



清华大学环境学院
SCHOOL OF ENVIRONMENT, TSINGHUA UNIVERSITY

The 13th Mercury and Multi-Pollutant Emission from Coal, 21-23rd May 2018

Evaluation of the effect of multiple air pollutants control in China's coal combustion units and future reduction recommendations

Qingru WU

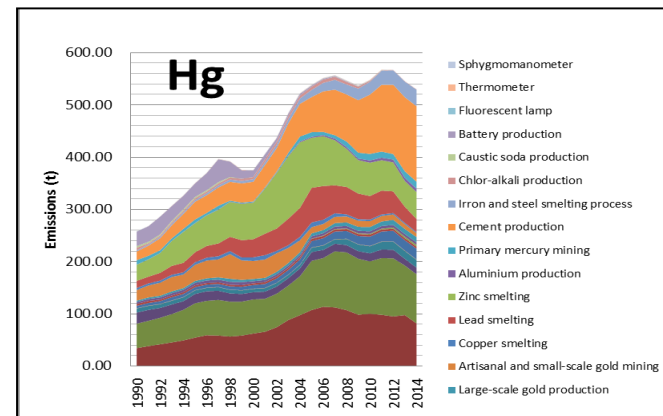
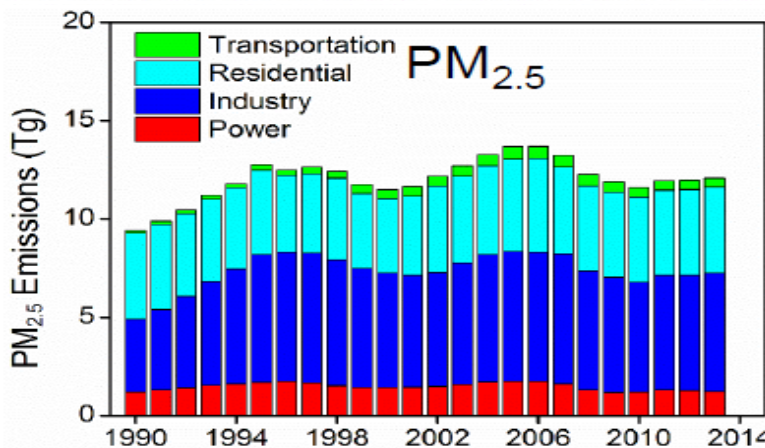
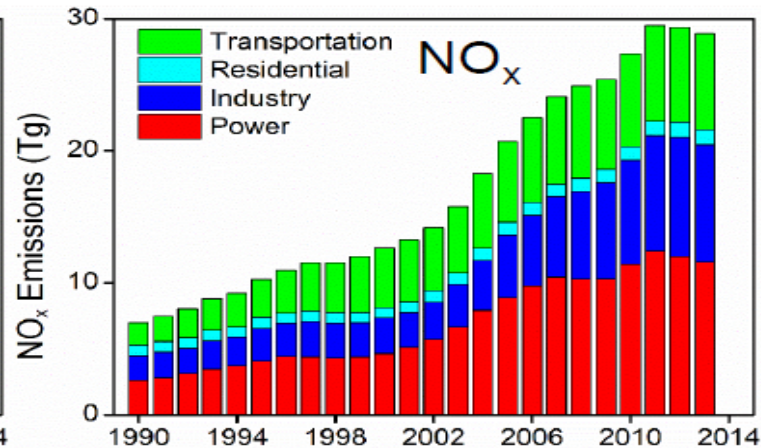
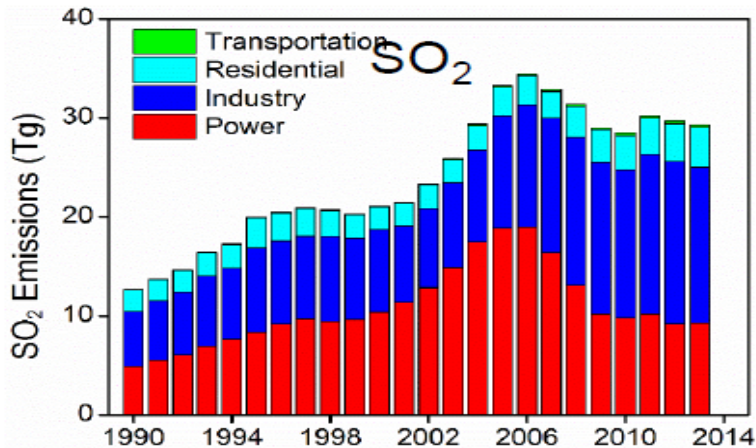
Tsinghua University, Beijing, China

May 22, 2018

Outline

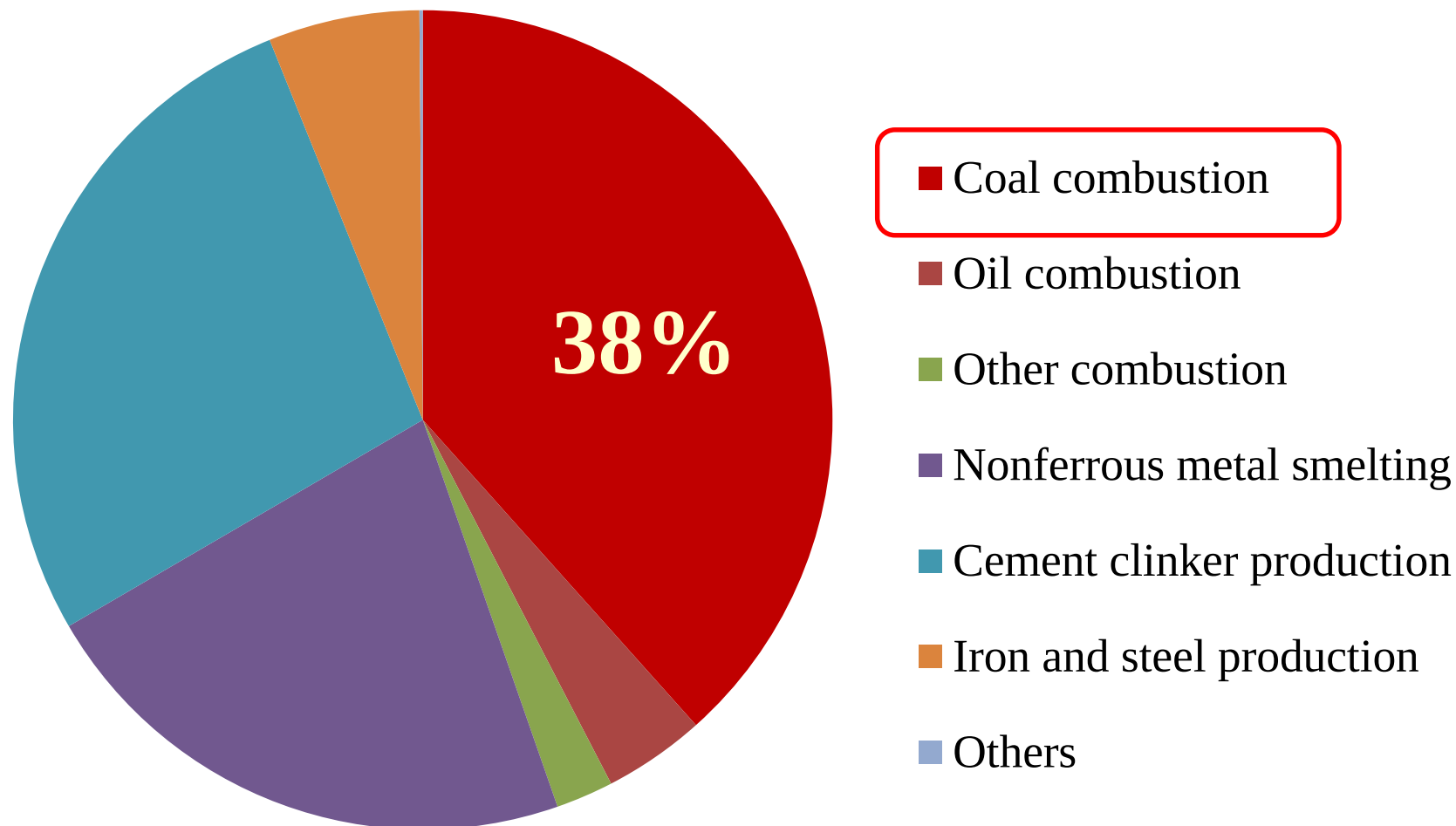
- **Air pollution issue in China**
- **Progress of air pollution control
in coal combustion**
- **Recommendations of future control**

Huge emissions of air pollutants in China



- China becomes the world's largest emitter of major air pollutants.
- The SO₂ and NO_x emissions of China in 2012 are **60%** and **45%** higher than the U.S. level in 2009, respectively.

Source contribution



Atmospheric Hg emissions in China, 2014

Disease burden of PM_{2.5} pollution in China

Sector contributions to population-weighted ambient PM_{2.5} and deaths, 2013

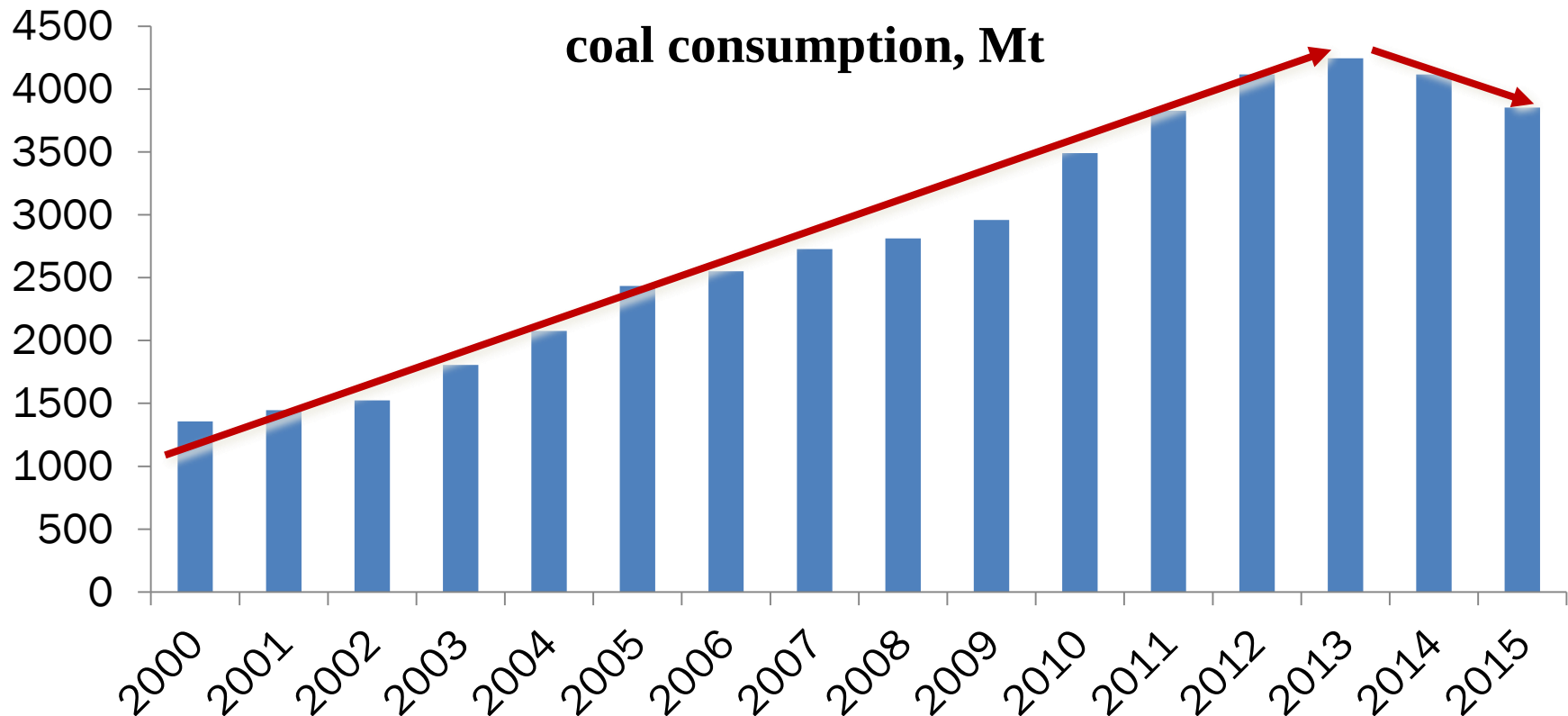
Subsector	Mean PM _{2.5}	Deaths
All ambient PM _{2.5}	54.3	916,000
Total Coal	21.9	366,000
Power plant coal	5.2	86,500
Industrial coal	9.4	155,500
Domestic coal	2.4	41,000
Non-Coal Industry	5.6	95,000
Domestic biofuel	8.0	136,500
Traffic	8.2	137,500
Open burning	4.1	70,000

PM_{2.5} emissions from coal combustion has led to **40%** of exposure to ambient PM_{2.5}, equal to **366,000** deaths

Outline

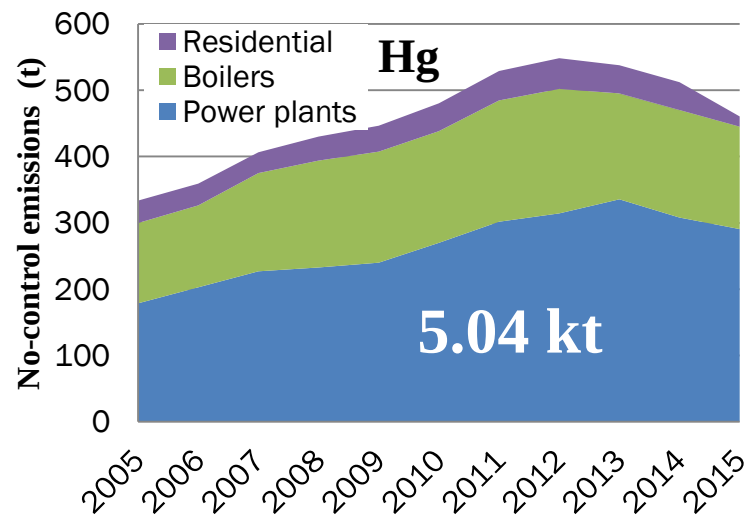
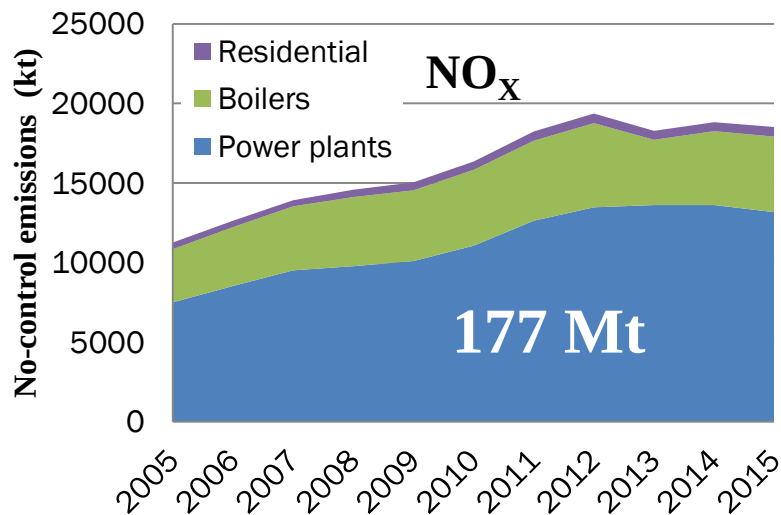
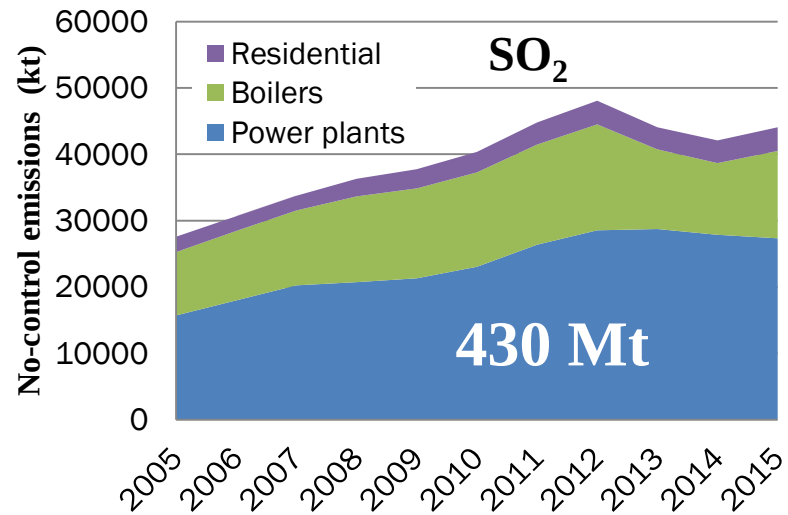
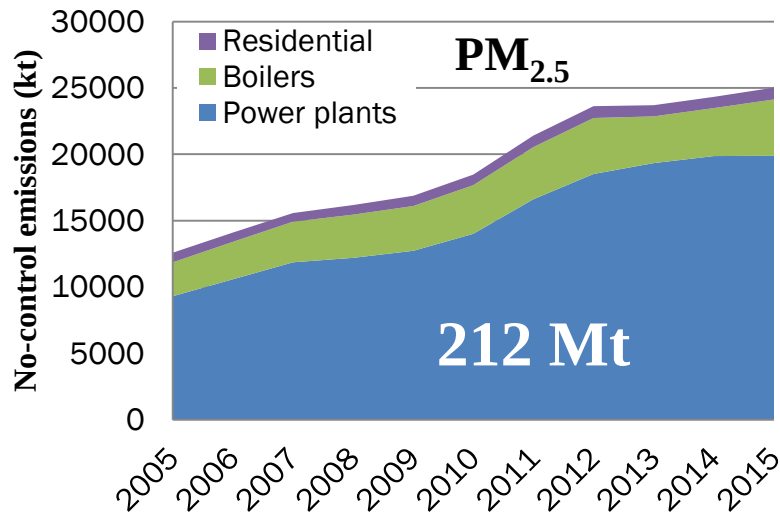
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Trends of coal consumption, 2000-2015



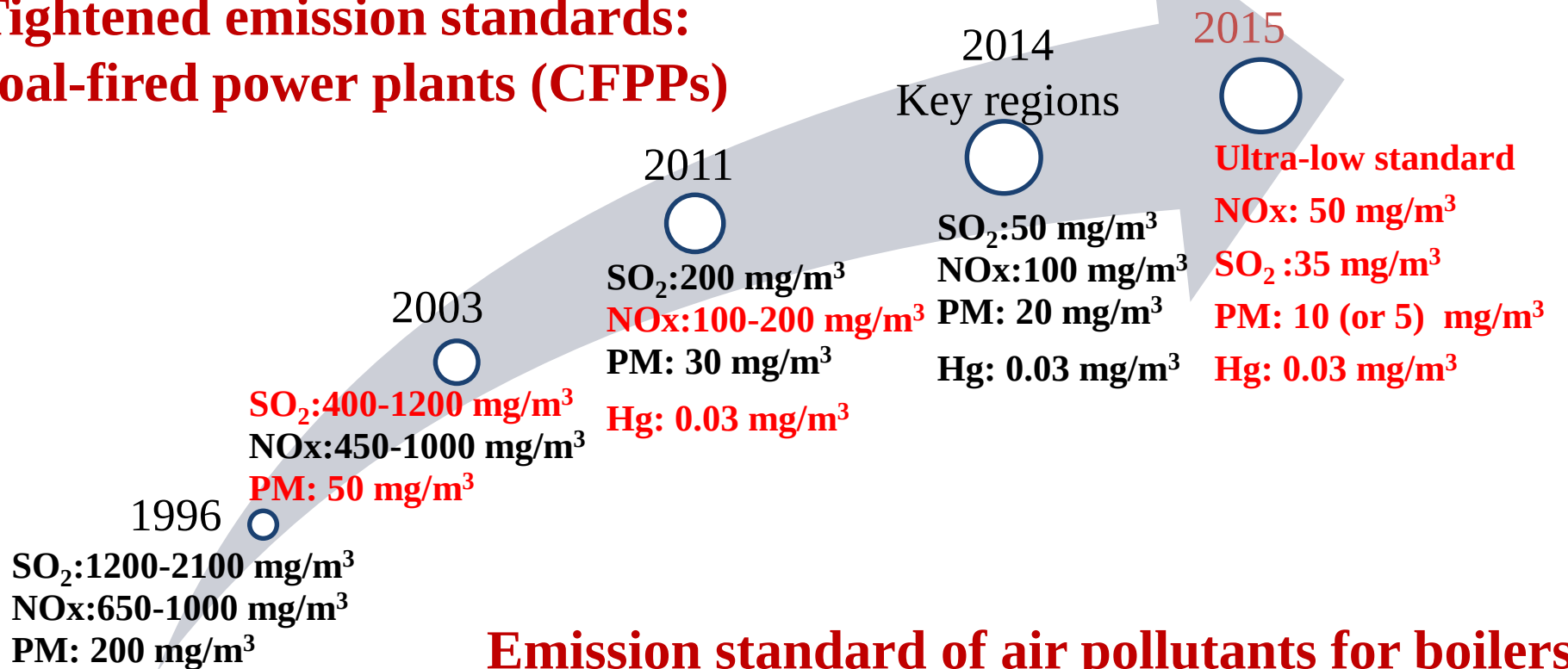
- China's coal consumption grew from **1.36 billion tons** in 2000 to **4.24 billion tons** in 2013, a rapid annual growth rate of **12%**.
- National coal consumption in 2015 decreased **by 6.5%** compared with that in 2013.

No-control emissions, 2005-2015



Evolution of emission standards

Tightened emission standards: coal-fired power plants (CFPPs)



Emission standard of air pollutants for boilers

2001

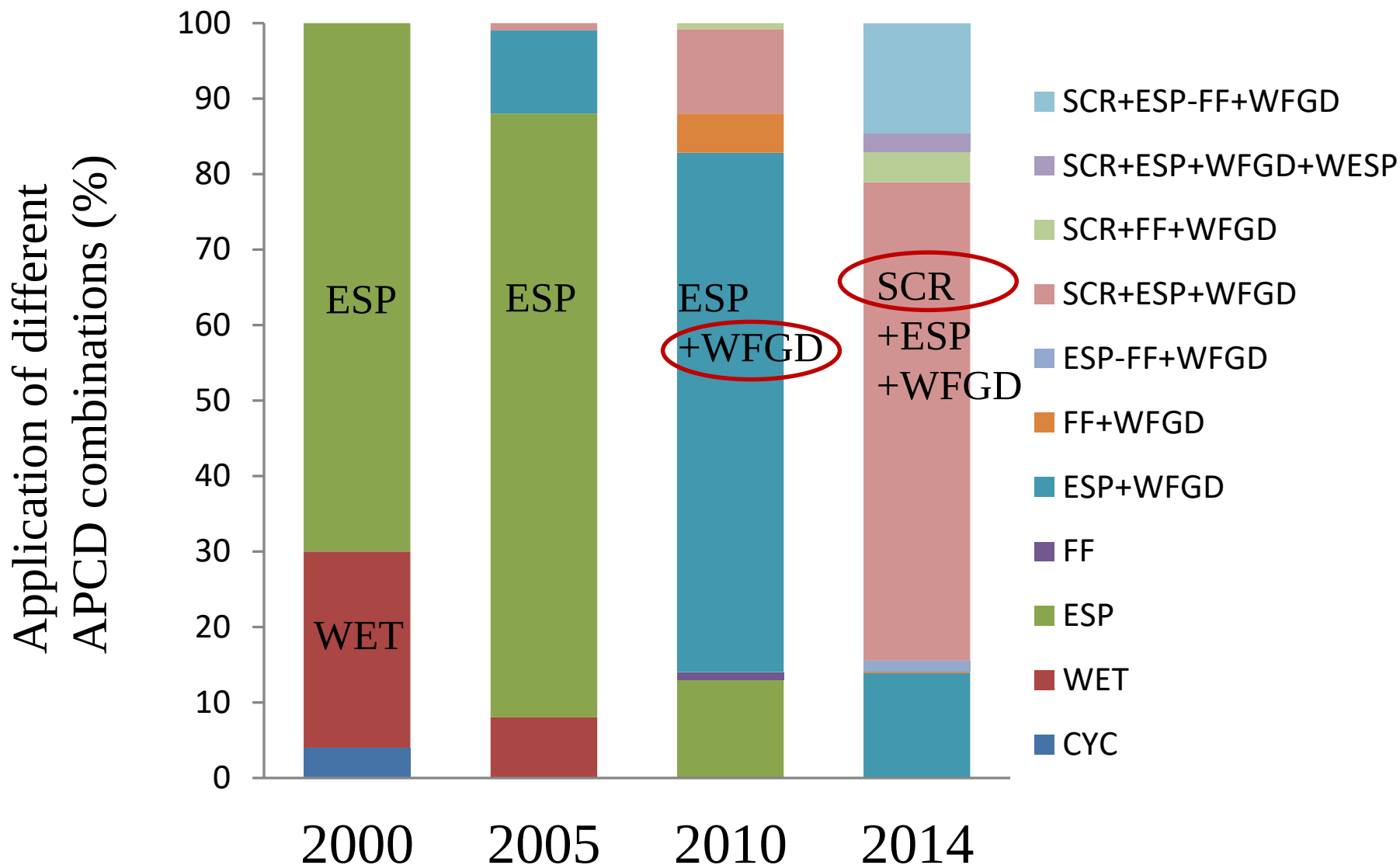
SO₂: 900 mg/m³
NO_x: No limit
PM: 80-250 mg/m³
Hg: No limit



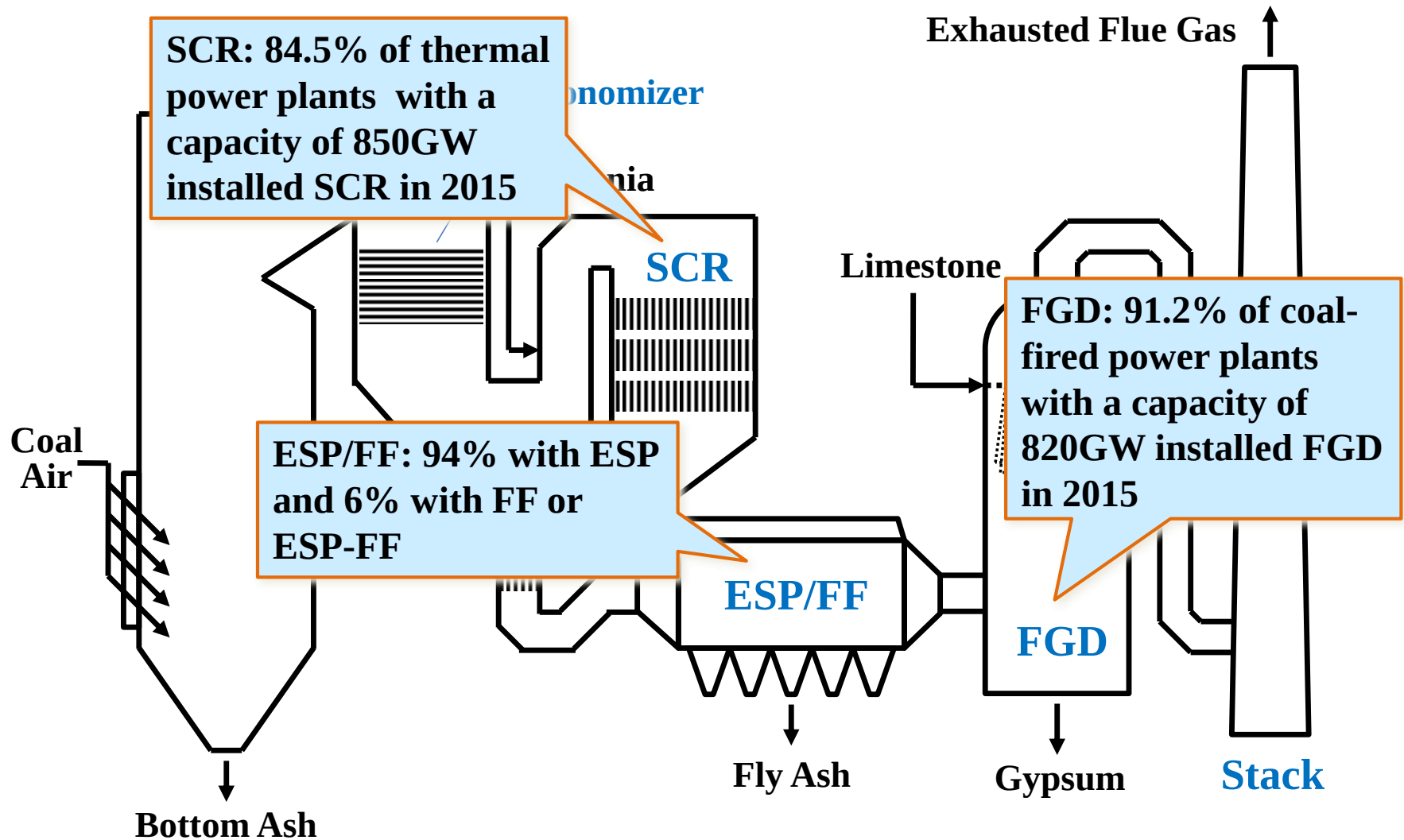
2014

SO₂: 400 mg/m³
NO_x: 400 mg/m³
PM: 80 mg/m³
Hg: 0.05 mg/m³

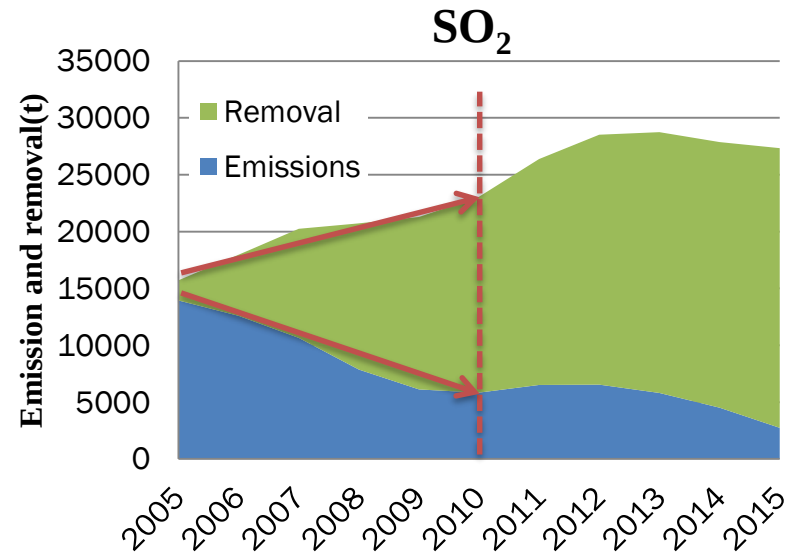
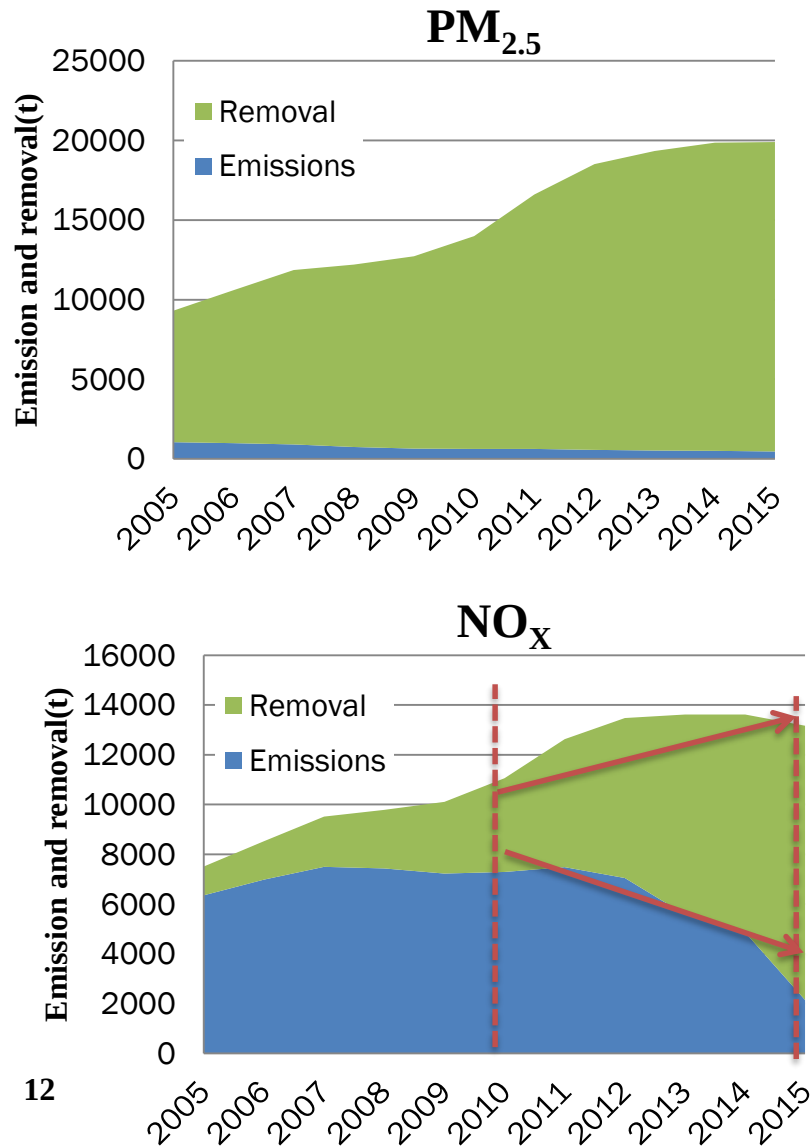
Improvement of air pollution control devices (APCDs)



Improvement of APCDs



Effective of pollution control, power plants



Cumulative removal, 2005-2015

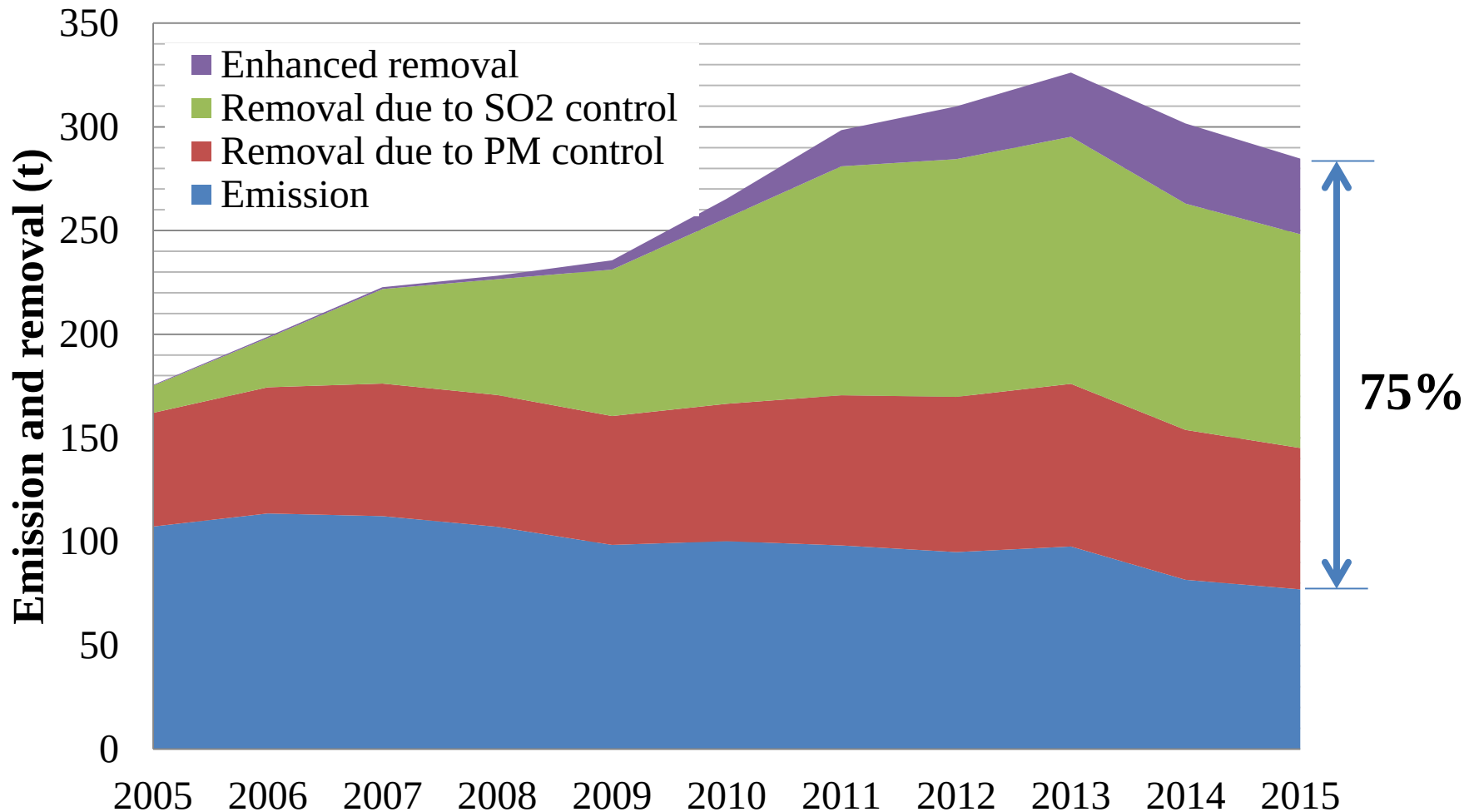
PM_{2.5} (95%), SO₂ (68%), and NO_x (43%)

Removal efficiency in 2015

PM_{2.5} (98%), SO₂ (90%), and NO_x (84%)

Impact on Hg emissions

Hg



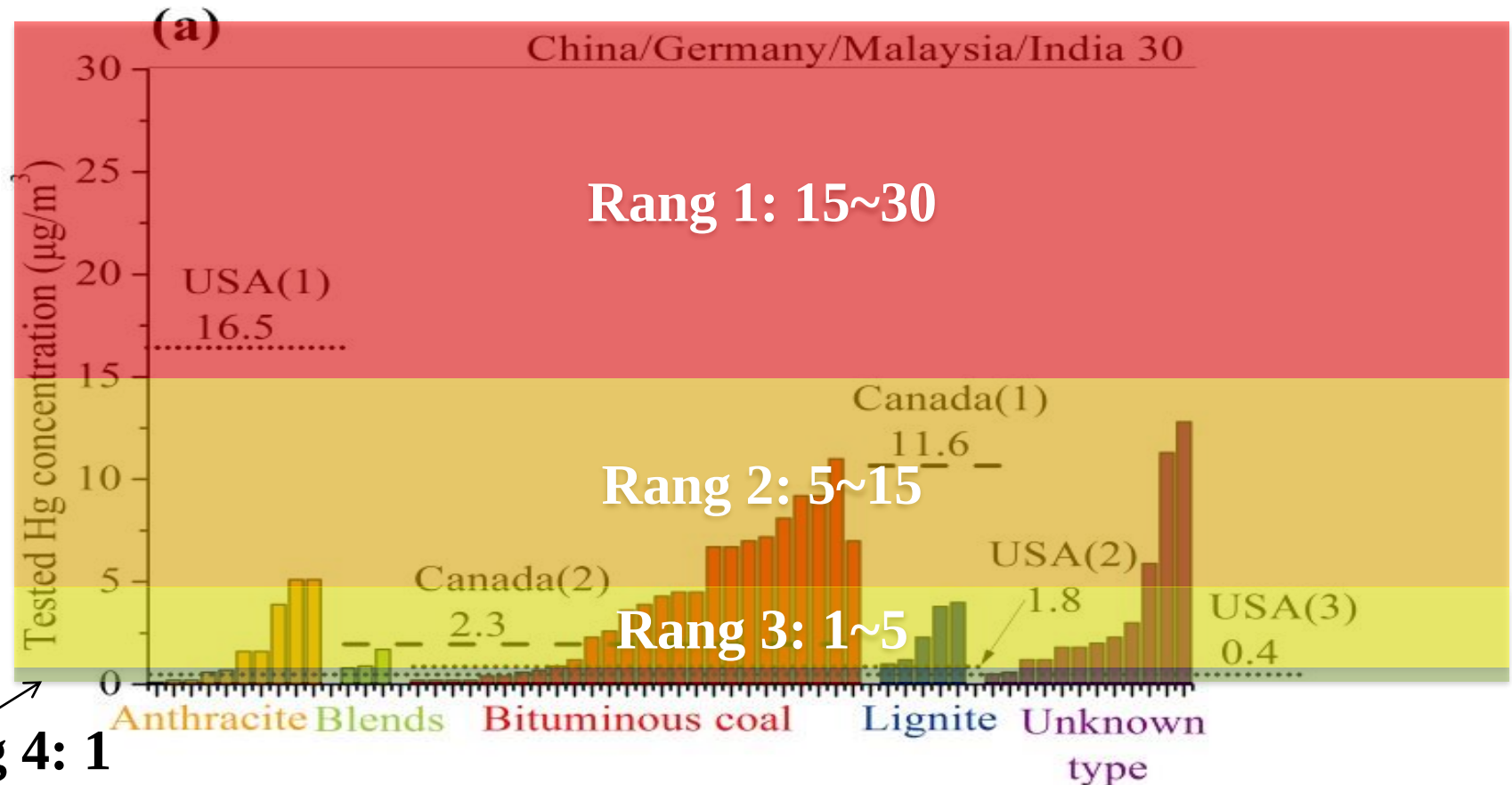
Outline

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Comparison of the emission limits

	Scale or plant type	SO ₂ mg/m ³	NO _x mg/m ³	PM mg/m ³	Hg μg/m ³
USA		~180	~140	~18 or 13	~0.4-16.5
Germany	<50MW	350-1300	300-500	20-50	30
	>=50 MW, existing plants	Daily: 200- 400; Half-hour: 400-800	Daily: 200- 400; Half-hour: 400-800	Daily: 20; Half-hour: 40	30
	>=50 MW, New plants (after Jan 7, 2014)	Daily: 150-400 Half-hour: 300- 800	Daily: 150-400 Half-hour: 300- 800	Daily: 10; Half-hour: 20	
European Union	Existing plants	200-400	200-300	20-30	1-4, 1-9, 1-7, 1- 10
	New plants	150-400	150-300	10-20	1-3, 1-5
Japan		150-300	172-3515	50-300 (or 30-150)	/
China		35	50	5 or 10	30

Emission limit evaluation



(a) Tested Hg concentrations. USA(1), (2), and (3), is the emission limits for existing CFPPs using low rank coal, existing CFPPs using non-low rank coal, and new CFPPs, respectively. Canada (1) and (2) are the emission limits for new CFPPs using lignite and blends (or bitumite), respectively.

Requirement on mercury removal efficiency

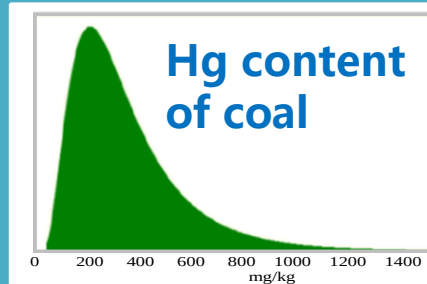
Expected
emission limit

8500-12000 m³/t coal
combusted in China

Required Hg
removal
efficiency of
APCDs

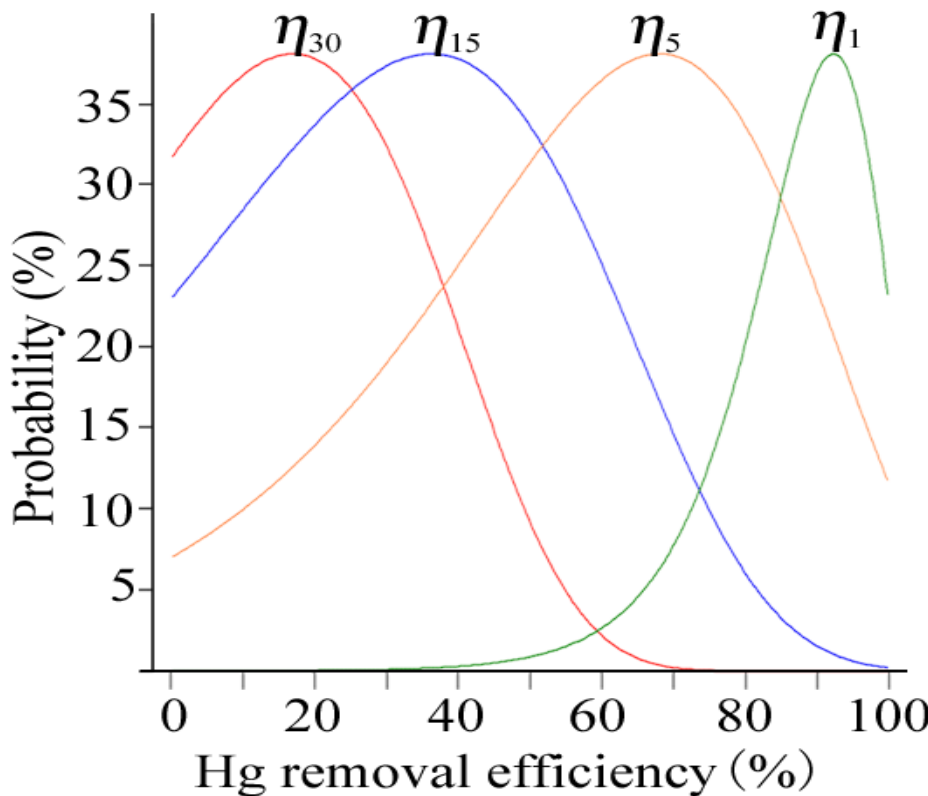
Monte
Carlo

$$\eta = 1 - \frac{\rho_{gas} \times V}{C_{coal} \times \gamma}$$



The proportion of Hg
released from coal to
the flue gas during the
combustion process

Requirement on mercury removal efficiency



Line	Hg removal efficiency (%)		
	P5	P50	P95
η_{30}	0.00	7.79	56.45
η_{15}	0.00	25.20	69.15
η_5	0.00	58.52	92.66
η_1	65.92	89.02	98.53

The P5, P50 and P95 means the probabilities of 5%, 50 and 95% that the actual results are no more than corresponding values read from the curve.

- At least one type of APCD combination in each technical path should achieve the P95 values.
- Likewise, the P5 value is regarded as the basic requirement of the technical paths.

Available APCD combinations

Technical pathway TP15

Type 1-3
15 $\mu\text{g m}^{-3}$

TP5

Type 1-8
5 $\mu\text{g m}^{-3}$

TP1

Type 2-12
5 $\mu\text{g m}^{-3}$

Type	APCD combinations	Tested Hg removal efficiency (%)
1	Specific Hg control technical paths. The dominant APCD combinations are SCR+SMR+ESP-FF/LTESP+WFGD or SCR+SMR+ESP+WFGD+WESP	
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

PC –pulverized coal furnace; CFB–circulating fluidized bed; ESP – electrostatic precipitator; WFGD – wet flue gas desulfurization; CFGD –circulating fluidized bed desulfurization; SCR – selective catalytic reduction; FF – fabric filter; WESP – wet electrostatic precipitator; LTESP – low temperature electrostatic precipitator; SMR – specific mercury removal, including the addition of Hg oxides.

Emission projection

Coal-quality-regarded probabilistic emission
factor model

$$E = \sum_i AL \cdot M \cdot R \cdot (1 - \eta) \cdot \theta_i$$

E – total emission

AL – activity level, that is coal consumption

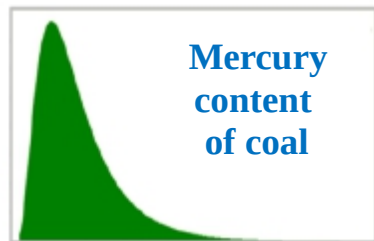
M – mercury content of coal as burned

R – mercury release
rate of coal boiler

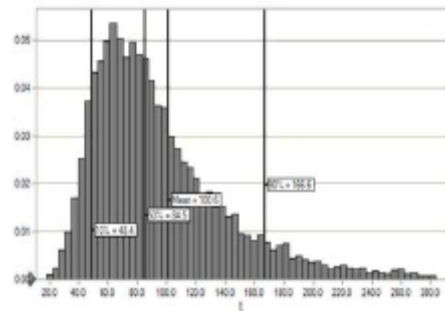
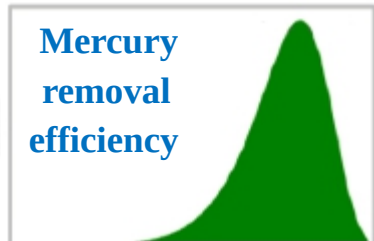
η – mercury removal
rate by APCDs

θ – Application proportion of APCD combination

i – the type of APCD combination



Monte Carlo
Simulation

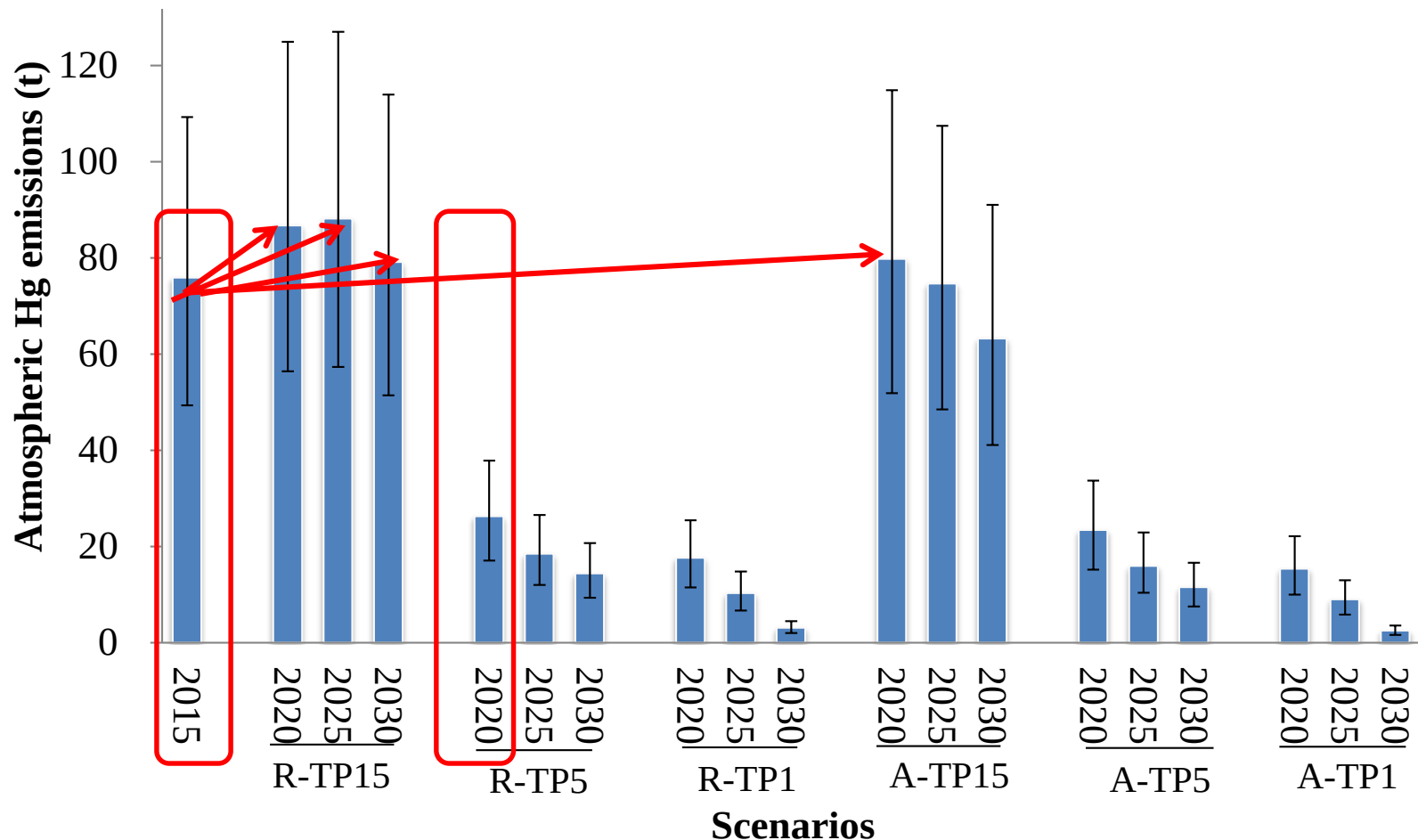


Future coal consumption

Parameters	R energy scenario			A energy scenario		
	2020	2025	2030	2020	2025	2030
AAGR of GDP (%)	7.0	6.0	5.0	6.5	5.5	4.5
GDP (103 billion USD)	14.61	19.56	24.96	14.28	19.10	24.37
Population (billion)	1.43	1.45	1.47	1.43	1.45	1.47
GDP per capita (USD)	10220	13488	16980	9983	13173	16580
Elasticity of electricity	0.76	0.61	0.45	0.65	0.53	0.40
Electric growth rate (%)	5.32	3.63	2.25	4.23	2.89	1.80
Total electricity (10 ³ GWh)	7438	8890	9936	7059	8139	8898
Percentage of CFPP electricity (%)	62.1	53.6	45.0	60.0	50.0	40.0
Coal-fired electricity (10 ³ GWh)	4619	4760	4471	4236	4070	3559
Standard coal consumption (g/kWh)	290	285	280	290	285	280
Coal consumption (Mt)	2180	2208	2038	1999	1888	1622

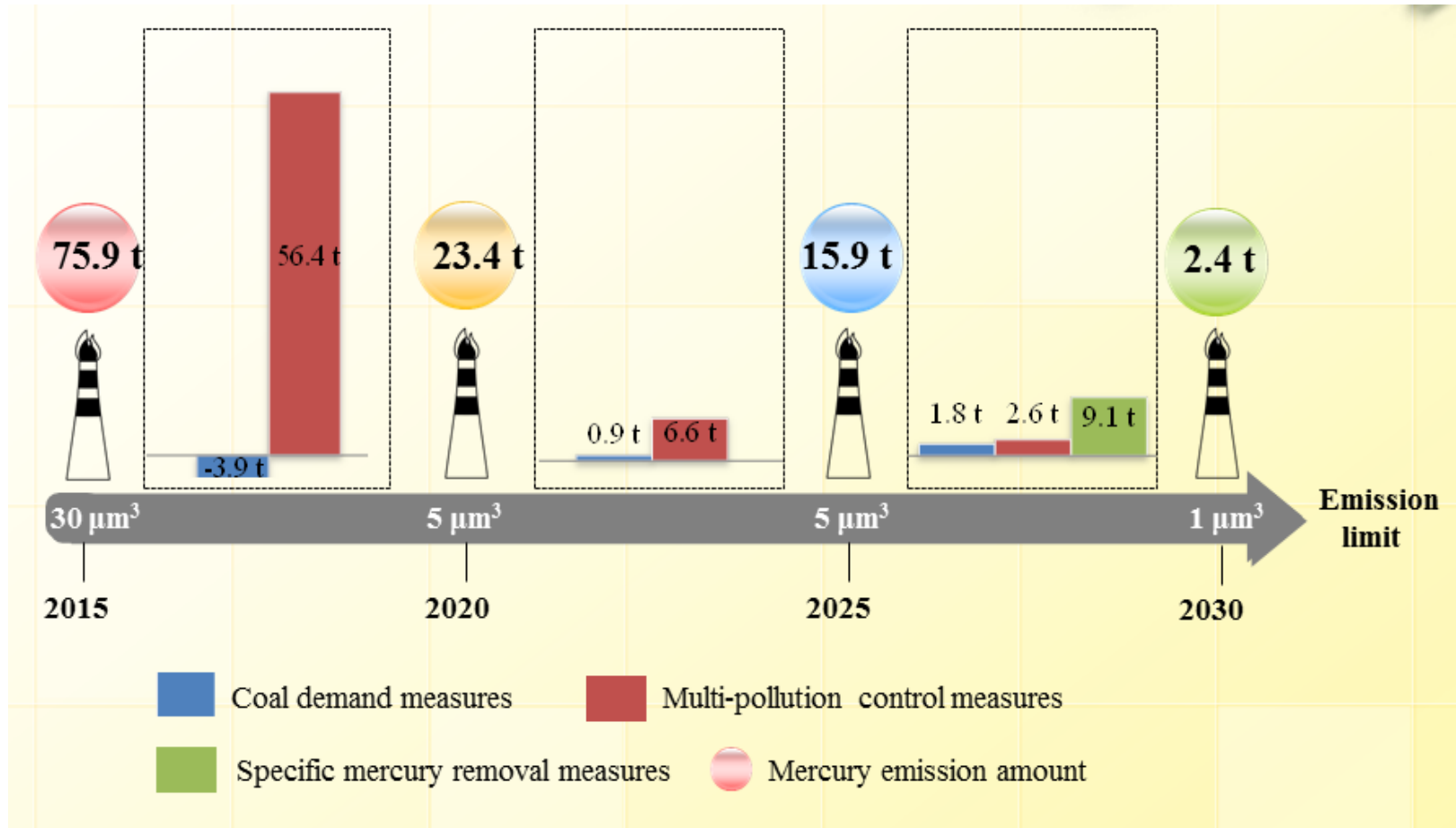
R energy scenario: Reference energy scenario; A energy scenario: Alternative energy scenario

Emission projection



- Emissions under A energy scenario are 14% lower than that under R energy scenario.
- TP15 scenario indicated that emission limit of $15 \mu\text{g}/\text{m}^3$ actually won't work during 2015-20.
- Large reduction of atmospheric Hg emissions will be in 2015-2020 by applying TP-5 technical path.

Emission-limit-oriented strategy



- Emission limit is recommended to be 5 $\mu\text{g}/\text{m}^3$ in 2020 and 2025 supported by primarily using multi-pollution control measures.
- During 2025-2030, both alternative energy measures and SMR technologies will further be applied to achieve Hg reduction and the emission limit of 1 $\mu\text{g}/\text{m}^3$ in 2030.

Take home message...

- China has achieved significant progress on the emission control of PM, SO₂, and NO_x in CFPPs.
- Existing Hg emission limit for CFPPs is still too loose, which is recommended to be revised to 5 µg/m³ around 2020 and 1 µg/m³ in 2030.
- Multi-pollution control technologies has been and will still the dominant Hg removal measure before 2025.
- Alternative energy measures and SMR technologies will aid to Hg emission control in CFPPs after 2025.

School of Environment, Tsinghua University

- Number of institute: 13;
- Number of faculty members: 110

Institute of Air Pollution and Control

- Formation and Emission of Air Pollutants
- Physical and Chemical Processes during the Transportation of Air pollutants
- Air Quality Simulation,
- Air Pollution Control Technology,
- Strategy and Countermeasures for air pollution control

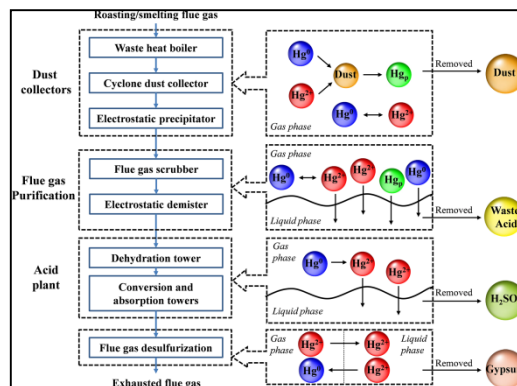


Contact

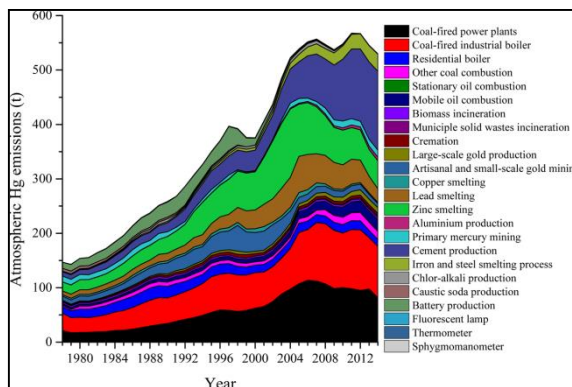


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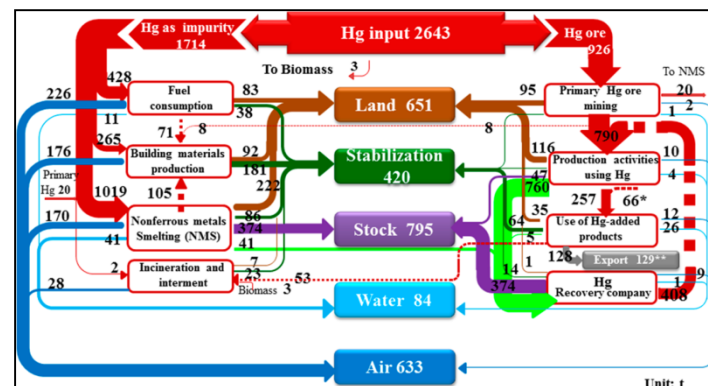
Research Interest



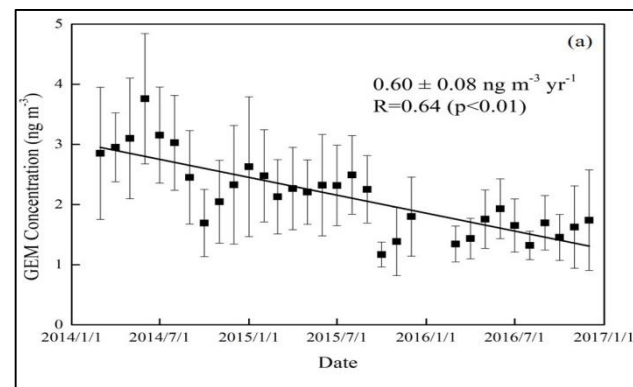
Source emission characteristics of trace metals



Emission Inventory of air
 pollutants



Materials flow analysis of trace metals



Mercury transportation and
 transformation in the air

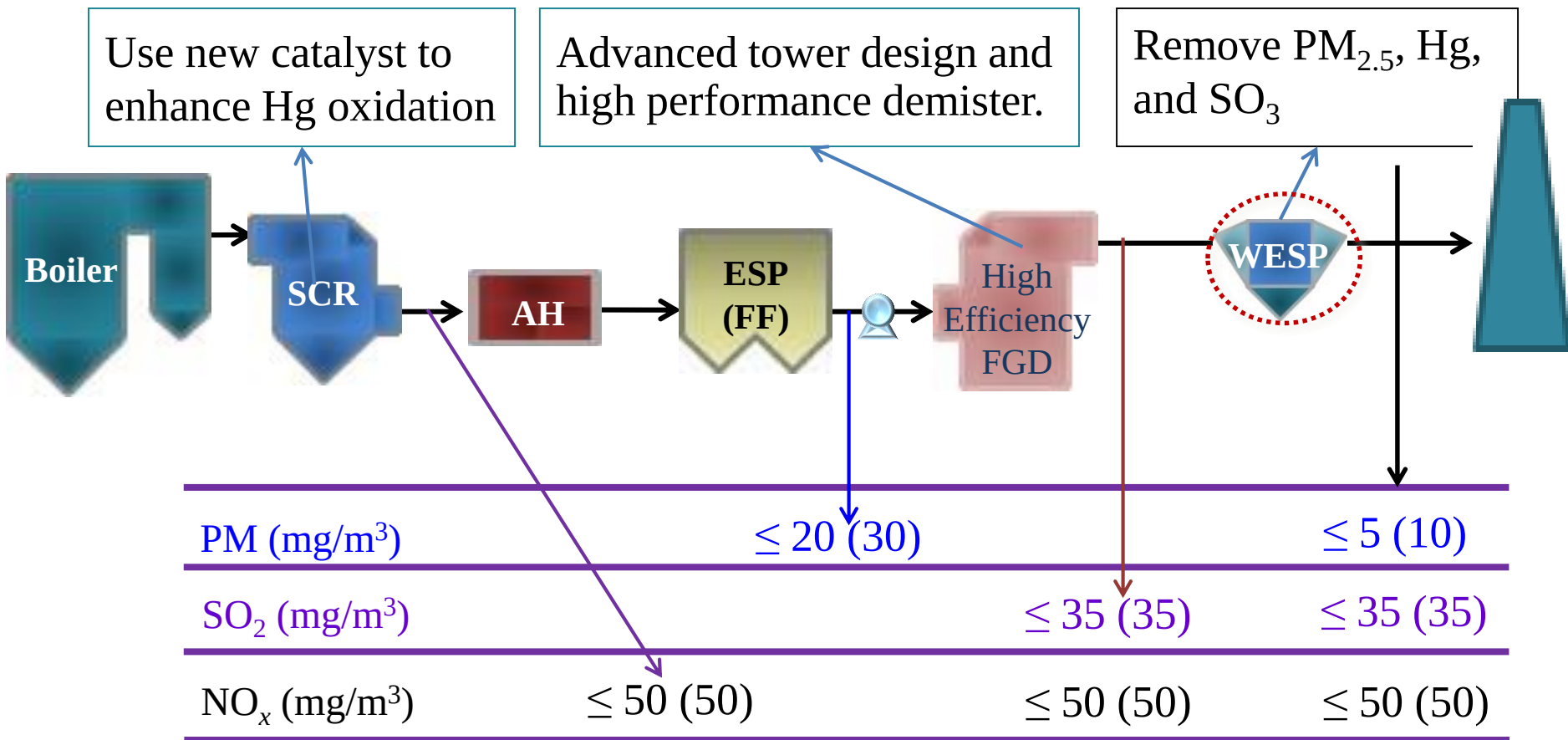


Thank you for your attention!

Promotion of ultra-low emission techniques

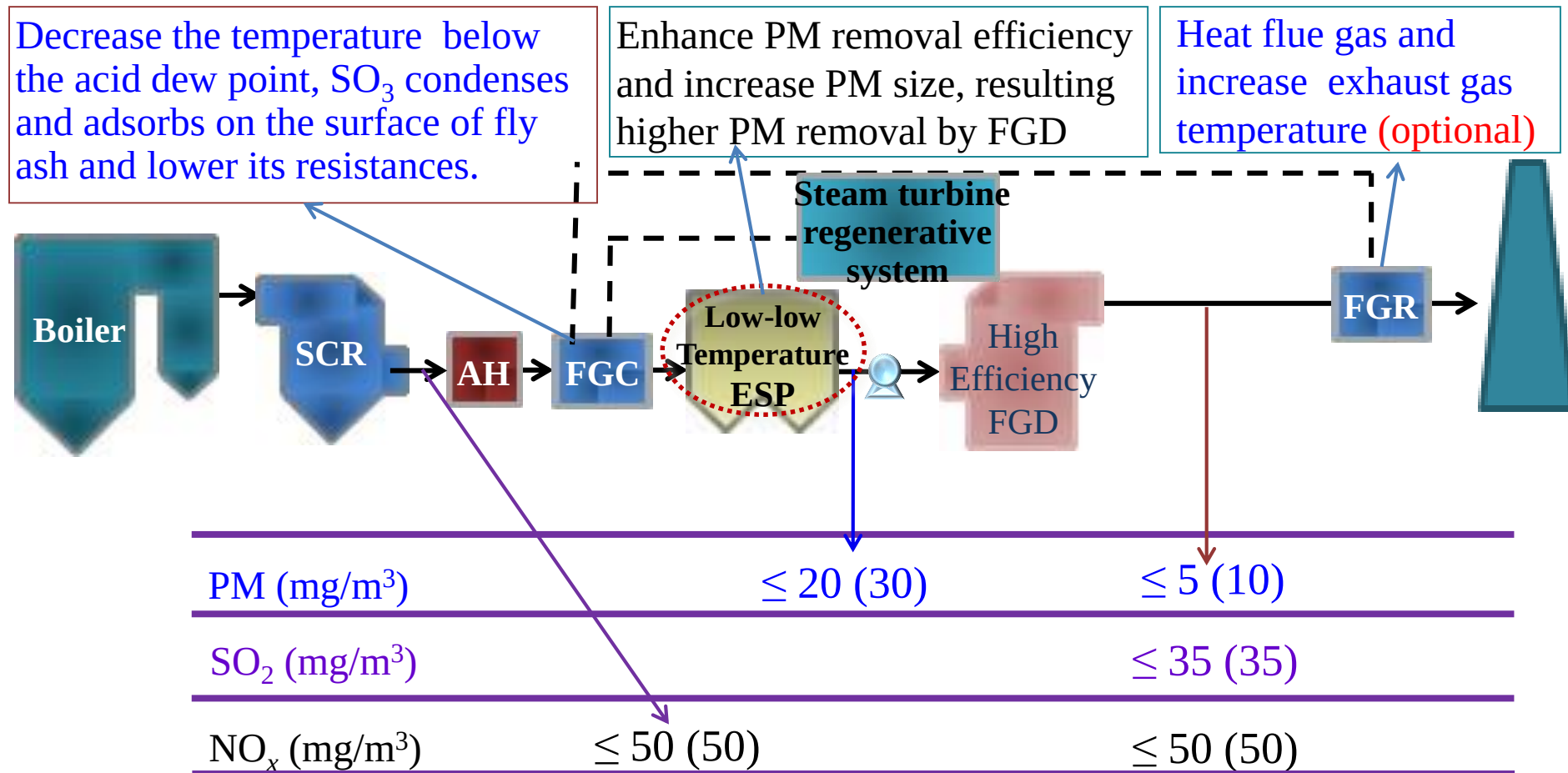
Typically two ways to meet the ultra low emission standard,

1. SCR + ESP(FF) + FGD + WESP



Promotion of ultra-low emission techniques

2. SCR + FGC + LTESP + FGD + FGR



Application rate of different APCD combinations

Type	APCD combinations	Application rate of different APCD combinations (%)									
		2015	2020			2025			2030		
			TP15	TP5	TP1	TP15	TP5	TP1	TP15	TP5	TP1
1	(PC+)ESP+WFGD	2.4	2.4	0.0	0.0	2.4	0.0	0.0	2.4	0.0	0.0
2	(CFB+)ESP+CFGD	10.2	10.2	3.6	3.6	10.2	2.0	1.5	10.2	0.0	0.0
3	(PC+)SCR+ESP+WFGD	64.4	64.4	9.4	9.1	64.4	2.4	1.7	64.4	0.0	0.0
4	(PC+)FF+WFGD	0.2	0.2	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.0
5	(PC+)SCR+FF+WFGD	3.6	3.6	0.6	0.6	3.6	0.2	0.2	3.6	0.0	0.0
6	(PC+)SCR+ESP(FF)+WFGD+WESP	2.8	2.8	26.6	0.4	2.8	29.3	0.6	2.8	29.1	0.0
7	(CFB+)ESP-FF+CFGD	0.0	0.0	6.5	4.0	0.0	7.8	7.7	0.0	10.9	0.0
8	(PC+)ESP-FF+WFGD	0.5	0.5	0.0	0.0	0.5	0.0	0.0	0.5	0.0	0.0
9	(PC+)SCR+ESP-FF/LTESP+WFGD	15.1	15.1	53.3	6.5	15.1	58.3	6.0	15.1	58.2	0.0
10	(CFB+)SCR+ESP+CFGD+FF	0.8	0.8	0.0	2.5	0.8	0.0	8.5	0.8	1.8	12.7
11	(PC+)SCR+SMR+ESP(FF)+WFGD+WESP	0.0	0.0	0.0	24.5	0.0	0.0	24.6	0.0	0.0	29.1
12	(PC+)SCR+SMR+ESP-FF+WFGD	0.0	0.0	0.0	48.9	0.0	0.0	49.2	0.0	0.0	58.2

Requirement of the Convention

