Air Pollution Control in China: Progress and Perspectives

Jiming Hao

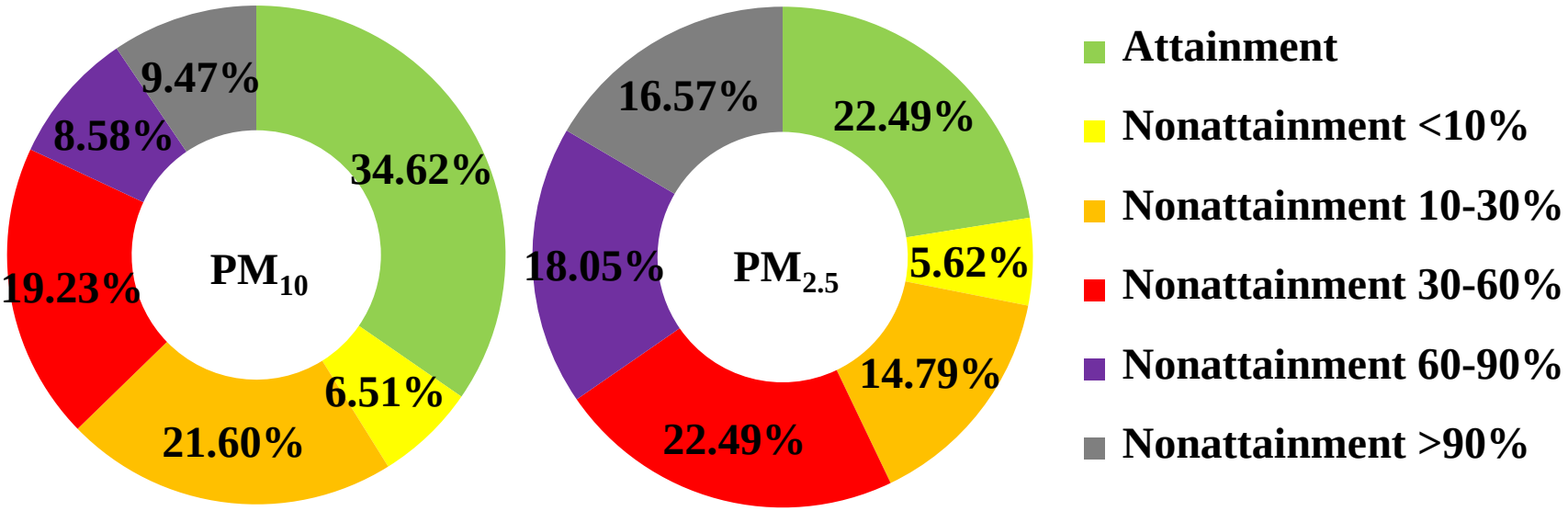
Tsinghua University

May 18, 2016

Outline

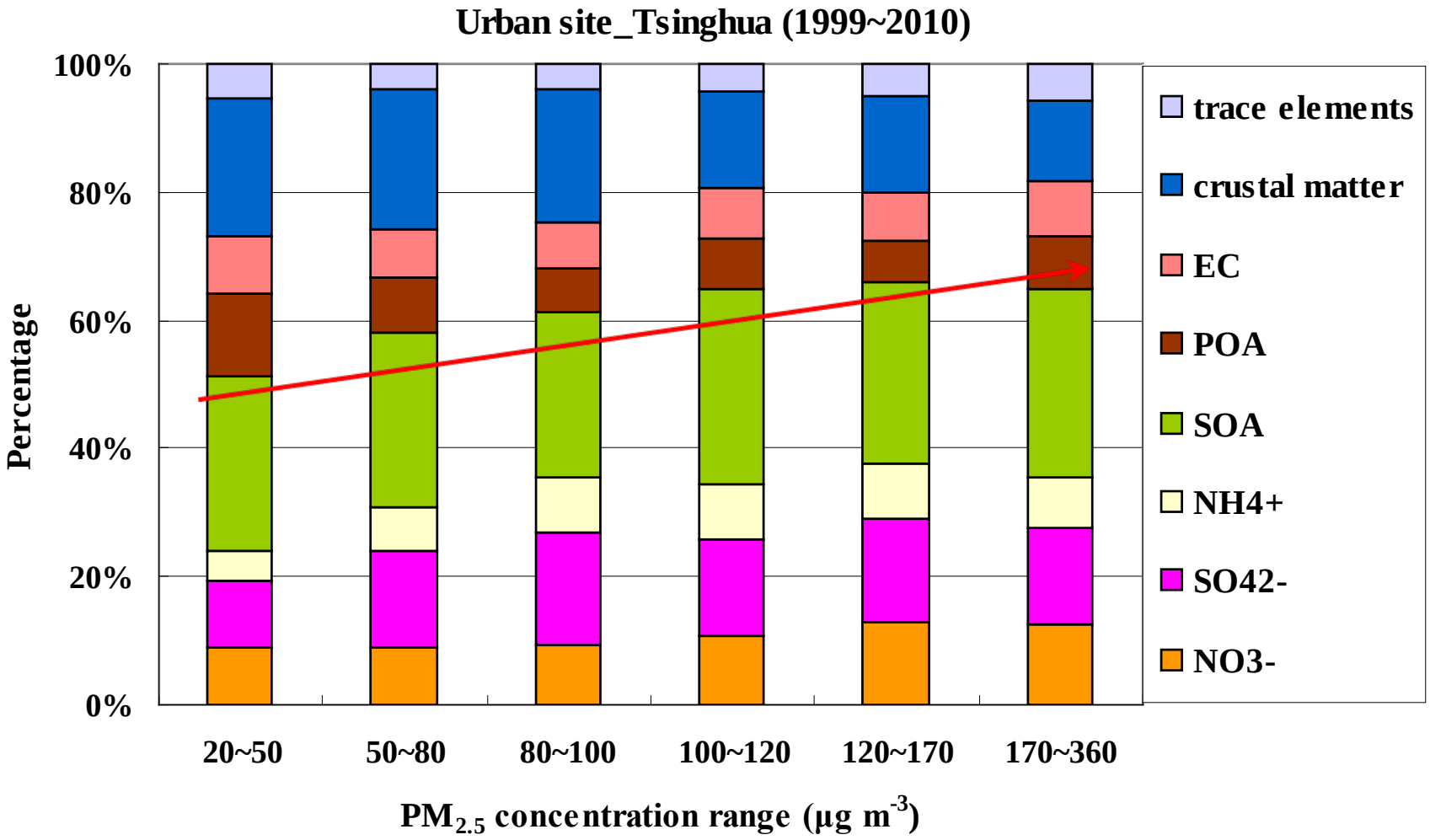
- **Overview of air pollution in China**
- **Progress of air pollution control in China**
  - **Emission and control of transportation**
  - **Emission and control of coal combustion**
  - **Control of air pollution in megacities and regions**
- **Perspectives**

Air pollution in China, 2015



Attainment of PM_{10} and $PM_{2.5}$ in 338 cities

High percentage of secondary PM

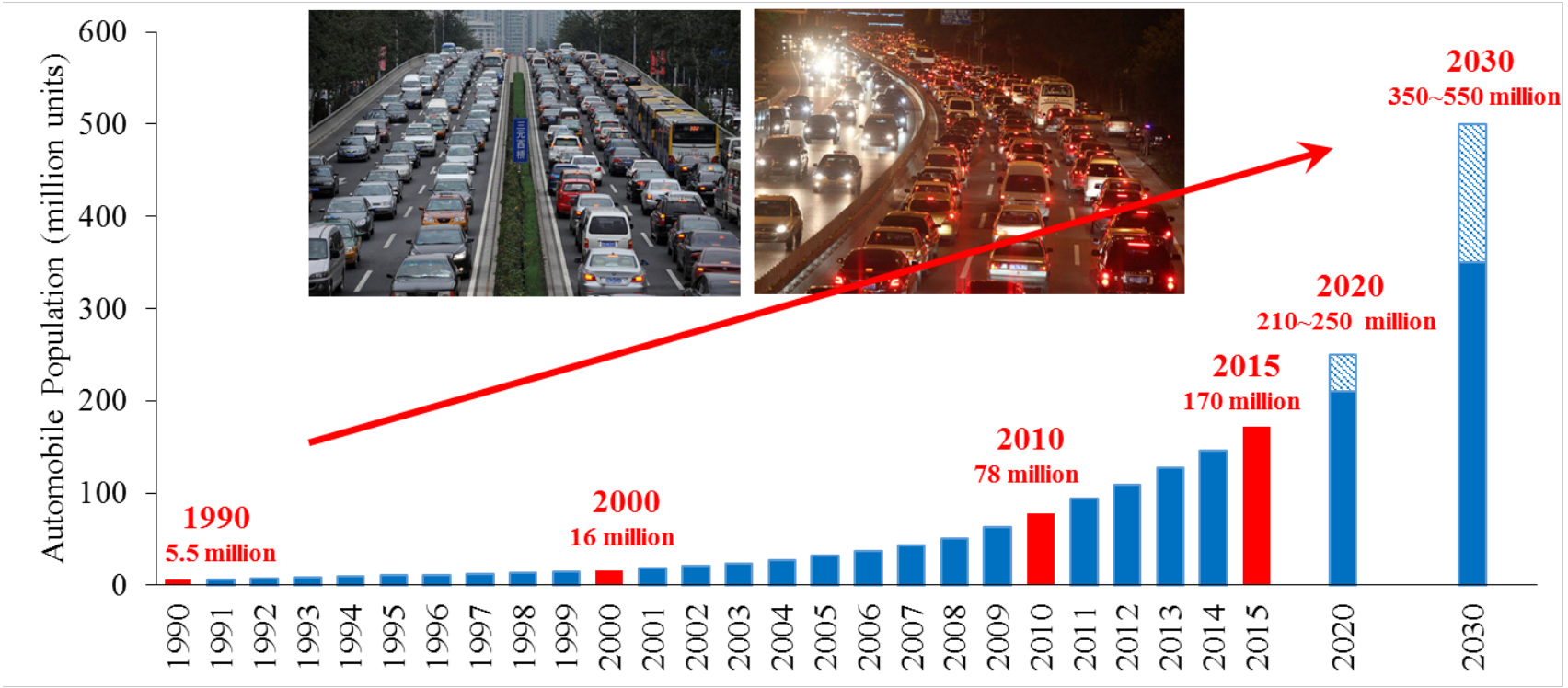


Outline

- Overview of air pollution in China
- Progress of air pollution control in China
  - Emission and control of transportation
  - Emission and control of coal combustion
  - Control of air pollution in megacities and regions
- Perspectives

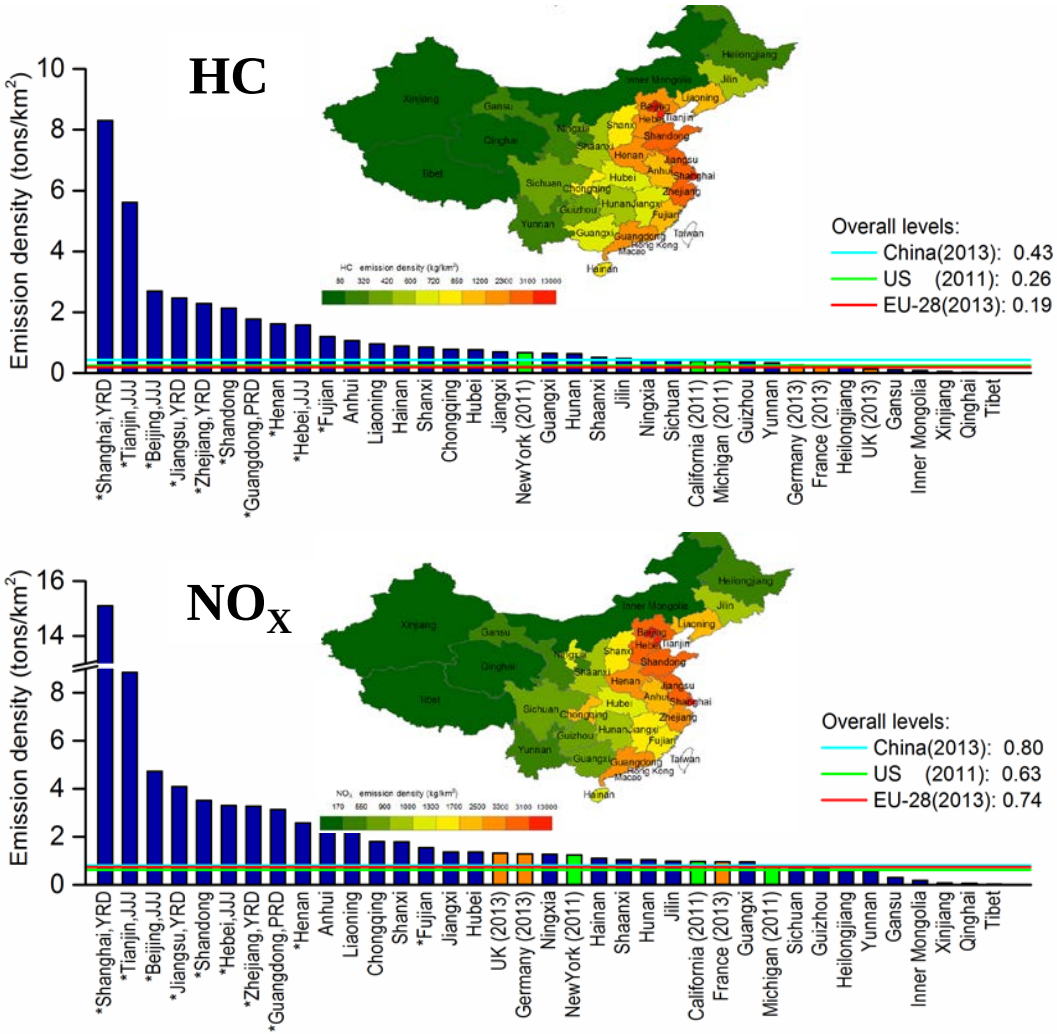
The growth of vehicle population in China, 1990-2030

- In 2009, China became the largest market with the vehicle sales worldwide.
- In 2013, China became the only country with sales of more than 20 million.
- Vehicle population in China will reach 210~250 million in 2020 and 350~500 million in 2030, 20~30 times of the number in 2000.
- China will rank as the No. 1 country in vehicle population before 2025.



East China is the key control area of vehicle emissions

- Vehicle emissions are concentrated in East China, especially in mega cities such as Beijing and Shanghai, due to much dense vehicle population and high travel mileage.
- The vehicle emission density in East China in 2012 is 2.1 and 3.6 ton/km^2 for HC and NO_X, respectively, several times higher than the average in China (0.4/0.8), EU-28 (0.2/0.7) and the U.S. (0.3/0.6).

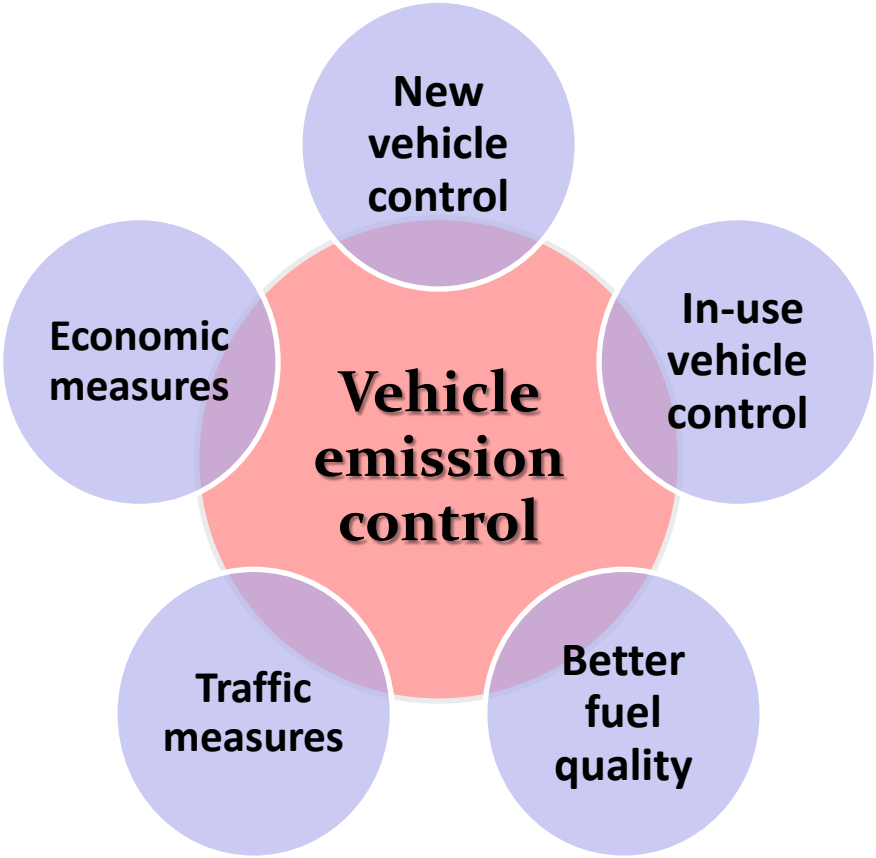


Since mid-1990's, studies on strategies for controlling vehicle emissions have been initiated in China

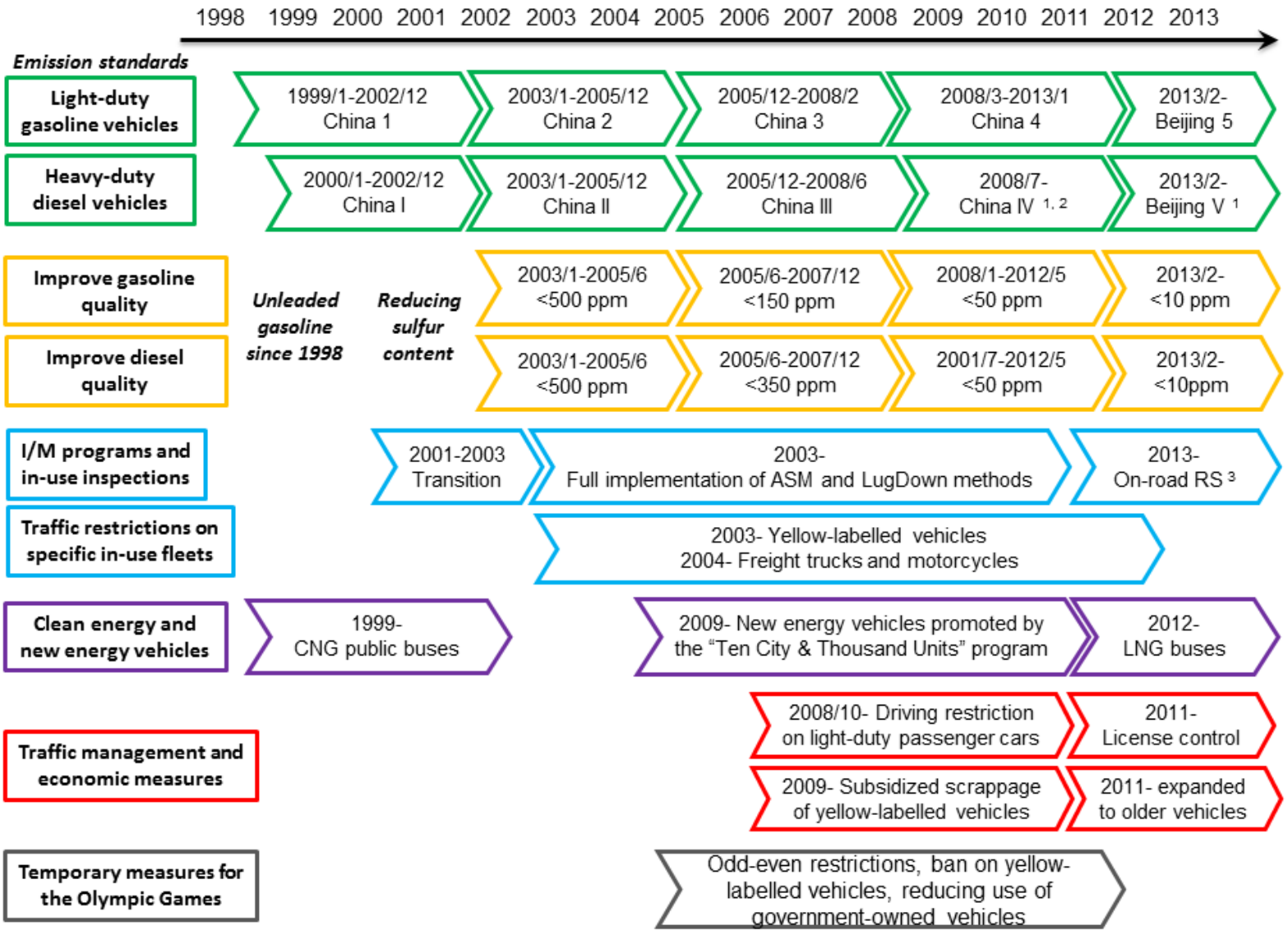
- **At national level, SEPA launched a first-ever comprehensive study in 1994, namely "*China's Strategies for Controlling Motor Vehicle Emissions*" (supported by the World Bank)**
  - ✓**More stringent emissions standards, such as Euro 1 and 2, were targeted for new vehicles.**
  - ✓ **Improvement of fuel quality (e.g., unleaded gasoline, lower sulfur in fuel) was emphasized to go with the same step while new emission standards were phasing in.**
  - ✓ **I/M program was evaluated, and enhanced I/M for typical cities, such as Beijing, was recommended.**
  - ✓**Beijing, the No.1 city in automobile market in China, was suggested to play a key role in controlling vehicle emissions, just like the role of California to the U.S.**

Beijing has been acting as the pioneer in controlling vehicle emissions in China since late 1990s

- **Beijing is the pioneer in controlling vehicle emissions within China, which has compelled the progress of emission and fuel quality standards in the national wide.**
- **A "vehicle-fuel-road" integrated control framework has been developed within the past 15 years.**



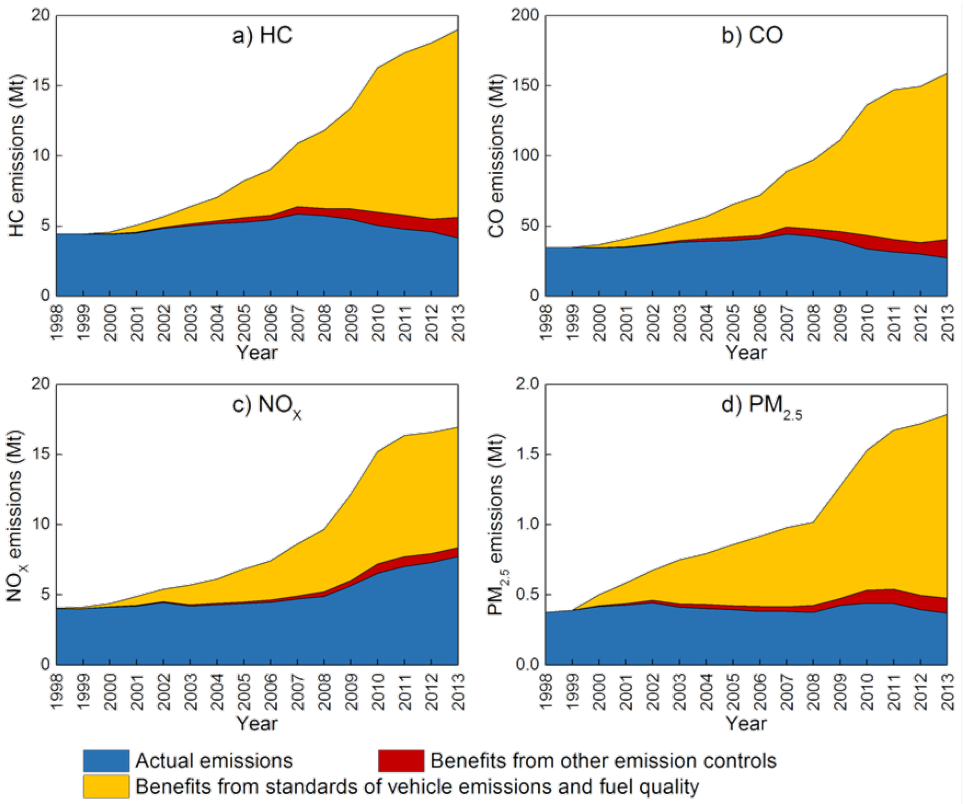
Beijing has been acting as the pioneer in controlling vehicle emissions in China since late 1990s



[1] only implemented for public fleets; [2] for freight trucks and long-distance coaches, they complied with the China IV emission standard from July 2013 as required by the Ministry of Environmental Protection; [3] remote sensing test

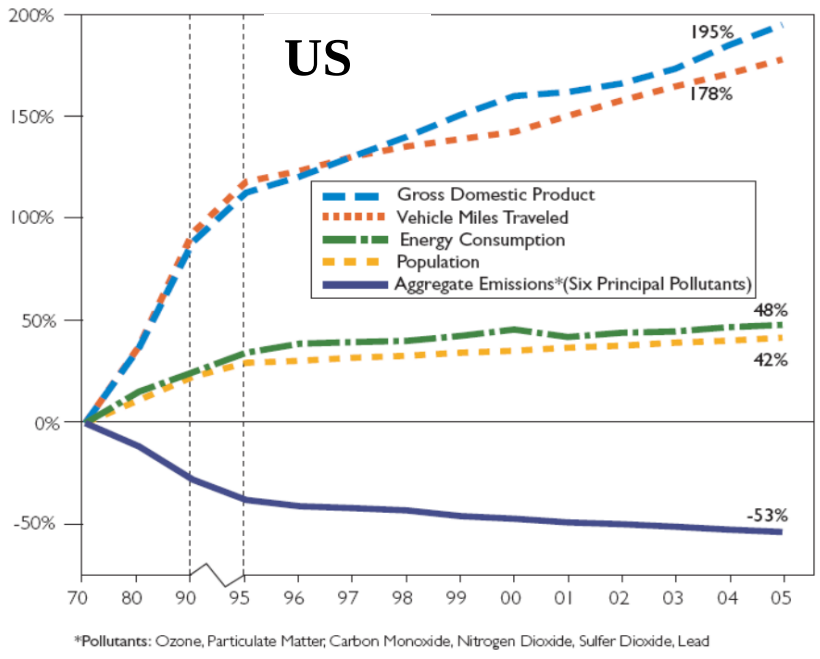
Thanks to the continuous control efforts, China's vehicle emissions started to decline

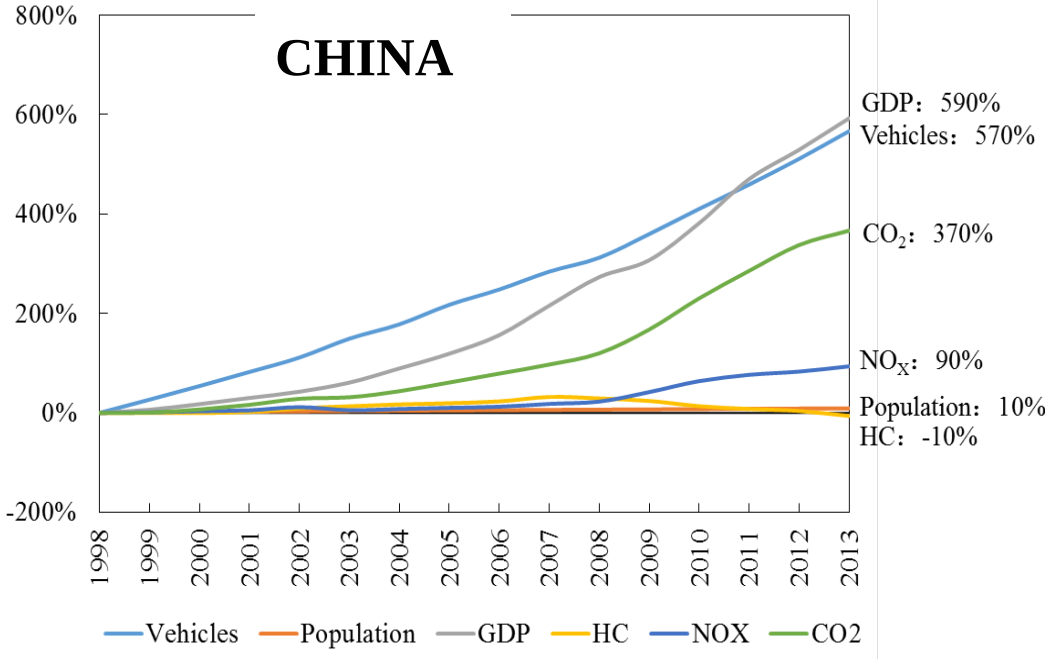
- **Although vehicle population increased by over 500% during the past 15 years, the national vehicle emissions started to decline:**
  - **HC and CO: peak in 2006-2007**
  - **$PM_{2.5}$: peak in 2010-2011**
  - **NO_X: peak in 2013**
- **Vehicle-related emissions in Beijing started to decline much earlier than the national level: peak in 2000-2002.**



Growth in vehicle market in China will continue to post big pressure on air pollutants and CO_2 mitigation

- **The control experience in the U.S. already shows a win-win strategy between developing its economy and protecting the environment, and China is on the right way as the U.S. has done over the past.**
- **In the next 20 years, China needs to push hard, to improve its fuel economy, to mitigate CO_2 and major air pollutant emissions (e.g., NO_X).**

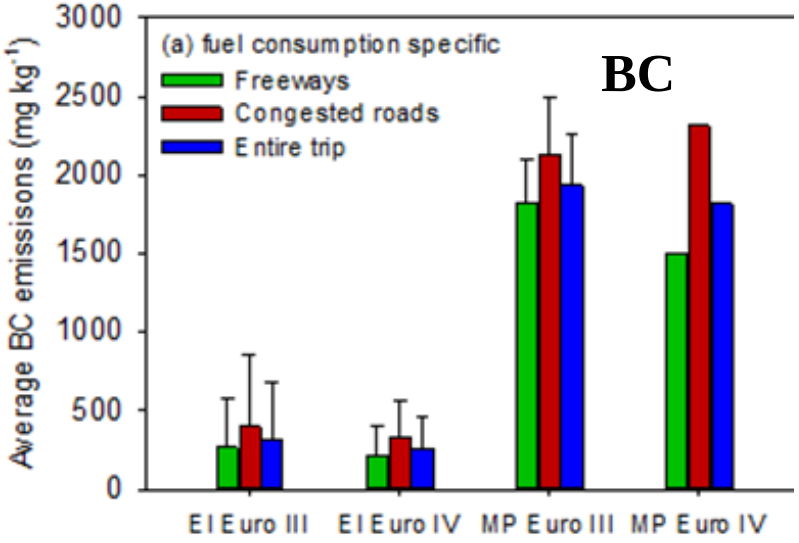


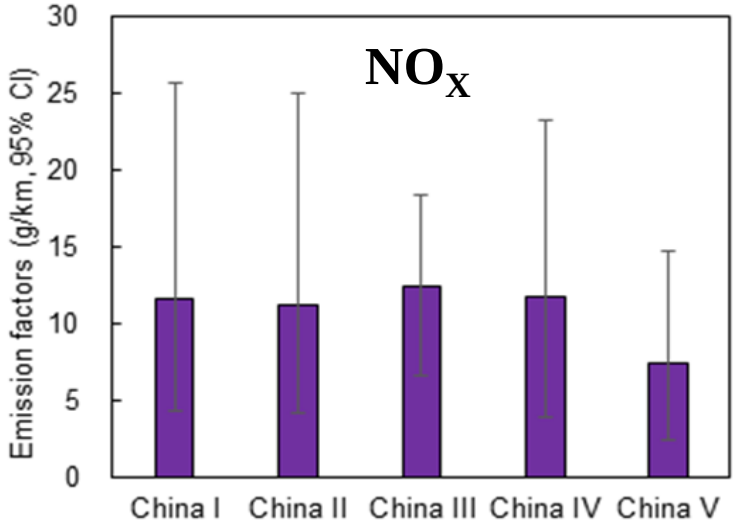


Major challenges and pathways towards future vehicle emission control in China

1) Real-world fuel economy and emission control for vehicles is now an international challenge, and enhancing compliance management and supervision becomes extremely important in China.

- Much higher on-road EC emissions were identified for those "Fake China III/IV" HDDVs with mechanical pump.
- On-road NO_X emission control for HDDVs is not satisfactory both in China and Europe.
- The gap between the on-road fuel economy and certificated fuel economy for cars becomes larger in China, similar like other countries pointed by ICCT.





Major challenges and pathways towards future vehicle emission control in China

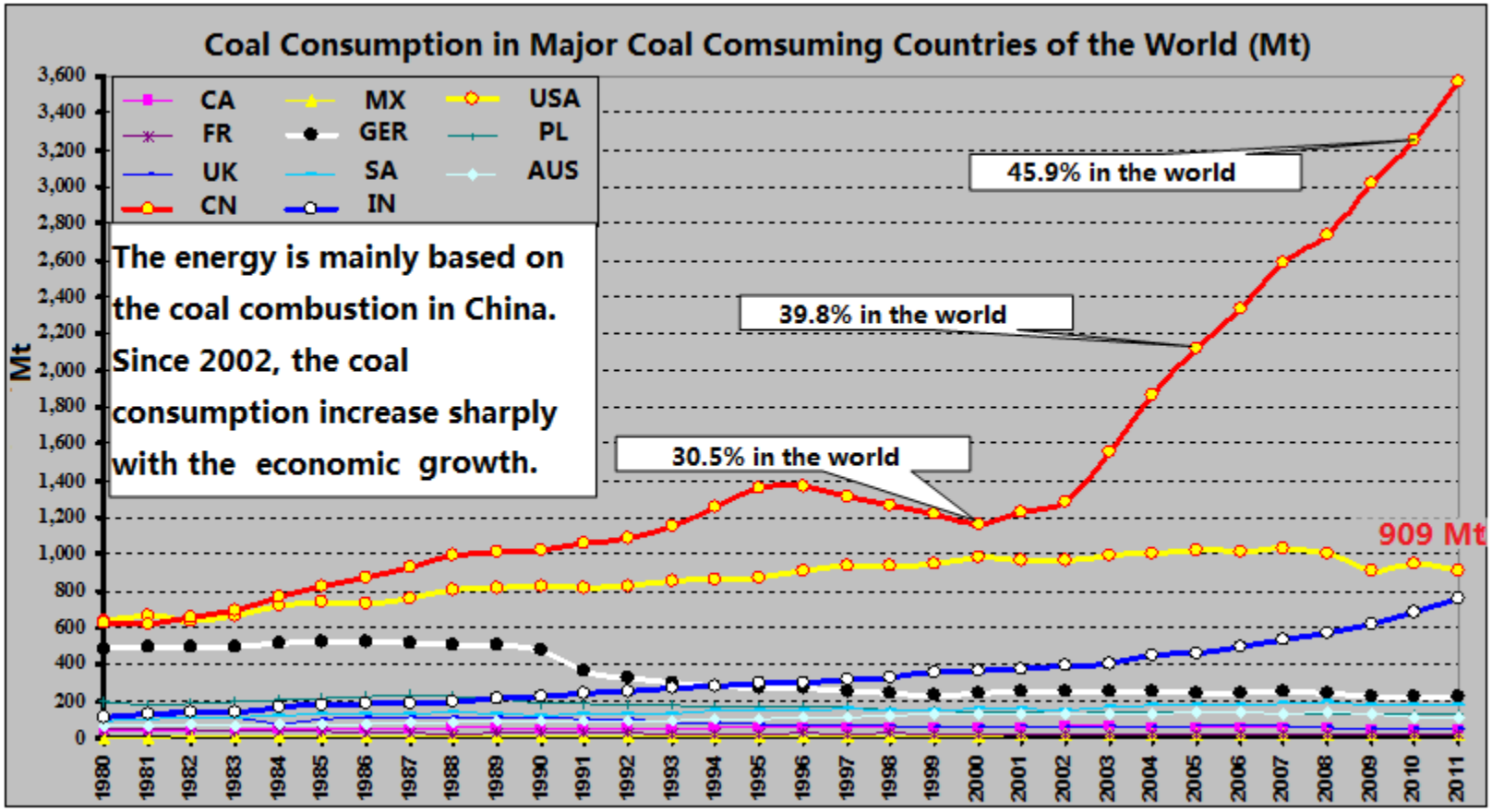
2) Launching the "National Clean Diesel Engine Campaign" to control both on-road and off-road diesel engines becomes very urgent.

- **Require DPF on as many vehicles and engines ASAP.**
- **Require low sulfur fuels for both on and off road applications ASAP.**
- **Mandatory retirement combined with financial and market measures to encourage early elimination of old diesel engines and optimization of the fleet structure.**
- **Shore power facilities intensified and natural gas and other clean energy options favored.**

Outline

- Overview of air pollution in China
- Progress of air pollution control in China
  - Emission and control of transportation
  - Emission and control of coal combustion
  - Control of air pollution in megacities and regions
- Perspectives

The trend of coal consumption in China

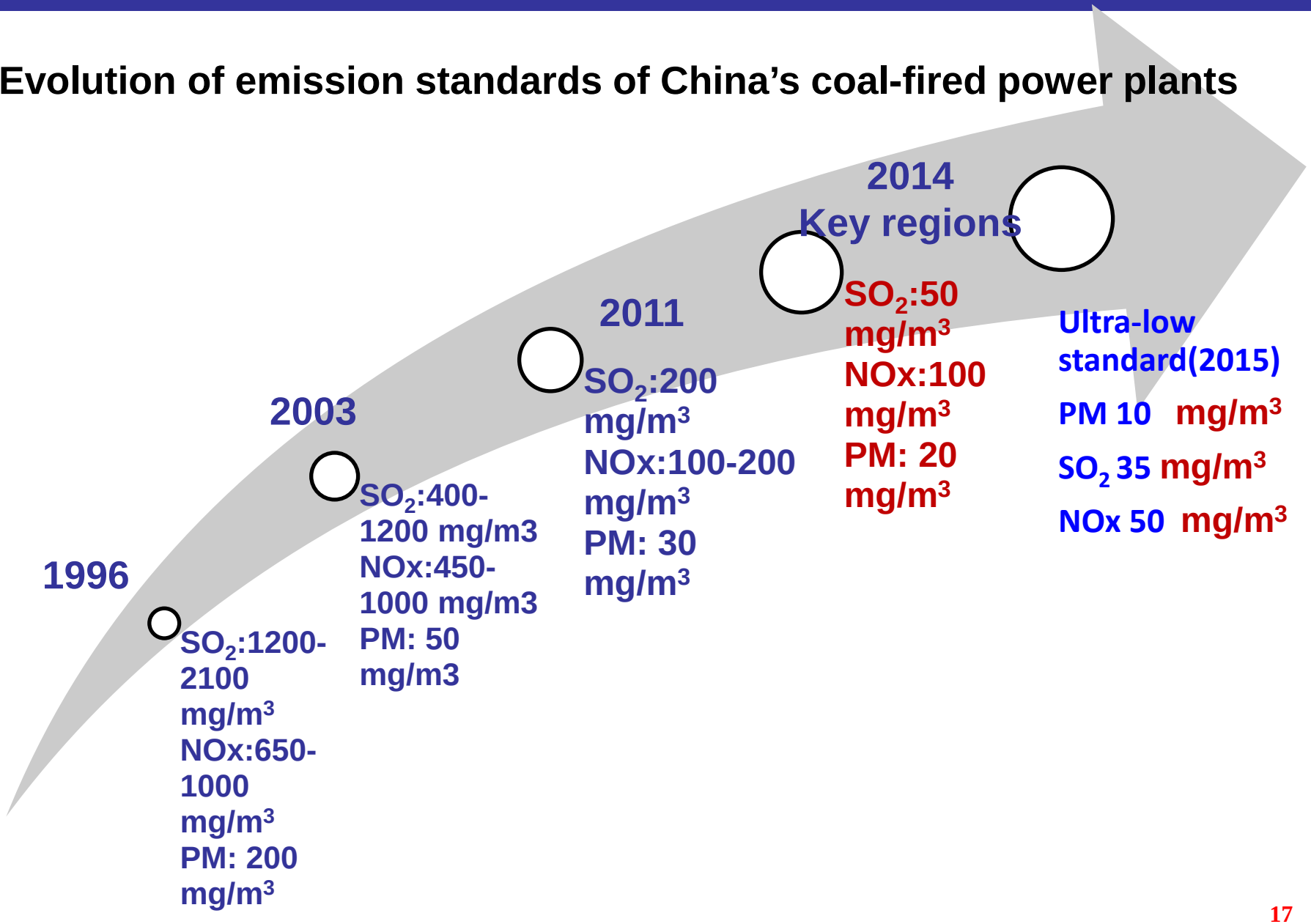


The ratio of coal-based energy in general energy consumption

- **2015, 66%;**
- **2030: 50%;**
- **2050: 30%.**

Tightened Emission Limit Standards

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



The advanced control technology

PM collection

- Compound electrostatic with fabric filter
- low-temperature ESP
- Wet ESP

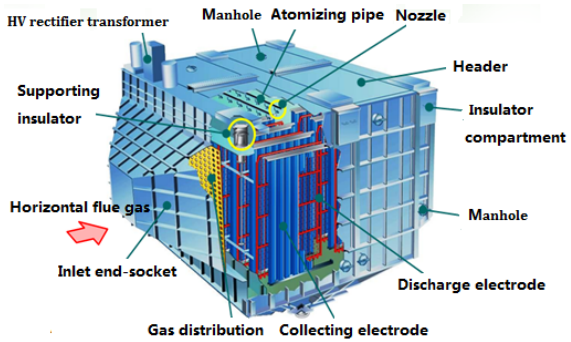
DeSOx

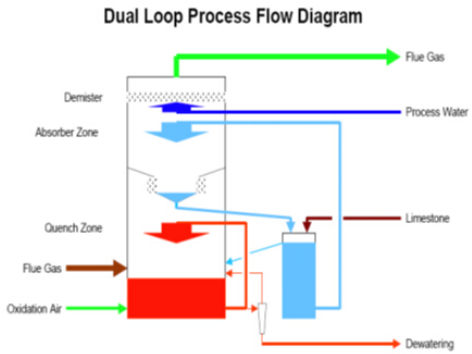
Enhanced FGD ways:

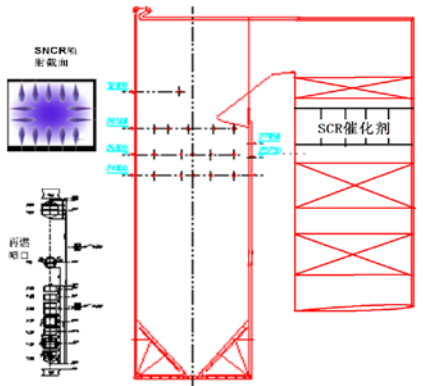
- Twin Tower
- Dual loop process
- High- efficiency absorber and absorbents

DeNOx

- Low NOx Combustion
- Selective Non-catalytic reduction (SNCR)
- Selective catalytic reduction (SCR)

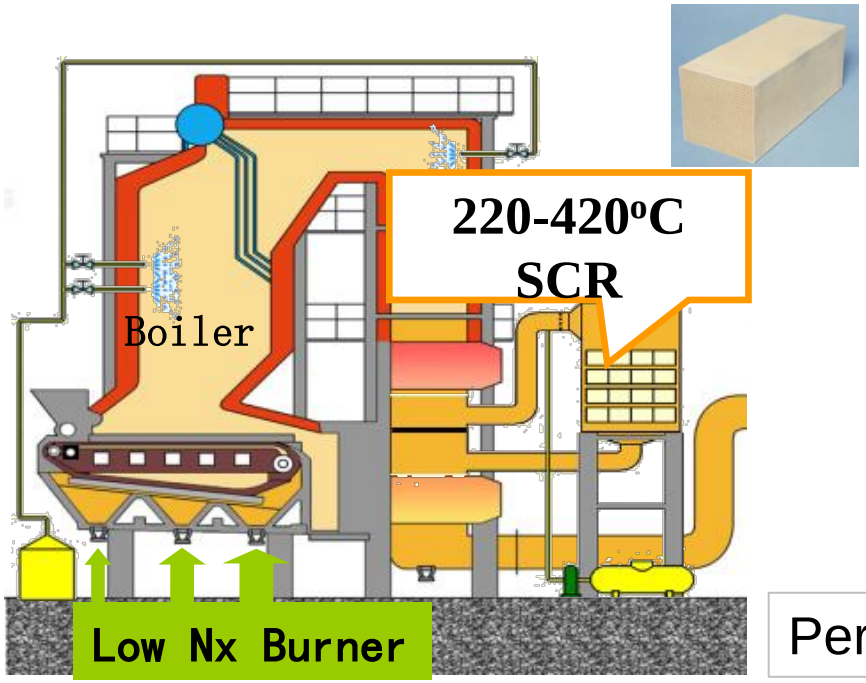


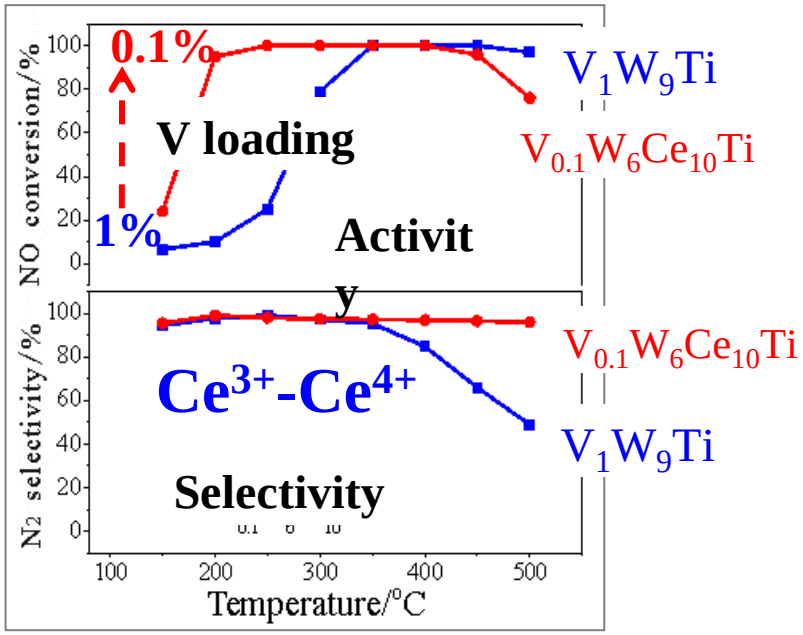




Removal of NOx at widen temperature window

DeNOx: Low NOx burner +SCR





Performance on the modified catalyst

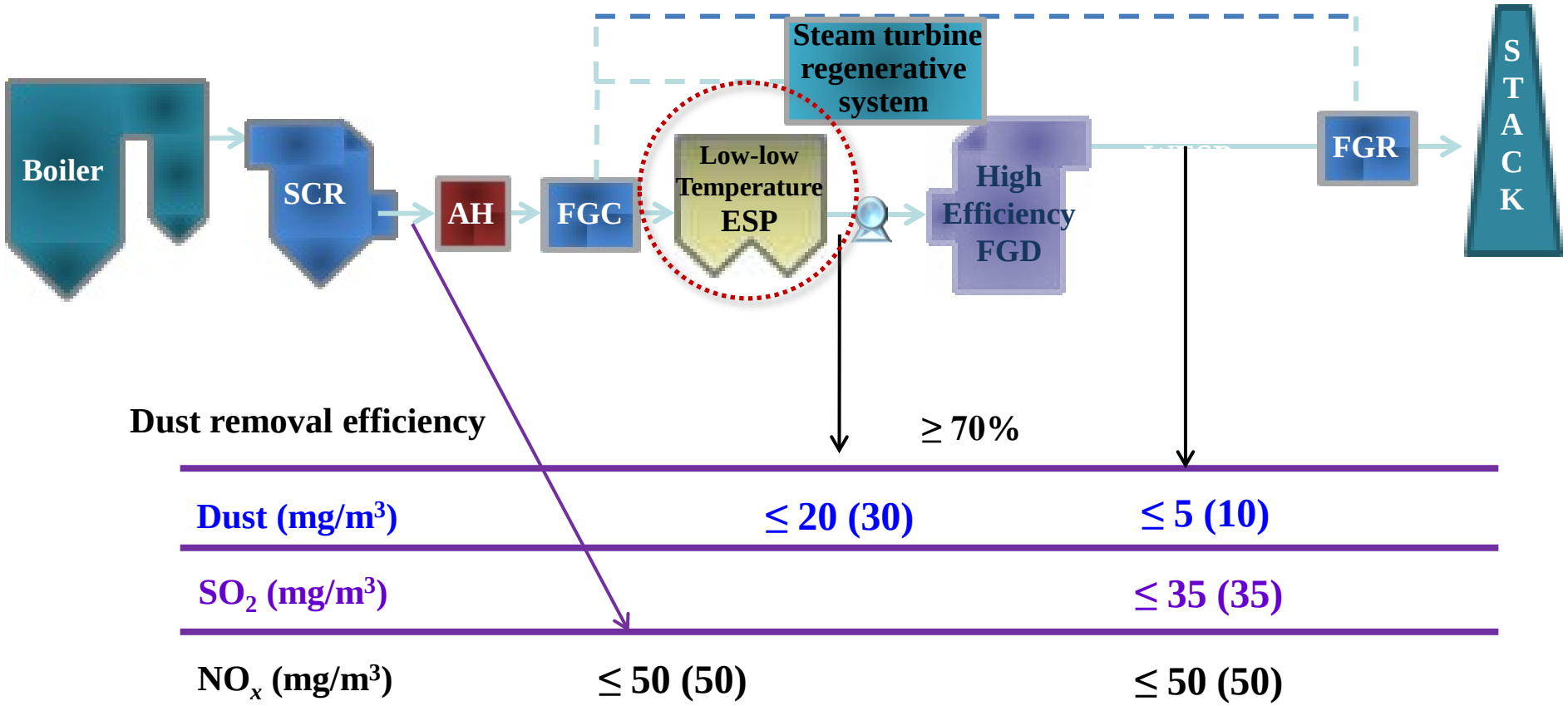
- Ceria enhance the redox property and broaden Temp. window
- Ceria improve N_2 selectivity and suppress the N_2O production.

Y. Peng, J.H. Li, et. al., Environ. Sci. Technol., 2012, 46: 2864.;
L. Chen, J.H. Li, et al. Environ. Sci. Technol. 2010, 44, 9590.

Integrated control technology

To meet the ultra low emission standard, typically two ways.

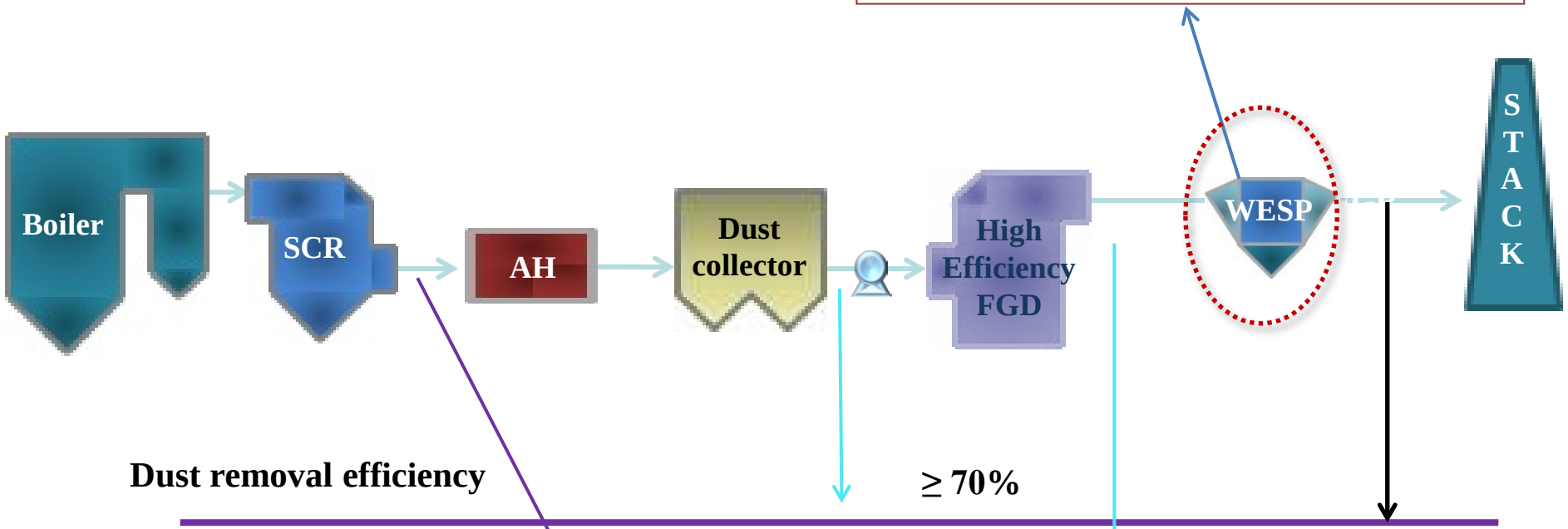
1. SCR + FGC + LTESP + FGD + FGR



Integrated control technology

2. SCR + ESP + FGD + WESP

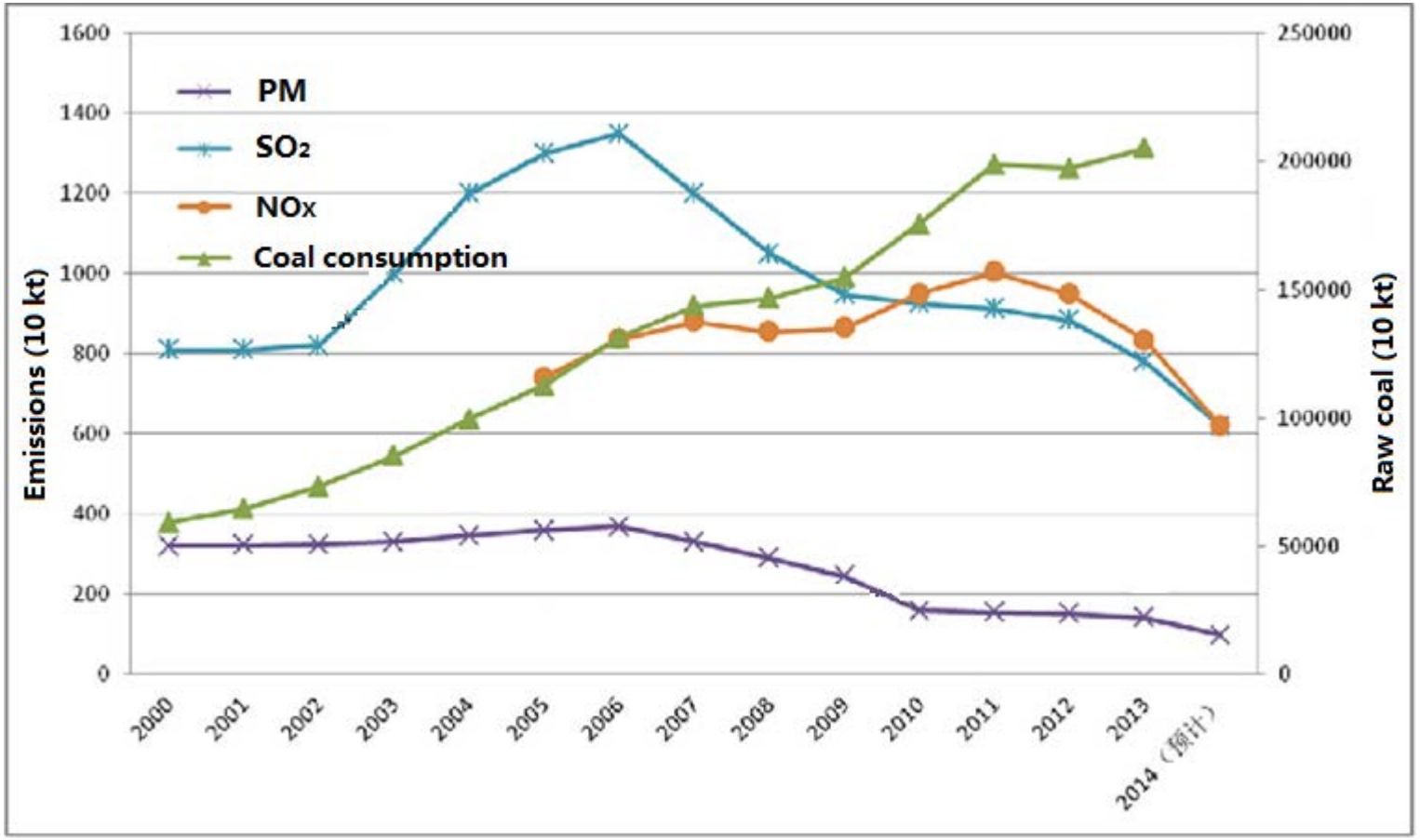
Removal of fine particulate, Mercury, and SO_3.



Dust removal efficiency	≥ 70%	
Dust (mg/m³)	≤ 20 (30)	≤ 5 (10)
SO_2 (mg/m³)	≤ 35 (35)	≤ 35 (35)
NO_x (mg/m³)	≤ 50 (50)	≤ 50 (50) ≤ 50 (50)

The amount of pollutants decrease since 2011

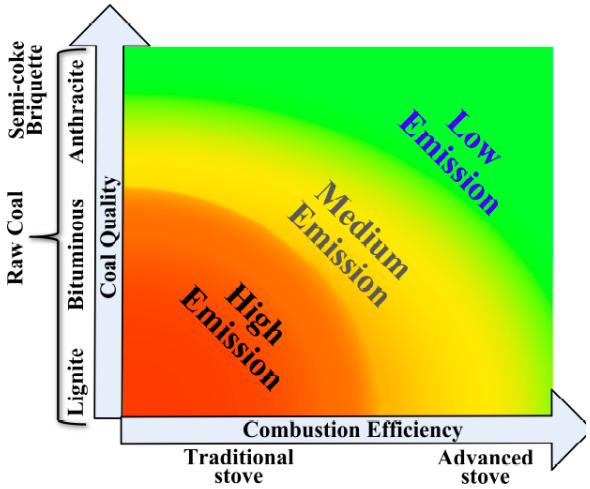
The major air pollutants PM, SO_2, NOx all decreased, although the coal consumption in 2014 is three times of that in 2000.



The trend of coal consumption and inventory of air pollutants

Controlling pollution from residential coal combustion

In China's residential sector, raw coal (~80% bituminous and ~20% anthracite) is often consumed in stoves with low efficiency. It's primary $PM_{2.5}$ emission accounts for more than 50% of total emission from all coal consumption in China.



Control strategies:

- **Switching to electricity and natural gas**
- **Replacing bituminous coal with anthracite**
- **Replacing raw coal (bituminous and anthracite) with processed coal (e.g., semi-coke, washed coal)**
- **Promoting better stoves (high energy efficiency and high combustion efficiency)**

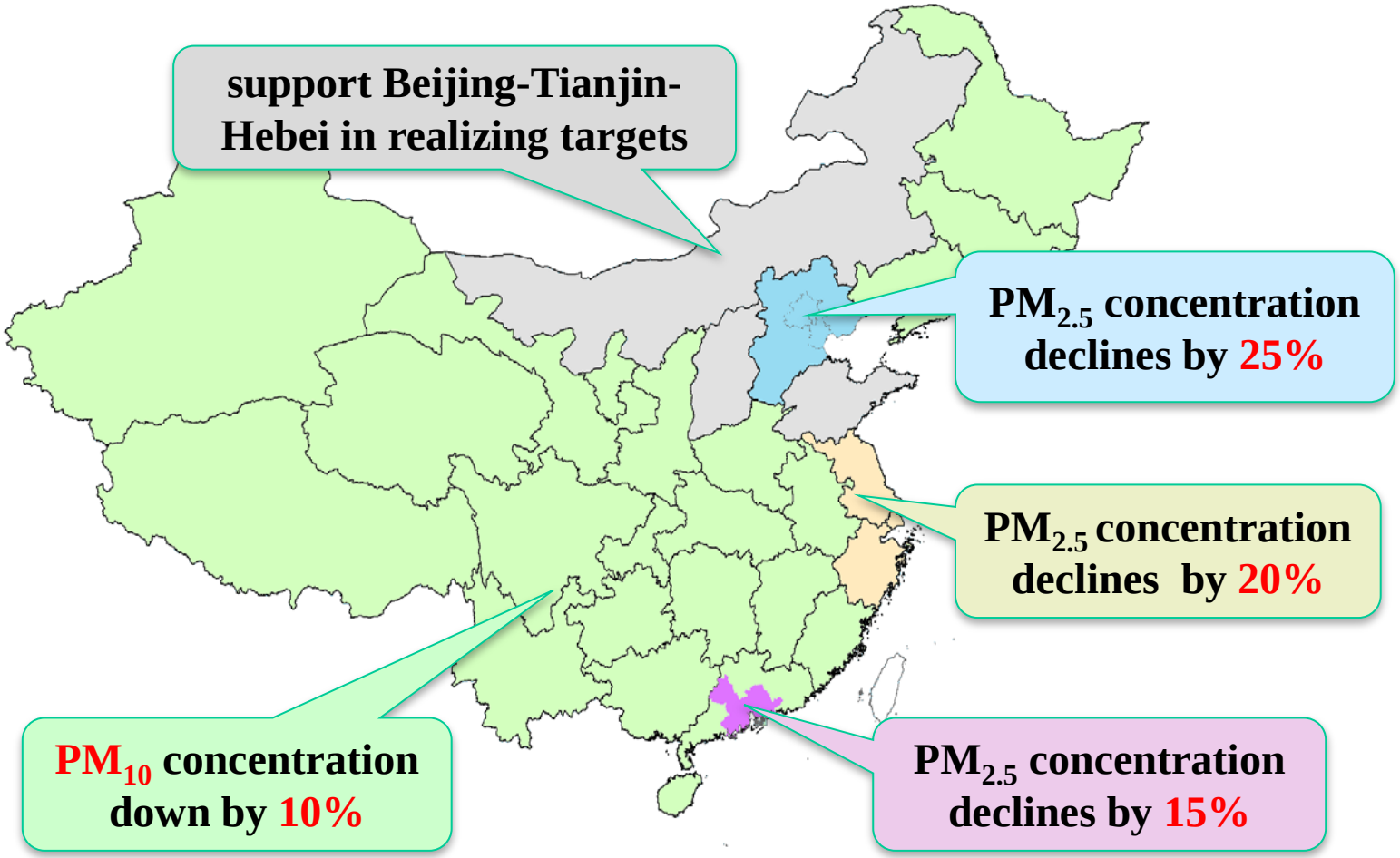
Li et al., Scientific Reports, 2016, 6: 19306

Outline

- Overview of air pollution in China
- Progress of air pollution control in China
  - Emission and control of transportation
  - Emission and control of coal combustion
  - Control of air pollution in megacities and regions
- Perspectives

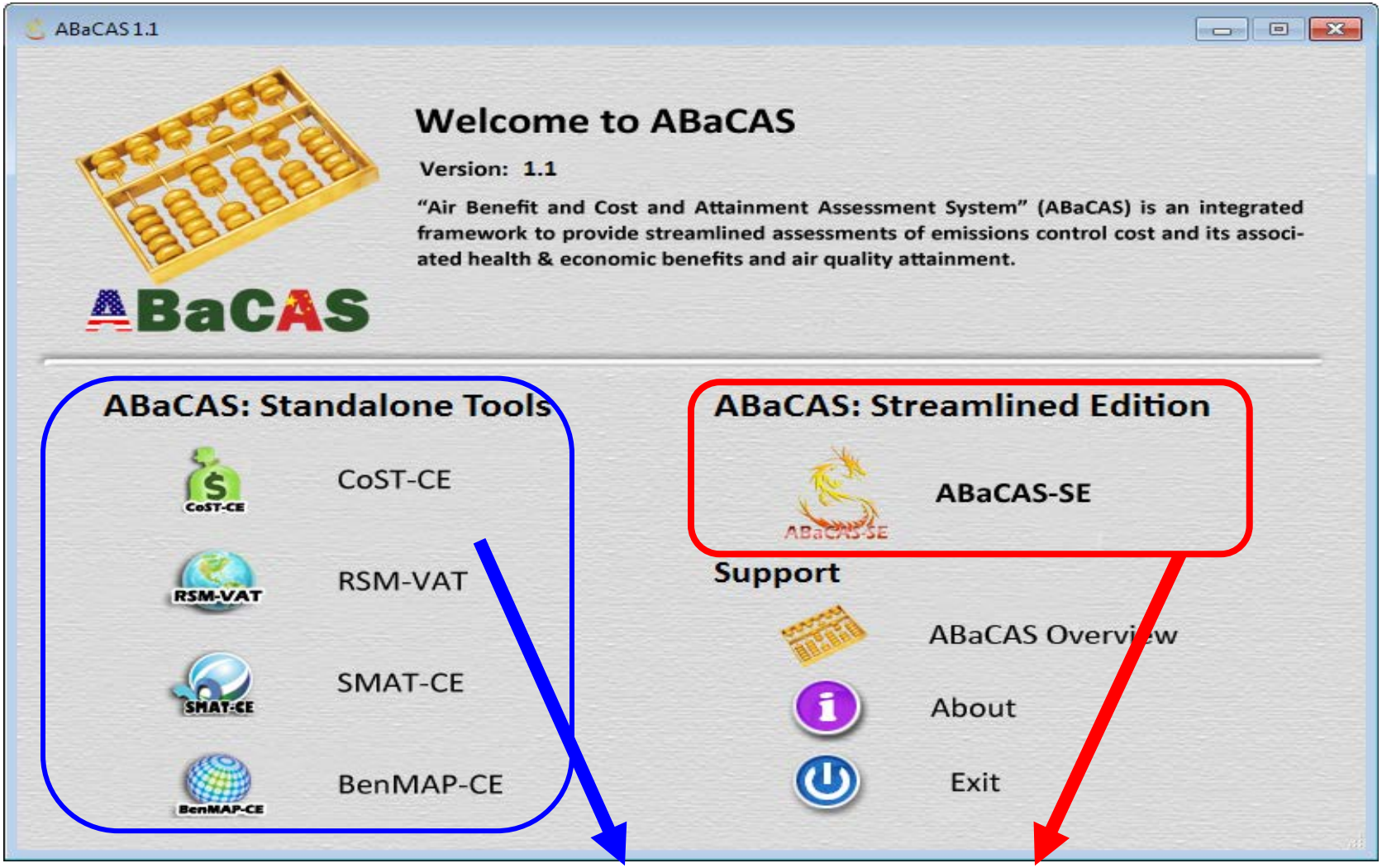
National Air Pollution Control Action Plan

- **Short-term air quality targets (2012~2017):**



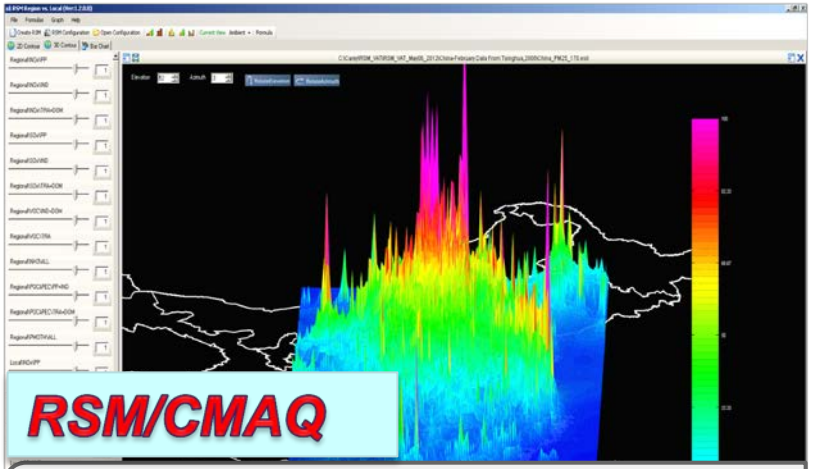
Sino-US collaborations: Development of Air Benefit and Cost and Attainment Assessment System

ABaCAS: An integrated AQ Decision Support System



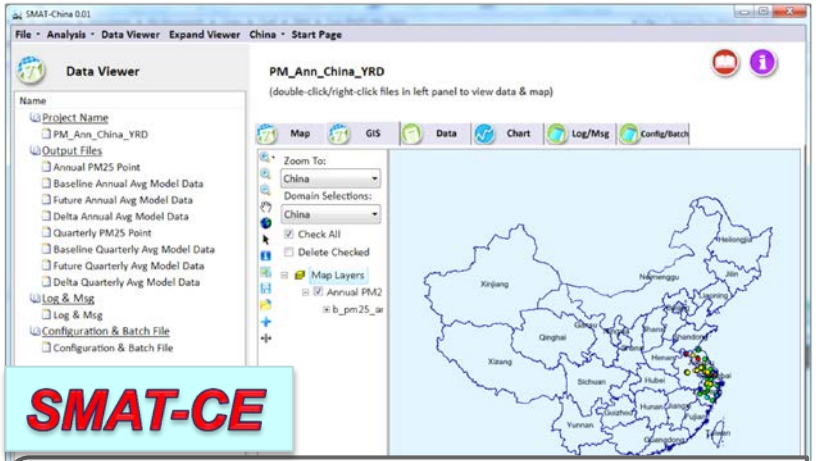
Developed for "Scientists" and "Policy Makers"

Sino-US collaborations: Development of Air Benefit and Cost and Attainment Assessment System



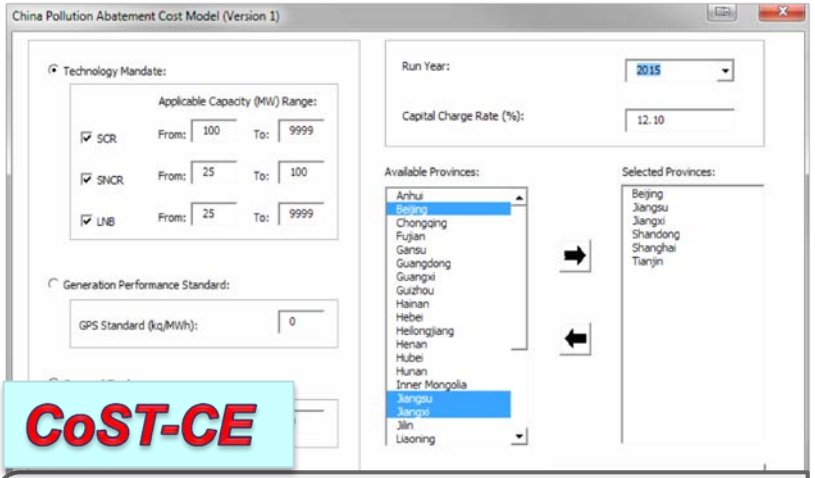
RSM/CMAQ

Provide Real-time Air Quality Response of Emissions Control



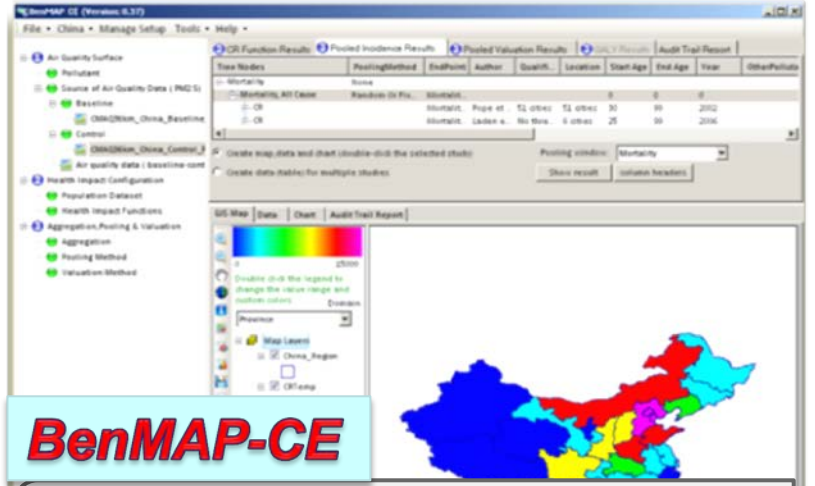
SMAT-CE

Provide Attainment Test/Demo for PM2.5 & O3 Non-attainment Areas



CoST-CE

Provide Emissions Control Cost Analysis and Estimate

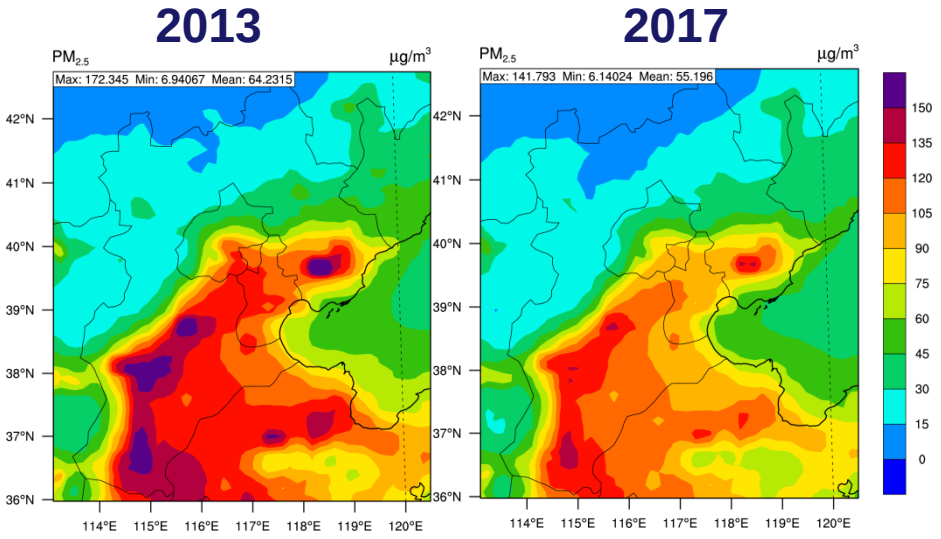


BenMAP-CE

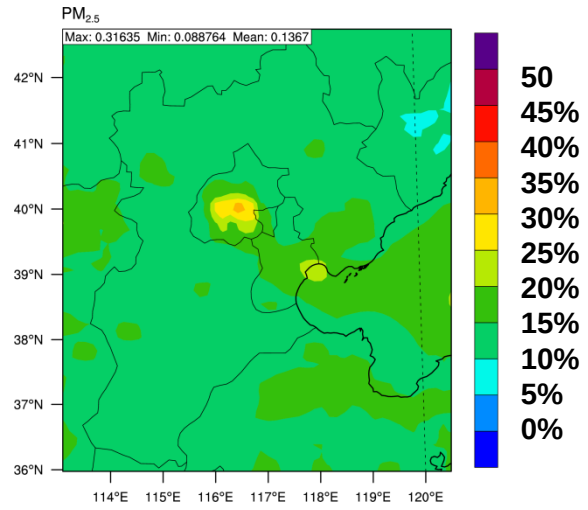
Provide Health Impacts and Economic Benefits Estimate

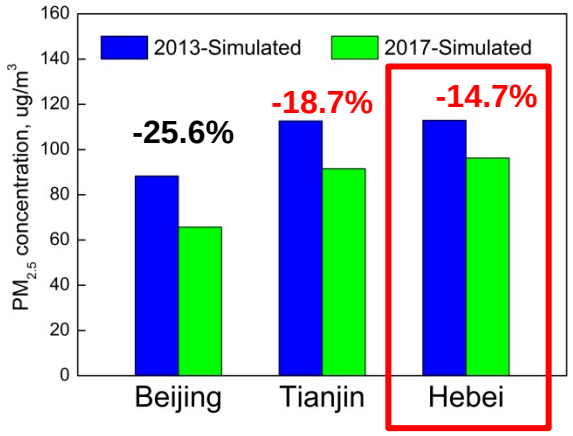
Pre-evaluation of the Action Plan in Jing-Jin-Ji

$PM_{2.5}$ concentration changes in BTH

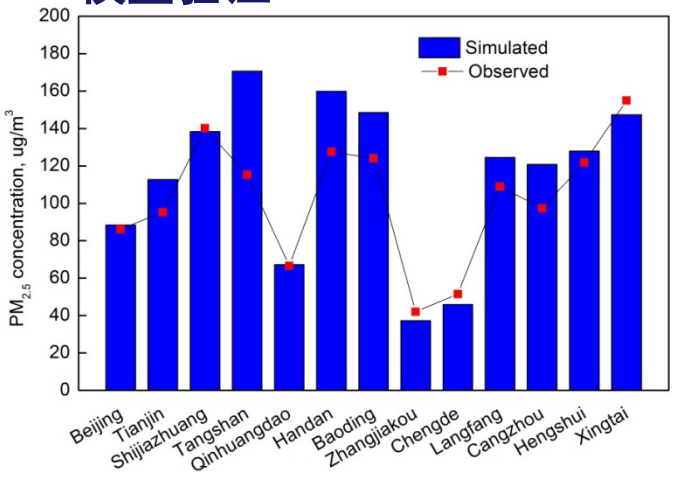


The percentage change of $PM_{2.5}$



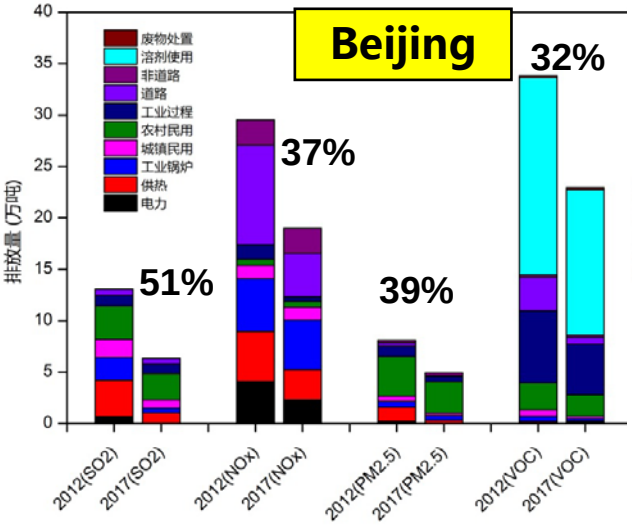


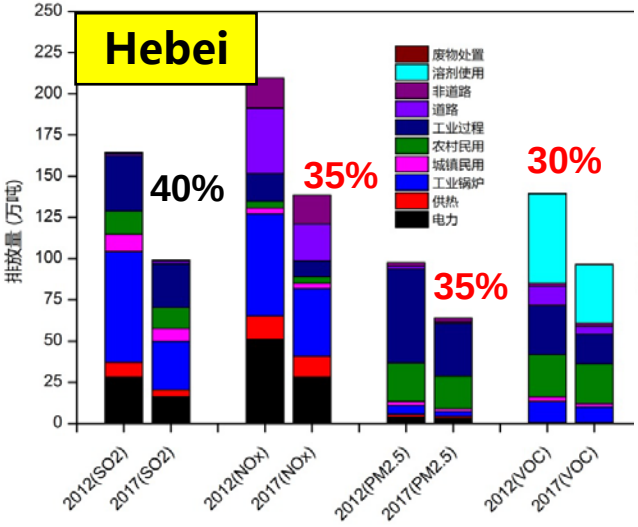
模型验证 Model Evaluation

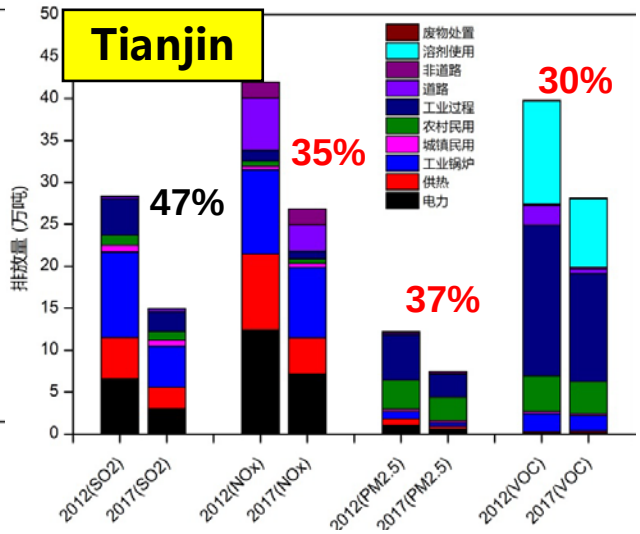


Enhanced reduction scenario： $PM_{2.5}$ changes

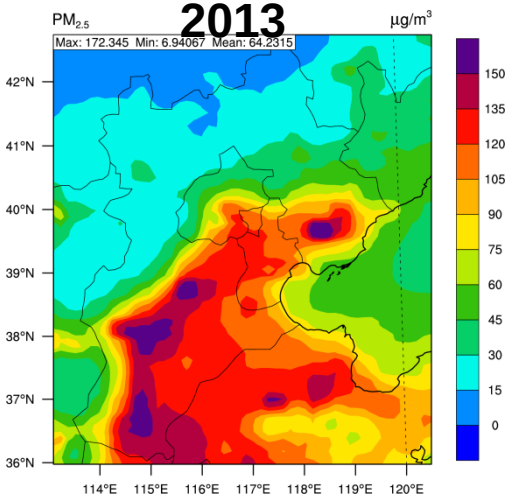
Emission changes

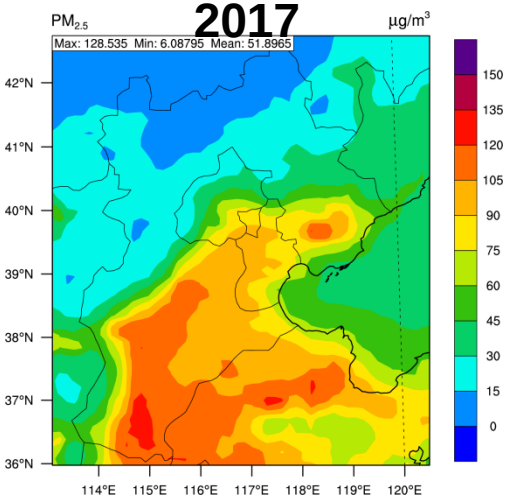


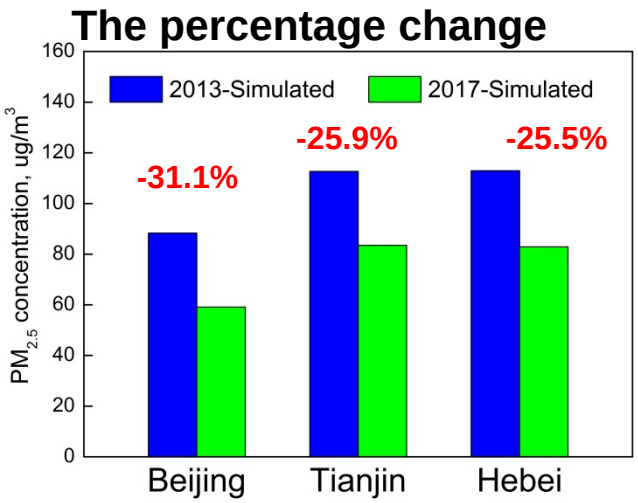




$PM_{2.5}$ concentration changes





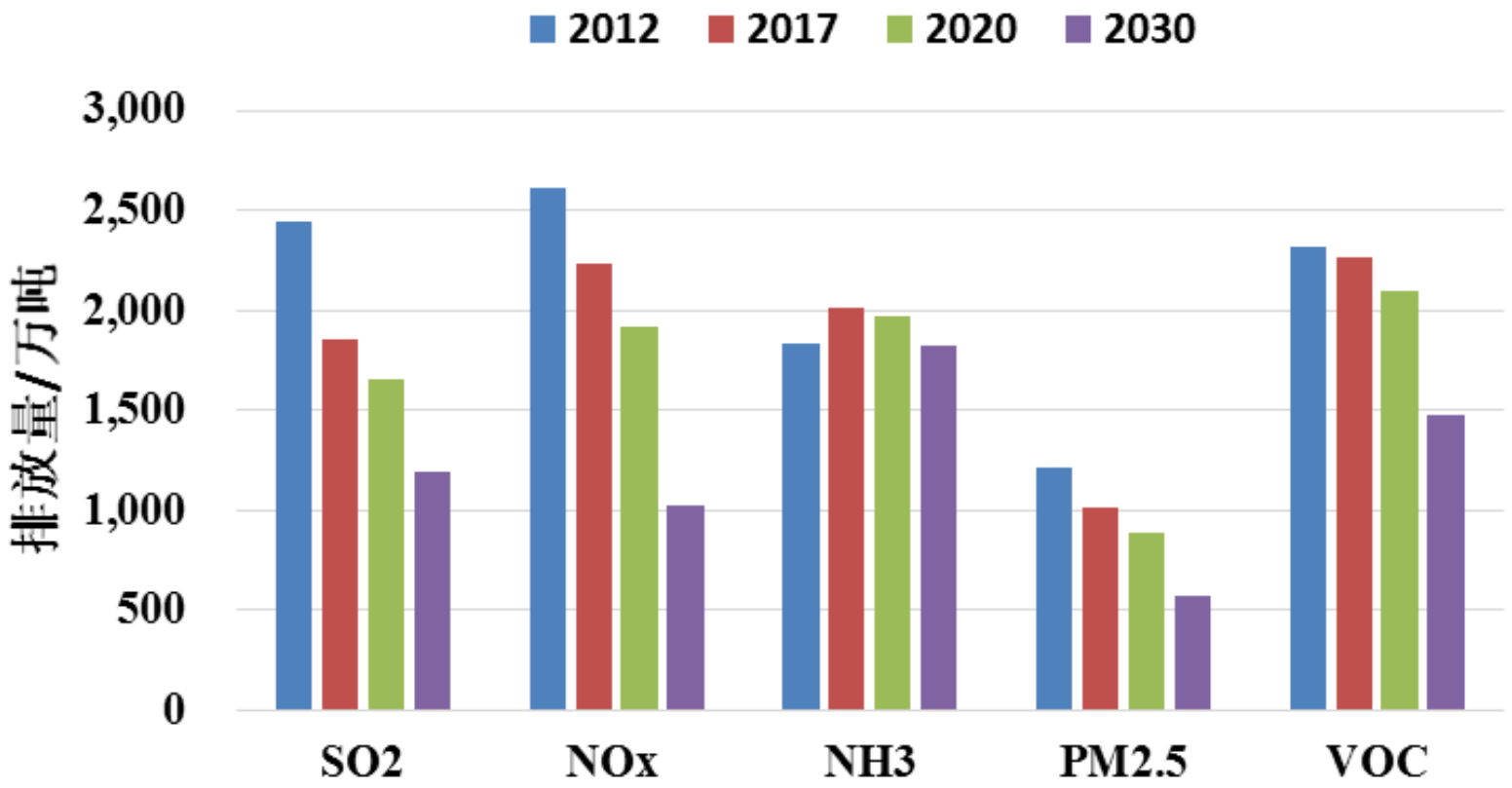


Outline

- Overview of air pollution in China
- Progress of air pollution control in China
  - Emission and control of transportation
  - Emission and control of coal combustion
  - Control of air pollution in megacities and regions
- Perspectives

Emission reductions for air quality attainment

- **Emission reductions required for whole China:**

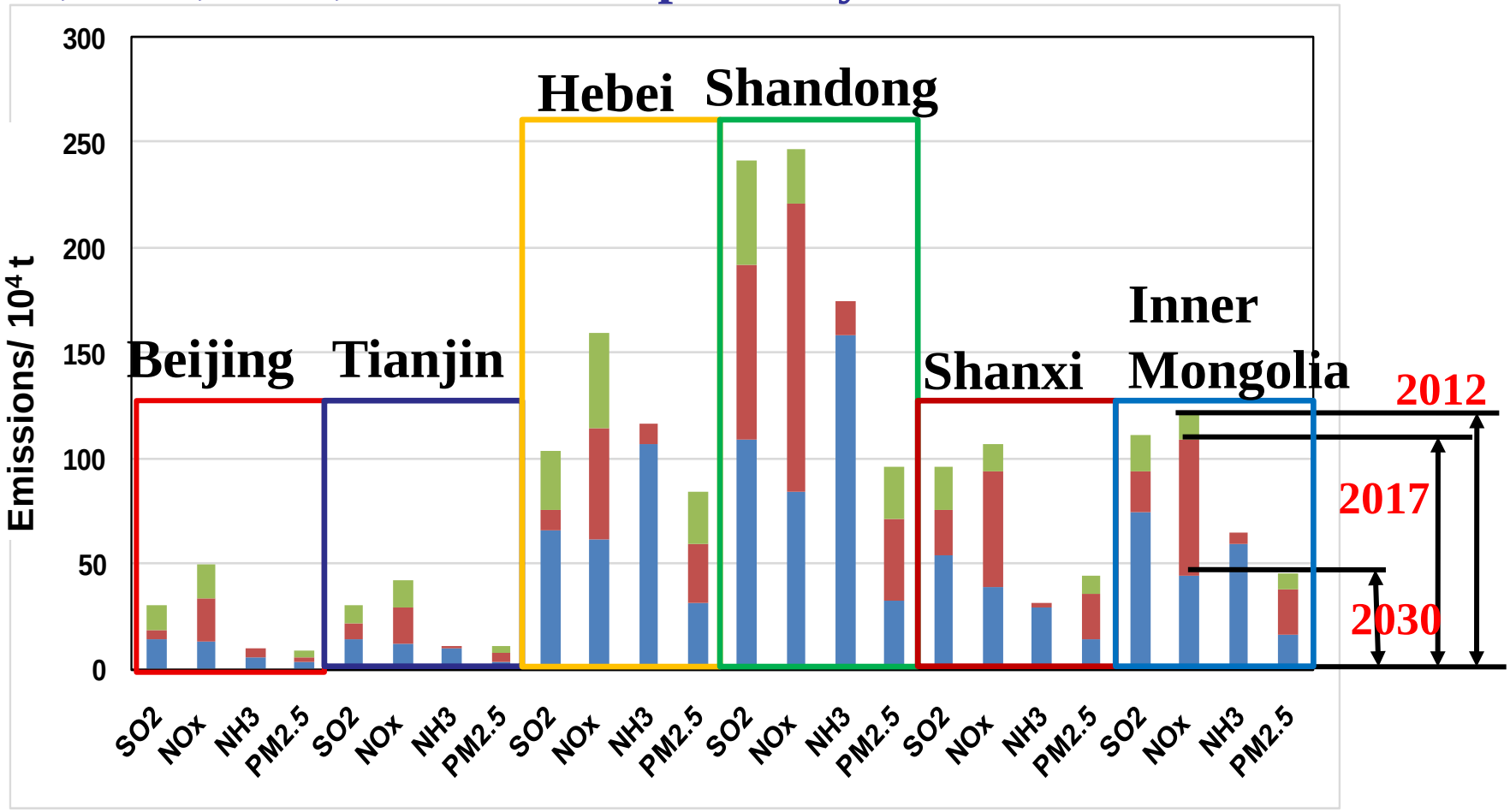


by 2030, the emissions of SO_2, NO_X, $PM_{2.5}$ and VOCs in China should be reduced by 52%, 65%, 57%, and 39% compared with those of 2012. The emissions of NH_3 should decrease slightly.

China's Air Pollution Problem Will Require Years to Solve!

Emission reductions for air quality attainment

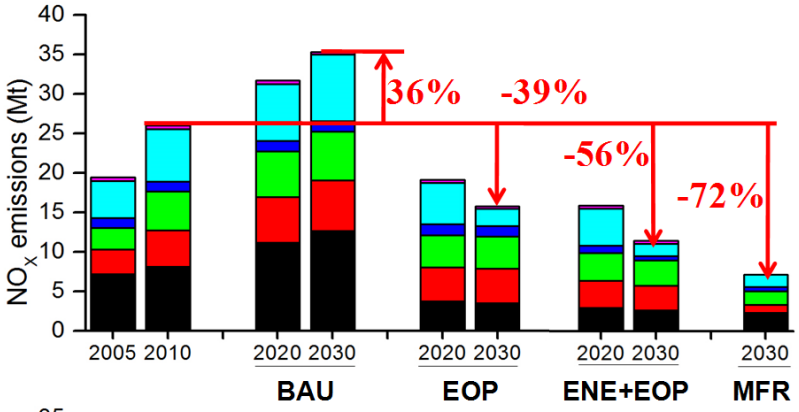
We should intensify emission control in heavily polluted areas. For example, SO_2, NO_X, $PM_{2.5}$, VOC and NH_3 emissions in the Beijing-Tianjin-Hebei Region in 2030 should be reduced by at least 59%, 72%, 70%, 44%, and 21% respectively.

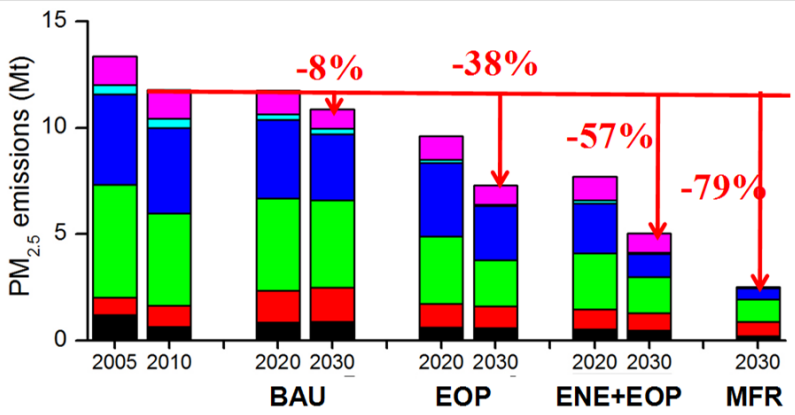


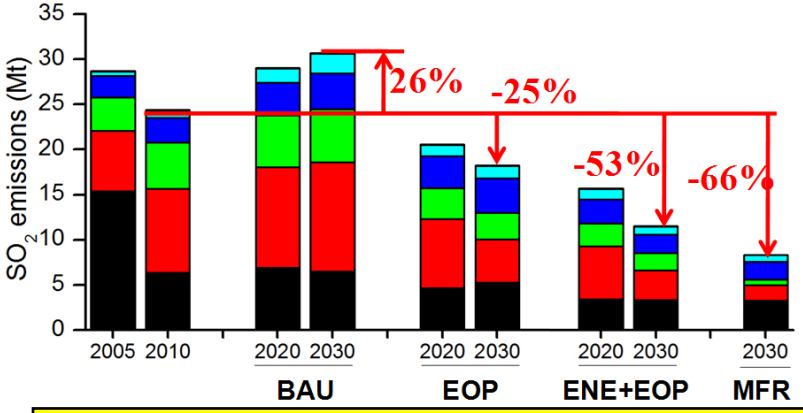
Emission reductions for air quality attainment

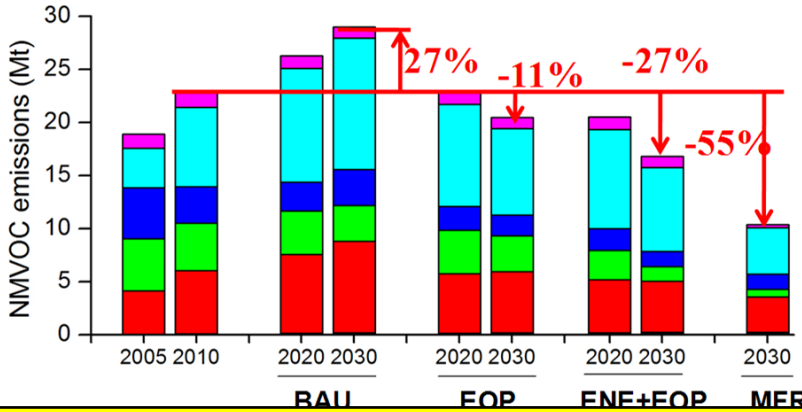
Emission Control Pathways

Either ENE+EOP or MFR scenario need to be adopted to achieve the air quality target by 2030 in China.









1) Business as usual (BAU); 2) End-of-pipe control (EOP)
3) Alternative energy policy + End of pipe control, (ENE+EOP)
4) Maximum Feasible Reduction (MFR)

International collaborations shall be enhanced

- **We share the same planet.**
- **China and the US represent the world's largest economies, largest energy consumers, and largest emitters of carbon pollution.**
- **Addressing air pollution and climate change provides opportunities for innovation and to build the clean energy economy of the future—a future that's safer and healthier for our children.**
- **Our collaboration and partnership are needed now more than ever**

Thank you for your attention!