping air quality regulators better manage information, improve effectiveness and transparency.
- Expand transparency by making information more accessible to the public; the public should be able to readily access data, both real-time and historic air quality and emissions data.
- Develop and use innovative enforcement approaches (e.g., data analytics and targeting) to achieve more widespread compliance.
- Establish provincial requirements for Material Safety Data Sheets (MSDS) or a similar program requiring the reporting of chemical constituents at a facility. The MSDS sheet includes information about the material and its physical and chemical properties, explains how to handle it safely, and describes how to respond to an exposure or spill.
- Establish a provincial "Community Right to Know" program to provide citizens with access to relevant information on chemicals manufactured or used by companies within their jurisdiction and to enable citizens to engage in the emergency planning/communication process.

14.11 PERMITTING

- Jiangsu Province should develop an operating permit program consistent with regulations and guidance developed pursuant to the permitting provisions in the APPCL.
- The program should apply to all sources above specific size thresholds. (In the U.S., all sources with a potential to emit more than 100 tons of traditional air pollutants or more than 10 tons of any hazardous air pollutant are required to get an operating permit.)
- The operating permit should include and serve to catalogue:
  - All requirements that apply to the source.

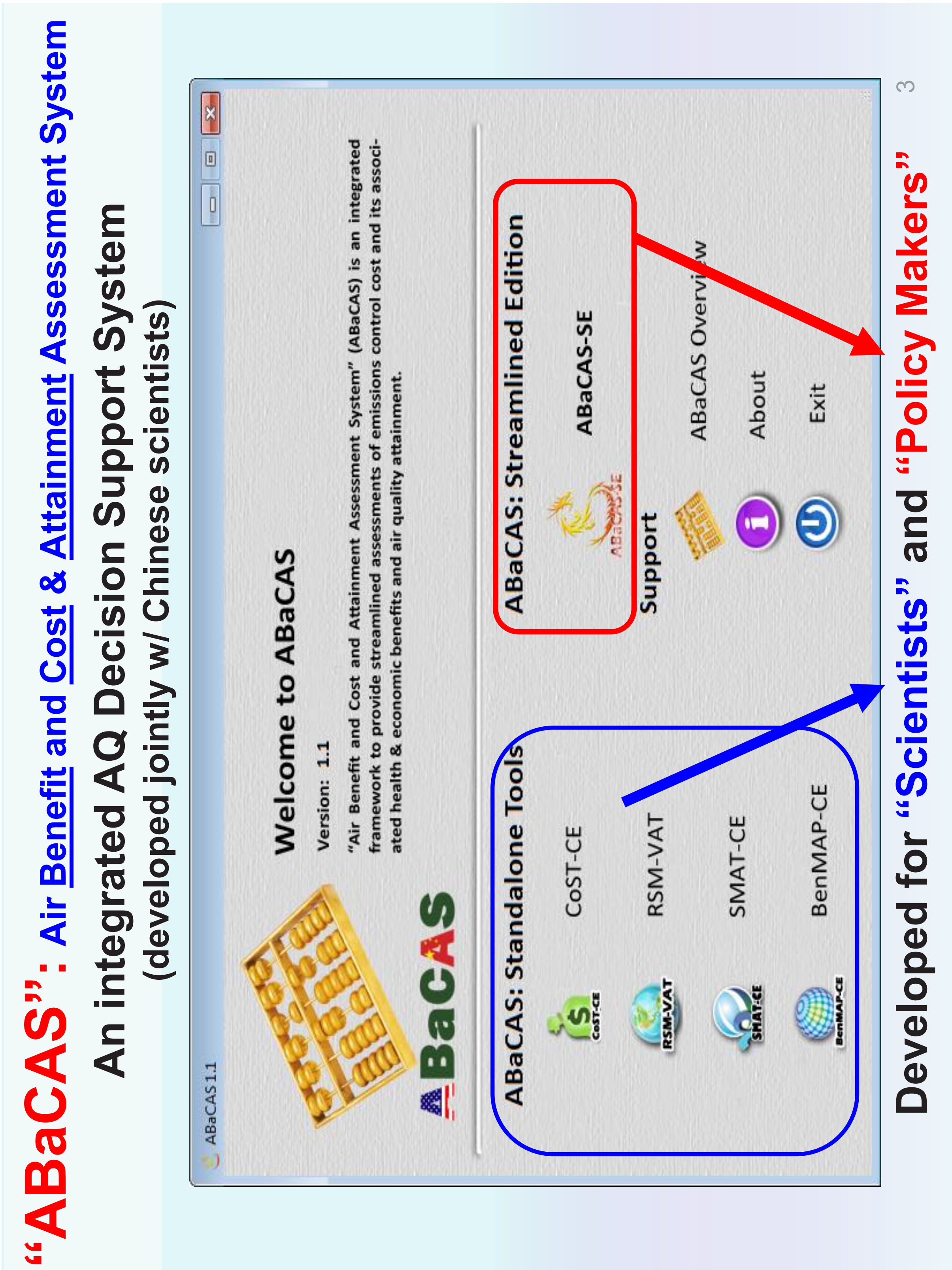
  - All emission standards, limits and averaging times that apply to specific emission units at the facility.
  - The related monitoring, reporting, recordkeeping, and test methods for each standard; and any other compliance requirements for the facility.
  - Any other operating limits, equipment or work practice requirements for sources at the facility.
  - Requirements for annual certification of compliance by a responsible company official.
  - Requirements to pay emission fees per ton of pollution emitted. Fees should be set at levels to adequately cover program costs.
  - Requirement for the company to report to the EPB any time it deviates from requirements in the permit.
- The program should have procedures for revising permits, for governmental and public review of permits, and for neighboring jurisdictions potentially impacted by downwind emissions to be involved prior to review and approval.

Appendix A

This appendix refers to a presentation by Dr. Carey Jang from USEPA on the recent development of the ABaCAS system in China.


大气污染控制费效与达标评估系统在中国之最新發展
Recent Development of Air Benefit and Cost and Attainment Assessment System (ABaCAS) in China
Air Pollution (PM2.5)
ABaCAS-China
Attainment & Cost/Benefit
Welcome to ABaCAS
Version: 1.1
ABaCAS: Standalone Tools
CoST-CE
RSM-VAT
SMAT-CE
BenMAP-CE
ABaCAS: Streamlined Edition
ABaCAS-SE
Support
ABaCAS Overview
About
Exit
长三角
PM2.5
2017:
20%↓
2030:
NAAQS
YRD
Suzhou
Shanghai
Jiaxing
Science
Policy
Actions
Carey Jang, Ph.D. 张志诚 美国环保署
U.S. EPA / Office of AQ Planning & Standards
9th RAQM & ABaCAS 2015
The 9th Regional Air Quality Management Conference and
Third Air Benefit and Cost and Attainment Assessment Conference
June 23-25, 2015 Guangzhou, China


Outline
Overview of Air Pollution Control Cost/Benefit and Attainment System in USA and China
Development of Next-Generation Integrated Air Quality Decision Support System:
"ABaCAS": Air Benefit and Cost and Attainment Assessment System
ABaCAS
Developed Jointly by an Elite Team of "US-China" Scientists
Streamlined "ABaCAS-SE"- 2017 & 2030 YRD cases and "ABaCAS" China (JJJ/YRD/PRD) Applications (2014/2015)


“ABaCAS”: Air Benefit and Cost & Attainment Assessment System
An integrated AQ Decision Support System
(developed jointly w/ Chinese scientists)
ABaCAS 1.1
ABaCAS
Welcome to ABaCAS
Version: 1.1
“Air Benefit and Cost and Attainment Assessment System” (ABaCAS) is an integrated framework to provide streamlined assessments of emissions control cost and its associated health & economic benefits and air quality attainment.
ABaCAS: Standalone Tools
CoST-CE
RSM-VAT
SMAT-CE
BenMAP-CE
ABaCAS: Streamlined Edition
ABaCAS-SE
Support
ABaCAS Overview
About
Exit
Developed for “Scientists” and “Policy Makers”
3

(2012: NAQQS)

NAAQS	PM2.5 (Annual)	PM2.5 (Daily)
China	35	75

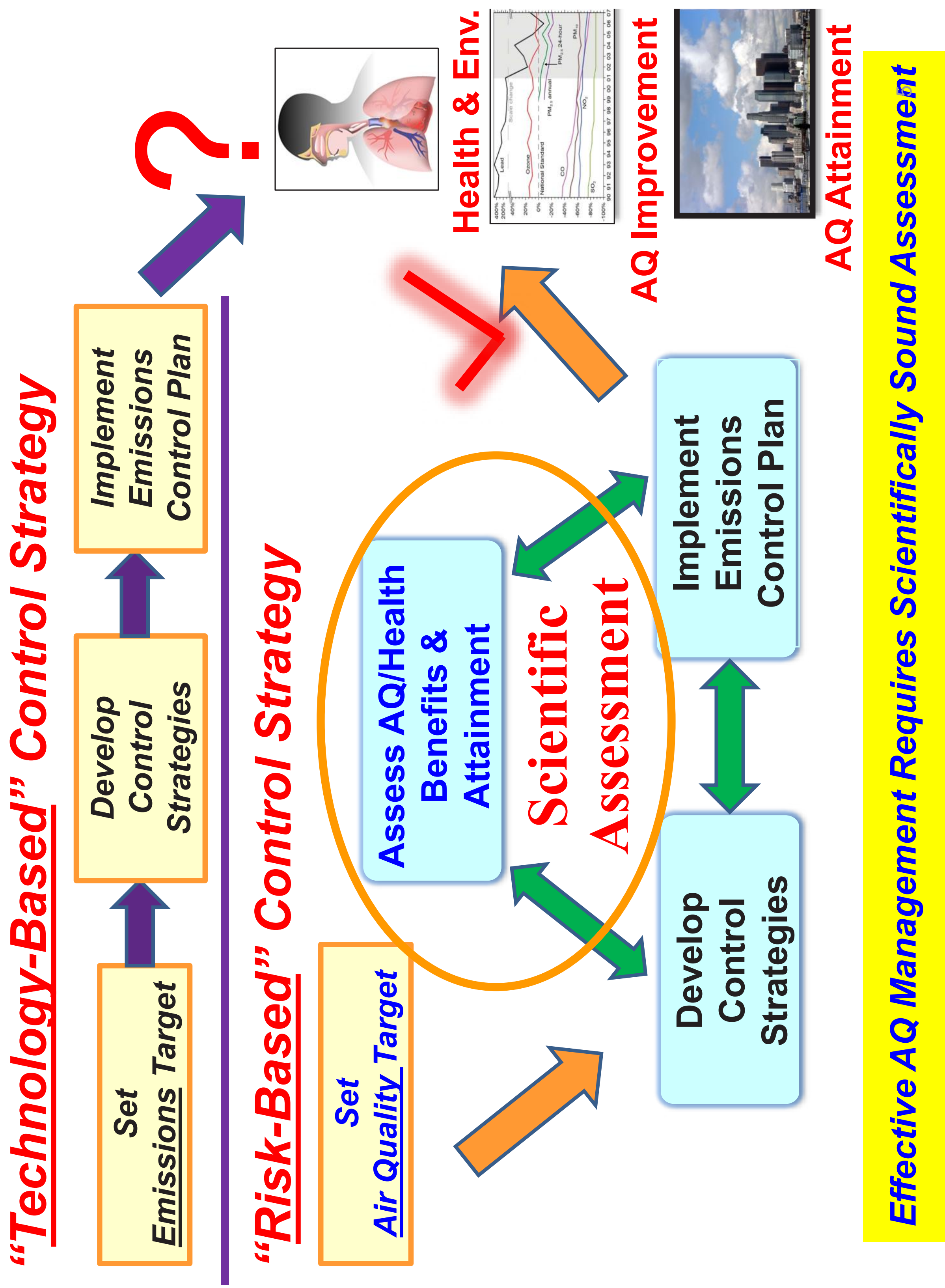
2010:

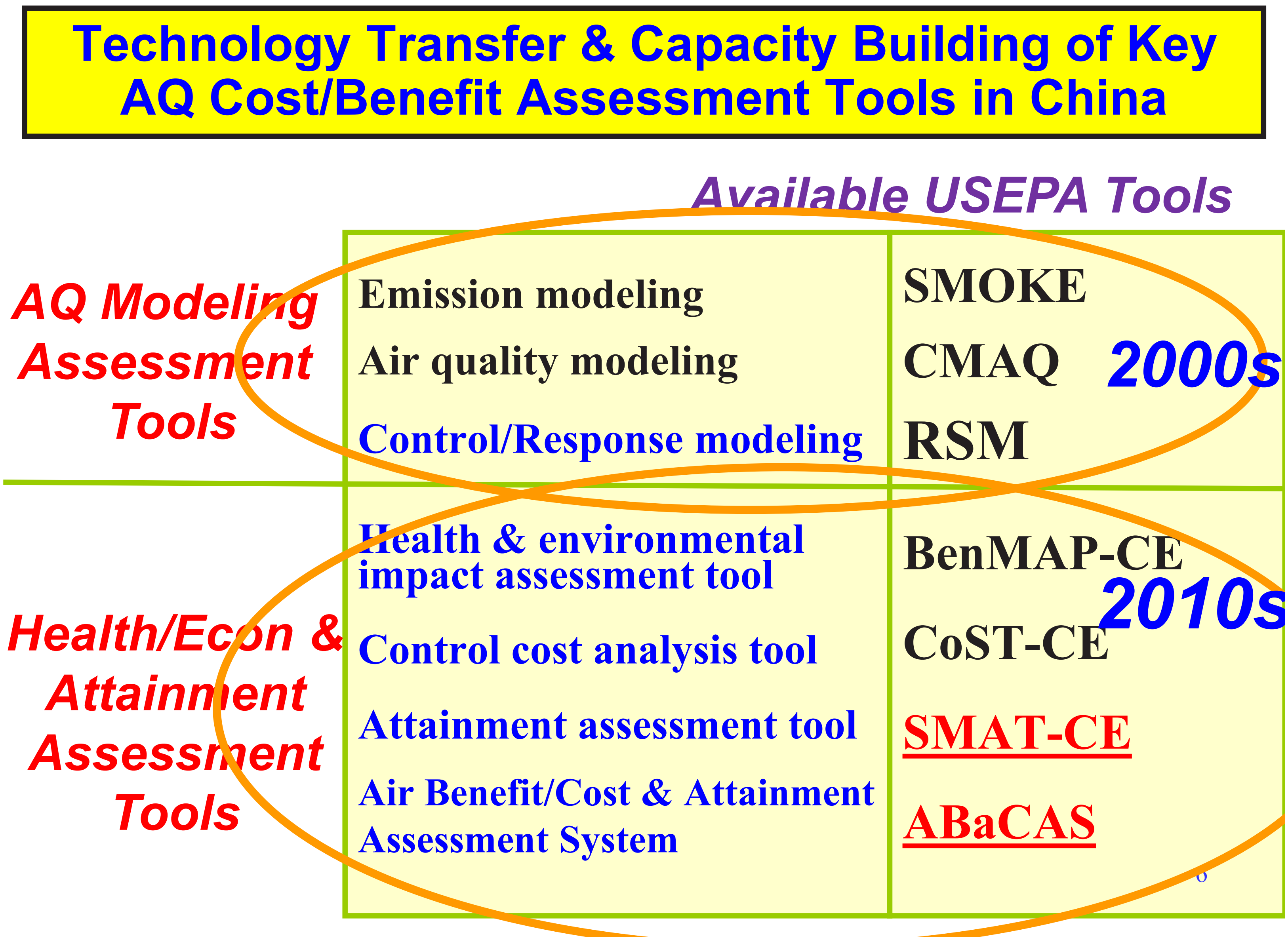
State Council's "Regional AQ Guidance"

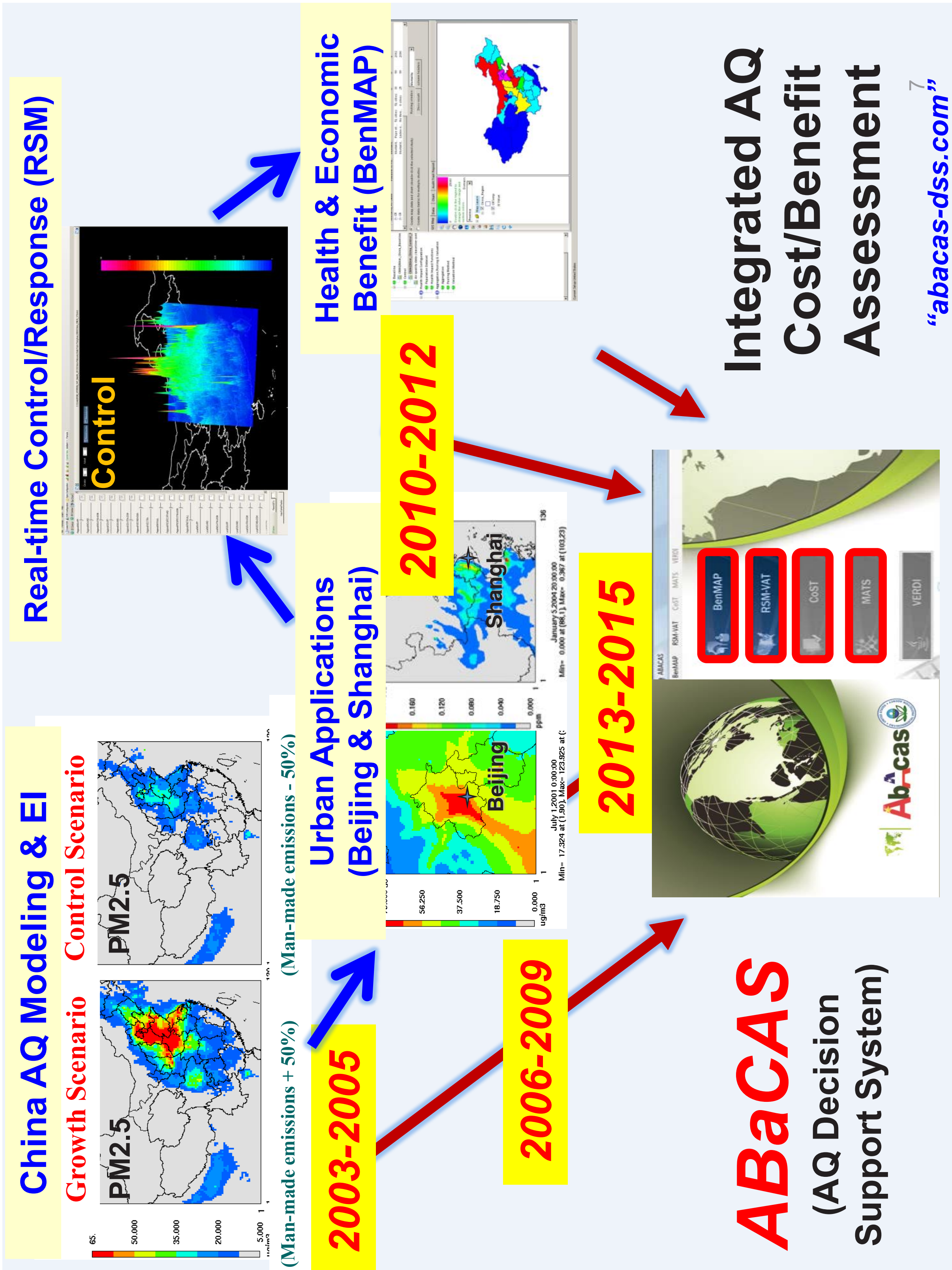
2013: AP Control Action Plan 大气国十条 (2012-2017)

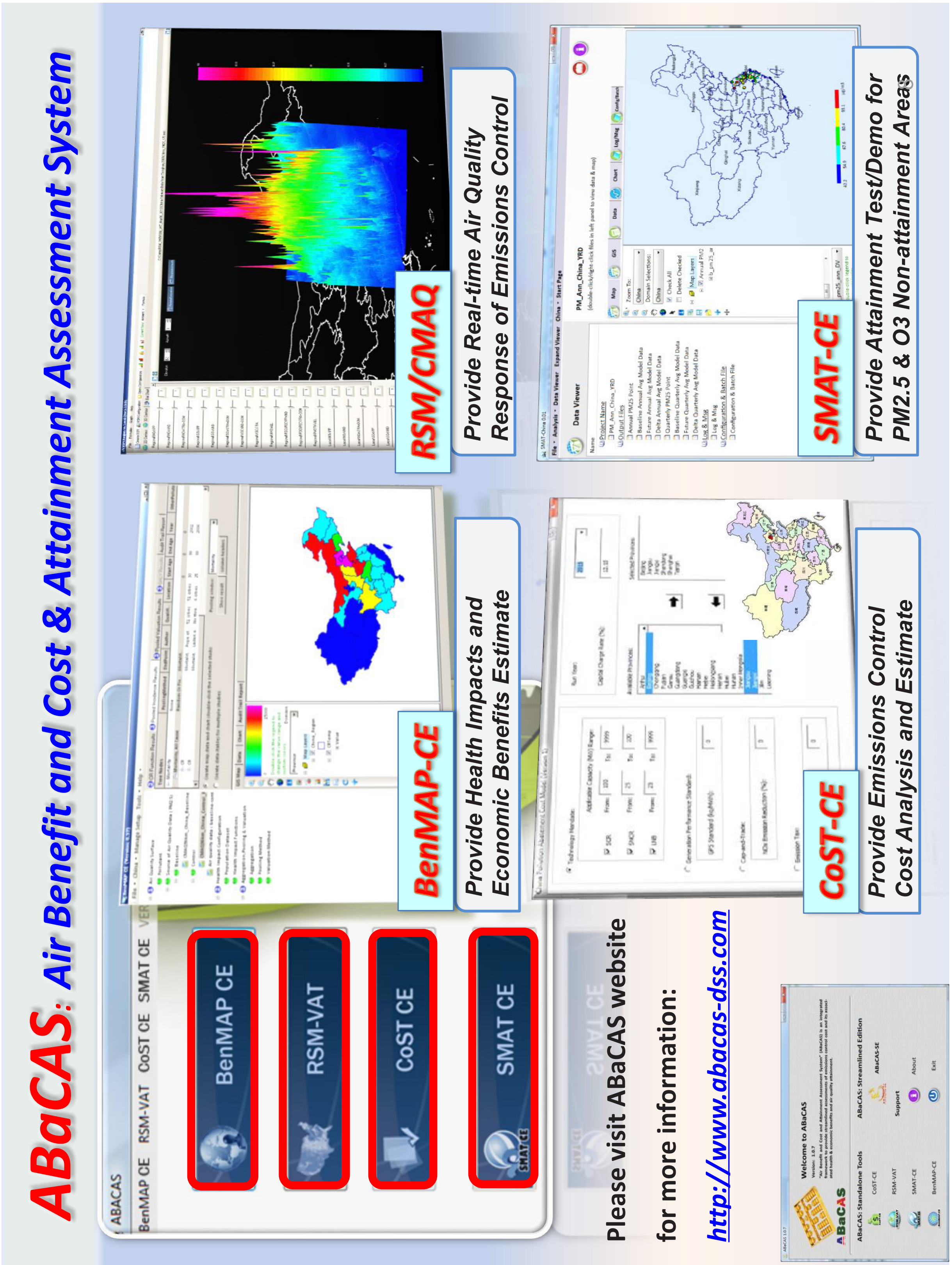
Region	Annual PM2.5
Jing-Jin-Ji	25% ↓
YRD	20% ↓
PRD	15% ↓
Beijing	60 ug/m3
Other Cities	10% ↓

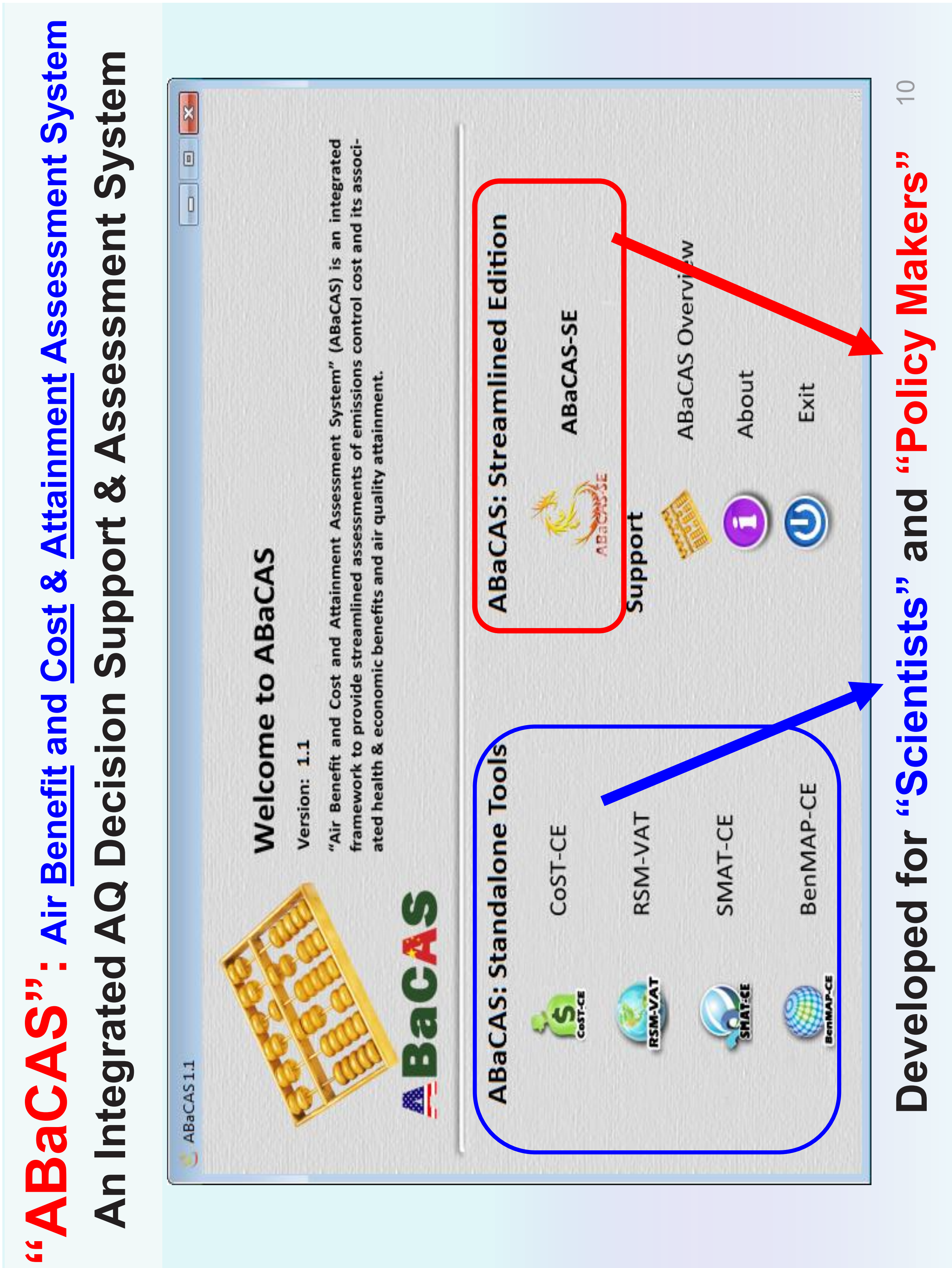
China's air pollution control policy has shifted from targeting "Emissions Reduction" (Technology-based) to targeting "Air Quality" (Risk-based)


"Technology-Based" Control Strategy
Set Emissions Target
Develop Control Strategies
Implement Emissions Control Plan
?
"Risk-Based" Control Strategy
Set Air Quality Target
Assess AQ/Health Benefits & Attainment
Scientific Assessment
Develop Control Strategies
Implement Emissions Control Plan
Health & Env.
AQ Improvement
AQ Attainment
Effective AQ Management Requires Scientifically Sound Assessment


Technology Transfer & Capacity Building of Key AQ Cost/Benefit Assessment Tools in China
Available USEPA Tools
AQ Modeling Assessment Tools
Emission modeling
SMOKE
Air quality modeling
CMAQ
Control/Response modeling
RSM
2000s
Health/Econ & Attainment Assessment Tools
Health & environmental impact assessment tool
BenMAP-CE
Control cost analysis tool
CoST-CE
Attainment assessment tool
SMAT-CE
Air Benefit/Cost & Attainment Assessment System
ABaCAS
2010s


China AQ Modeling & EI
Growth Scenario
Control Scenario
PM2.5
PM2.5
(Man-made emissions + 50%)
(Man-made emissions - 50%)
2003-2005
Urban Applications
(Beijing & Shanghai)
Beijing
Shanghai
2006-2009
Real-time Control/Response (RSM)
Control
2010-2012
Health & Economic
Benefit (BenMAP)
2013-2015
BenMAP
RSM-VAT
CoST
MATS
VERDI
Integrated AQ
Cost/Benefit
Assessment
"abacas-dss.com"
ABaCAS
(AQ Decision
Support System)


ABaCAS: Air Benefit and Cost & Attainment Assessment System
ABACAS
BenMAP CE
RSM-VAT
CoST CE
SMAT CE
BenMAP-CE
Provide Health Impacts and Economic Benefits Estimate
RSM/CMAQ
Provide Real-time Air Quality Response of Emissions Control
CoST-CE
Provide Emissions Control Cost Analysis and Estimate
SMAT-CE
Provide Attainment Test/Demo for PM2.5 & O3 Non-attainment Areas
Please visit ABaCAS website
for more information:
http://www.abacas-dss.com


"ABaCAS": Air Benefit and Cost & Attainment Assessment System
An Integrated AQ Decision Support & Assessment System
ABaCAS 1.1
ABaCAS
Welcome to ABaCAS
Version: 1.1
"Air Benefit and Cost and Attainment Assessment System" (ABaCAS) is an integrated framework to provide streamlined assessments of emissions control cost and its associated health & economic benefits and air quality attainment.
ABaCAS: Standalone Tools
CoST-CE
RSM-VAT
SMAT-CE
BenMAP-CE
ABaCAS: Streamlined Edition
ABaCAS-SE
Support
ABaCAS Overview
About
Exit
Developed for "Scientists" and "Policy Makers"
10

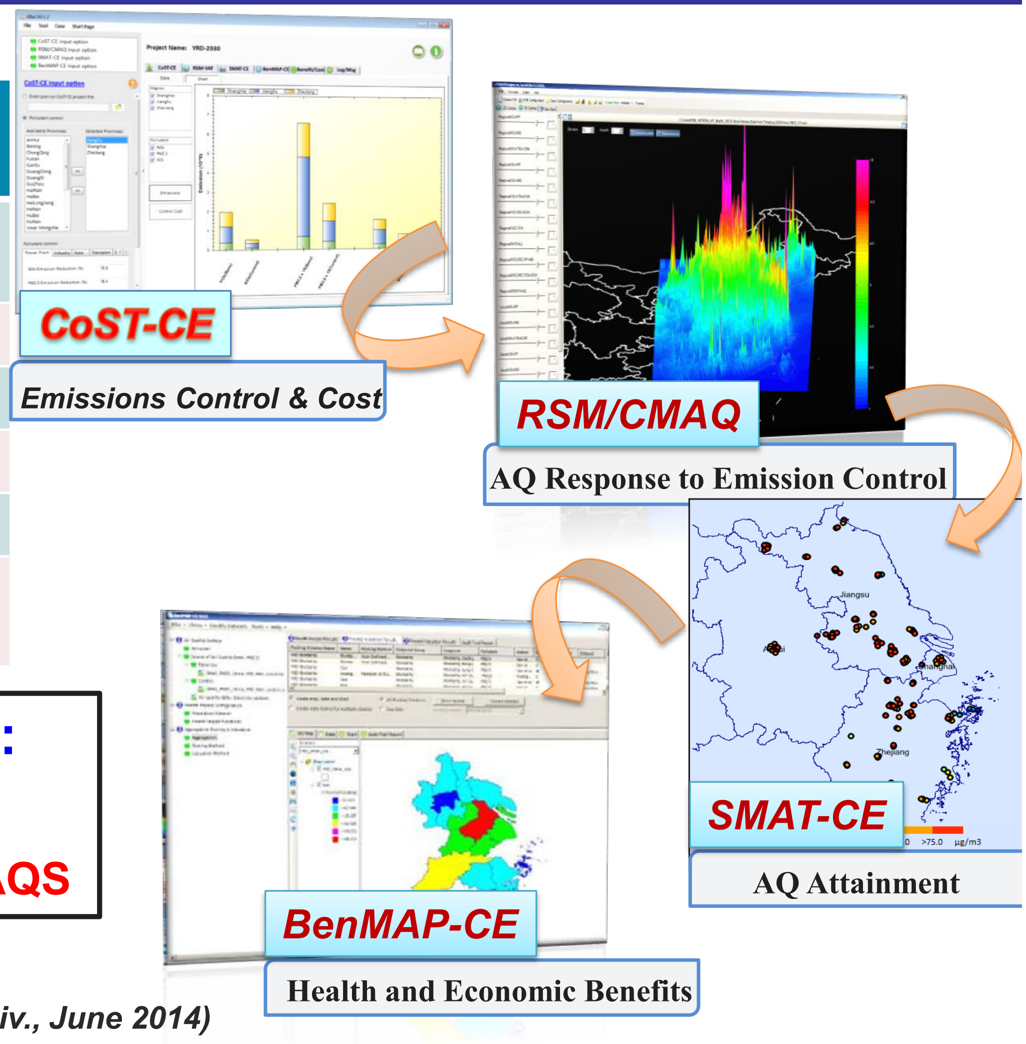
ABaCAS-SE：YRD Pilot Case Study

National AP Control Plan 大气污染防治行动计划	
区域	年均$PM_{2.5}$
京津冀 (JJJ)	25% ↓
长三角 (YRD)	20% ↓
珠三角 (PRD)	15% ↓
北京 (Beijing)	60 ug/m^3
其他主要城市 (333 个)	10% ↓ (PM_{10})

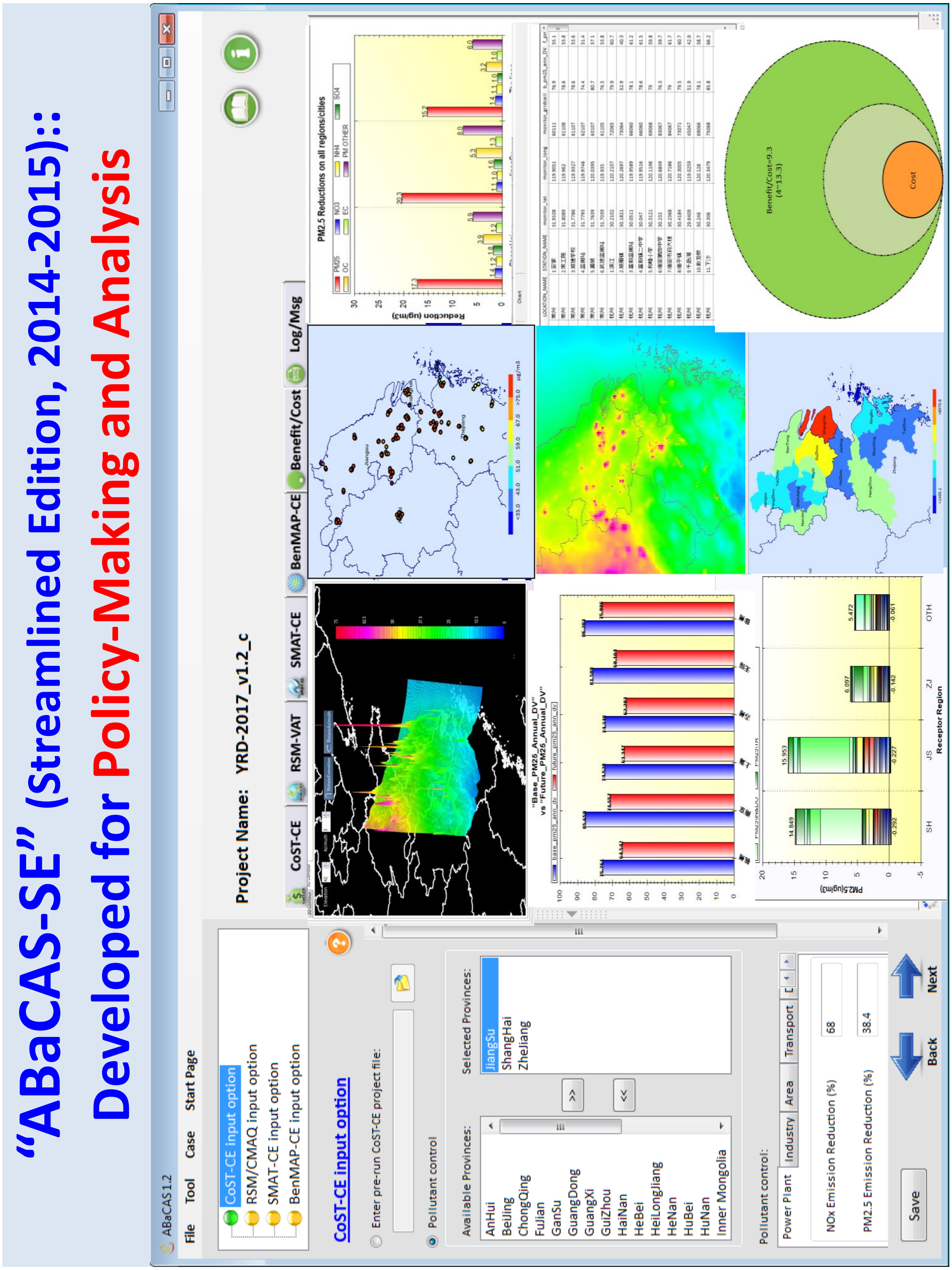
AQ Attainment in YRD:

2017: PM2.5 20% ↓

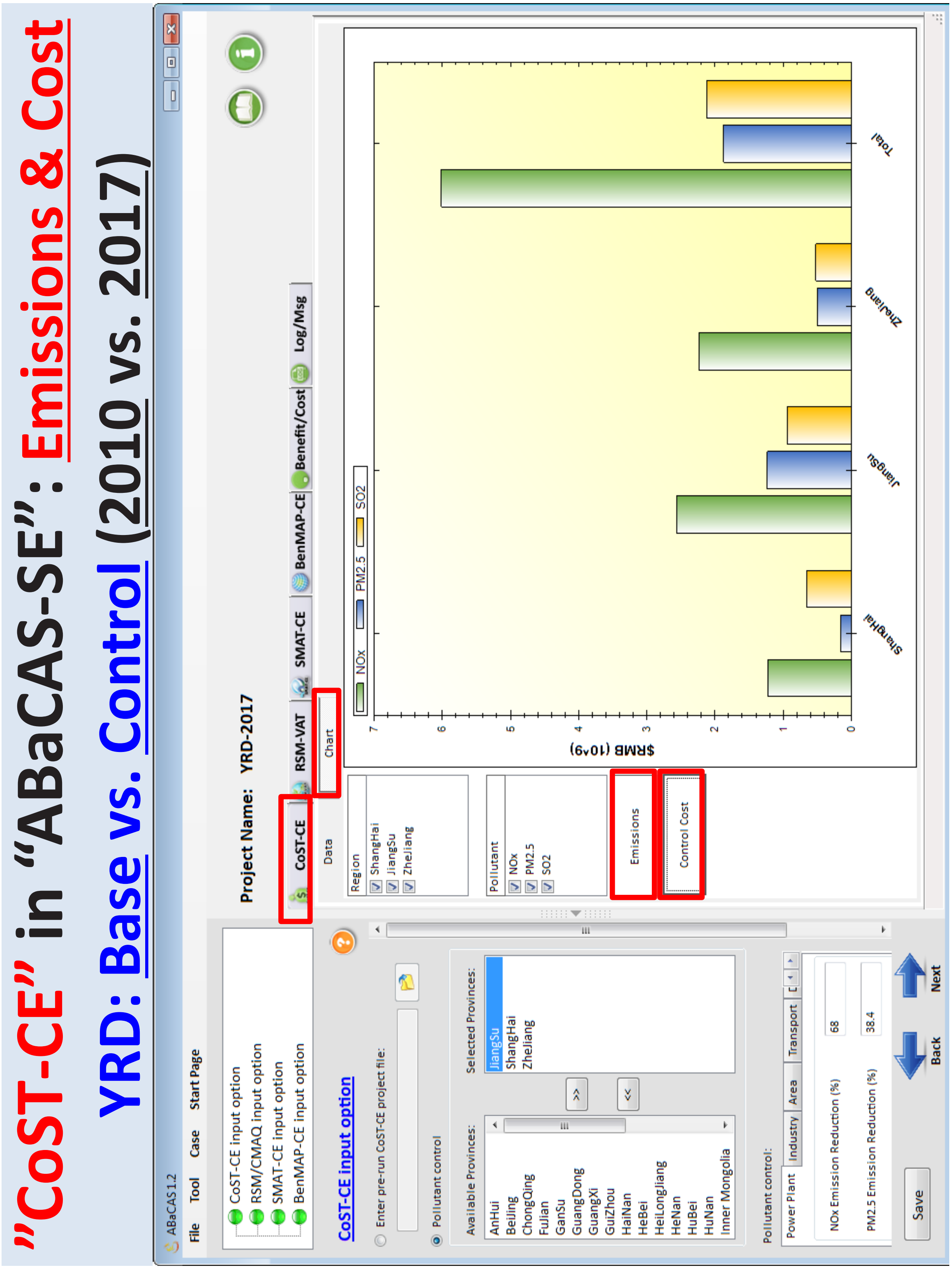
2030: Attain China NAAQS

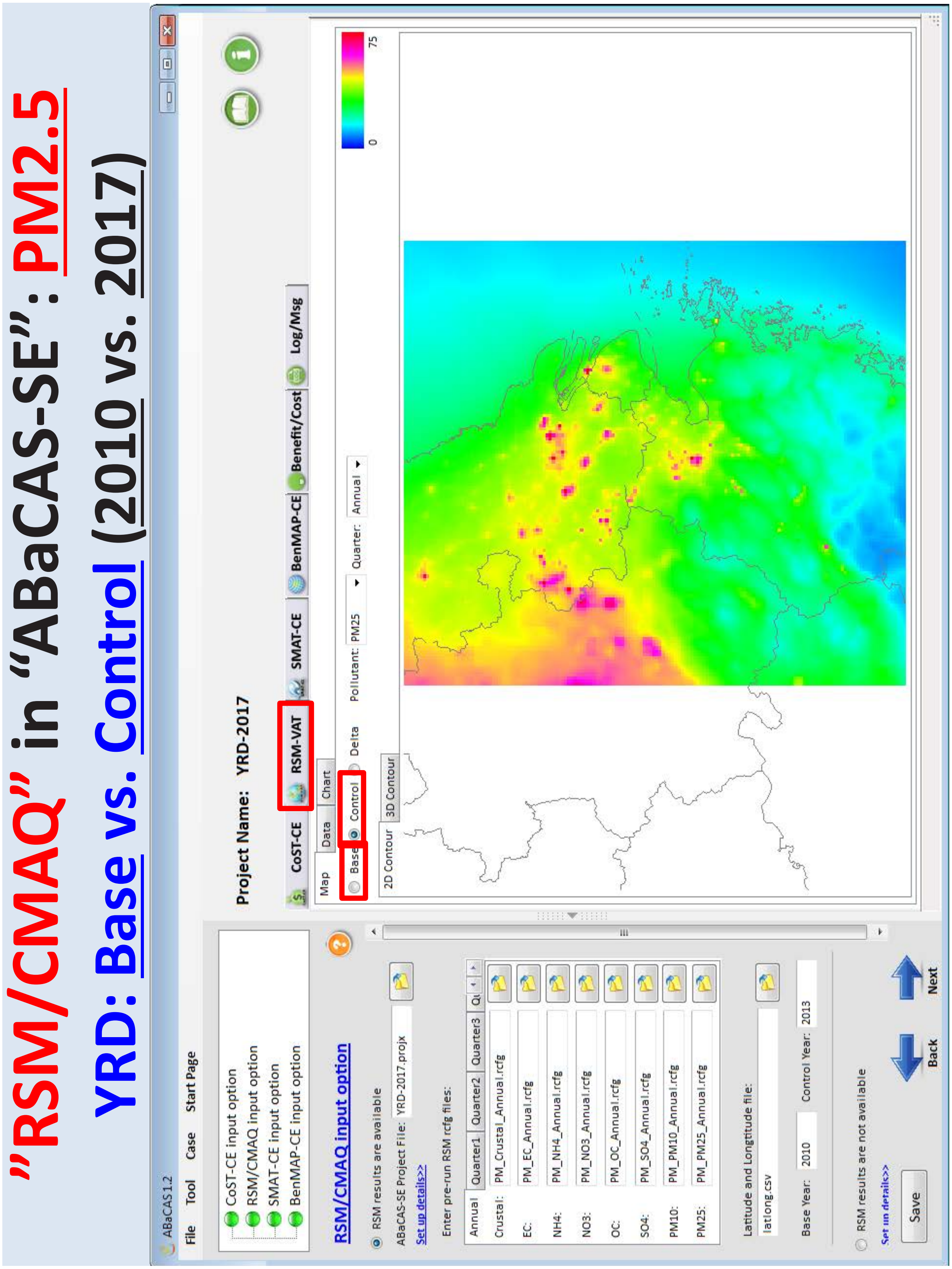


(PI: Prof. Shuxiao WANG, Tsinghua Univ., June 2014)

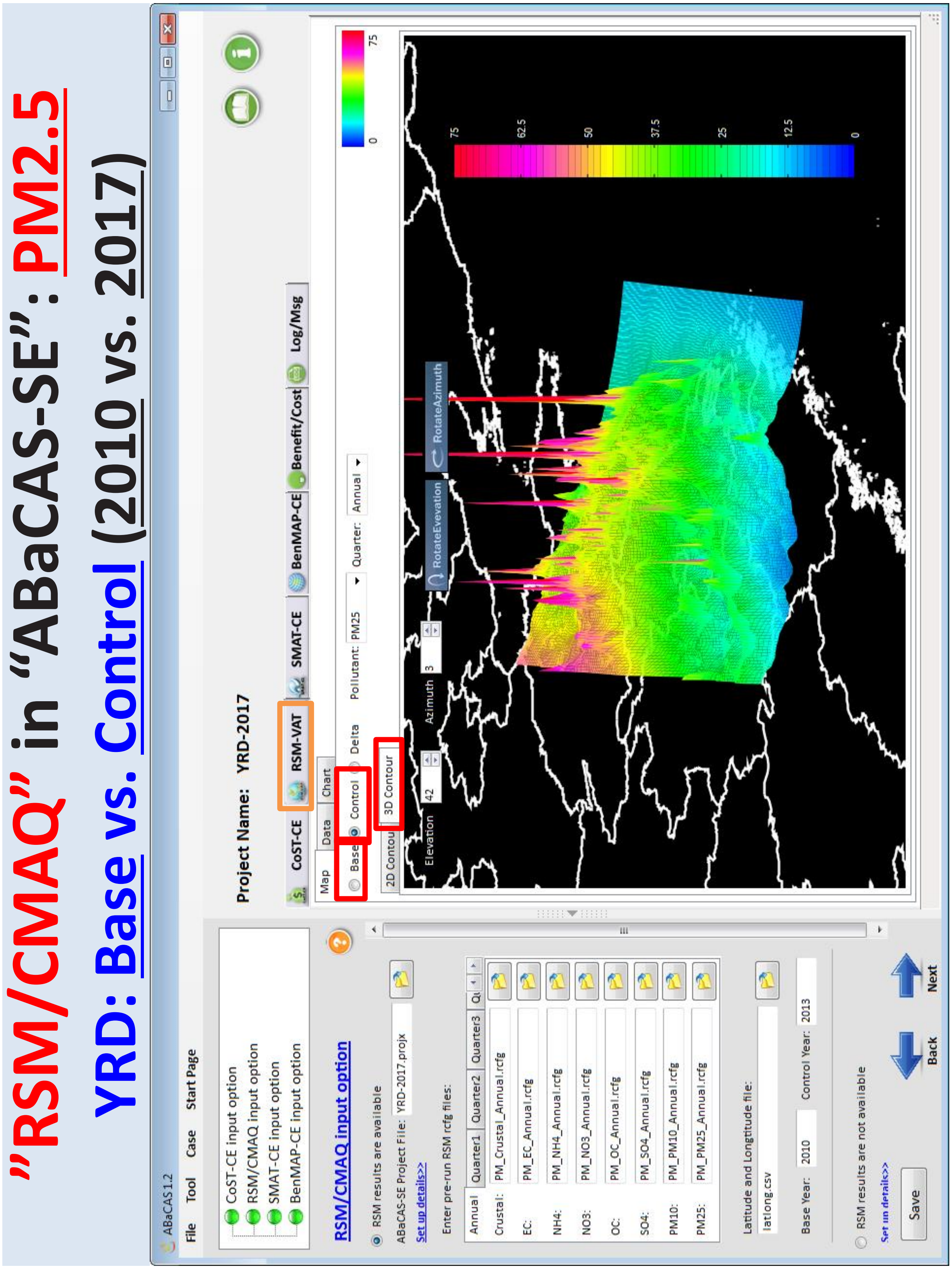

"ABaCAS-SE" (Streamlined Edition, 2014-2015)::
Developed for Policy-Making and Analysis
Project Name: YRD-2017_v1.2_c
CoST-CE
RSM-VAT
SMAT-CE
BenMAP-CE
Benefit/Cost
Log/Msg
CoST-CE input option
RSM/CMAQ input option
SMAT-CE input option
BenMAP-CE input option
Enter pre-run CoST-CE project file:
Pollutant control
Available Provinces:
Selected Provinces:
JiangSu
ShangHai
ZheJiang
Pollutant control:
Power Plant
Industry
Area
Transport
NOx Emission Reduction (%)
68
PM2.5 Emission Reduction (%)
38.4
Save
Back
Next
PM2.5 Reductions on all regions/cities
Benefit/Cost=9.3
Cost
Receptor Region

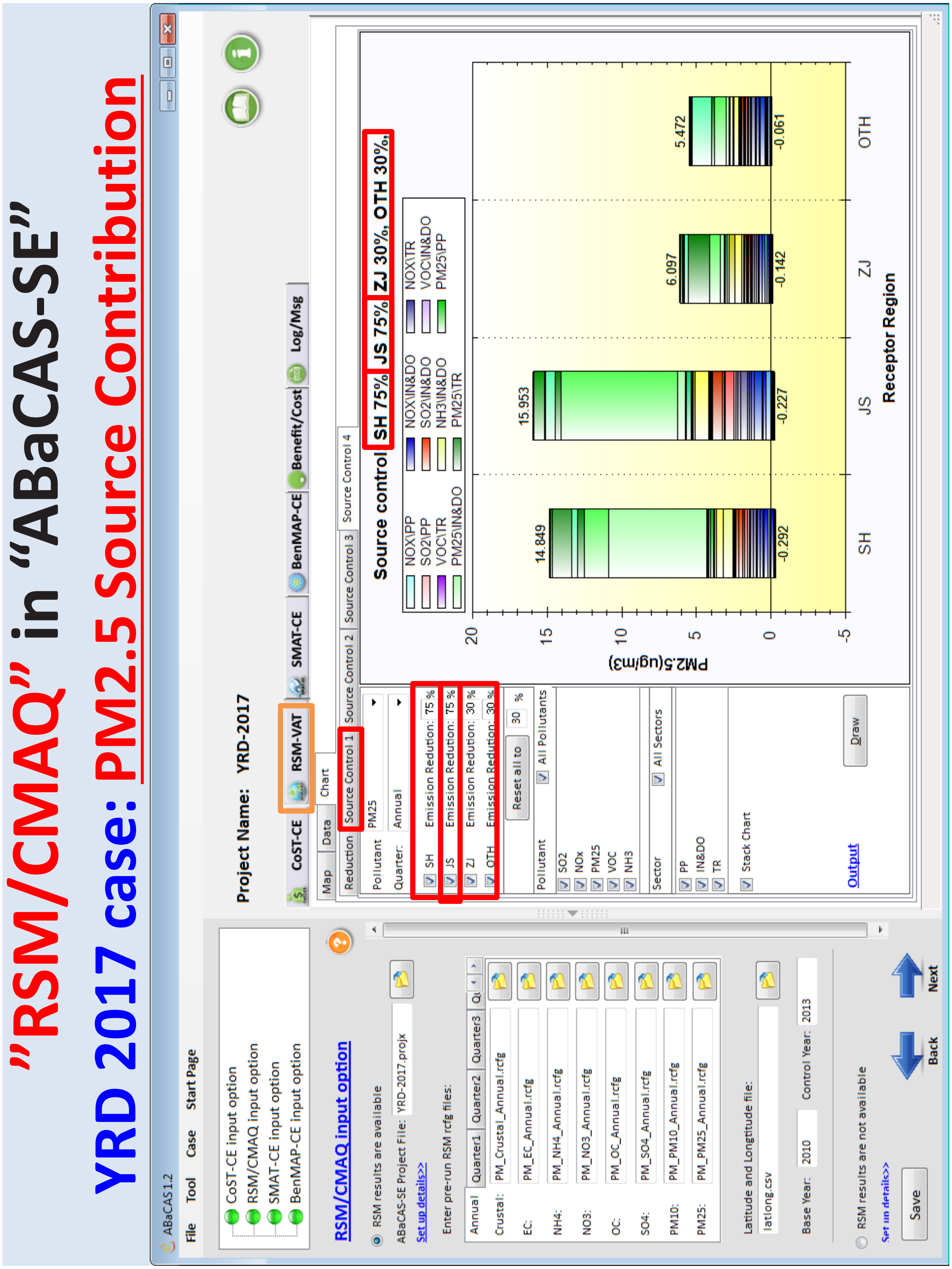

"CoST-CE" in "ABaCAS-SE"
YRD 2017 Case Study
ABaCAS1.2
File Tool Case Start Page
CoST-CE input option
RSM/CMAQ input option
SMAT-CE input option
BenMAP-CE input option
CoST-CE input option
Enter pre-run CoST-CE project file:
Pollutant control
Available Provinces:
AnHui
Beijing
ChongQing
FuJian
GanSu
GuangDong
GuangXi
GuiZhou
HaiNan
HeBei
HeiLongJiang
HeNan
HuBei
HuNan
Inner Mongolia
Selected Provinces:
JiangSu
ShangHai
ZheJiang
Pollutant control:
Power Plant
Industry
Area
Transport
NOx Emission Reduction (%)
68
PM2.5 Emission Reduction (%)
38.4
Save
Back
Next
Project Name: YRD-2017
CoST-CE
RSM-VAT
SMAT-CE
BenMAP-CE
Benefit/Cost
Log/Msg
Data
Chart
System Output
Province Level
Unit Level
Factor file
Total Removal Cost
Total PM2.5 Removal Cost (Million RMB)
1,873.9
Total NOx Removal Cost (Million RMB)
6,014.0
Total SO2 Removal Cost (Million RMB)
2,118.9
Total VOC Removal Cost (Million RMB)
0
Total NH3 Removal Cost (Million RMB)
0
PM25 Emission
Baseline PM2.5 Emission (Thousand Ton)
660.4
PM2.5 COST per TON (Yuan/Ton)
8,458.2
PM2.5 Emission Removed (Thousand Ton)
221.5
PM2.5 Emission Removed (%)
33.5
NOx Emission
Baseline NOx Emission (Thousand Ton)
1,977.6
NOx COST per TON (Yuan/Ton)
6,852.9
NOx Emission Removed (Thousand Ton)
877.6
NOx Emission Removed (%)
44.4
SO2 Emission
Baseline SO2 Emission (Thousand Ton)
1,550.2
SO2 COST per TON (Yuan/Ton)
4,226.6
SO2 Emission Removed (Thousand Ton)
501.3
SO2 Emission Removed (%)
32.3
VOC Emission
Baseline VOC Emission (Thousand Ton)
0
VOC COST per TON (Yuan/Ton)
0
VOC Emission Removed (Thousand Ton)
0
VOC Emission Removed (%)
0

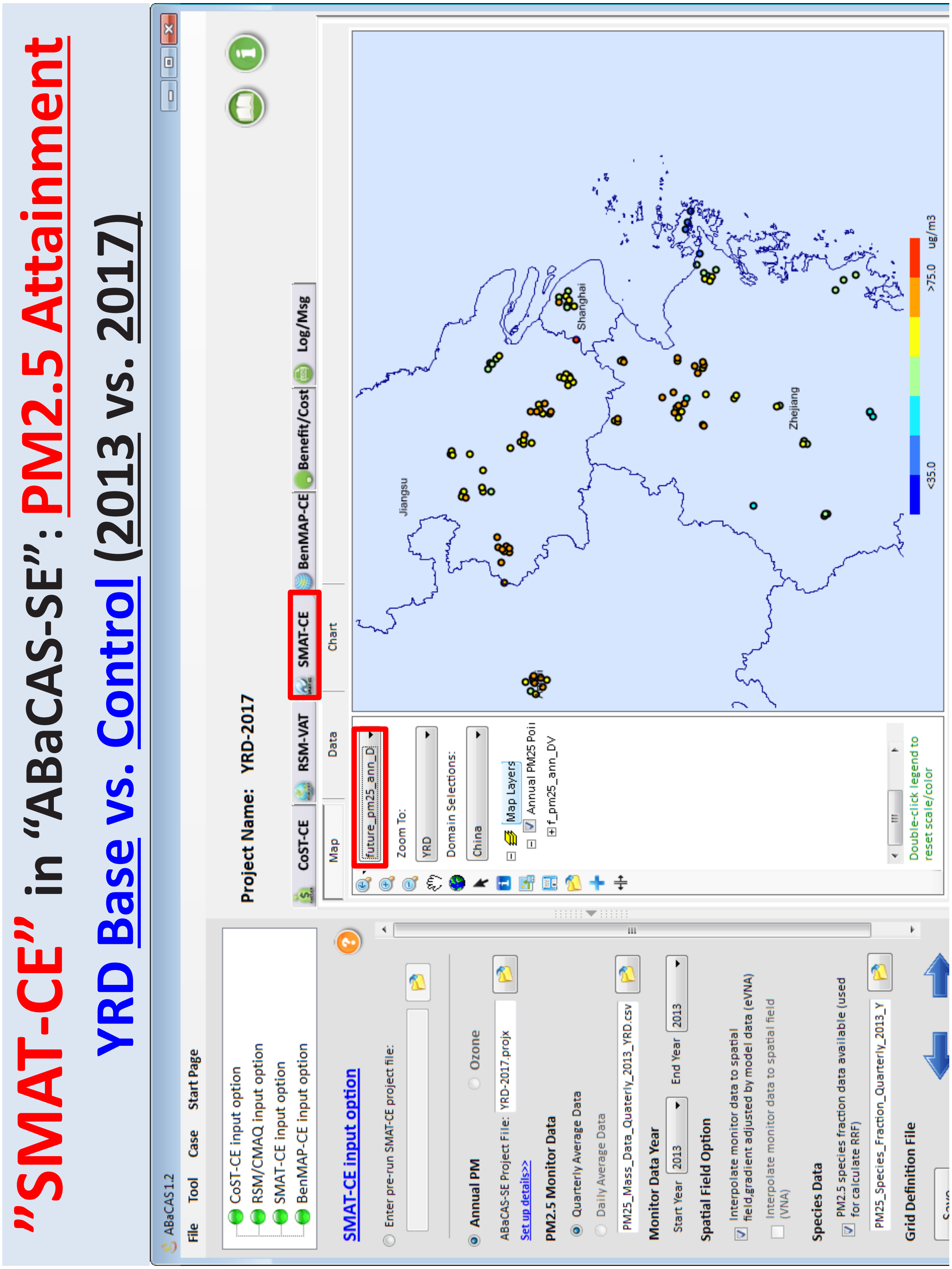

"CoST-CE" in "ABaCAS-SE": Emissions & Cost
YRD: Base vs. Control (2010 vs. 2017)
ABaCAS 1.2
File Tool Case Start Page
CoST-CE input option
RSM/CMAQ input option
SMAT-CE input option
BenMAP-CE input option
Project Name: YRD-2017
CoST-CE
RSM-VAT
SMAT-CE
BenMAP-CE
Benefit/Cost
Log/Msg
Data
Chart
CoST-CE input option
Enter pre-run CoST-CE project file:
Pollutant control
Available Provinces:
AnHui
Beijing
ChongQing
Fujian
GanSu
GuangDong
GuangXi
GuiZhou
HaiNan
HeBei
HeiLongJiang
HeNan
HuBei
HuNan
Inner Mongolia
Selected Provinces:
JiangSu
ShangHai
ZheJiang
Pollutant control:
Power Plant
Industry
Area
Transport
NOx Emission Reduction (%)
68
PM2.5 Emission Reduction (%)
38.4
Save
Back
Next
Region
ShangHai
JiangSu
ZheJiang
Pollutant
NOx
PM2.5
SO2
Emissions
Control Cost
NOx
PM2.5
SO2
$RMB (10^9)
0
1
2
3
4
5
6
7
ShangHai
JiangSu
ZheJiang
Total

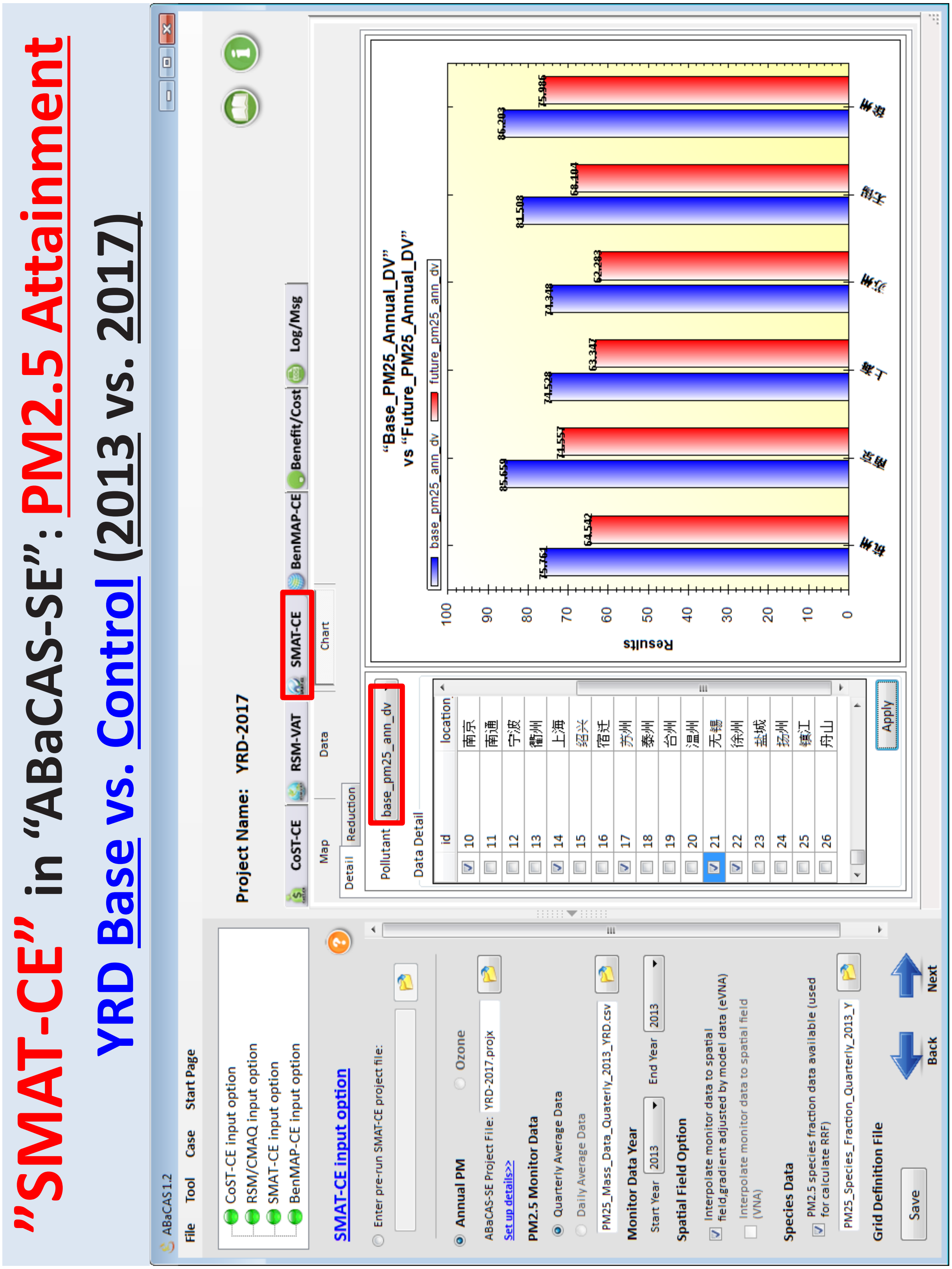


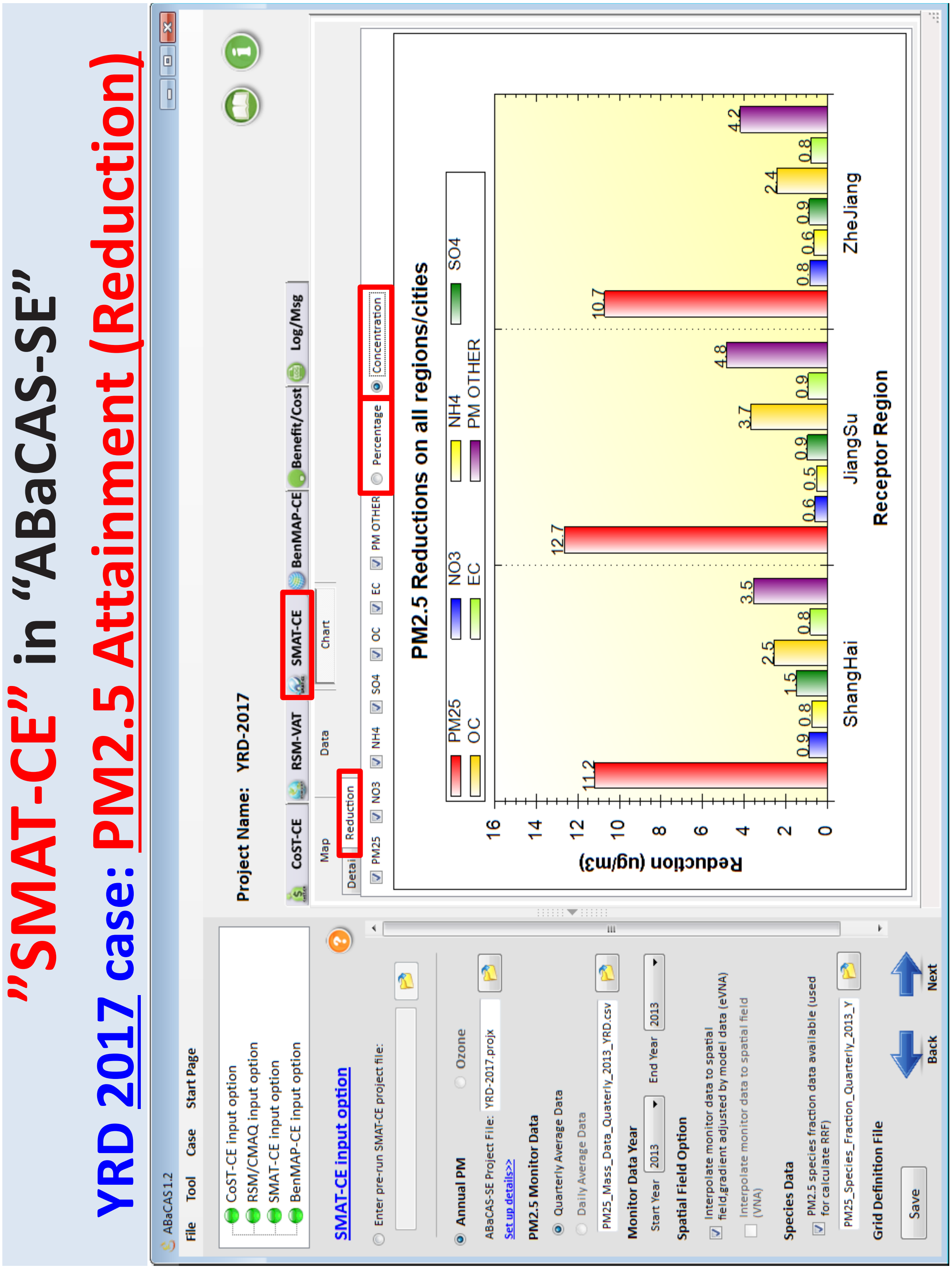
”RSM/CMAQ” in “ABaCAS-SE”: PM2.5
YRD: Base vs. Control (2010 vs. 2017)
ABaCAS1.2
File Tool Case Start Page
CoST-CE input option
RSM/CMAQ input option
SMAT-CE input option
BenMAP-CE input option
RSM/CMAQ input option
RSM results are available
ABaCAS-SE Project File: YRD-2017.projx
Set up details>>
Enter pre-run RSM rcfg files:
Annual Quarter1 Quarter2 Quarter3
Crustal: PM_Crustal_Annual.rcfg
EC: PM_EC_Annual.rcfg
NH4: PM_NH4_Annual.rcfg
NO3: PM_NO3_Annual.rcfg
OC: PM_OC_Annual.rcfg
SO4: PM_SO4_Annual.rcfg
PM10: PM_PM10_Annual.rcfg
PM25: PM_PM25_Annual.rcfg
Latitude and Longtitude file:
latlong.csv
Base Year: 2010 Control Year: 2013
RSM results are not available
Save
Back
Next
Project Name: YRD-2017
CoST-CE RSM-VAT SMAT-CE BenMAP-CE Benefit/Cost Log/Msg
Map Data Chart
Base Control Delta Pollutant: PM25 Quarter: Annual
2D Contour 3D Contour
0
75

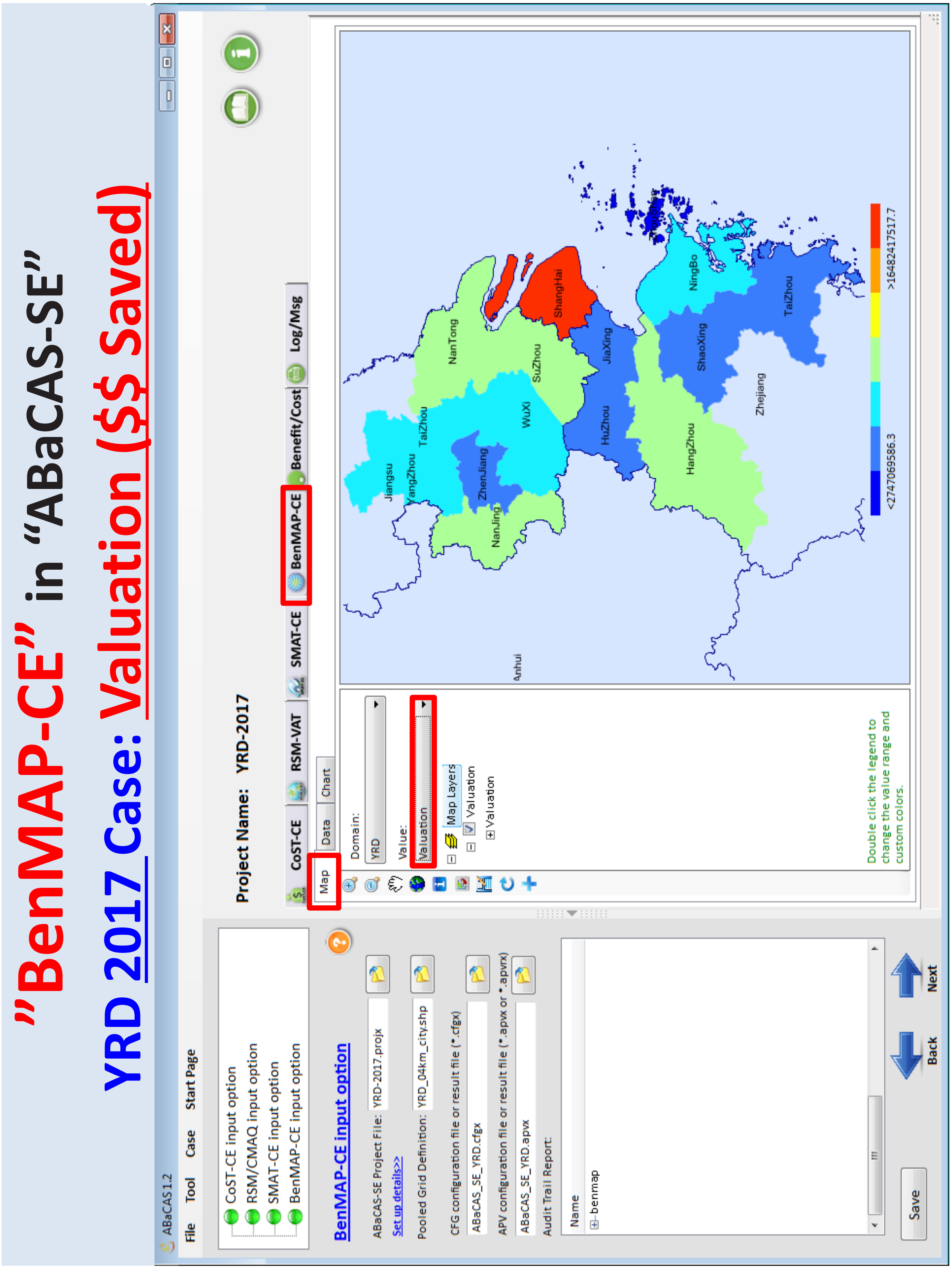

"RSM/CMAQ" in "ABaCAS-SE": PM2.5
YRD: Base vs. Control (2010 vs. 2017)
ABaCAS1.2
File
Tool
Case
Start Page
CoST-CE input option
RSM/CMAQ input option
SMAT-CE input option
BenMAP-CE input option
RSM/CMAQ input option
RSM results are available
ABaCAS-SE Project File: YRD-2017.projx
Set up details>>
Enter pre-run RSM rcfg files:
Annual
Quarter1
Quarter2
Quarter3
Crustal: PM_Crustal_Annual.rcfg
EC: PM_EC_Annual.rcfg
NH4: PM_NH4_Annual.rcfg
NO3: PM_NO3_Annual.rcfg
OC: PM_OC_Annual.rcfg
SO4: PM_SO4_Annual.rcfg
PM10: PM_PM10_Annual.rcfg
PM25: PM_PM25_Annual.rcfg
Latitude and Longtitude file:
latlong.csv
Base Year: 2010
Control Year: 2013
RSM results are not available
Set up details>>
Save
Back
Next
Project Name: YRD-2017
CoST-CE
RSM-VAT
SMAT-CE
BenMAP-CE
Benefit/Cost
Log/Msg
Map
Data
Chart
Base
Control
Delta
Pollutant: PM25
Quarter: Annual
2D Contour
3D Contour
Elevation 42
Azimuth 3
RotateEvevation
RotateAzimuth
0
75
12.5
25
37.5
50
62.5

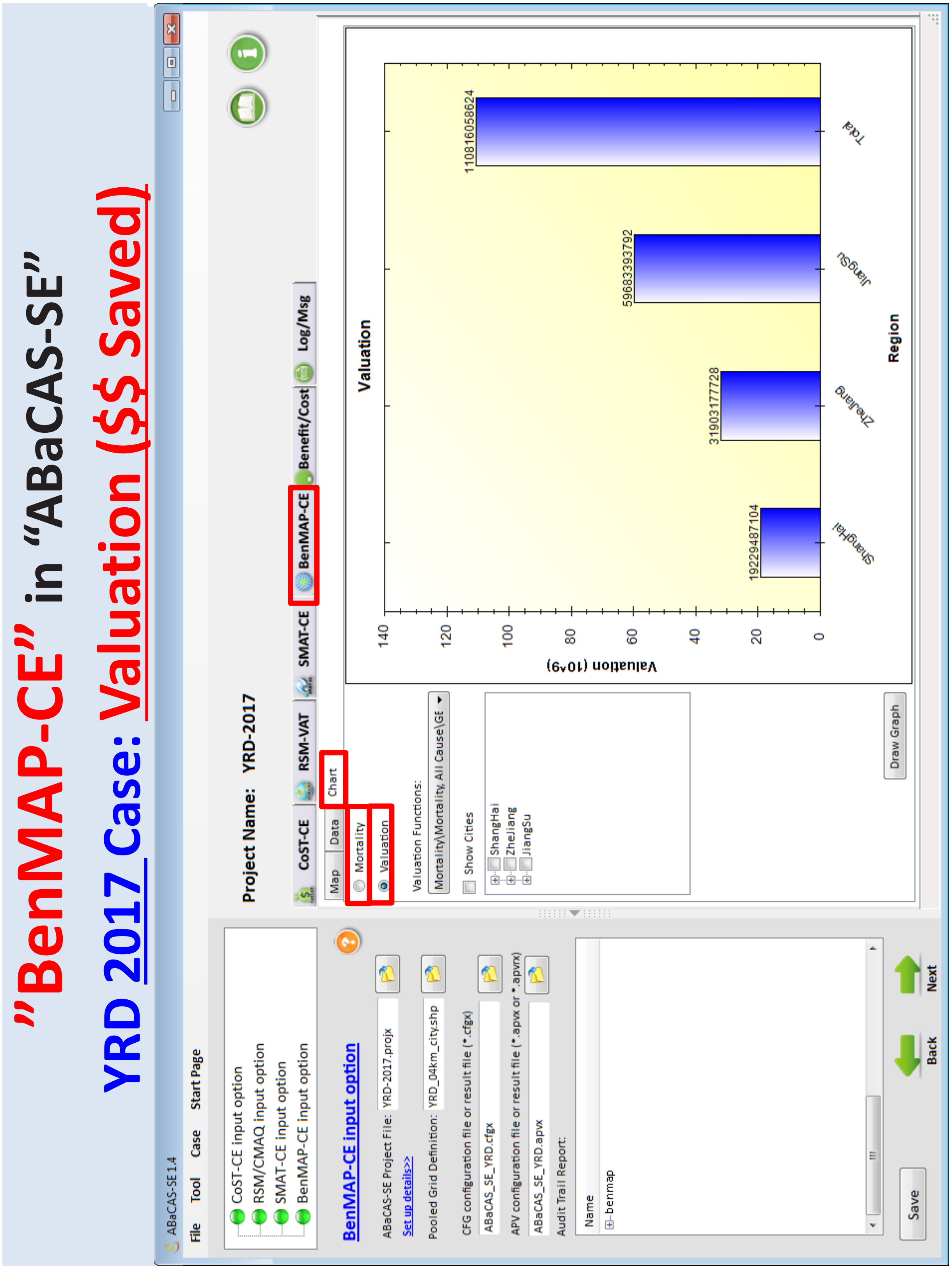

”RSM/CMAQ” in “ABaCAS-SE”
YRD 2017 case: PM2.5 Source Contribution
Project Name: YRD-2017
Source control SH 75%, JS 75%, ZJ 30%, OTH 30%,
Receptor Region
PM2.5(ug/m3)

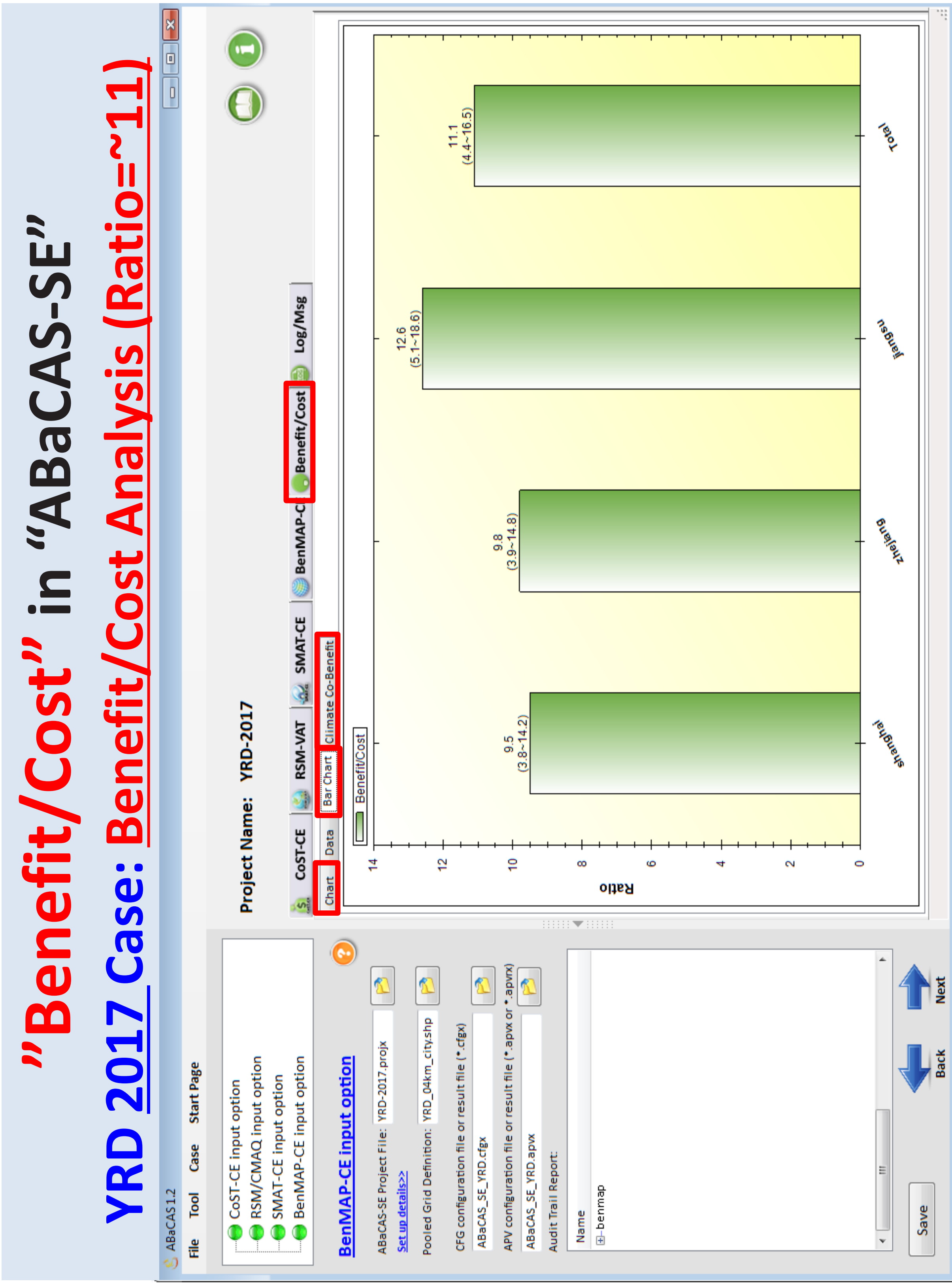

"SMAT-CE" in "ABaCAS-SE": PM2.5 Attainment
YRD Base vs. Control (2013 vs. 2017)
ABaCAS1.2
File Tool Case Start Page
CoST-CE input option
RSM/CMAQ input option
SMAT-CE input option
BenMAP-CE input option
Project Name: YRD-2017
CoST-CE
RSM-VAT
SMAT-CE
BenMAP-CE
Benefit/Cost
Log/Msg
Map
Data
Chart
SMAT-CE input option
Enter pre-run SMAT-CE project file:
Annual PM
Ozone
ABaCAS-SE Project File: YRD-2017.projx
Set up details>>
PM2.5 Monitor Data
Quarterly Average Data
Daily Average Data
PM25_Mass_Data_Quaterly_2013_YRD.csv
Monitor Data Year
Start Year 2013
End Year 2013
Spatial Field Option
Interpolate monitor data to spatial field,gradient adjusted by model data (eVNA)
Interpolate monitor data to spatial field (VNA)
Species Data
PM2.5 species fraction data available (used for calculate RRF)
PM25_Species_Fraction_Quarterly_2013_Y
Grid Definition File
Zoom To:
YRD
Domain Selections:
China
Map Layers
Annual PM25 Poi
f_pm25_ann_DV
Double-click legend to reset scale/color
Jiangsu
Shanghai
Zhejiang
<35.0
>75.0
ug/m3

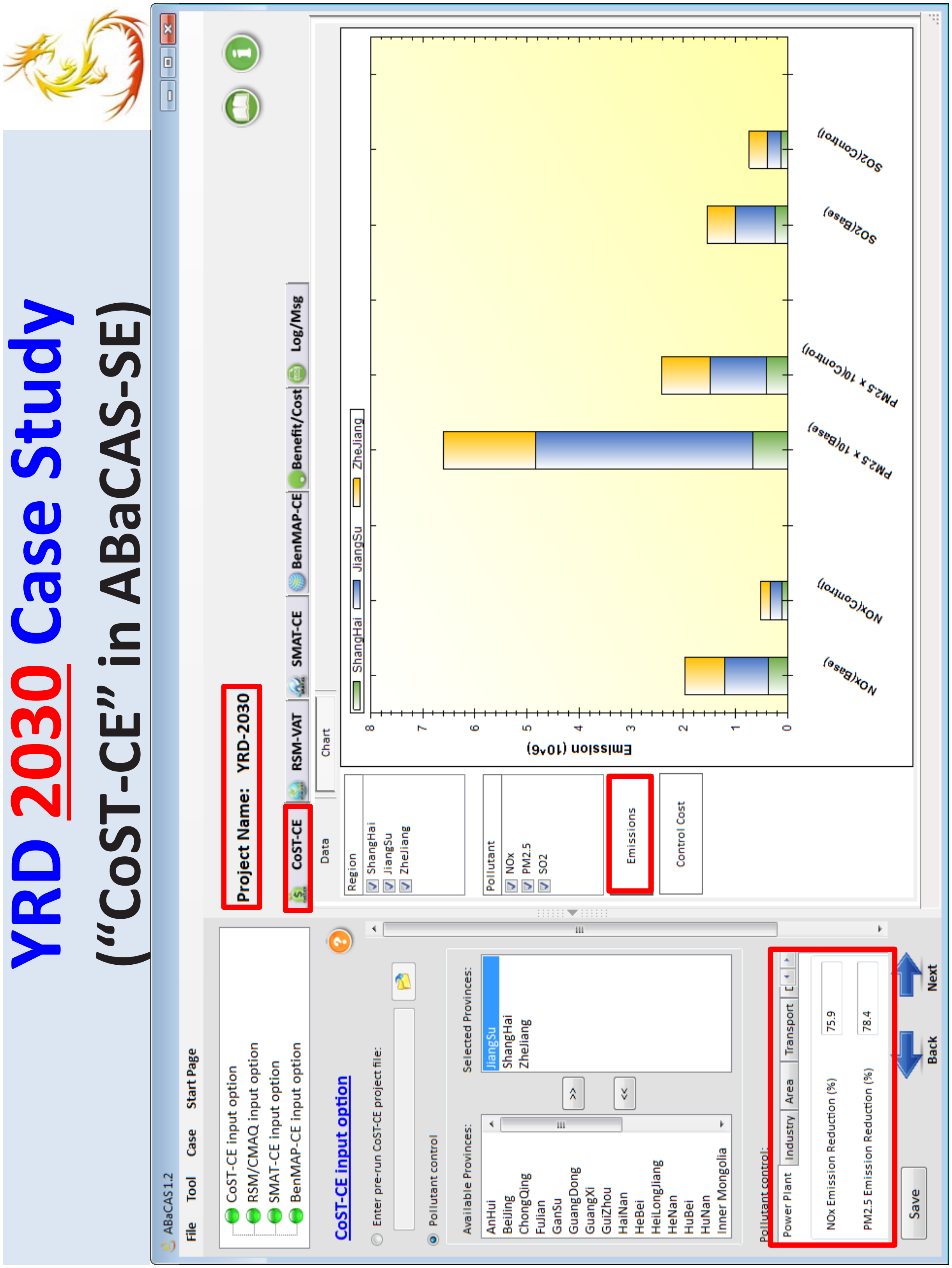

"SMAT-CE" in "ABaCAS-SE": PM2.5 Attainment
YRD Base vs. Control (2013 vs. 2017)
ABaCAS1.2
File Tool Case Start Page
CoST-CE input option
RSM/CMAQ input option
SMAT-CE input option
BenMAP-CE input option
SMAT-CE input option
Enter pre-run SMAT-CE project file:
Annual PM
Ozone
ABaCAS-SE Project File: YRD-2017.projx
Set up details>>
PM2.5 Monitor Data
Quarterly Average Data
Daily Average Data
PM25_Mass_Data_Quaterly_2013_YRD.csv
Monitor Data Year
Start Year 2013
End Year 2013
Spatial Field Option
Interpolate monitor data to spatial field,gradient adjusted by model data (eVNA)
Interpolate monitor data to spatial field (VNA)
Species Data
PM2.5 species fraction data available (used for calculate RRF)
PM25_Species_Fraction_Quarterly_2013_Y
Grid Definition File
Save
Back
Next
Project Name: YRD-2017
CoST-CE
RSM-VAT
SMAT-CE
BenMAP-CE
Benefit/Cost
Log/Msg
Map
Data
Chart
Detail
Reduction
Pollutant base_pm25_ann_dv
Data Detail
id
location
Apply
"Base_PM25_Annual_DV"
vs "Future_PM25_Annual_DV"
base_pm25_ann_dv
future_pm25_ann_dv
Results
75.764
64.542
85.659
74.557
74.528
63.347
74.348
62.283
81.508
68.404
86.203
75.986

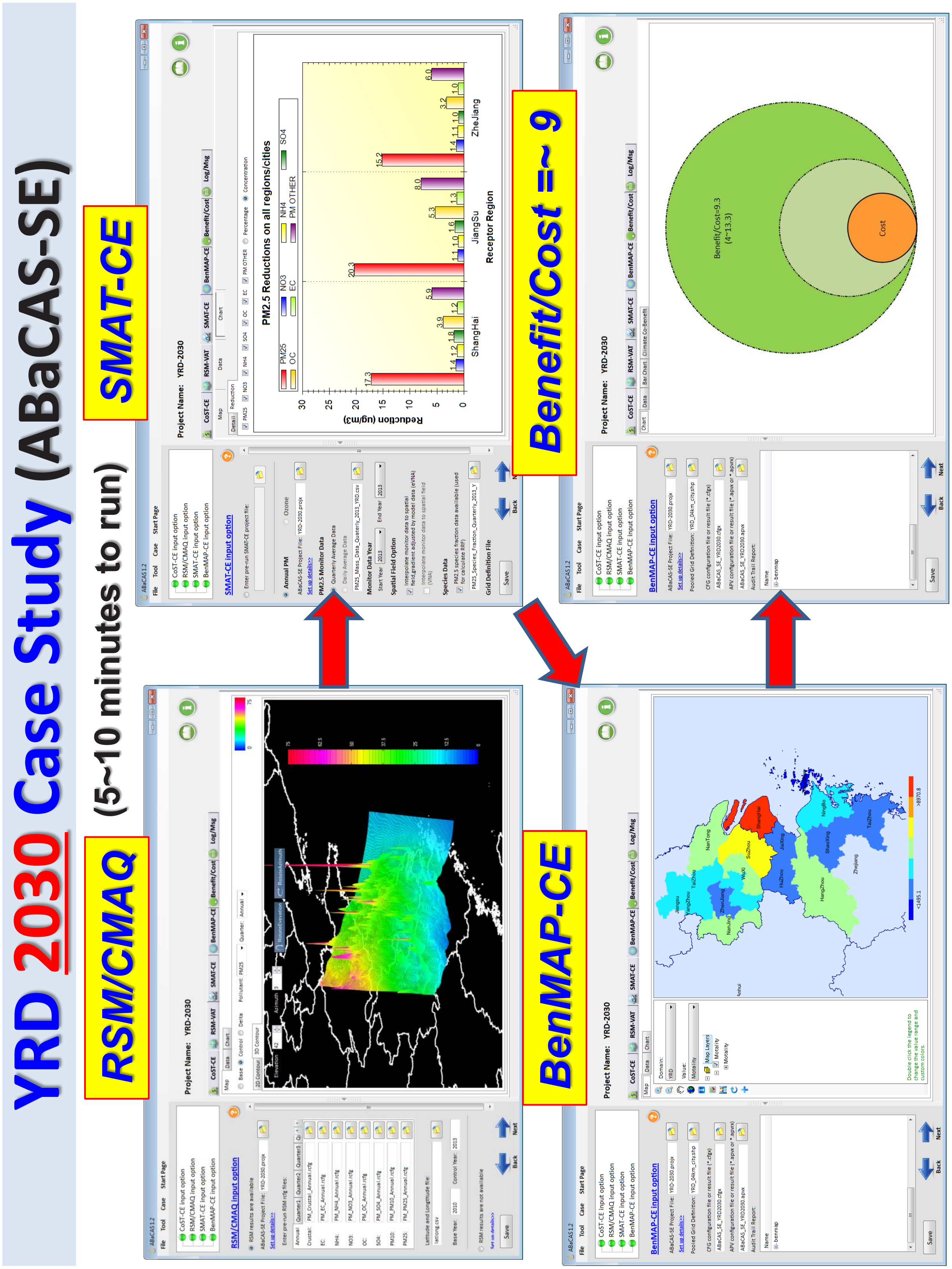

"SMAT-CE" in "ABaCAS-SE"
YRD 2017 case: PM2.5 Attainment (Reduction)
ABaCAS1.2
File Tool Case Start Page
CoST-CE input option
RSM/CMAQ input option
SMAT-CE input option
BenMAP-CE input option
SMAT-CE input option
Enter pre-run SMAT-CE project file:
Annual PM
Ozone
ABaCAS-SE Project File: YRD-2017.projx
Set up details>>
PM2.5 Monitor Data
Quarterly Average Data
Daily Average Data
PM25_Mass_Data_Quaterly_2013_YRD.csv
Monitor Data Year
Start Year 2013
End Year 2013
Spatial Field Option
Species Data
Grid Definition File
Save
Back
Next
Project Name: YRD-2017
CoST-CE
RSM-VAT
SMAT-CE
BenMAP-CE
Benefit/Cost
Log/Msg
Map
Data
Chart
Reduction
PM25 NO3 NH4 SO4 OC EC PM OTHER
Percentage
Concentration
PM2.5 Reductions on all regions/cities
Reduction (ug/m3)
Receptor Region
ShangHai
JiangSu
ZheJiang

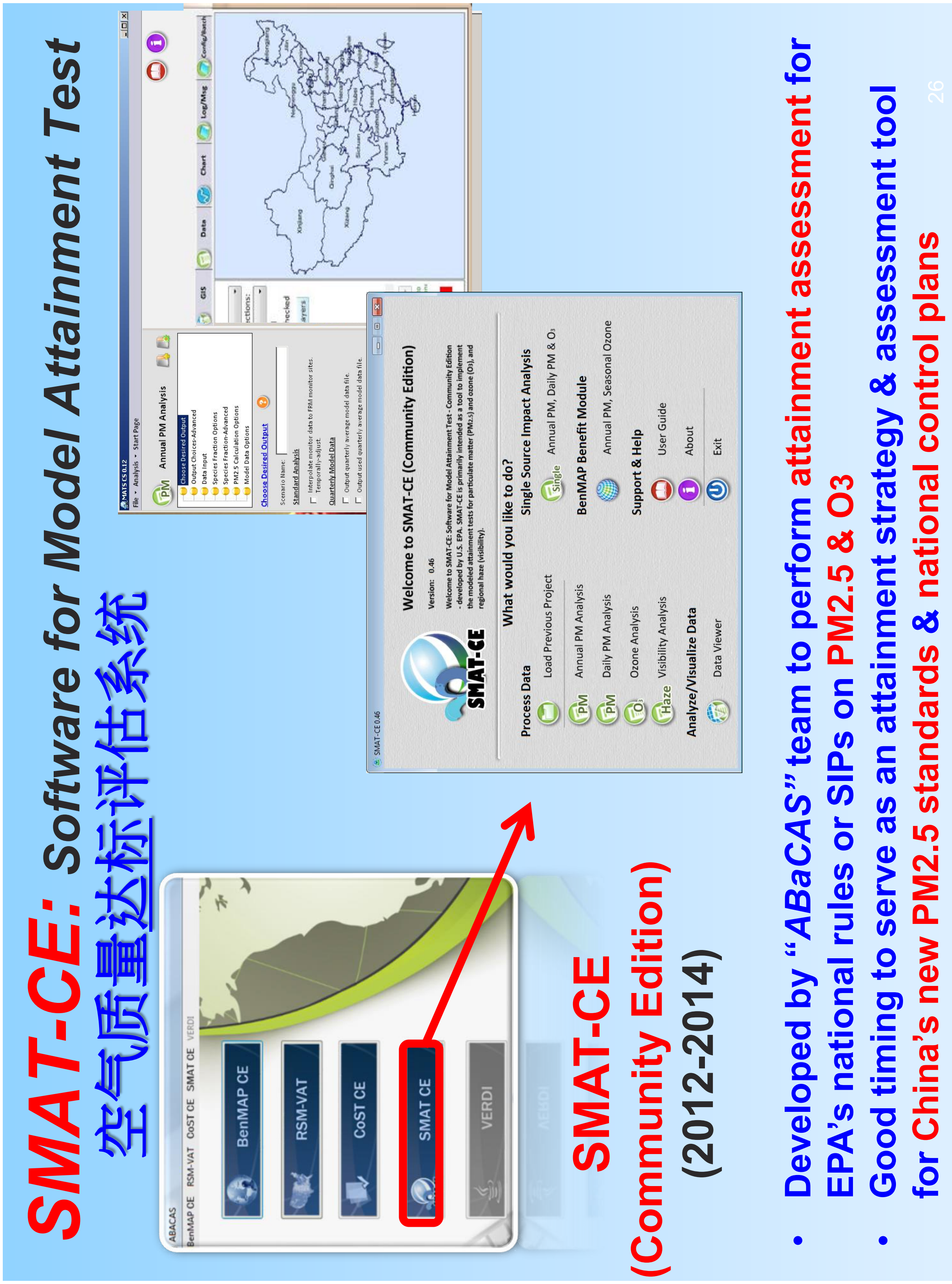

”BenMAP-CE” in “ABaCAS-SE”
YRD 2017 Case: Valuation ($$ Saved)
ABaCAS1.2
File Tool Case Start Page
CoST-CE input option
RSM/CMAQ input option
SMAT-CE input option
BenMAP-CE input option
BenMAP-CE input option
ABaCAS-SE Project File: YRD-2017.projx
Set up details>>
Pooled Grid Definition: YRD_04km_city.shp
CFG configuration file or result file (*.cfgx)
ABaCAS_SE_YRD.cfgx
APV configuration file or result file (*.apvx or *.apvrx)
ABaCAS_SE_YRD.apvx
Audit Trail Report:
Name
benmap
Save
Back
Next
Project Name: YRD-2017
CoST-CE
RSM-VAT
SMAT-CE
BenMAP-CE
Benefit/Cost
Log/Msg
Map
Data
Chart
Domain:
YRD
Value:
Valuation
Map Layers
Valuation
Valuation
Double click the legend to change the value range and custom colors.
Jiangsu
YangZhou
TaiZhou
NanTong
ZhenJiang
NanJing
WuXi
SuZhou
ShangHai
JiaXing
HuZhou
HangZhou
ShaoXing
NingBo
TaiZhou
Zhejiang
Anhui
<2747069586.3
>16482417517.7


"BenMAP-CE" in "ABaCAS-SE"
YRD 2017 Case: Valuation ($$ Saved)
ABaCAS-SE 1.4
File Tool Case Start Page
CoST-CE input option
RSM/CMAQ input option
SMAT-CE input option
BenMAP-CE input option
BenMAP-CE input option
ABaCAS-SE Project File: YRD-2017.projx
Set up details>>
Pooled Grid Definition: YRD_04km_city.shp
CFG configuration file or result file (*.cfgx)
ABaCAS_SE_YRD.cfgx
APV configuration file or result file (*.apvx or *.apvrx)
ABaCAS_SE_YRD.apvx
Audit Trail Report:
Name
benmap
Save
Back
Next
Project Name: YRD-2017
CoST-CE
RSM-VAT
SMAT-CE
BenMAP-CE
Benefit/Cost
Log/Msg
Map
Data
Chart
Mortality
Valuation
Valuation Functions:
Mortality\Mortality, All Cause\GE
Show Cities
ShangHai
ZheJiang
JiangSu
Draw Graph
Valuation
Valuation (10^9)
140
120
100
80
60
40
20
0
19229487104
31903177728
59683393792
110816058624
ShangHai
ZheJiang
JiangSu
Total
Region


”Benefit/Cost” in “ABaCAS-SE”
YRD 2017 Case: Benefit/Cost Analysis (Ratio=~11)
ABaCAS 1.2
File
Tool
Case
Start Page
CoST-CE input option
RSM/CMAQ input option
SMAT-CE input option
BenMAP-CE input option
BenMAP-CE input option
ABaCAS-SE Project File:
YRD-2017.projx
Set up details>>
Pooled Grid Definition:
YRD_04km_city.shp
CFG configuration file or result file (*.cfgx)
ABaCAS_SE_YRD.cfgx
APV configuration file or result file (*.apvx or *.apvrx)
ABaCAS_SE_YRD.apvx
Audit Trail Report:
Name
benmap
Save
Back
Next
Project Name: YRD-2017
CoST-CE
RSM-VAT
SMAT-CE
BenMAP-CE
Benefit/Cost
Log/Msg
Chart
Data
Bar Chart
Climate Co-Benefit
Benefit/Cost
Ratio
9.5
(3.8~14.2)
9.8
(3.9~14.8)
12.6
(5.1~18.6)
11.1
(4.4~16.5)
Shanghai
Zhejiang
Jiangsu
Total

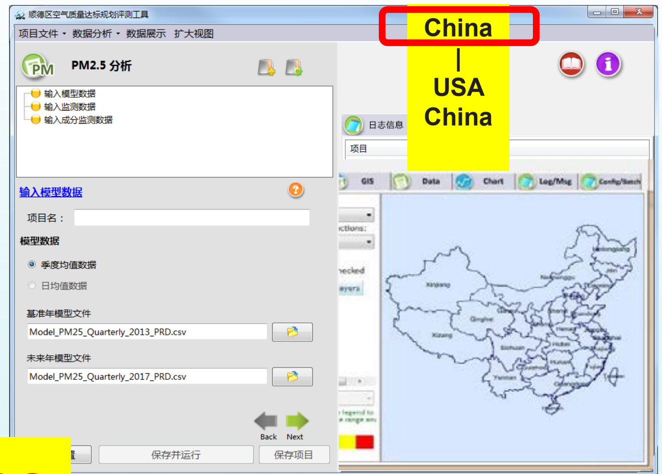

YRD 2030 Case Study
("CoST-CE" in ABaCAS-SE)
Project Name: YRD-2030


YRD 2030 Case Study (ABaCAS-SE)
(5~10 minutes to run)
RSM/CMAQ
SMAT-CE
BenMAP-CE
Benefit/Cost =~ 9
PM2.5 Reductions on all regions/cities

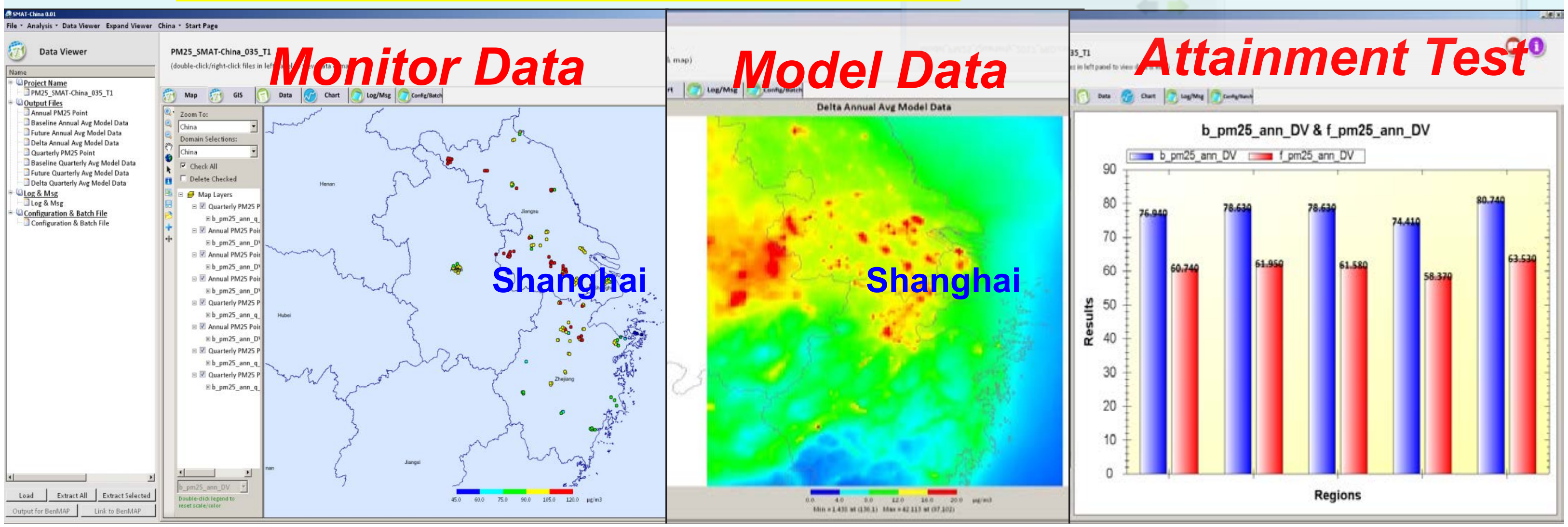

SMAT-CE: Software for Model Attainment Test
空气质量达标评估系统
SMAT-CE
(Community Edition)
(2012-2014)
Developed by "ABaCAS" team to perform attainment assessment for EPA's national rules or SIPs on PM2.5 & O3
Good timing to serve as an attainment strategy & assessment tool for China's new PM2.5 standards & national control plans
BenMAP CE
RSM-VAT
CoST CE
SMAT CE
VERDI
Welcome to SMAT-CE (Community Edition)
What would you like to do?
Process Data
Load Previous Project
Annual PM Analysis
Daily PM Analysis
Ozone Analysis
Visibility Analysis
Analyze/Visualize Data
Data Viewer
Single Source Impact Analysis
Annual PM, Daily PM & O3
BenMAP Benefit Module
Annual PM, Seasonal Ozone
Support & Help
User Guide
About
Exit
26

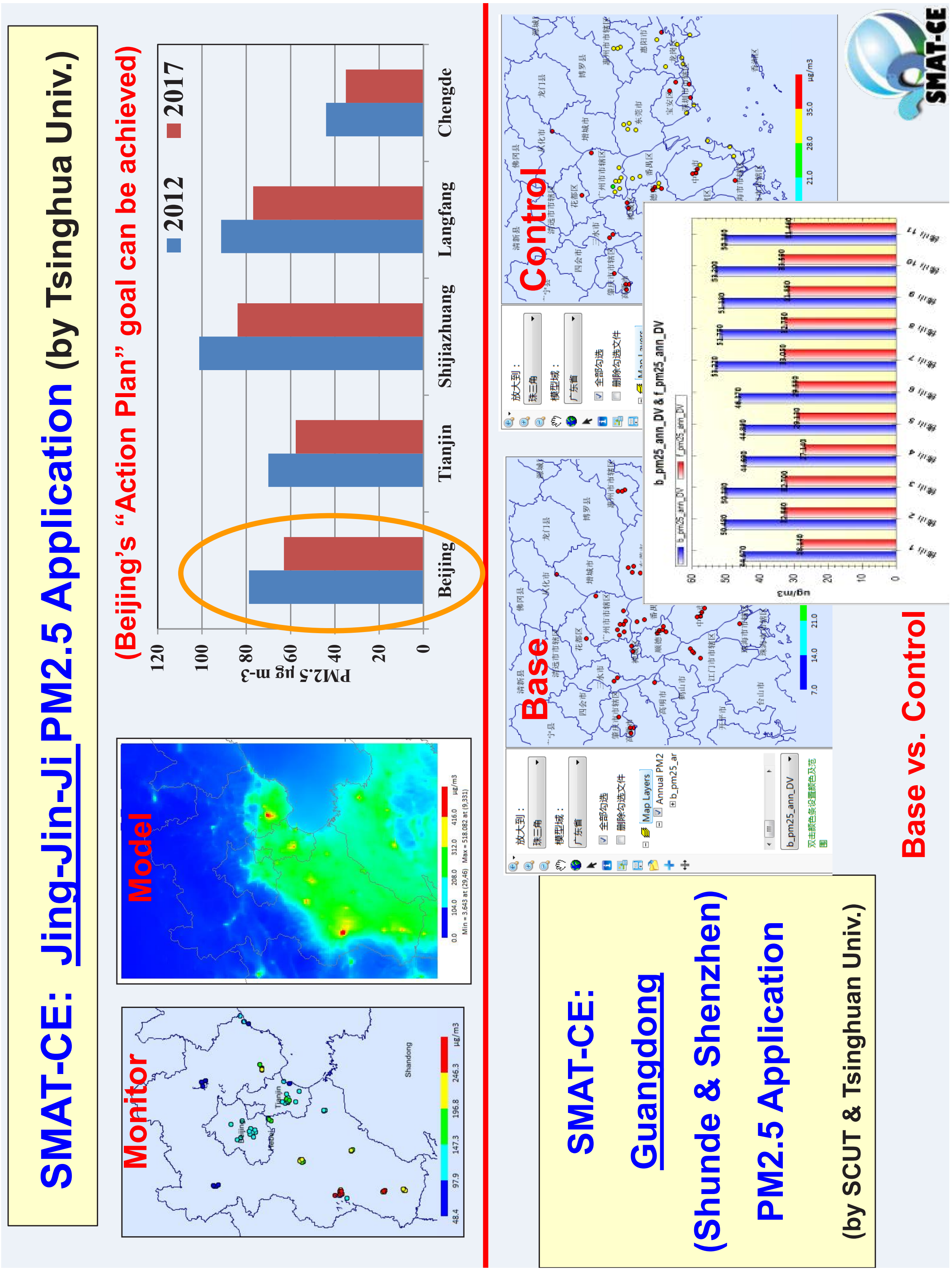
"SMAT-China" Prototype Development

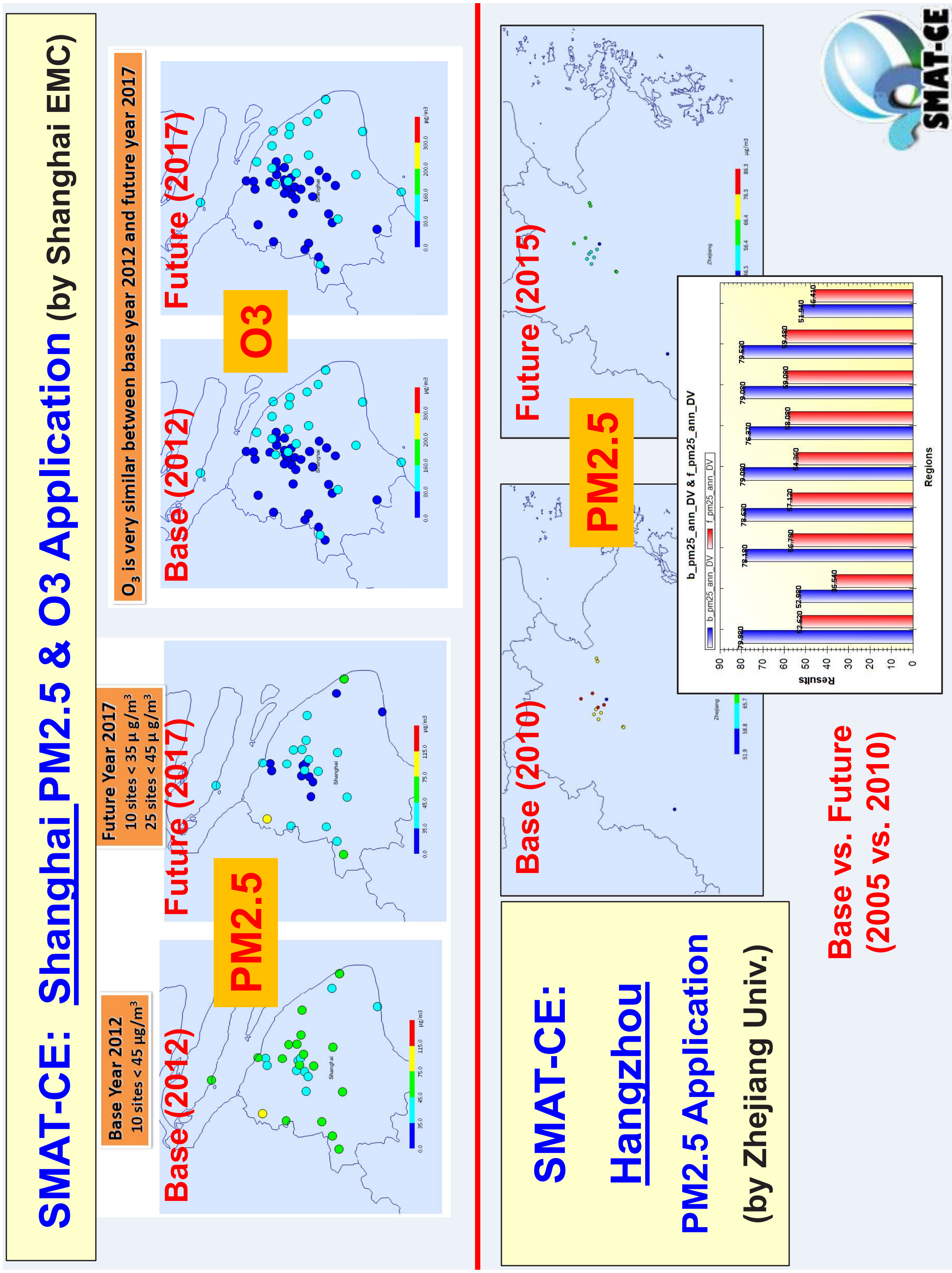
- *"SMAT-China"*: a customized version for China based on *"SMAT-CE"*
- Modified functions/GUI & data inputs to accommodate different monitor data structure & technologies in China (e.g., optional PM2.5 species)

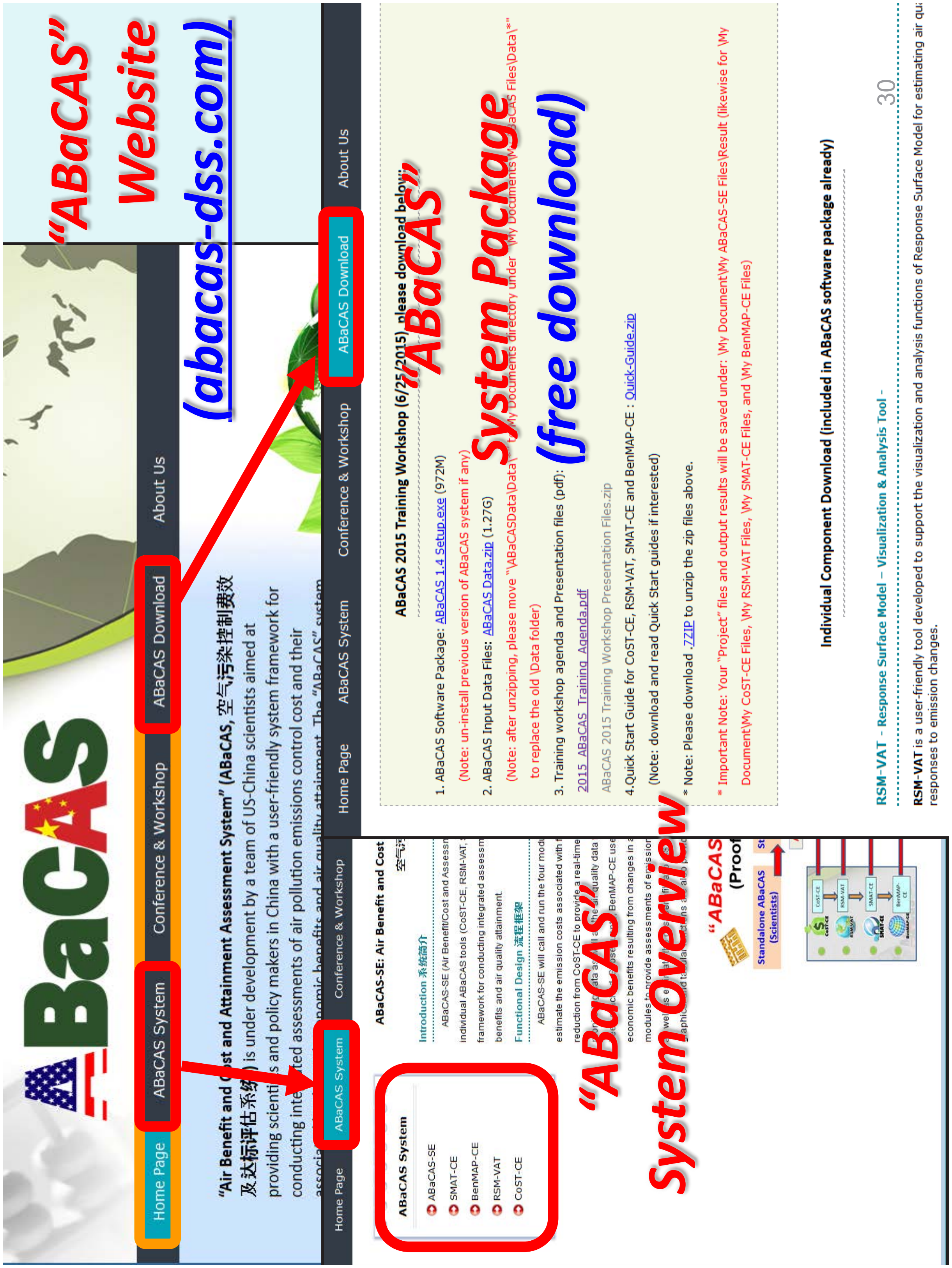


YRD/Shanghai Pilot Case




SMAT-CE: Jing-Jin-Ji PM2.5 Application (by Tsinghua Univ.)
(Beijing's "Action Plan" goal can be achieved)
Monitor
Model
2012
2017
PM2.5 μg m-3
Beijing
Tianjin
Shijiazhuang
Langfang
Chengde
SMAT-CE:
Guangdong
(Shunde & Shenzhen)
PM2.5 Application
(by SCUT & Tsinghuan Univ.)
Base
Control
Base vs. Control
SMAT-CE


SMAT-CE: Shanghai PM2.5 & O3 Application (by Shanghai EMC)
Base Year 2012
10 sites < 45 μg/m3
Future Year 2017
10 sites < 35 μg/m3
25 sites < 45 μg/m3
Base (2012)
Future (2017)
PM2.5
O3 is very similar between base year 2012 and future year 2017
Base (2012)
Future (2017)
O3
SMAT-CE:
Hangzhou
PM2.5 Application
(by Zhejiang Univ.)
Base (2010)
Future (2015)
PM2.5
b_pm25_ann_DV & f_pm25_ann_DV
Results
Regions
Base vs. Future
(2005 vs. 2010)
SMAT-CE


"ABaCAS" Website
(abacas-dss.com)
"ABaCAS" System Package
(free download)
"ABaCAS" System Overview
Home Page
ABaCAS System
Conference & Workshop
ABaCAS Download
About Us
ABaCAS 2015 Training Workshop (6/25/2015), please download below:
Individual Component Download (included in ABaCAS software package already)
RSM-VAT - Response Surface Model – Visualization & Analysis Tool -

"ABaCAS-China" Project Team

China:

- *Tsinghua Univ.:* HAO Jiming, WANG Shuxiao, WU Yue, etc.
- *South China Univ. of Technology:* YE Daiqi, ZHU Yun, XIE Junping, etc.
- *Zhejiang Univ.:* CEN Kefa, GAO Xiang, LUO Kun, CHEN Linghong, etc.
- *Chinese Academy of Environmental Sciences:* CHAI Fahe, GAO Jian, etc.
- *Chinese Academy of Environ. Planning:* LEI Yu, XUE Wenbo, etc.
- *Shanghai Academy of Sciences:* CHEN Changhong, Li Li, etc.
- *Shanghai EMC:* FU Qingyan, WANG Qian, etc.
- *Sponsors/Partners:* Energy Foundation, Clean Air Alliance of China, Clean Air Asia, etc.

USA:

- *EPA:* Carey JANG, Dale Evarts, Jeremy Schreifels, Scott Voorhees, etc.
- *Univ. of Tennessee:* Joshua FU, Xinyi DONG, Jian SUN, etc.

Appendix B

Table B-1 of this appendix reflects longstanding guidance from the U.S. EPA to ensure limits are practically enforceable.[1] In general, a limit is practically enforceable when the limit specifies the seven parameters listed in Table B-1. This appendix also includes additional examples of these parameters in Table B-2.

Table B-1 Parameters that make air quality emission limits practically enforceable

REQUIREMENT TO ENSURE PRACTICAL ENFORCEABILITY	EXAMPLE
A technically accurate emissions limitation.	10 mg PM/m^3 at 6 percent O_2
The portions of the facility that are subject to the limitation.	Each coal-fired boiler that produces steam used for generating electricity.
The time period (or averaging period) used when calculating compliance with the limitation.	Rolling average of the preceding 12 operating hours. Hours when the boiler is not combusting coal shall not be included when calculating 12-hour averages.
The reference method and testing requirements that must be used to determine compliance.	**Option 1.** Compliance with the limitation shall be determined as the average emission rate during monthly tests. Each monthly test shall be comprised of three individual test runs. Each test run must gather emissions data for at least 4 hours using EPA RM 5B. **Option 2.** Compliance with the limitation shall be determined using a continuous emissions monitoring system (CEMS) capable of determining the concentration of filterable particulate in mg PM/m^3 and the concentration of oxygen in the flue gas. This PM CEMS must be initially calibrated and maintained using protocols approved by Jiangsu EPD.
Continuous monitoring	Sources that do not install a PM CEMS must continuously monitor the total power and secondary current of the ESP to ensure the 12-hour averages of these parameters remain within the ranges observed in the most recent compliance test.
Recordkeeping	The operator must maintain records of the following parameters: 1. Copies of all PM compliance tests under Option 1 or used to calibrate the PM CEMS under Option 2. 2. Under Option 2, a time-stamped database must be maintained for the following parameters: a. The average PM concentration in mg/m^3 for each hour of operations. b. The average oxygen concentration for each hour. c. The average generating load in MW.
Reporting Requirement	By the 15th day of each month, the operator must submit a report to the Jiangsu EPD that includes the following information: 1. The average emission rate in mg/m^3 at 6% O_2 for each 12-hour operating period that ended during the previous month. 2. The average generating load in MWh for each 12-hour operating period.

Table B-2 Additional examples of averaging periods used for emissions limits in the U.S.

SECTOR	ACTIVITY	POLLUTANT	LIMIT	AVERAGING PERIOD	MONITORING TECHNOLOGY OR TEST METHOD
Electric Power	Coal-fired Power Boiler	Nitrogen Oxides (NO_X)	100 mg/m^3 at 6% O_2	30-day rolling average	NO_X CEMS - Dilution Extractive, Chemiluminescence.
Electric Power	Coal-fired Power Boiler	Particulate Matter (PM)	30 mg/m^3 at 6% O_2	24-hour block average	PM CEMS – Forward Light Scatter. Instrument Must Meet USEPA PS-11 and 40 CFR Part 60, Appendix F, Procedure 2.
Electric Power	Coal-fired Power Boiler	Sulfur Dioxide (SO_2)	100 mg/m^3 at 6% O_2	30-day rolling average	SO_2 CEMS – Dilution Extractive, UV Fluorescence.
Electric Power	Coal-fired Power Boiler	Sulfuric Acid Mist (H_2SO_4)	5 mg/m^3 at 6% O_2	6-hour average	Semi-annual Stack Test Method CTM-013A or Comparable Method.
Electric Power	Coal-fired Power Boiler	Mercury (Hg)	0.002 mg/m^3 at 6% O_2	12-month rolling average	Hg CEMS – Cold Vapor Atomic Fluorescence or Sorbent Trap System
Petroleum Refineries	FCCU Regenerators controlled by ESPs.	PM	1.0 g/kg coke burned for existing FCCUs 0.5 g/kg coke burned for new FCCUs	3-hour rolling average total power and secondary current	Continuously monitor and record total power and secondary current to the ESP.
Petroleum Refineries	New FCCU Regenerators controlled by wet scrubbers	PM	1.0 g/kg coke burned for existing FCCUs 0.5 g/kg coke burned for new FCCUs	3-hour rolling average pressure drop and liquid-to-gas ratio.	Continuously monitor and record pressure drop and liquid-to-gas ratio.
Petroleum Refineries	New and existing FCCU Regenerators	SO_2	50 ppmv at 0% excess air 25 ppmv at 0% excess air	7-day rolling average 365-day rolling average	SO_2 CEMS in exhaust stack or continuous H_2S monitor for central fuel gas lines.
Petroleum Refineries	New FCCU Regenerators	NO_X	80 ppmv at 0% excess air	7-day rolling average	NO_X CEMS
Petroleum Refineries	New and existing FCCU Regenerators	VOC	≤500 ppmv CO	1-hour average	CO CEMS or temperature and oxygen level operating limits

References

1. http://www.epa.gov/sites/production/files/2015-07/documents/potoem.pdf

Air Quality Management Planning Framework

August 2016