International Experience on $PM_{2.5}$ Control

$PM_{2.5}$ 控制的国际经验

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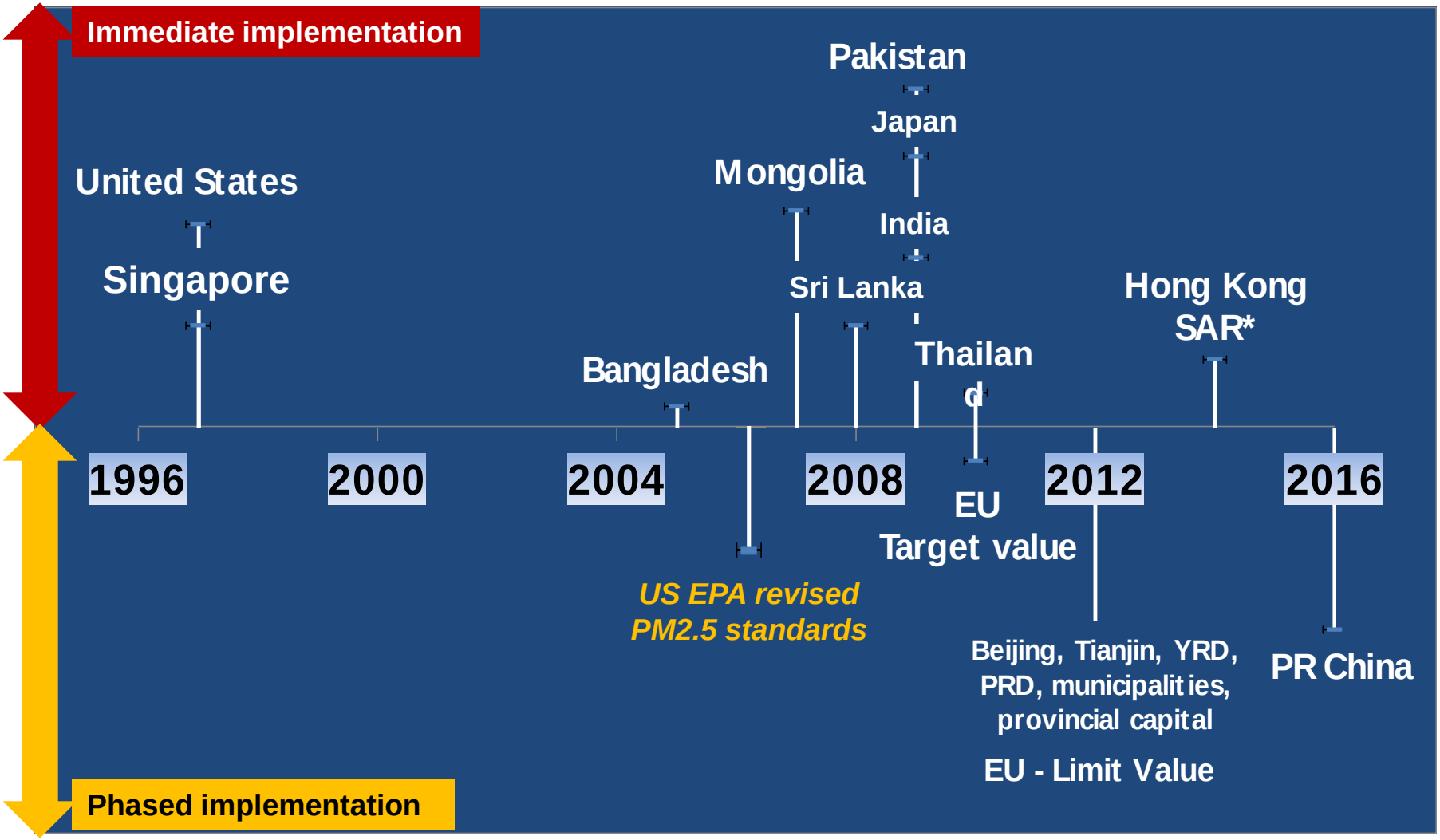
8 May 2012

Presentation Outline
报告目录

- Target-setting: PM2.5 standards and $PM_{2.5}$ implementation in Asia and internationally
  目标设定：PM2.5标准 及其实施-亚洲与国际经验
- Steps for selecting PM2.5 control measures
  筛选PM2.5控制措施的步骤
- List of potential control measures
  控制措施清单
- Development of PM2.5 implementation program
  相关规划的编制与实施
  - City experiences
- Recommendations
  政策建议

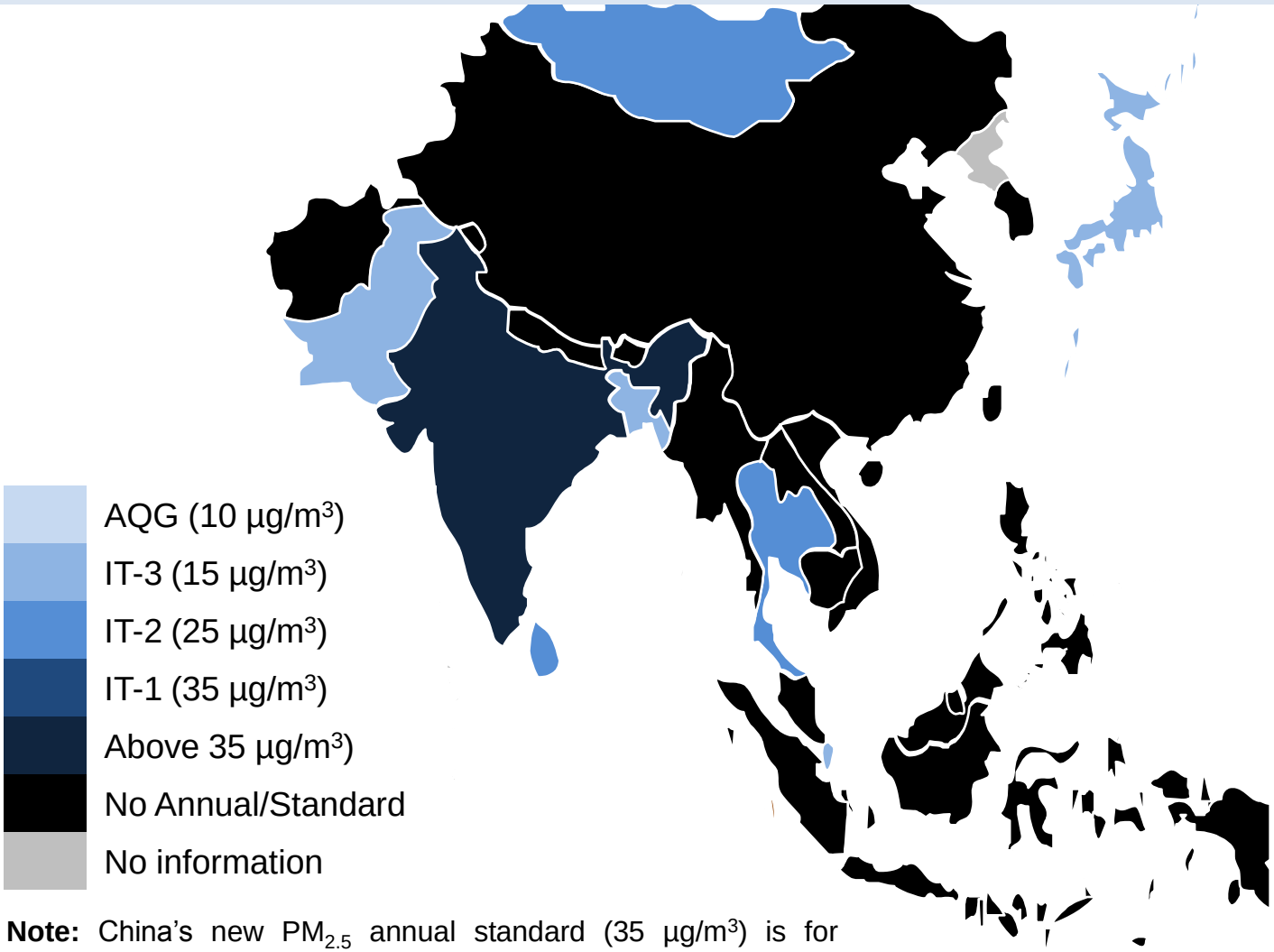
Timeline of $PM_{2.5}$ establishment in Asia
亚洲国家/城市PM2.5标准设定时间



HK SAR* - under discussion

Source: CAI-Asia, 2012

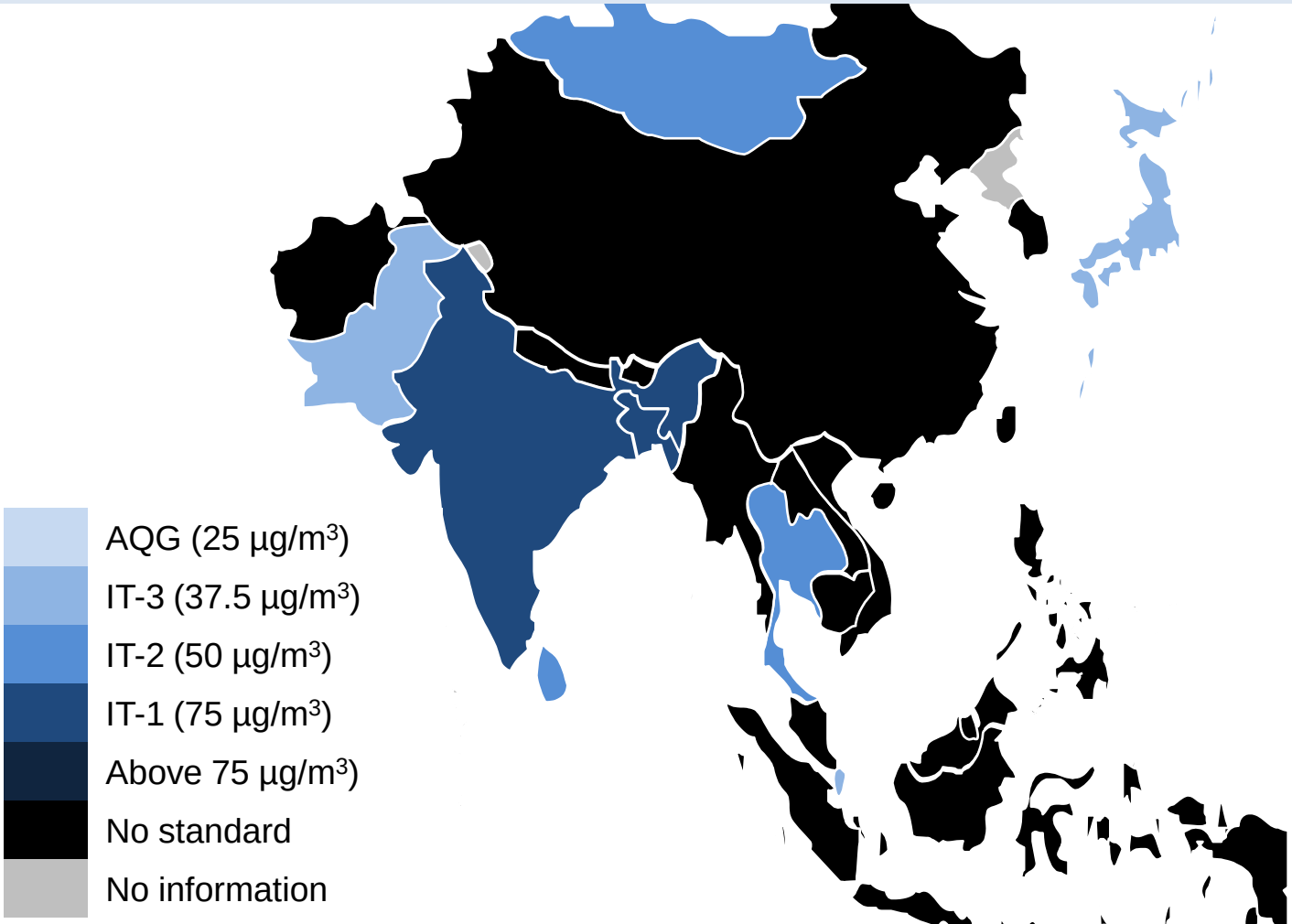
Status of Annual $PM_{2.5}$ Standards in Asia (March 2012)
国家/城市$PM_{2.5}$年均浓度标准（截止2012年3月）



Note: China's new $PM_{2.5}$ annual standard (35 µg/m^3) is for national implementation in 2016. 2012 implementation of new standard: for Beijing, Tianjin, YRD, PRD, municipalities and provincial capital cities

Source: CAI-Asia, 2012

Status of 24-hour $PM_{2.5}$ Standards in Asia (March 2012)
国家/城市$PM_{2.5}$日均浓度标准（截止2012年3月）



Note: China's new $PM_{2.5}$ annual standard (35 µg/m^3) is for national implementation in 2016. 2012 implementation of new standard: for Beijing, Tianjin, YRD, PRD, municipalities and provincial capital cities

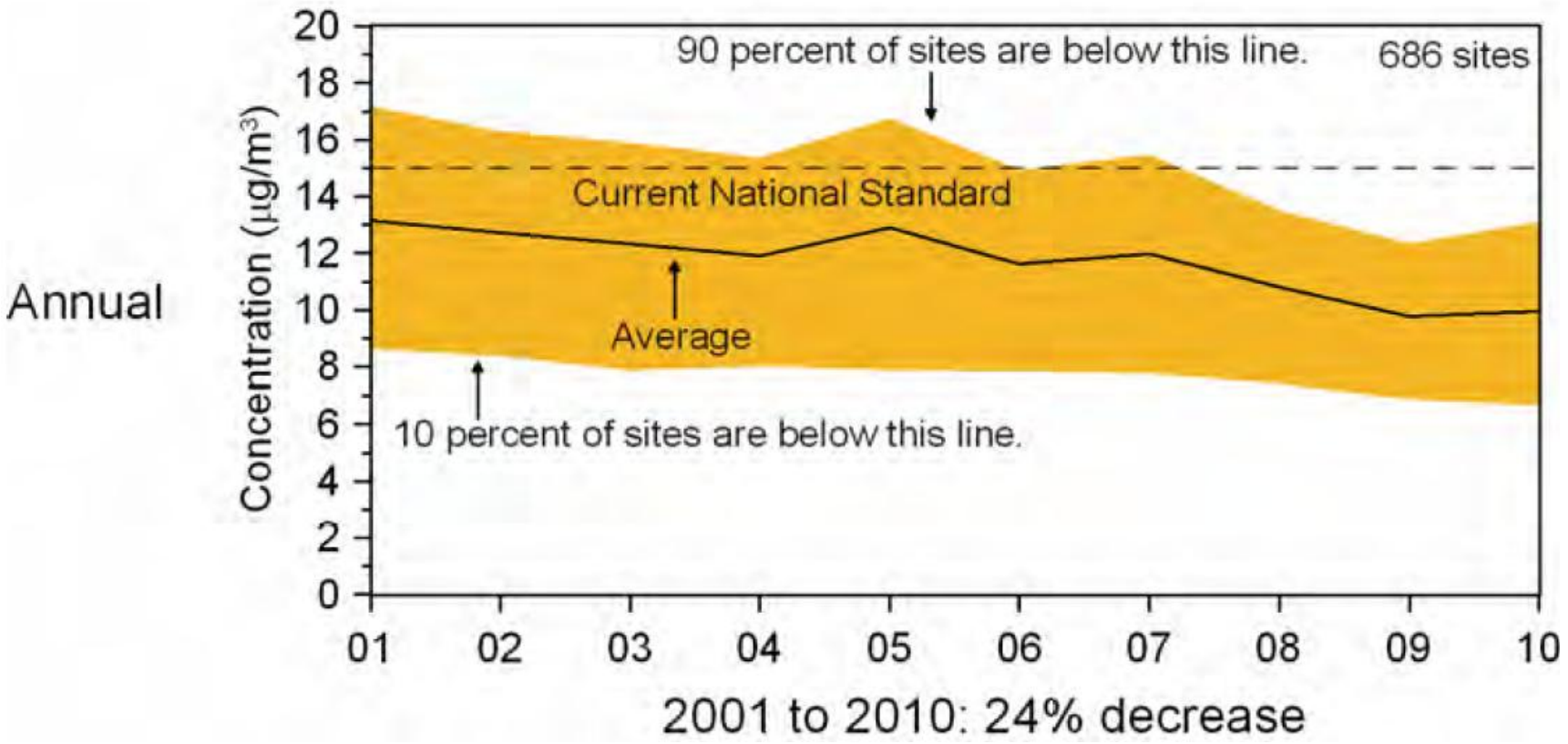
Source: CAI-Asia, 2012

Addressing $PM_{2.5}$ takes time: US
$PM_{2.5}$ 的管理需要时间与过程：美国

US EPA Timeline for PM2.5 NAAQS Implementation
美国EPA PM2.5的环境空气质量标准执行时间

1997	US EPA established PM2.5 standards | Annual: 15µg/m3 ; 24-hr: 65µg/m3
Apr 2005	39 non-attainment areas designated for 1997 standards
Dec 2006	2006 revised PM NAAQS Annual: 15 µg/m3 ; 24-hr: 35 µg/m3
Dec 2007	States recommend designations for 2006 revised PM2.5 standards
Apr 2008	**PM2.5 State plans due for 1997 standards**
2008-2009	Final designations for 2006 PM2.5 standards (effective date 60-90 days later; 2009-10)
Apr 2010-15	**Attainment date** for areas designated in 2005 for 1997 standards
Apr 2012-13	**PM2.5 State plans due for 2006 standards**
Apr 2014-20	**Attainment date** for areas designated in 2009-10

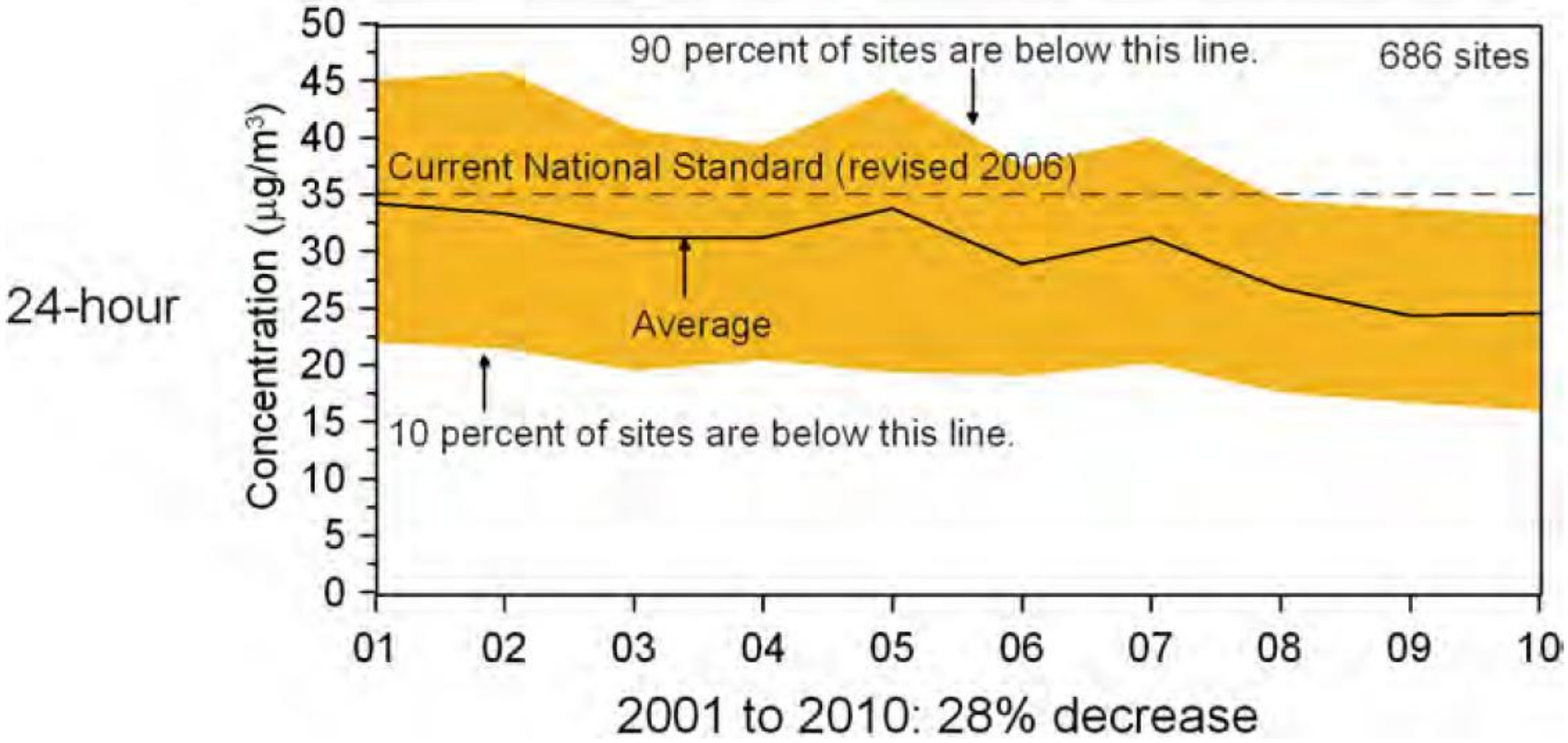
Trends in PM2.5 Concentration: US (1)
美国PM2.5浓度变化趋势（1）



Nationally, annual and 24-hour PM2.5 concentrations declined by 24 and 28 percent, respectively, between 2001 and 2010

http://www.epa.gov/airtrends/2011/report/particlepollution.pdf

Trends in PM2.5 Concentration: US (2)
美国PM2.5浓度变化趋势（2）



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http://www.epa.gov/airtrends/2011/report/particlepollution.pdf

Addressing $PM_{2.5}$ takes time: Europe
$PM_{2.5}$ 的管理需要时间与过程：欧洲

Directive 2008/50/EC: Ambient AQ and Cleaner Air for Europe
指引 2008/50/EC：环境空气质量 与欧洲清洁空气

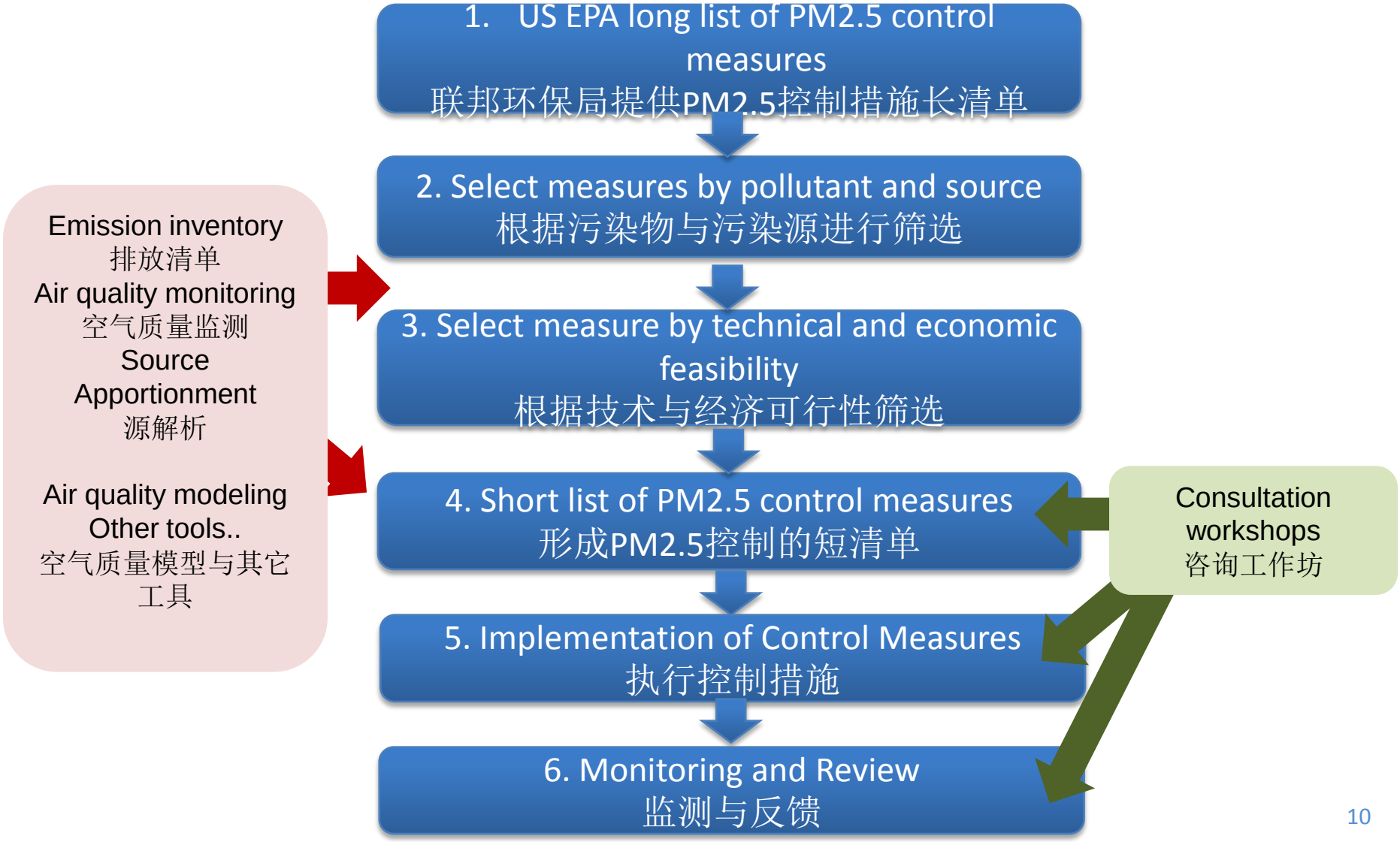
May 2008	PM2.5 standard introduced by new Directive 2008/50/EC | **Annual: 25 µg/m3**
Jan 2010	PM2.5 Target value (objective) entered into force (**25 µg/m3)**
2013	Air Quality Directive review
Jan 2015	PM2.5 Limit value (standard) entered into force (**25 µg/m3)**
Jan 2020	Annual PM2.5 Limit value to become **20 µg/m3** National exposure reduction target should be met – based on AEI

2 kinds of targets in Europe: 两种目标设置

- Target and limit values 污染控制
- Exposure 减少暴露

Average Exposure Indicator （平均暴露指数）expressed in µg/m3 (AEI) is based on measurements in urban background locations (1 station per 1 million people). It is taken as a three-calendar year running annual mean concentration averaged over all sampling points.

Steps in Selecting $PM_{2.5}$ control measures – US
控制措施筛选的步骤—美国



Step 1 - Long list of Potential Control Measures for $PM_{2.5}$ and Precursors (1)
第一步—PM2.5及其前体物控制措施长清单（1）

List of Potential Control Measures for PM2.5 and Precursors (2007)
PM2.5及其前体物的控制措施（2007）

	Stationary source 固定源	On-road mobile source 道路移动源	Non-road mobile source 非道路移动源	TOTAL 总数
$PM_{2.5}$	31	37	34	**102**
SO_2	35	11	6	**52**
NOx	130	38	36	**204**
VOC		29		**29**
NH_3		5		**5**
TOTAL	**196**	**120**	**76**	

**This list is not exhaustive.*
***USEPA is planning to post a new version.*
Source: http://www.epa.gov/pm/measures/pm_control_measures_tables_ver1.pdf

Step 1 - Long list of Potential Control Measures for $PM_{2.5}$ and Precursors (2)
第一步—PM2.5及其前体物控制措施长清单（2）

Stationary Source Control Measures for PM2.5

See cover note for important notes and caveats on the use of these tables

Draft Version 1.

Source category	Emissions reduction measure	Control efficiency (%)	Cost effectiveness ($/ton reduced)	Cost Year	Notes/caveats	Other pollutants controlled	References for more information
Ferrous Metals Processing - Iron and Steel Production - Blast Furnace Casthouse	Capture Hood Vented to a Baghouse	85	Not available		Based on engineering judgments and data which for some plants may be outdated.		**EPA 2006a**, Pechan 2006
Ferrous Metals Processing - Iron and Steel Production - BOF	Secondary Capture and Control System	85	$5,000		Based on engineering judgments and data which for some plants may be outdated.		**EPA 2006a**, Pechan 2006
Ferrous Metals Processing - Iron and Steel Production - Sinter Plant	Install baghouse to control emissions from sinter cooler	99	$5,000	2001$	Based on engineering judgments and data which for some plants may be outdated.		**EPA 2006a**, Pechan 2006
Petroleum Refinery Catalytic and Thermal Cracking Units	Wet Scrubbing	85 - 95	Not Available				**MARAMA, 2006**
Petroleum Refinery Catalytic and Thermal Cracking Units	Electrostatic Precipitators	>95%	$3,500 - $6,600				**MARAMA, 2006;** SCAQMD, 2003
Petroleum Refinery Catalytic and Thermal Cracking Units	Sodium bisulfite (SBS) injection	Not Available	Not Available				**MARAMA, 2006**
Stationary diesel engines including generators and other prime service engines	Diesel oxidation catalyst (where DPF not feasible)	20	$1,000-$2,000	2003$	Cost effectiveness is based on the combined CO, HC, NOx and PM		**NESCAUM 2003**, STAPPA and ALAPCO 2006

Source: http://www.epa.gov/pm/measures/pm_control_measures_tables_ver1.pdf

Step 2.A - Selection of Control Measures by Pollutant
第二步A—根据污染物进行控制措施筛选

Hierarchy of measures to address PM2.5 and precursors
PM2.5及其前体物的控制措施

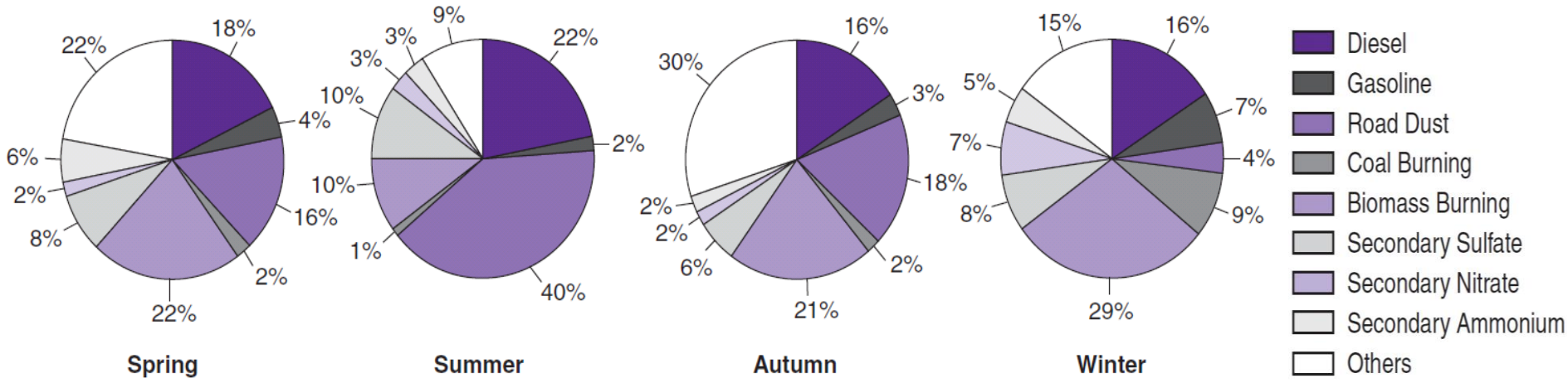
$PM_{2.5}$ and precursor	Need to be evaluated for control measures?
Direct $PM_{2.5}$	Required
SO_2	Required
NOx	Required, unless it is shown that NOx emissions do not significantly contribute to $PM_{2.5}$ concentrations
VOC	Not required, unless it is shown that VOC emissions significantly contribute to $PM_{2.5}$ concentrations
Ammonia	Not required, unless it is shown that ammonia emissions significantly contribute to $PM_{2.5}$ concentrations

Source: US EPA - Final Clean Air Fine Particle Implementation Rule for the 1997 PM2.5 Standards

Step 2.B - Identify Source Contribution to $PM_{2.5}$ (1)
第二步B- 识别PM2.5的污染贡献来源（1）

- Contribution of sources of the precursor to $PM_{2.5}$
  PM2.5前体物的污染源贡献
- Variation of PM2.5 and precursors concentrations by season
  不同季节PM2.5的差异与前体物浓度
- Interactions of PM2.5 and precursors
  PM2.5及前体物的反应

Source Apportionment (PM2.5) Results for Delhi, India (2001)



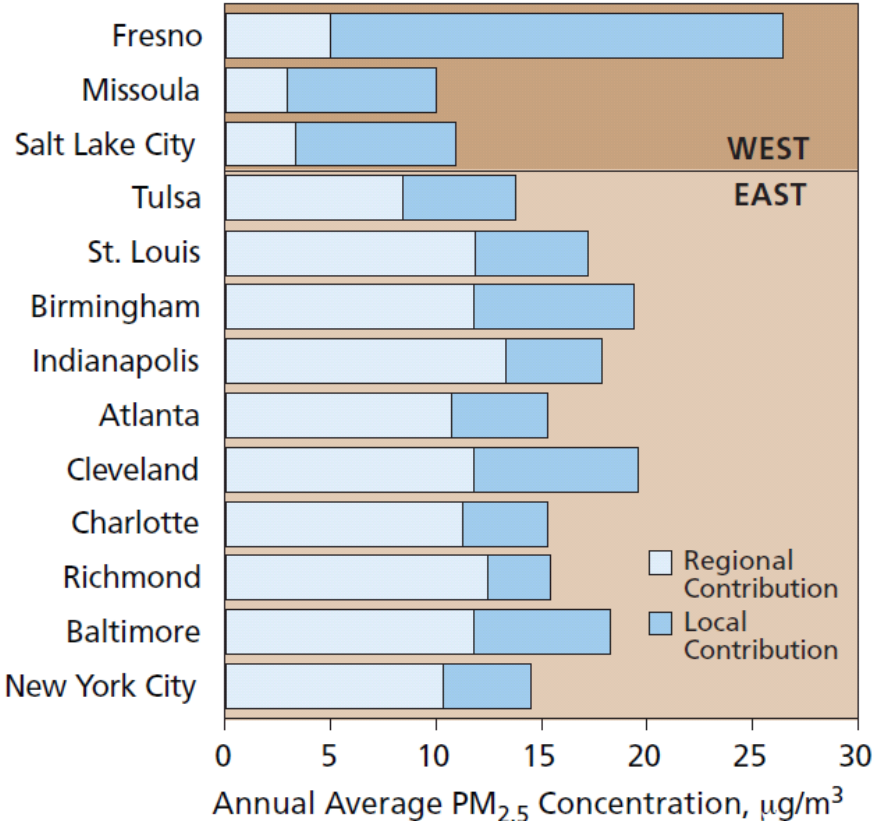
Step 2.B - Identify Source Contribution to $PM_{2.5}$ (2)
第二步B- 识别PM2.5的污染贡献来源（2）

- PM pollution is both local and regional

  PM即是局地污染又是区域污染

  - Lifetime days to weeks, regional distribution over urban scale to 1000s of km
- Regional and local components of the PM problem needs to be evaluated in selecting control measures

  在选择控制措施时，需要摸清区域与局地PM组份



Note: *Urban and nearby rural PM2.5 concentrations suggest substantial regional contributions to fine particles in the East. http://vista.cira.colostate.edu/improve.*

Step 2.B - Identify Source Contribution to $PM_{2.5}$ (3)
第二步B- 识别PM2.5的污染贡献来源（3）

Tools to assess whether a source contributes significantly to $PM_{2.5}$ concentrations
评估某个污染源是否对PM2.5浓度产生重大贡献的工具

- Photochemical modeling 光化学模型
- Photochemical source apportionment tools 光化学源解析工具
- Receptor modeling 受体模型
- Analysis of ambient monitoring data, speciation data, and trends 大气监测数据分析、形态数据与趋势
- Analysis of emissions inventories and trends 排放清单与趋势分析

Source: Damberg, R., 2007. Policies for Addressing PM2.5 Precursor Emissions

Step 3.A – Select measure by technical feasibility
第三步A-通过技术可行性筛选措施

- **Control Efficiency (CE)**: Does the measure work in reducing in reducing PM2.5 and/or its precursors?
  控制效率：措施能否有效减少PM2.5及其前体物？
- Consider factors such as:
  需要考虑的要素：
  - Process and operating conditions
  - Raw materials
  - Physical Plant layout
  - Non-air quality and energy impacts
  - Time needed to install and operate controls

Source: Smith, T., 2007. PM2.5 Implementation Rule RACT/RACM

Sample Stationary Source Control Measures for PM2.5
PM2.5固定源控制措施示例

Source Category	Emissions reduction measure	CE (%)
Stationary diesel engines including generators and other prime service engines	Diesel oxidation catalyst (where DPF not feasible)	20
	Diesel particulate filter	80-90
Ferrous Metals Processing - Iron and Steel Production – Sinter Plant	Install baghouse to control emissions from sinter cooler	99

Source: List of Potential Control Measures for PM2.5 and Precursors (2007)

Step 3.B - Select measure by economic feasibility
第三步B—通过经济可行性筛选措施

- **Cost Effectiveness费用有效性**: Is the cost of the potential measure reasonable for the regulated entity to bear?
- **Cost (USD)/ton reduced单位减排成本**: an indicator of reasonableness but ability to absorb may differ across categories
- Feasibility may depend on availability of public funding and resources
  是否可行要看资金来源的可得性
- If there are severe impacts on local economy, economic analysis is needed
- 如果对当地经济影响较大，需要进行经济分析

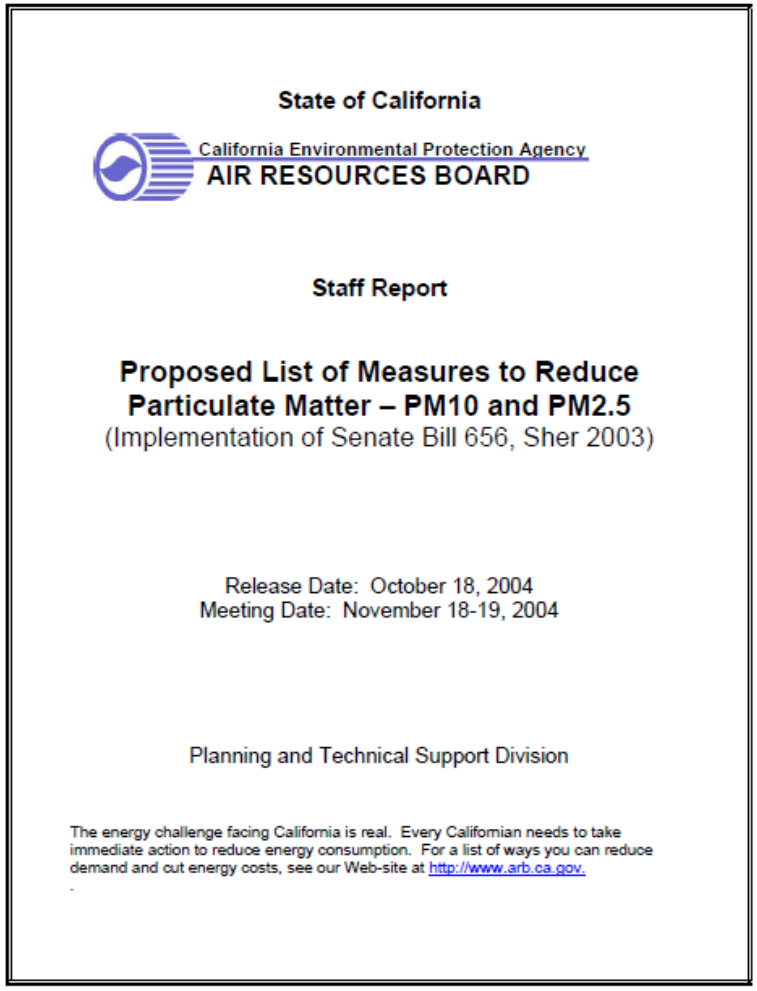
Sample NOx control measures for Cement Kilns
NOx控制措施示例

Emissions reduction measure	CE (%)	USD/ton reduced	Cost Year
Biosolids injection	23	$310	1999$
Low NOx Burner	27-40	$166-$1,299	2004$
Mid-Kiln Firing	33-41	$166-$1,299	2004$
Selective Catalytic Reduction (SCR)	31-95	$600-$3,700	1999$

Source: List of Potential Control Measures for PM2.5 and Precursors (2007)

Source: Smith, T., 2007. PM2.5 Implementation Rule RACT/RACM

Step 4 - Short list of $PM_{2.5}$ control measures (1)
第四步-PM2.5控制的短清单(1)



State of California

California Environmental Protection Agency
AIR RESOURCES BOARD

Staff Report

Proposed List of Measures to Reduce Particulate Matter – PM10 and PM2.5
(Implementation of Senate Bill 656, Sher 2003)

Release Date: October 18, 2004
Meeting Date: November 18-19, 2004

Planning and Technical Support Division

The energy challenge facing California is real. Every Californian needs to take immediate action to reduce energy consumption. For a list of ways you can reduce demand and cut energy costs, see our Web-site at http://www.arb.ca.gov.

Information included for each control measure

控制措施的信息包括：

- Title and Number 名称与数量
- Source Category Affected 污染源分类
- Emissions Inventory 排放清单
- Current Control 控制现状
- Future Control Options未来限制项
- Future Incentive Options 未来鼓励项
- Discussion 讨论
- Recommendations 政策建议
- Potential Projected Reductions 减排潜力

Step 4 - Short list of $PM_{2.5}$ control measures (2)
第四步-PM2.5控制的短清单(2)

Appendix I: Candidate Control Measures

Boilers, Steam Generators, and Process Heaters, 2 - 5 MMBtu/hr (S-COM-2)

(Electrical Utilities, Cogeneration, Oil & Gas Production – Combustion, Petroleum Refining – Combustion, Manufacturing & Industrial, Food & Agricultural Products Processing, Service & Commercial, Other – Fuel Combustion)

Source Category:
This source category includes a wide range of industries including but not limited to medical facilities, educational institutions, office buildings, prisons, military facilities, hotels and industrial industries.

Emissions Inventory:
Data reflects current controls and regulations, but does not include any reductions from proposed controls.

Pollutant	2005	2009	2010	2011	2012	2013	2014
Tons per day – winter season							
NOx	3.66	3.78	3.84	3.89	3.94	3.99	4.05
PM2.5	0.35	0.36	0.37	0.37	0.38	0.38	0.39
SO_2	3.17	3.30	3.37	3.43	3.49	3.55	3.61
Tons per day – annual average							
NOx	3.47	3.59	3.65	3.70	3.75	3.80	3.86
PM2.5	0.32	0.33	0.34	0.35	0.35	0.36	0.36
SO_2	3.17	3.30	3.37	3.43	3.49	3.55	3.61

- **EIC Affected:** 020-005-0110-0000; 050-070-0110-0000; 050-995-0110-0000; 050-995-0120-0000; 050-995-1500-0000; 052-070-0110-0000; 060-010-0110-0000; 060-995-0110-0000; 060-995-0120-0000; 060-995-1500-0000; 099-995-0000-0000; 310-356-0110-0000; 310-995-1600-0000; 410-400-2036-0000
- The EIC include emissions from all units rated less than 5 MMBtu/hr. To more

Current Control:
- District Rule 4307 sets NOx limits at 30 ppmv effective in 2009. This is approximately 70% NOx control from uncontrolled levels.
- Natural draft units operating in oil fields or refineries, glycol reboilers, and units that

Future Control Options:
- Mandate NOx limits for school boilers, natural draft units operating in oil fields or refineries, glycol reboilers, and units that operate no more than 5 billion Btu per year. (currently undergoing rule amendment development process).
- Replacing with electric heaters is also an option since almost all facilities are in areas connected to existing commercial electric grid system.

Future Incentive Options
- Additional reductions can be achieved by providing incentives for replacement or

Incentive Option	# of Units	MMBtu/hr	Capacity Factor	Emissions (tons per day)	Emission Reductions (tons per day)	Total Cost	Capital Cost	Cost Effectiveness (dollars per ton)
Low NOx Retrofit (30 ppm)	380	3.5	0.5	0.798	0.511	$17,733,460	$46,667	$11,124
Low NOx Replacement (30 ppm)	380	3.5	0.5	0.798	0.511	$24,553,700	$64,615	$15,402
Ultra Low Nox Replacement (15 ppm)	380	3.5	0.5	0.798	0.694	$57,000,000	$150,000	$26,327

Discussion:
- The District has legal authority to regulate air emissions units located at stationary sources.

Recommendation:
- Rule 4307 is currently undergoing rule development process to implement the control measure in the Ozone Plan. The draft amendments would include removing the exemption for school boilers, glycol reboilers, and natural draft units located in the oilfields

Incentives:
- Retrofit and replacement of school boilers to meet BARCT standards (30 ppm) are relatively cost effective incentive options. Grant history indicates that participation is higher for programs that offer full replacement as opposed to retrofit
- Consider adopting a backstop rule to assure participation in the incentive program and improve cost effectiveness.

Projected Reductions:
Calculated reductions assuming the recommended emission limits described above:

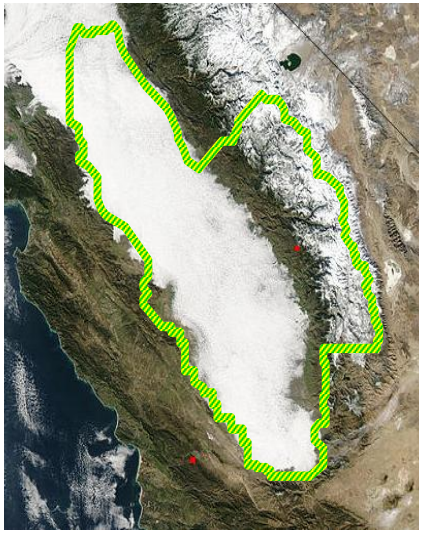
Pollutant	2009	2010	2011	2012	2013	2014
Tons per day – winter season						
NOx	0	0	0	0	0	0
PM2.5	0	0	0	0	0	0

Step 5 – Implementation of Measures
第五步—措施实施

Prioritization/screening of control measures based on
控制措施的排序/筛选，基于：

- Pollutants reduced – NOx, PM2.5, VOC, SO2, or multiple pollutants
  污染物减排—NOx, PM2.5, VOC, SO2或多种污染物
- Magnitude of emissions from source and likely emission reductions
  污染源排放量与减排潜力
- Availability of funds for investment
  资金可得性
- Institutional arrangements
  机构设置
- Socioeconomic impacts
  社会-经济影响
- Public acceptability
  公众接受度

Development of $PM_{2.5}$ Implementation Program: San Joaquin Valley Experience
PM2.5控制规划实施： San Joaquin Valley 经验



San Joaquin Valley, USA

Area: ~25,000 mi^2

Population: 3.97 mln (2010)

Geography: mountain barriers, 'bowl shape'

Unfavorable meteorology: strong inversions, light winds

Dominated by Mobile sources

Rule Development Process 规制发展过程

- Scoping meeting
- Three workshops
- Outreach events

Source: Hunsaker 2007. PM Controls in the San Joaquin Valley

Summary of Strategies

控制策略总结

- Indirect Source Review (PM2.5, PM10, NOx)
- Residential Wood Combustion (PM2.5, PM10, NOx)
- Fugitive Dust regulations (prohibitions)
- Agriculture burning prohibition (NOx and PM)
- Boilers & stationary IC engines (NOx)
- Incentives
- Innovative Measures: examples"
  - Green Fleets
  - Truck Replacement/Retrofit/Repower
  - Heat Island Mitigation
  - Episodic and Regionally-Focused CMs
  - Community Clean Air Fund
- State Strategy

Development of $PM_{2.5}$ Implementation Program: New Jersey Experience
PM2.5控制规划实施：新泽西经验

New Jersey, USA

Area: 22,608 km^2

Population: 8.82 mln (2011)

Bordered on the N and NE by New York and on W by Pennsylvania

Key Precursor: Sulfates

Summary of Strategies
控制策略总结

- **Point sources点源**: EGU Performance strategies
- **Point and area sources点源/面源**: Fuel strategies
- **Area sources面源**: Wood combustion
- **Onroad and nonroad sources交通源**: Diesel idling reductions, Diesel idling law, I/M program

Timeline: Identification of Strategies
时间轴：识别控制策略

- June 29, 2005 - First Workshop
  - Six workgroups formed
    - Diesel initiatives
    - Gasoline Cars and Trucks
    - Homes and Restaurants
    - Non-Automobile Gasoline Engines
    - Stationary Combustion Sources
    - Volatile Organic Compounds
- Summer of 2005
  - Workgroups meet - brainstorming
- Fall/Winter 2005
  - Workgroups submit reports to NJDEP
  - Air workshop - November 14, 2005
  - ~ 250 potential control measures
- May 17, 2006
  - Second Workshop; 60 white papers

Source: Krietzman 2007. PM2.5 Implementation Program New Jersey Perspective

Recommendations
政策建议

- Build and strengthen capacity for characterization of PM2.5 (air quality monitoring, source apportionment, emissions inventory, etc)
  建设与加强PM2.5污染识别的能力（空气质量监测、源解析、排放清单等）
- PM2.5 control requires multi-pollutant approach: Continue firm implementation of existing measures for PM10, SO2, NOx and even VOC
  PM2.5的控制需要结合多种污染物控制：继续落实现有的PM10, SO2, NOx 与VOC控制措施
- MEP to come up with a China-specific long list of PM2.5 and its precursors control measures with control efficiency and cost effectiveness estimates
  环保部提供中国的PM2.5前体物控制措施清单、及其控制效率与费用有效性估算信息
- Explore average exposure indicator concept
  探索平均暴露指数的概念

References on Control Measures
控制措施 参考资料

- STAPPA/ALAPCO menu of options
- US EPA Lists of Potential Control Measures for PM2.5 and Precursors
- EPA website: http://www.epa.gov/pm/measures.html
- Ozone Transport Commission
  - Identification and Evaluation of Candidate Control Measures
  - Technical Support Document at http://www.otcair.org/document.asp?fview=Report#
- CARB Proposed List of Measures to Reduce Particulate Matter – PM10 and PM2.5
- South Coast AQMP
  - Control technology info in Appendix A: http://www.aqmd.gov/aqmp/AQMPintro.htm
- LADCO White Papers
  - http://www.ladco.org/Regional_Air_Quality.html
- San Joaquin Valley Air Basin
  - Candidate control measures in Appendix I http://www.valleyair.org/air_quality_plans/docs/AQ_Ozone_2007_Adopted/26%20Appendix%20I%20April%202007.pdf

For more information: www.cleanairinitiative.org

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