Air Pollution Control in China: Progress and Perspectives

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Air Pollution Control in China: Historical Progress

Phase 1: 1970～1990

- **Main source**: Point sources (industry)
- **Major pollutants**: TSP
- **Scale of air pollution**: Local
- **Air quality management:** Emission concentration, smoke and dust control, point sources, local management
- **Milestones**：
  - ✓ 1973, 1st national comprehensive emission standard —The three wastes emission standard of industry
  - ✓ 1987, Air Pollution law, targeting industry and coal-burning pollution

Phase 2: 1990～2000

- **Main source**: Coal burning, industry
- **Major pollutants**: SO_2,TSP
- **Air pollution problems**: Smoke, acid rain
- **Scale of air pollution**: local + regional
- **Air quality management:** Emission concentration, coal burning control, point sources, local management
- **Milestones**：
  - ✓ 1998, SO_2 and acid rain control zone; 2000, total emission amount control of SO_2 in the SO_2 and acid rain control zone

Phase 3: 2000～2010

- **Main source**: Coal burning, industry, dust, vehicles
- **Major pollutants**: SO_2、TSP、NO_x、PM_{10}
- **Air pollution problems**: Smoke (coal burning), acid rain, haze/PM2.5, photochemical pollution, regional complex air pollution
- **Scale of air pollution**: Regional + global
- **Air quality management:** Single pollutant total amount control, coal burning emission control, point sources, local management with start of multi -pollutants management, trial of regional control in some key regions.
- **Milestones**:
  - ✓ 2000, amendment of air pollution law: total amount control in SO_2 and acid rain control zone, vehicle emission control, dust control
  - ✓ Total emission amount control of SO_2 was expanded to whole country
  - ✓ Regional corporation for Beijing Olympics, Guangzhou Asian Games and Shanghai Expo

Emission Standards—Stationary Sources

Upgrade of Emission Standard-PM

1996
National
200mg/m^3

2002
Beijing
50mg/m^3

2003
National
50mg/m^3

2007
Beijing
10mg/m^3

Emission Standard of Air Pollutants for Thermal Power Plants

Dust emission limit of newly built, expanded and transformed boilers in China

Upgrade of Emission Standard-SO2

1996
National
1200~2100mg/m^3

2002
Beijing
100~150mg/m^3

2003
National
400~1200mg/m^3

2007
Beijing
50mg/m^3

Emission Standard of Air Pollutants for Coal--Burning Oil-Burning Gas-Fired Boilers

Dust emission limit of newly built, expanded and transformed boilers in Beijing

Emission Standards—Vehichle Sources

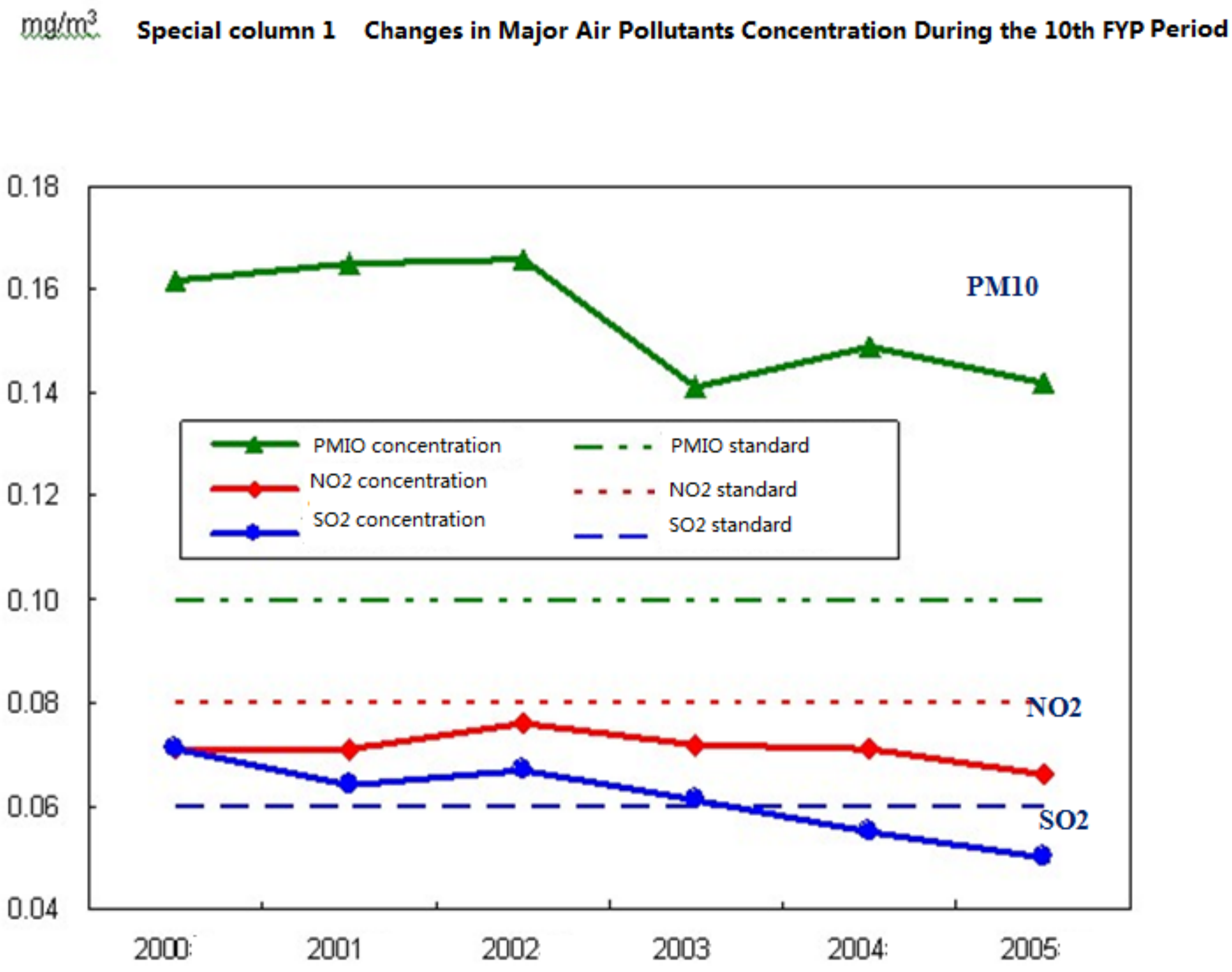
Emission standards for gasoline vehicles

Country	Standard \ Year	90	91	92	93	94	95	96	97	98	99	2000	01	02	03	04	05	06	07	08	09	10	11
US	Emission Standard	Tier0				Tier1										Tier2							
US	S content	338								0~500						Avg.120 Max.300		Avg.30 Max.80					
EU	Emission Standard			EURO1				EURO2				EURO3					EURO4			EURO5			
EU	S content				1000			500				150					50				10		
CHINA	Emission Standard												CHN1				CHN2			CHN3		CHN4	
CHINA	S content									1000					800		500		150				
BEIJING	Emission Standard										CHN1			CHN2				CHN3		CHN4			
BEIJING	S content														500		150		50				

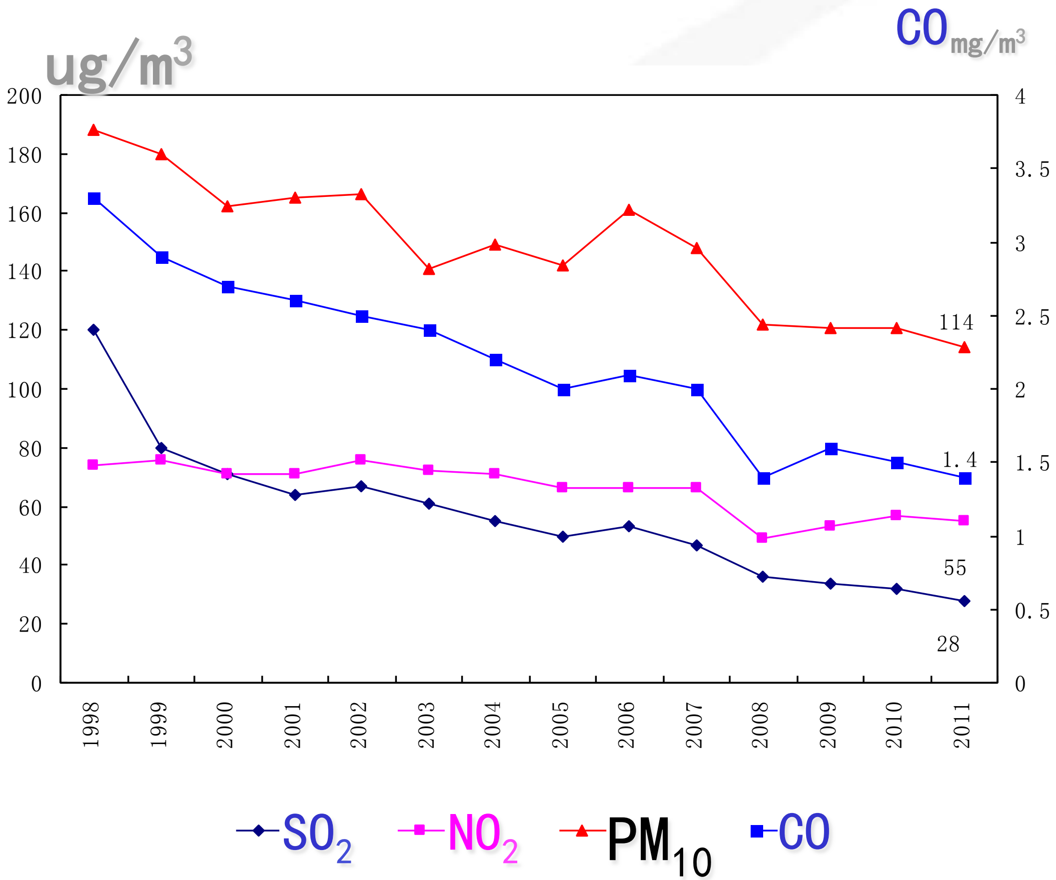
Emission standards for diesel vehicles

Country	Standard \ Year	90	91	92	93	94	95	96	97	98	99	2000	01	02	03	04	05	06	07	08	09	10	11
US	Emission Standard	Tier0				Tier1										Tier2							
US	S content	2000			500											30		15					
EU	Emission Standard			EURO1				EURO2				EURO3					EURO4			EURO5			
EU	S content	3000				2000		500				350					50			10			
CHINA	Emission Standard										CHN1						CHN2			CHN3		CHN4	
CHINA	S content					10000								2000		500							
BEIJING	Emission Standard										CHN1			CHN2			CHN3			CHN4		CHN5	
BEIJING	S content															500	350		50				

Air Quality Trends: 2000-2005



Air quality Improved with Socio-economic Development in Beijing

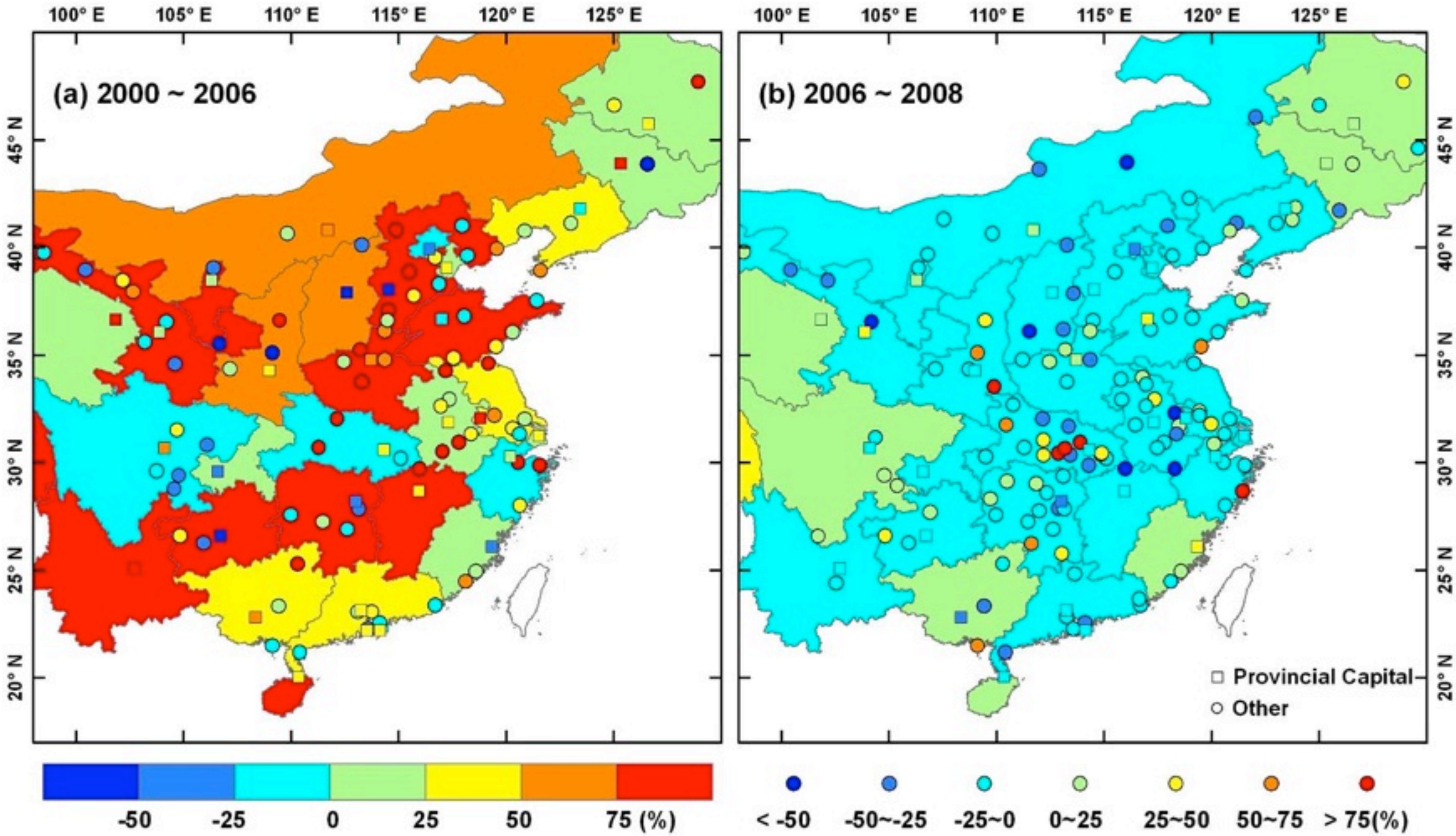


With the efforts of air pollution treatment in past years, concentrations of main pollutants are declining:

- ✓ **SO_2:↓77%**
- ✓ **NO_2: ↓26%**
- ✓ **PM_{10}: ↓39%**
- ✓ **CO: ↓58%**

However, there is still a gap between air quality and public expectation.

SO_2 Emission and Concentrationin China

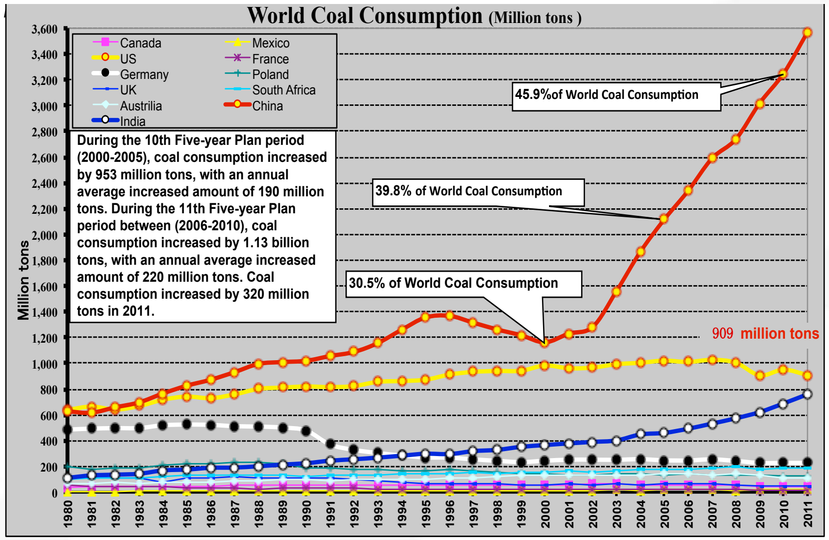


The percentage change of SO_2 emission (provinces) and SO_2 concentrations (cities) in China.

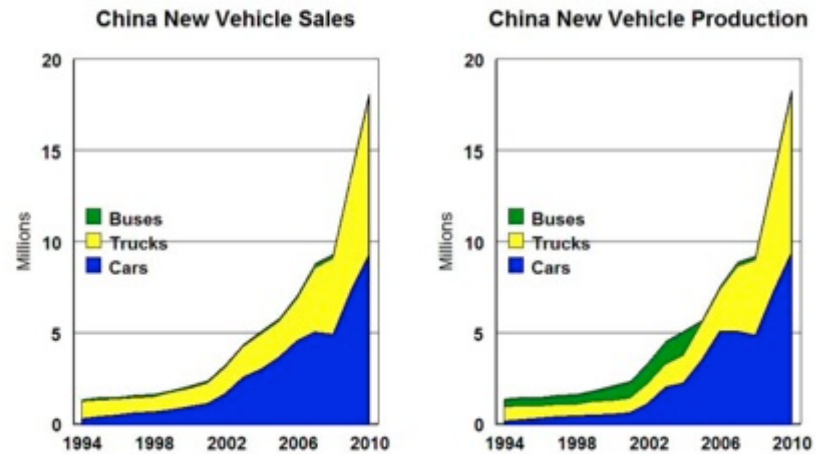
Lu et al., ACP, 2010

Rapid Industrialization in China

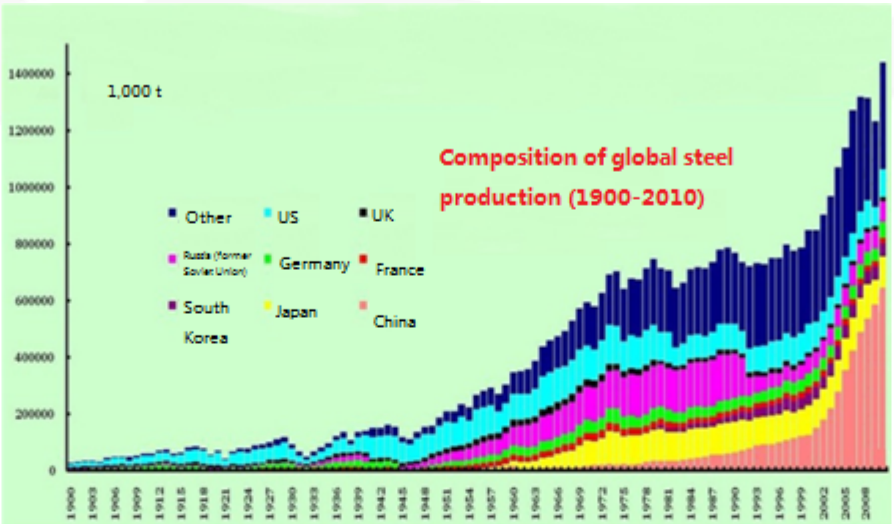
Energy Consumption



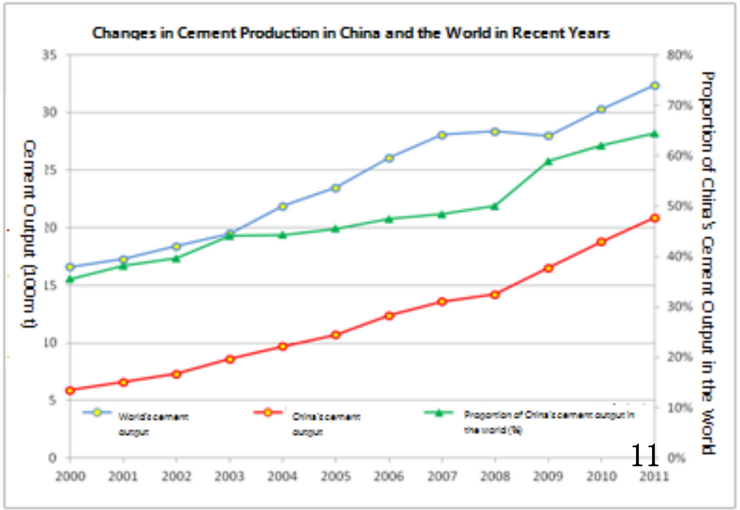
Vehicle Population



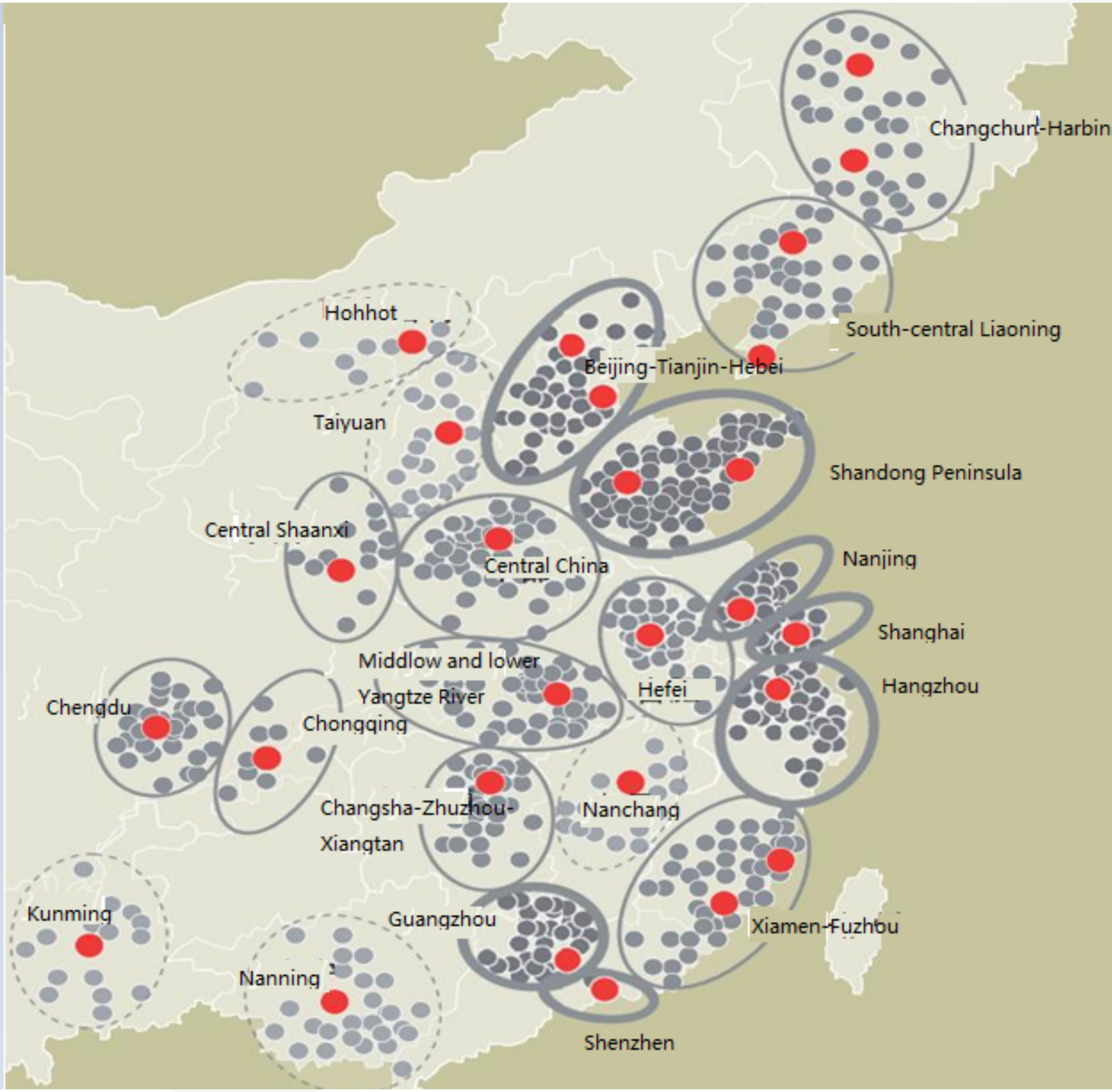
Steel Production



Cement Production

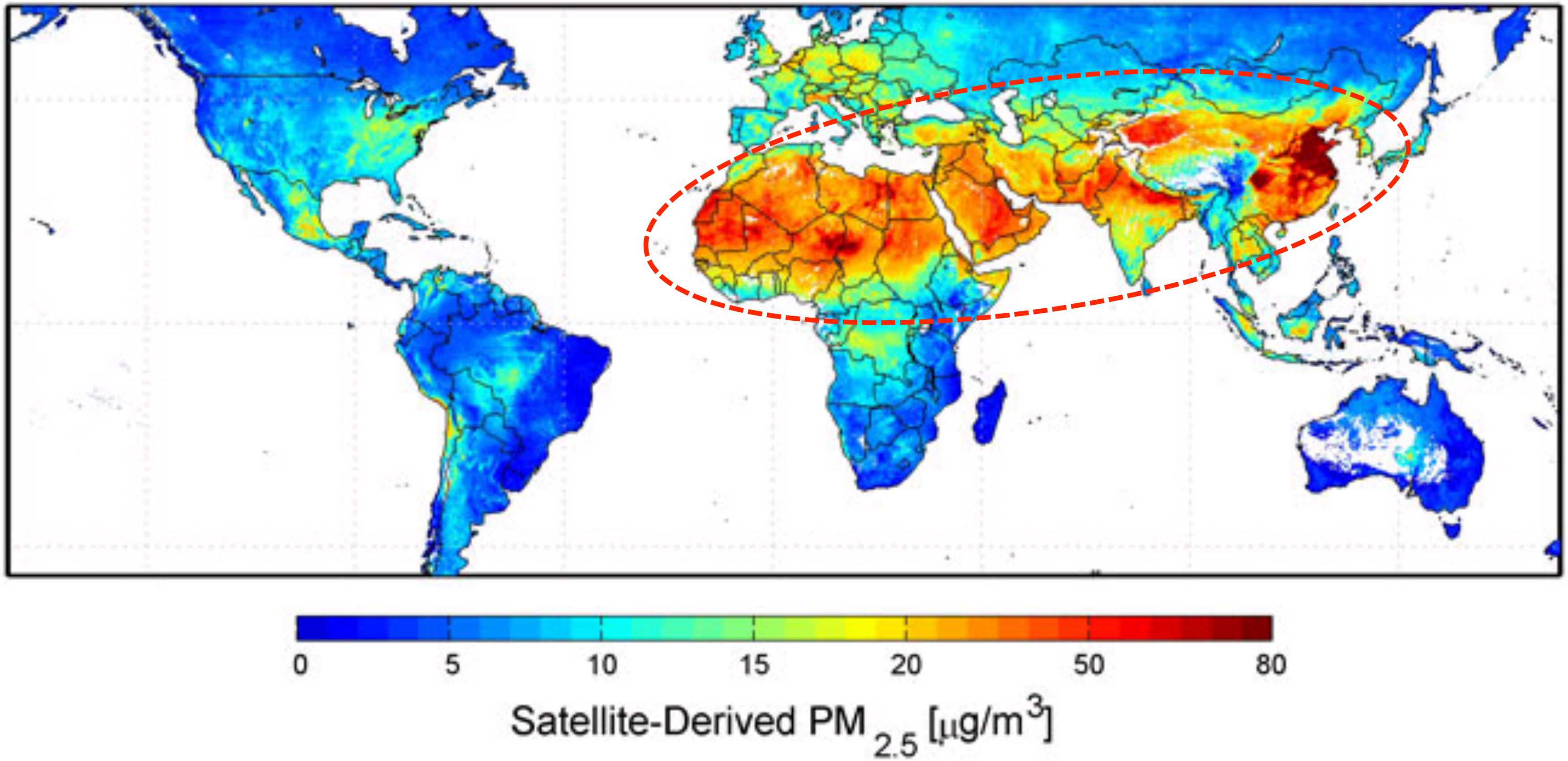


Rapid Urbanization in China



Name of city group Number of cities	City group GDP	Hub city GDP
Large city group		
Beijing-Tianjin-Hebei (37)	10.8%	7.9%
Shanghai (19)	10.8%	6.2%
Shandong Peninsula (67)	9.0%	2.1%
Hangzhou (38)	6.7%	1.6%
Guangzhou (24)	6.6%	2.6%
Nanjing (27)	4.8%	1.8%
	4.3%	2.9%
Medium city group		
South-central Liaoning (30)	4.3%	2.4%
Xiamen-Fuzhou (42)	4.2%	1.4%
Middle and lower Yangtze River (42)	4.0%	1.8%
Central China (40)	3.8%	0.7%
Changchun-Harbin (36)	3.6%	1.6%
Chengdu (29)	3.2%	1.6%
Hefei (29)	2.8%	0.8%
Changsha-Zhuzhu-Xiangtan (28)	2.2%	0.8%
Central Shaanxi (15)	1.9%	1.2%
Chongqing (6)	1.8%	1.5%
Small city group		
Nanning (28)	1.8%	0.3%
Nanchang (22)	1.7%	0.6%
Taiyuan (19)	1.4%	0.5%
Hohhot (10)	1.3%	0.4%
Kunming (16)	1.1%	0.5%

$PM_{2.5}$: 2001-2006



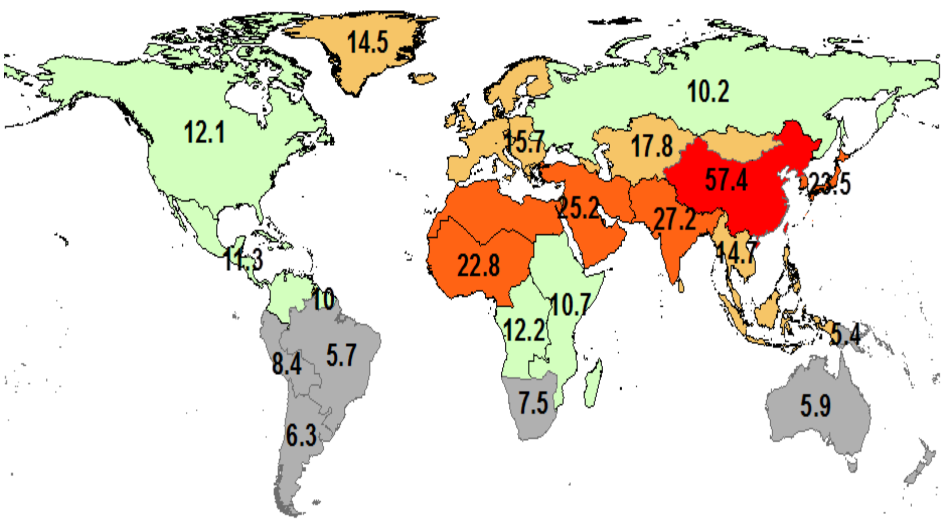
van Donkelaar et al., *Environmental Health Perspectives* 2010

http://www.nasa.gov/topics/earth/features/health-sapping.html

Environmental Science & Technology
Article
pubs.acs.org/est

Exposure Assessment for Estimation of the Global Burden of Disease Attributable to Outdoor Air Pollution

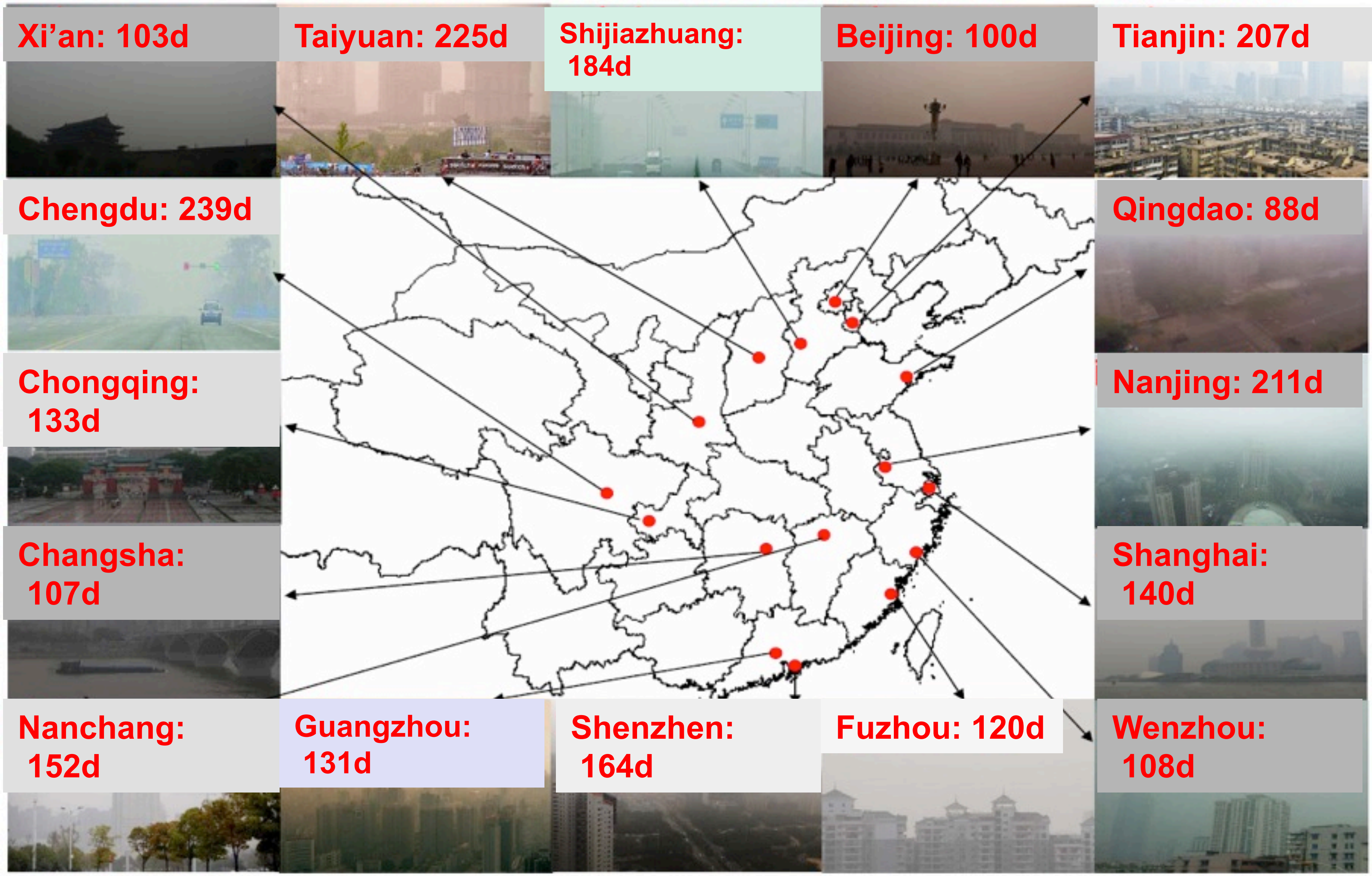
Michael Brauer,*,† Markus Amann,‡ Rick T. Burnett,§ Aaron Cohen,‖ Frank Dentener,⊥ Majid Ezzati,# Sarah B. Henderson,▽ Michal Krzyzanowski,○ Randall V. Martin,◆,¶ Rita Van Dingenen,⊥ Aaron van Donkelaar,◆ and George D. Thurston+



Regional average population-weighted $PM_{2.5}$ concentration in 2005

- **Estimate global $PM_{2.5}$ concentration as per the scale of 10km x 10km**
- **Estimate based on satellite (AOD), atmospheric transmission model and surface observation**
- **South/east Asia is the region with the world's highest $PM_{2.5}$ concentration**
- **89% of world's population live in areas with $PM_{2.5}$ concentration higher than the WHO's AQG (average annual 10 μg /m^3)**

Smog in Many Cities



Air Quality of Chinese Cities from Global

- According to the report released by the World Bank in 2012, the health losses of diseases and pre-mature death of the public triggered by PM_{10} pollution in 2009 accounted for 2.8% of GDP.

- In 2011, the WHO released the air quality report of world cities with PM_{10} as the major factor which showed that Beijing ranked 1,035th among 1,082 cities and Haikou, a city with sound air quality in China, ranked behind the 800th position.

China’s Strategic Targets

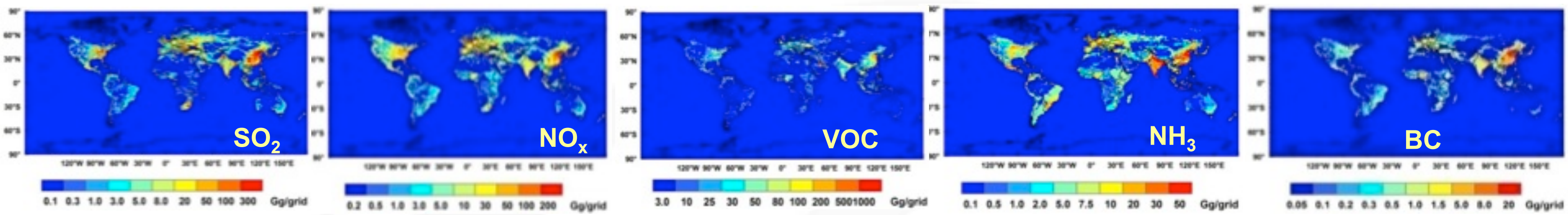
The Ministry of Environment Protection of China and the Chinese Academy of Engineering jointly completed the Studies on China’s Macro Environment Strategy from 2007 to 2009, a critical project that summarizes the past, guides the present work, and plans the future.

Overall atmospheric environment protection target by 2050:

Through comprehensive air pollution control, China works to greatly reduce the concentration of various pollutants in the air, significantly improve air quality in cities and major regions, fully reach national air quality standards, basically realizes the concentration standard for ambient air quality of the World Health Organization (WHO) , and meet the requirement for public health and ecological safety. (China hopes to integrate with the standard system of the WHO.)

Air Pollution Control in China: Efforts since 2010

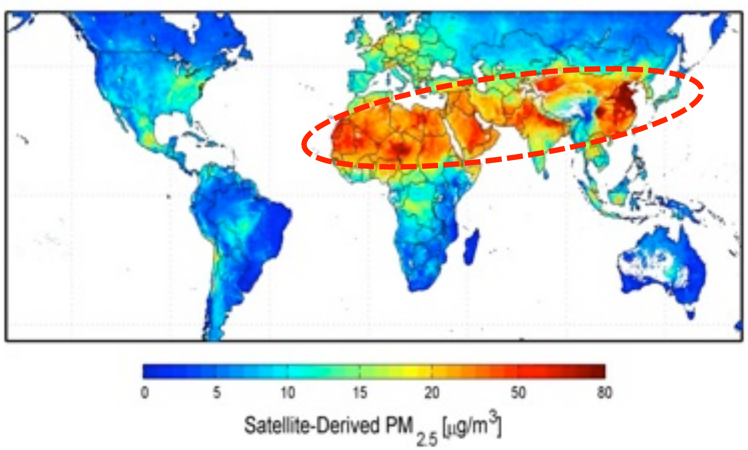
Phase 4: 2010—

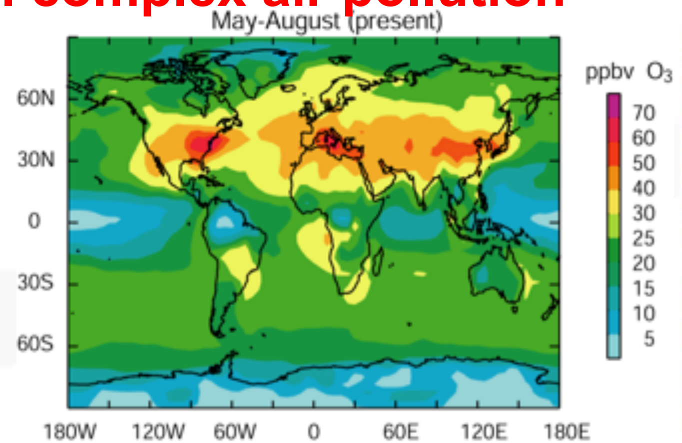


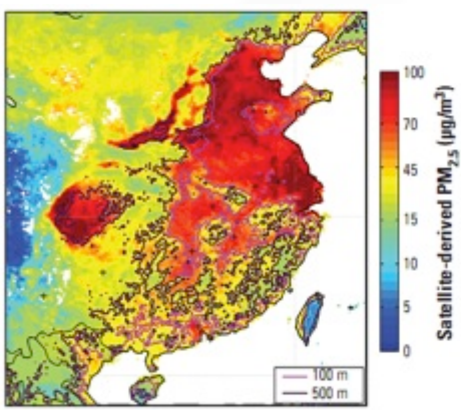
He Kebin, Zhang Qiang etc.

Emission of multi pollutants

Regional complex air pollution







van Donkelaar et al., *Environmental Health Perspectives* 2010

van Donkelaar et al., 2010

- High concentration of PM$_{2.5}$
- High PM$_{2.5}$/PM$_{10}$
- High SOA in PM$_{2.5}$
- Low visibility

- High O$_3$
- High atmosphere oxidability

- City centered regional pollution

Integrate SO_2 and NO_X Emission into the Obligatory Targets in the 12th FYP

	SO2 (million tons)	NOx (million tons)
Emission in 2010	22.08	21.57
Projected increment emission (2010-2015)	4.17	5.34
Increased emission reduction capacity (2010-2015)	5.97	7.6
Proportion of emission reduction (2010-2015)	8%	10%

Environment Standards Optimized, Industries Upgraded and Emission Limits

Evolution of emission standards of China's coal-fired power plants

1996
China
SO_2:1200-2100mg/m^3
NOx:650-1000mg/m^3
PM: 200mg/m^3

2003
China
SO_2: 400-1200mg/m^3
NOx:450-1000mg/m^3
PM: 50mg/m^3

2011
China
SO_2:200mg/m^3
NOx:100-200mg/
PM: 30mg/m^3

Ambient Air Quality Standards (GB3095-2012）

Attachment

ICS 13.040.20
Z 50

National Standard of the People's Republic of China

GB 3095—2012
Replace GB 3095—1996 GB 9137—88

Ambient air quality standards

This electronic edition is a release version. Please subject to the formal standard text published by China Environmental Science Press.

Released on Feb. 29, 2012 Effective as of Jan. 1, 2016

Ministry of Environment Protection
The State Administration of Quality Supervision, Inspection and Quarantine

Table 1 Concentration Limits of Basic Ambient Air Pollutants

SN	Pollutants	Average time	Concentration Limit		Unit
			Level 1	Level 2	
1	Sulfur dioxide (SO_2)	Yearly Average	20	60	μg/m³
		Daily average	50	150	
		Hourly average	150	500	
2	Nitrogen dioxide (NO_2)	Yearly Average	40	40	
		Daily average	80	80	
		Hourly average	200	200	
3	Carbon monoxide (CO)	Daily average	4	4	μg/m³
		Hourly average	10	10	
4	Ozone (O_3)	Average maximum in 8 hrs per day	100	160	μg/m³
		Hourly average	160	200	
5	Particulate matter (grain size less than	Yearly Average	40	70	
	or equal to 10 um)	Daily average	0	150	
6	Particulate matter (grain size less than or equal to 2.5 um)	Yearly Average	15	35	
		Daily average	35	75	

Table 2 Concentration Limits of Other Ambient Air Pollutants

SN	Pollutants	Average time	Concentration Limit		Unit
			Level 1	Level 2	
1	Total suspended particulates (TSP)	Yearly average	80	200	μg/m³
		Daily average	120	300	
2	Nitrogen oxide (NO_x)	Yearly average	50	50	
		Daily average	100	100	
		Hourly average	250	250	
3	Lead (Pb)	Yearly Average	0.5	0.5	
		Quarterly average	1	1	
4	Benzo-a-pyrene (BaP)	Yearly Average	0.001	0.001	
		Daily average	0.002 5	0.002 5	

Four strategic Turning Points

Objective	Pollutants	Focus	Scale
emissions	Coal fired	industry	local
↓	↓	↓	↓
Air quality	Multi -pollutants	Multi -sources	regional

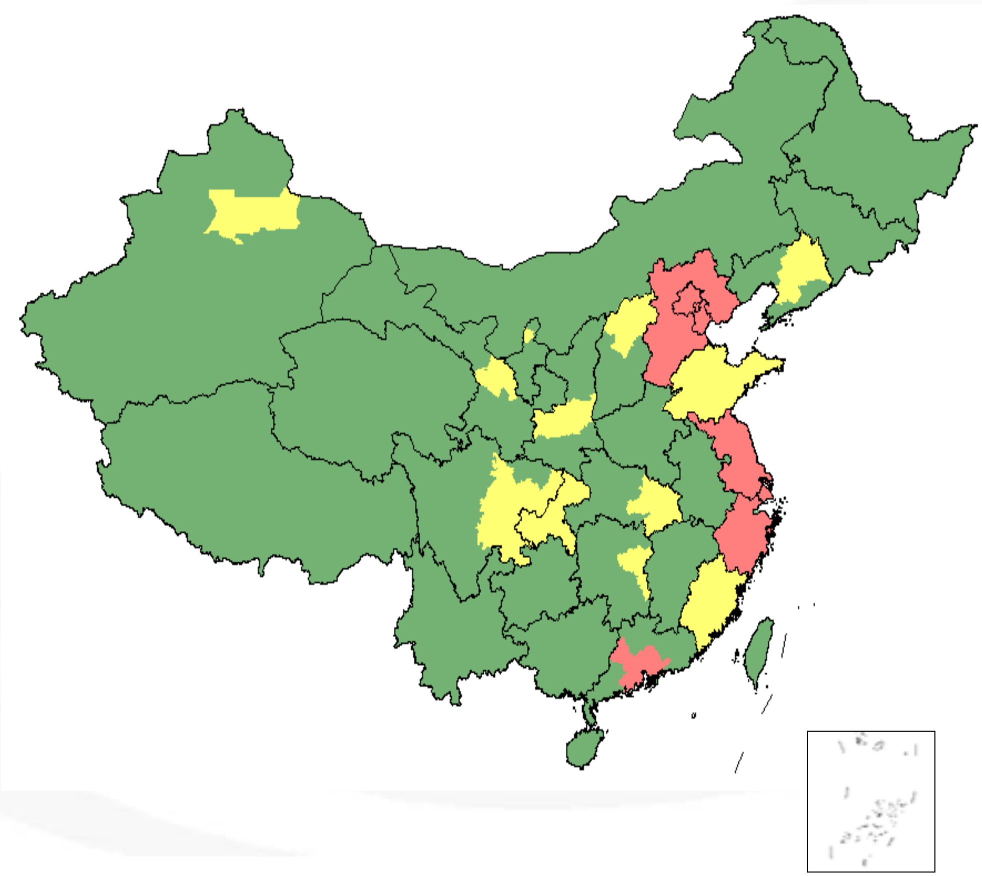
- **Milestones:**

  two critical documents issued by State Council

  ✓ **2012, the *12th FYP on air pollution control for key regions* heralds the four turning points for the first time.**

  ✓ **2013, the *action plan of air pollution control* indicates a new air quality management after the four turning points.**

The 12th FYP on Air Pollution Control for Key Regions



3 regions and 10 city clusters

1. Beijing-Tianjin-Hebei
2. Yangzi river delta
3. Pearl river delta
4. Middle Liaoning
5. Shandong
6. Wuhan region
7. Changsha-Zhuzhou-Xiangtan
8. Chengdu-Chongqing
9. The west coast of the Taiwan Straits
10. North Shanxi
11. South Shaanxi
12. Gansu-ningxia
13. Urumuqi

- Totally 13 regions, including 19 provinces, 117 cities, 1.3256 km2
- Emission intensity is 2.9-3.6 times higher than national average
- 82% cities are non-attainment, according to the new air quality standard
- Complex air pollution, including $PM_{2.5}$、 O_3

Planning Targets of Key Regions

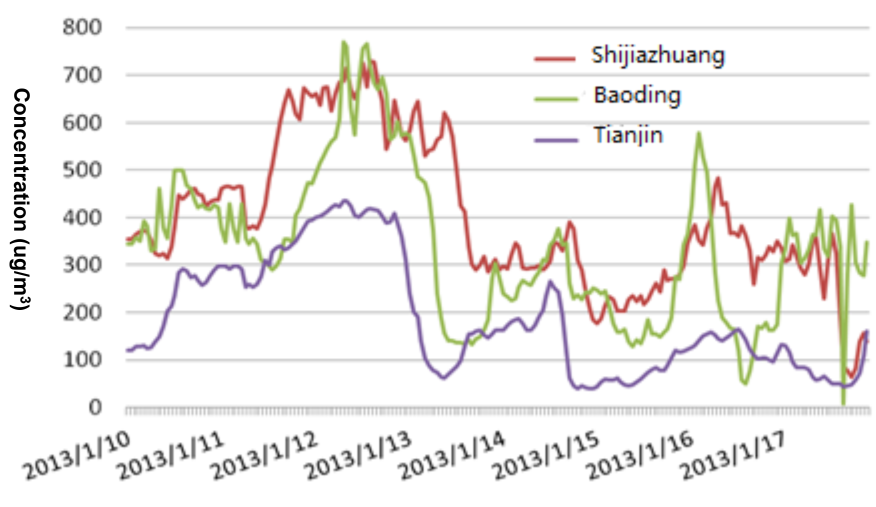
Focus on both emission reduction and air quality

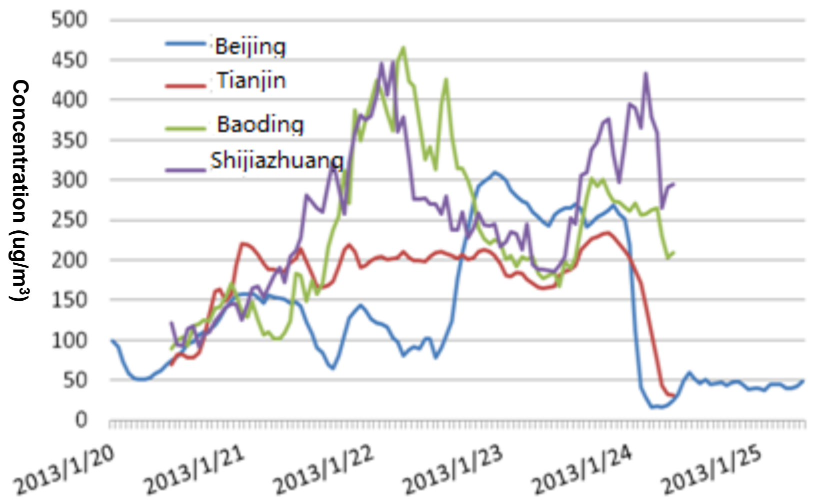
Category		Index	Value
Air quality	1	Annual SO_2 reduction	10%
	2	Annual NO_2 reduction	8%
	3	Annual PM_{10} reduction	10%
	4	Annual $PM_{2.5}$ reduction	5%
	5	O3 non-attainment days reduction	5%
Emission control	6	SO_2 emission reduction	12%
	7	NO_x emission reduction	13%
	8	Dust emission reduction	10%
	9	VOCs emission reduction (key sectors)	14%

China Regional Haze Pollution Episodes

Jan. 2013: features

1300 thousands km2	In some region, it lasts 3 weeks	PM2.5 concentration is higher than the instrument max	850 million people exposed





Action Plan on Prevention and Control of Air Pollution

or 10 measures from the State Council:

Breakthrough in AQ management

Objectives and principals

1. **Accelerate AQ improvement:** An enhanced plan based on current 12th FYP to make greater change

2. **Highlight the key regions:** Higher target for key regions (Beijing-tianjin-Hebei, YRD, PRD)

3. **Differentiate the priorities:** $PM_{2.5}$ for the key regions, and PM_{10} for the other

Top-level Design at the Height of National Strategy

Objectives:

After 5 years of commitment, the number of days under heavy pollution would be significantly reduced, nationwide air quality would be improved, air quality in Beijing-Tianjin-Hebei, YRD, PRD and other regions would be evidently improved.

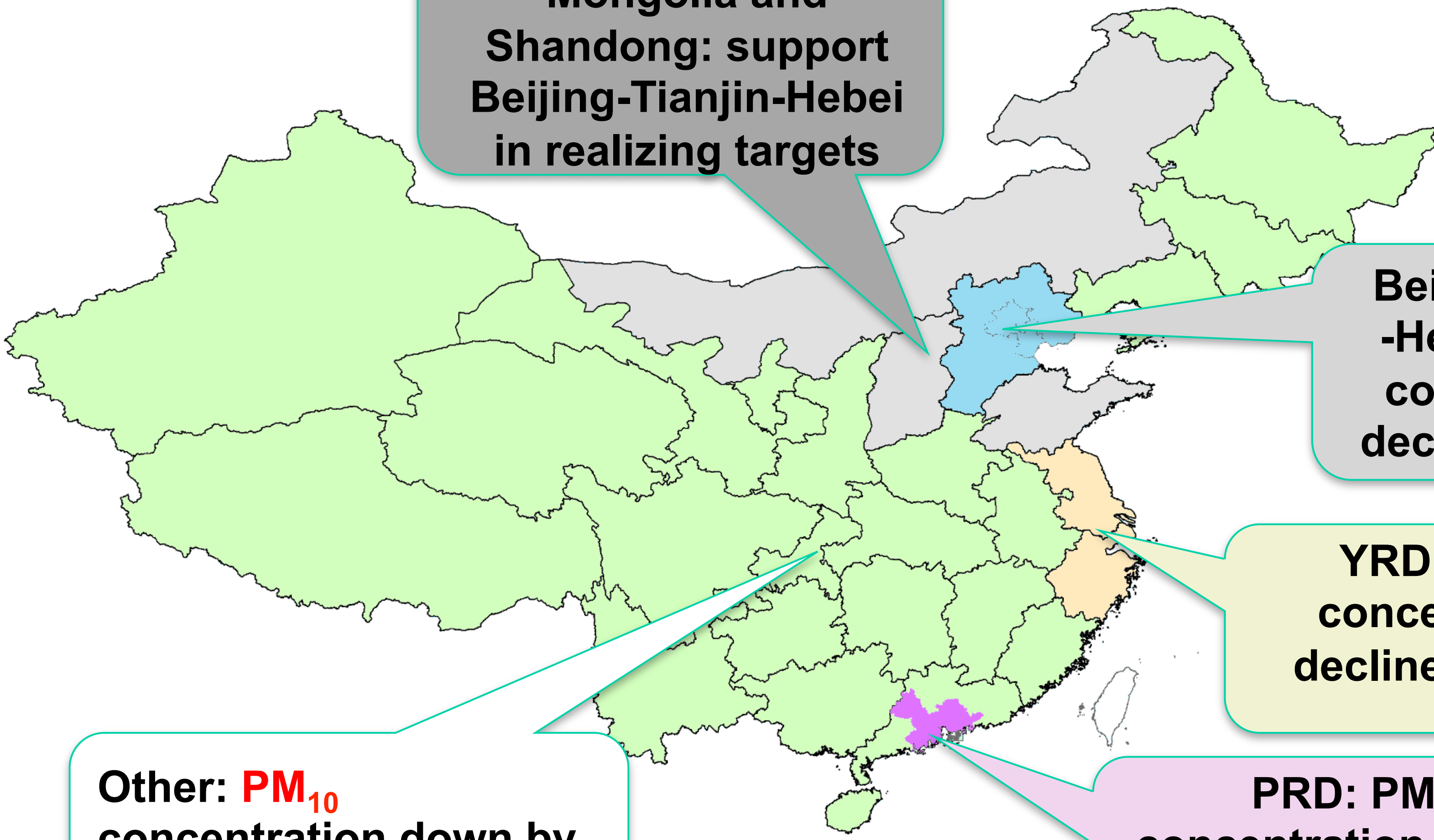
Heavy pollution weather would be basically eliminated and nationwide air quality evidently improved in another 5 years.

Indicators:

by 2017, PM_{10} concentration in prefecture cities and above across the country would be down by more than 10% based on the 2012 level and the number of fine days would be increased year by year.

Concentration of PM in Beijing-Tianjin-Hebei, YRD, PRD and other regions would decrease by more than 25%, 20%, and 15% respectively based on the 2012 level, and average annual concentration of PM would be controlled at about 60μg/m3 in Beijing.

Region-Cased Control



Shanxi, Inner Mongolia and Shandong: support Beijing-Tianjin-Hebei in realizing targets

Beijing-Tianjin -Hebei: PM2.5 concentration declines by 25%

YRD: PM2.5 concentration declines by 20%

PRD: PM2.5 concentration declines by 15%

Other: PM_{10} concentration down by 10%

Important Factors of Air Pollution: 1. Accelerate industrial restructuring

Compliance of SO_2, NO_X, smoke and dust, VOCs emission with requirements becomes the precondition for approving environmental assessment

Strengthen the standards for environmental protection, energy consumption and quality, and facilitate the exit of overcapacity of high energy consumption and pollution industries

Fulfill the task of eliminating backward capacity of 21 key industries during the 12th FYP period one year ahead of schedule

Important Factors of Air Pollution: 2. Speed up clean energy utilization

Optimize energy structure

- By 2017, the proportion of coal nationwide should be declined to less than 65%; coal consumption in Beijing-Tianjin-Hebei, YRD and PRD would witness negative growth

Promote clean coal utilization

- By 2017, the selection rate of raw coal would reach more than 70%; scattered raw coal combustion would be reduced

Increase clean energy supply

- More than 150 billion m^3 of natural gas pipeline transportation capacity would be newly added

Important Factors of Air Pollution: 2. Speed up clean energy utilization

If newly-added 150 billion m3 natural gas supply would be used to replace some coal consumption of coal-burning industrial boilers, it's expected to reduce emission of 3.59-5.79 million tons of SO_2, 0.6 to 1.6 million tons of NOx, 1.34-2.72 million tons of smoke.

Emission factors				Remarks
	SO_2	NO_x	PM	
Coal-burning industrial boiler (kg/t)	10-16	3-5.7	3.8-7.5	
Gas-fired industrial boiler (kg/10k·m^3)	5.53	33.15	2.21	New standard for gas-fired industrial boiler

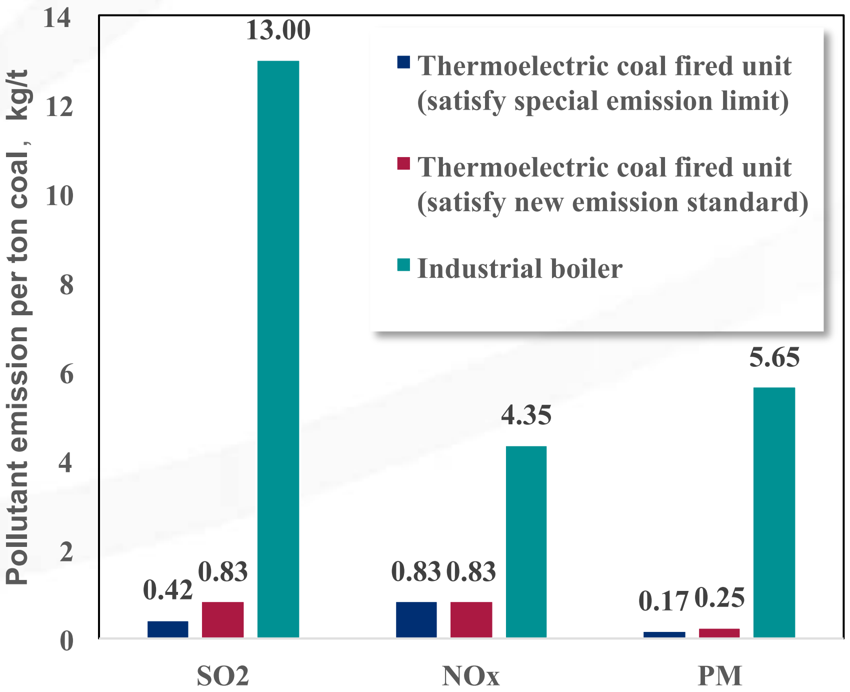
Important Factors of Air Pollution: 2. Speed up clean energy utilization

Replacing coal-burning industrial boiler with CHP shows evident emission reduction.

According to equivalent replacement principle, if CHP boiler replaces some small industrial boiler (according to measurement, coal consumption of coal-burning industrial boiler below 20t/h is 266 million tons)

◆When CHP boiler reaches new emission standard (GB 13223-2011), emission of 2.48-4.08 million tons of SO_2, 0.62 to 1.34 million tons of NOx, 0.95 to 1.94 million tons of dust would be reduced;

◆When CHP boiler reaches special emission limit value (GB 13223-2011), emission of 2.57-4.16 million tons of SO_2, 0.62 to 1.34 million tons of NOx, 0.97 to 1.95 million tons of dust would be reduced.



Important Factors of Air Pollution: 3. Tighten vehicle emission control

Control vehicle population in metropolises

Beijing, Shanghai, Guangzhou and other megacities strictly limit vehicle population

Improve fuel oil quality

By the end of 2015, major cities in Beijing-Tianjin-Hebei, YRD, PRD and other regions would supply vehicle-use gasoline and diesel oil with the sulphur content no more than 10ppm; by the end of 2017, vehicle-use gasoline and diesel oil with the sulphur content no more than 10ppm would be supplied across the country.

Rapidly eliminate yellow label cars

By 2015, 5 million yellow label cars in Beijing-Tianjin-Hebei, YRD, PRD and other regions would be basically eliminated. By 2017, yellow label cars across the country would be basically eliminated.

Important Factors of Air Pollution: 3. tighten vehicle emission control

Enhance management of vehicle environment protection

Tighten annual inspection of in-use vehicles, Non-compliance vehicles on the environmental protection qualification label are not allowed to drive on roads.

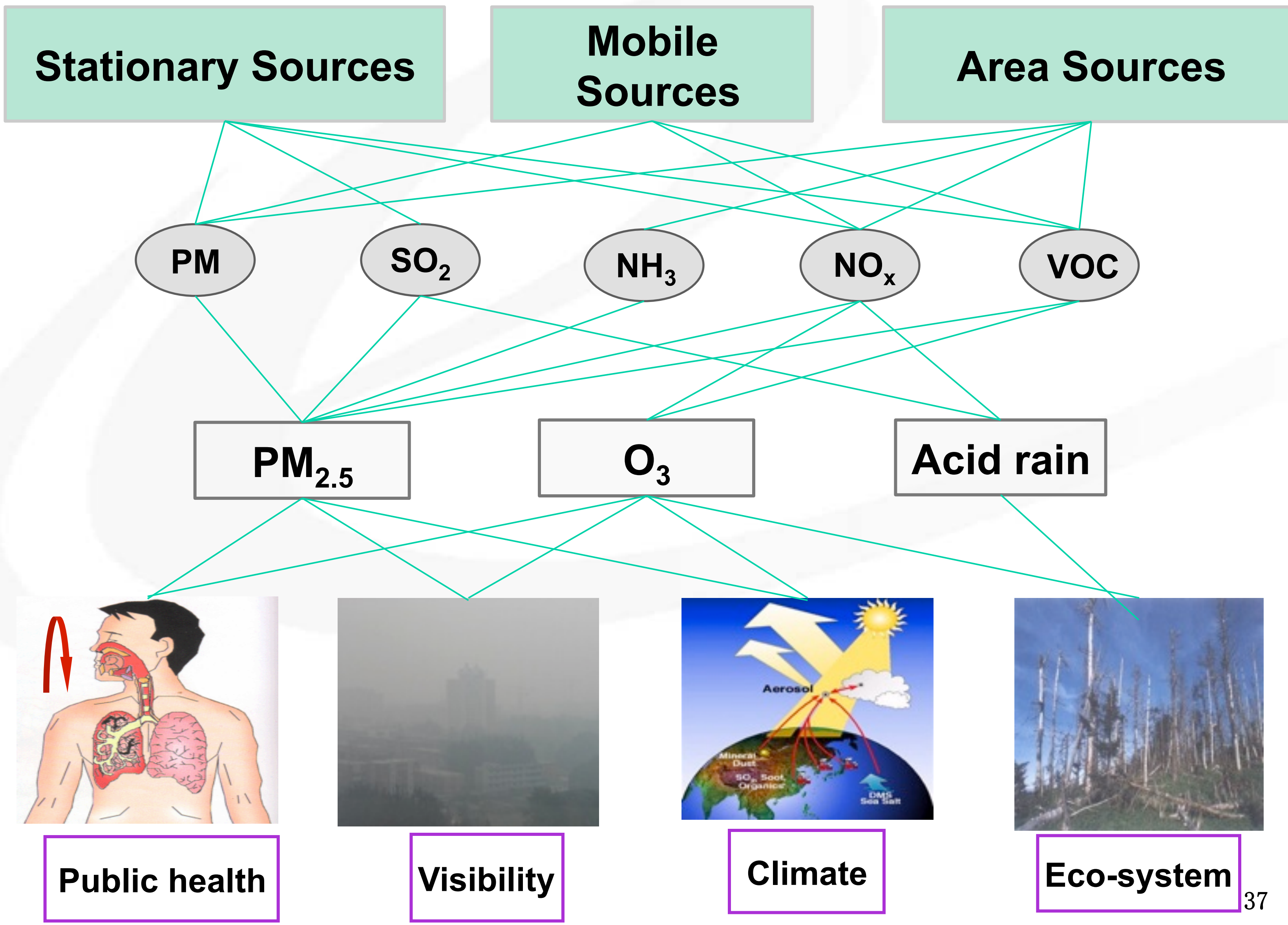
Accelerate the upgrading and replacement of low speed ve

From 2017, new low-speed trucks shall meet the same energy saving and emission standard as light trucks.

Vigorously promote new energy vehicles

Bus, sanitation, and other industrial and governmental departments shall take the lead in using new energy vehicles. Personal purchase shall be encouraged. Beijing and other cities would increase or replace more than 60% of new energy and clean fuel buses in total buses.

Co-control of Multi-pollutants



Regional Coordination Mechanism in Beijing-Tianjin-Hebei and YRD

Departments of the State Council

Provincial governments

- Address evident regional environmental issues in a coordinated manner
- Organize environmental assessment conference, joint law enforcement by environmental and other departments, information sharing, early warning and emergency treatment, among other works
- Report on work progress
- Clearly define periodical work requirements, priorities and major tasks.

Special Requirements for Beijing-Tianjin-Hebei

Beijing-Tianjin-Hebei + Shanxi-Inner Mongolia-Shandong

Pollution control requirements higher than national average

Tightened elimination of backward productivity of iron & steel, cement and other industries

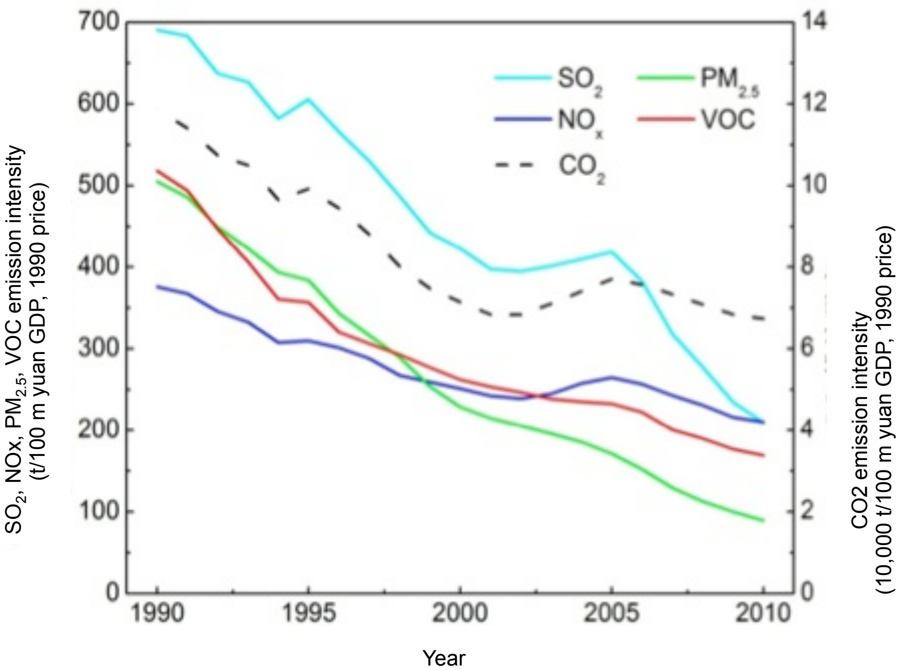
Reduction in coal consumption by **83 million tons**

Strengthen joint control and supervision and evaluation mechanism

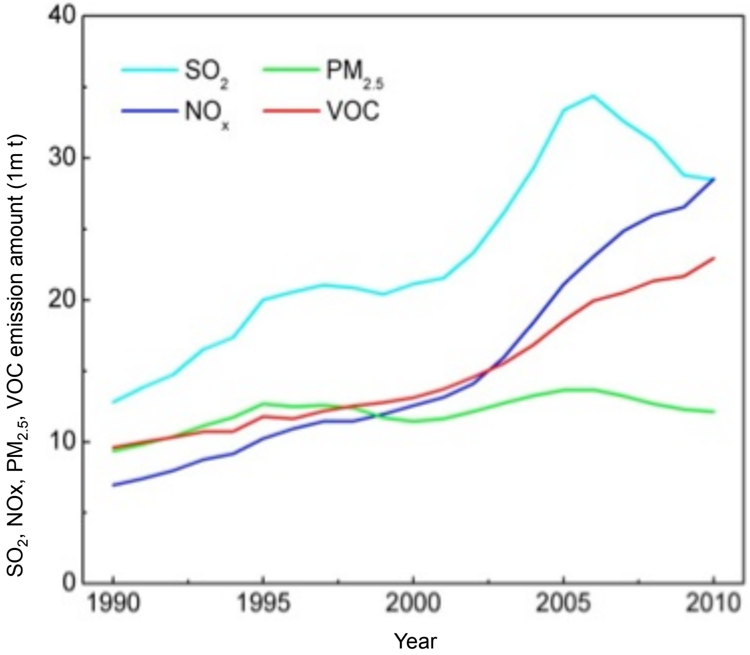
Air pollution control in China:
Perspectives

Emission Reduction of Multiple Pollutants

Emission intensity per unit GDP (100 million)



Total emission amounts



Requiring Great Efforts to Achieve Goals

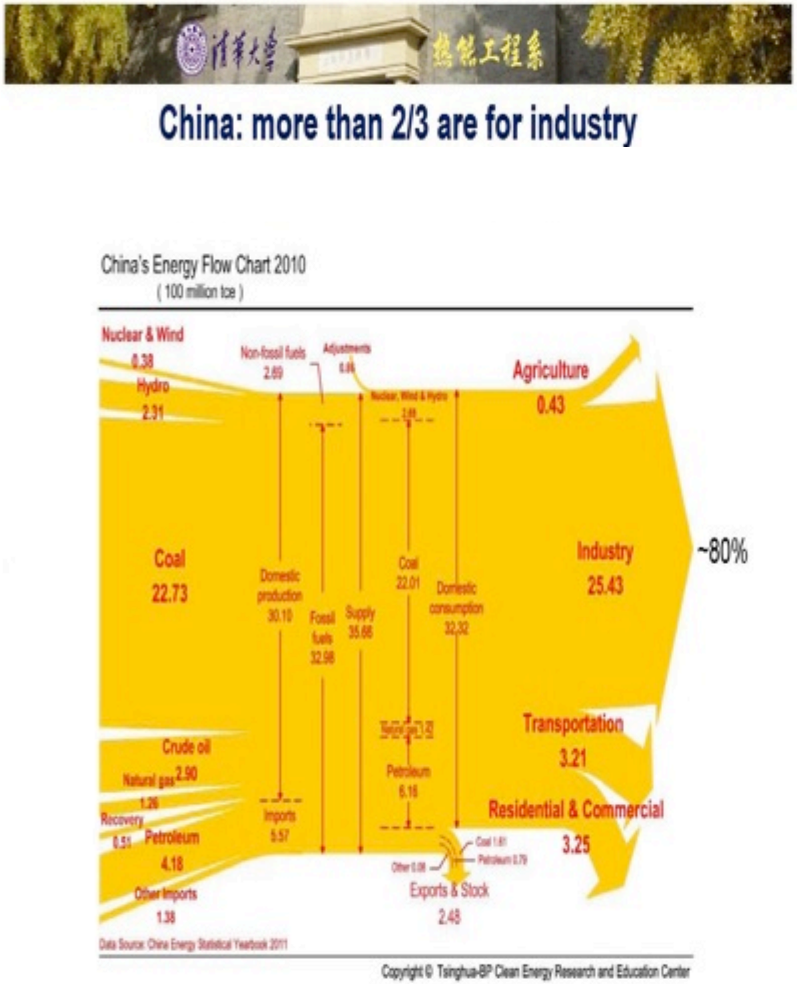
- **In order to achieve targets, the degree of emission reduction of multiple pollutants is much larger than ever.**

Comparison of percentage of pollutants emission reduction targets

	SO_2	NO_X	PM	VOCs
(To guarantee) action plan	>15%	>20%	>20%	>7%
12^{th} FYP	>8%	>10%	N/A	N/A
11^{th} FYP	>10%	N/A	N/A	N/A

- **The proportion of emission reduction is higher for three major regions.**

Co-benefit of Energy Saving to Air Pollution Control



Gap between energy consumption of China's industrial products and international advanced level

Unit energy consumption (kgce/t)	China	International advanced level	Gap (%)
Iron & steel	625	550	13.6
Cement	151	118	28.0
Ethylene	1003	629	59.5

- Improve energy efficiency in industrial production
- Enhance materials R&D and management, and reinforce energy efficiency in building sector
- Decrease oil consumption in transportation

Scientific Planning for Urbanization

- **Integrate industrial and energy adjustment requirements into urbanization:** Tighten industrial threshold, control expansion of backward productivity; reinforce infrastructure construction, ensure clean energy supply.

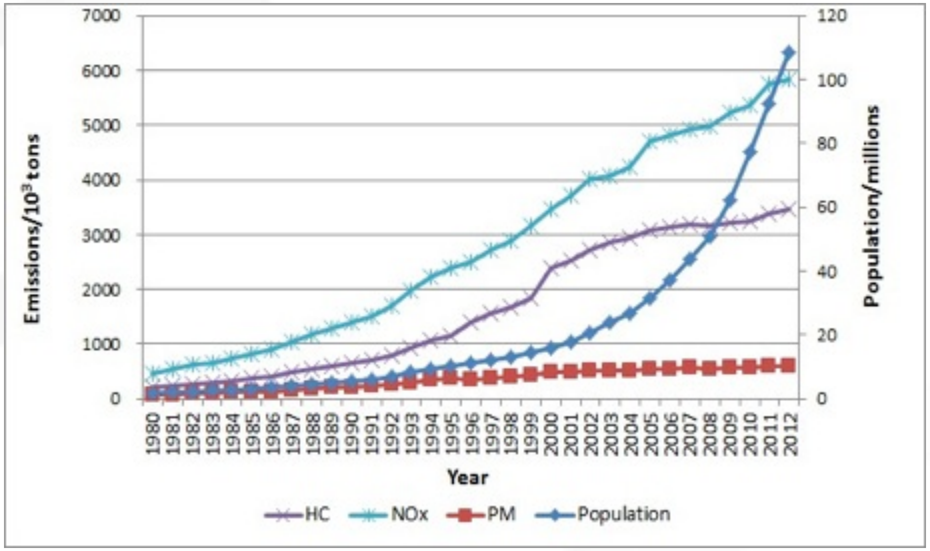
- **Make scientific urban planning:** Reasonably plan the size of cities, remain prudent in developing cities with 10 million population; control urban coal consumption to reduce coal burning pollution.

- **Urban space design:** Optimize transportation system to reduce vehicle pollution.

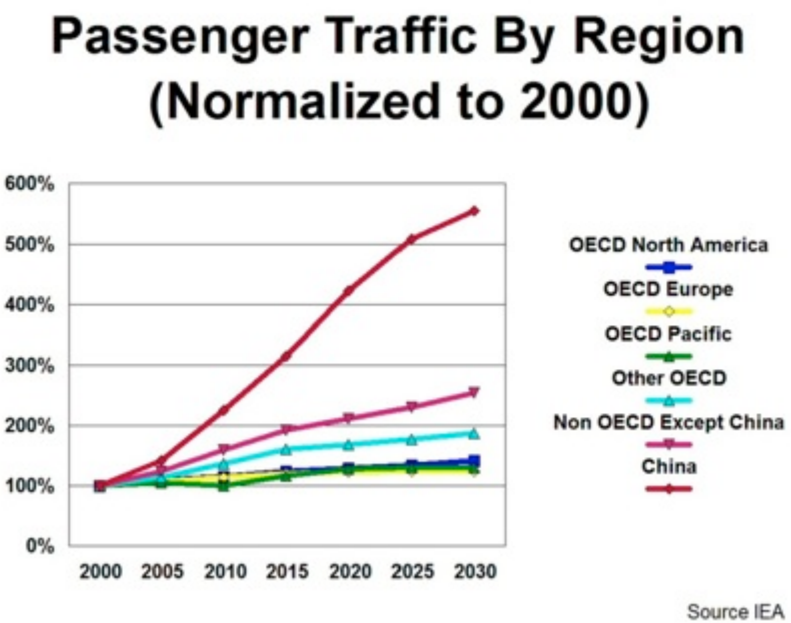
- **O_3 pollution：** Improve O_3 control in key regions along with in-depth PM pollution control.

Mobile Source Pollution Control

- Properly deal with pressure of vehicle population and frequent vehicle utilization
- Actively promote off-road mobile source pollution control

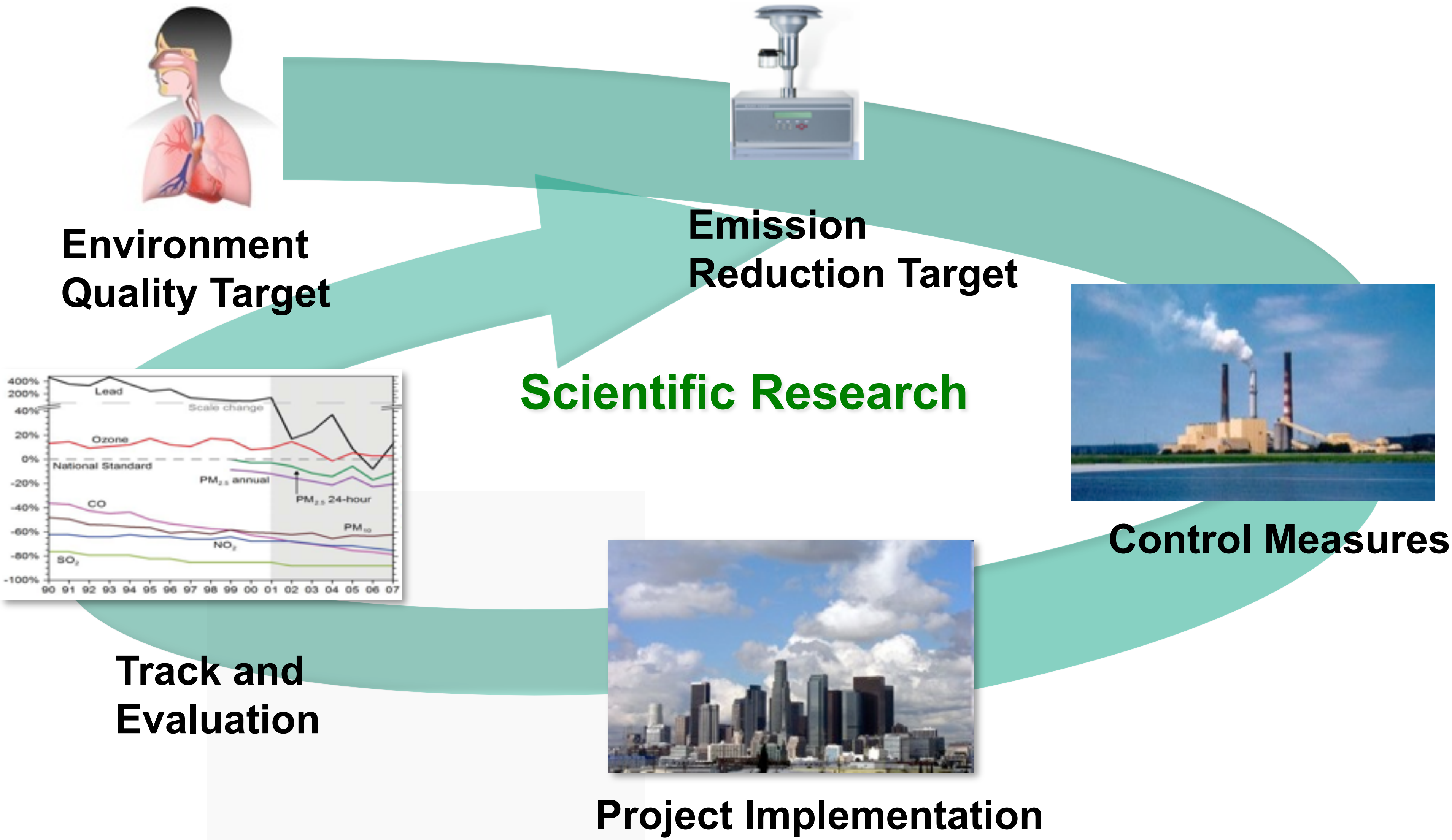


Rapid vehicle increase largely offsets the emission reduction outcome



Traffic demand will greatly increase

Long-term, Constant and Prudent Progressive Commitment



Conclusion: A Long-term Task for Air Control

1. Air pollution is local, regional and global;
2. Improving ambient air quality calls for focusing on primary pollutants and secondary pollutants formed in the air environment;
3. Total emission reduction is more important than concentration control by standards for air pollution control. The emission reduction by 30-50% could help evident air quality improvement;
4. Air quality management needs long-term efforts on sustainable development and improvement. It requires regional coordination and cooperation among governments, enterprises and the public. To get real blue skies, resolve and patience are needed.

Thank You!