



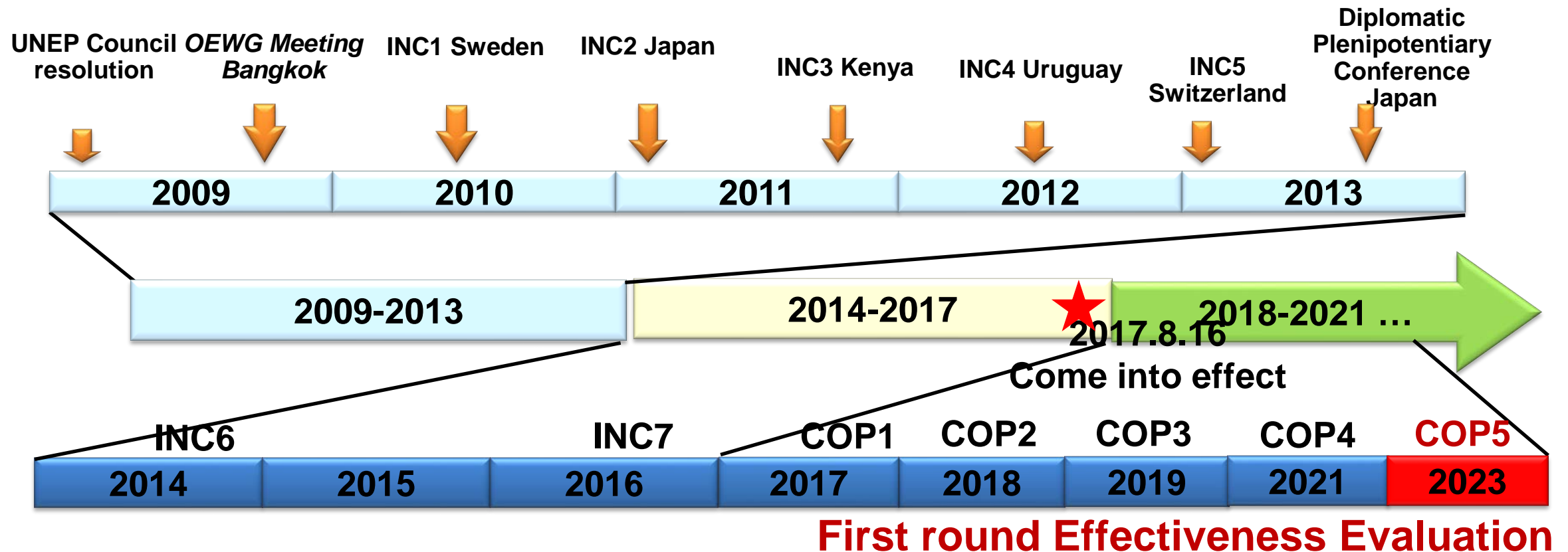
# Drivers of global mercury emissions during 2017-2022

**Shuxiao Wang, Qingru Wu, Gehui Zhang, Xiaoming Gu**  
**Tsinghua University**  
**2024/7/25**



# Minamata Convention on Mercury

**Effectiveness evaluation: Conference of the Parties shall evaluate the effectiveness of this Convention, beginning no later than six years after the date of entry into force of the Convention and periodically thereafter at intervals to be decided by it.**



# Effectiveness evaluation of Minamata Convention

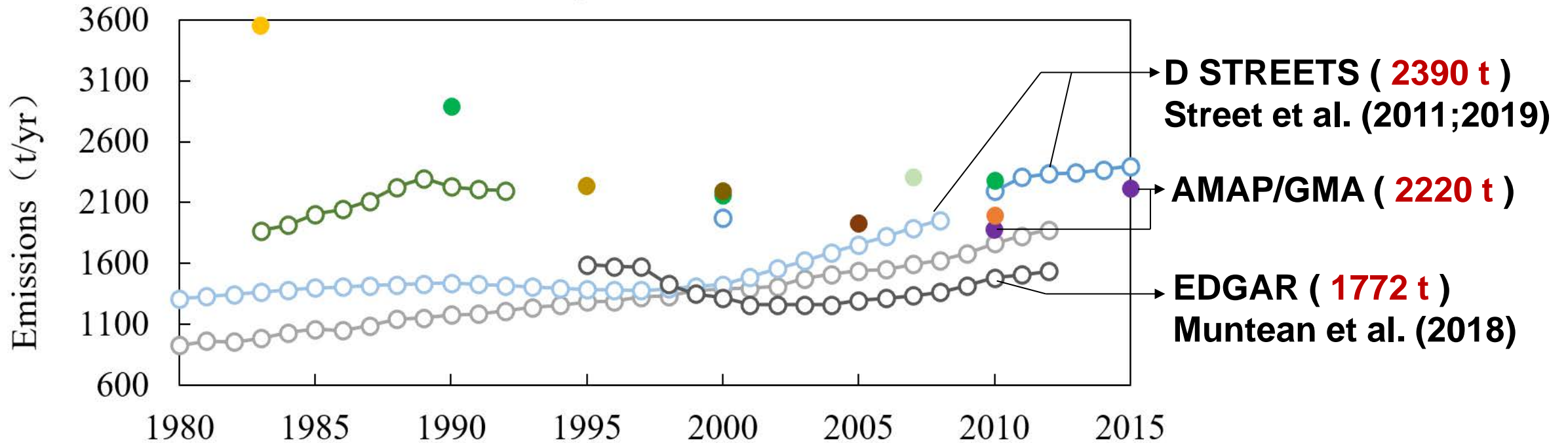
The effectiveness evaluation is guided by four overarching policy questions:\*

- (a) Have the Parties taken actions to implement the Minamata Convention?**
- (b) Have the actions taken resulted in changes in mercury supply, use, emissions and releases into the environment?**
- (c) Have those changes resulted in changes in levels of mercury in the environment, biotic media and vulnerable populations that can be attributed to the Minamata Convention?**
- (d) To what extent are existing measures under the Minamata Convention meeting the objective of protecting human health and the environment from mercury?**

\* See document UNEP/MC/COP.3/14

# How much mercury was emitted to air in base year?

Existing estimates of global Hg emissions using emission factor method:



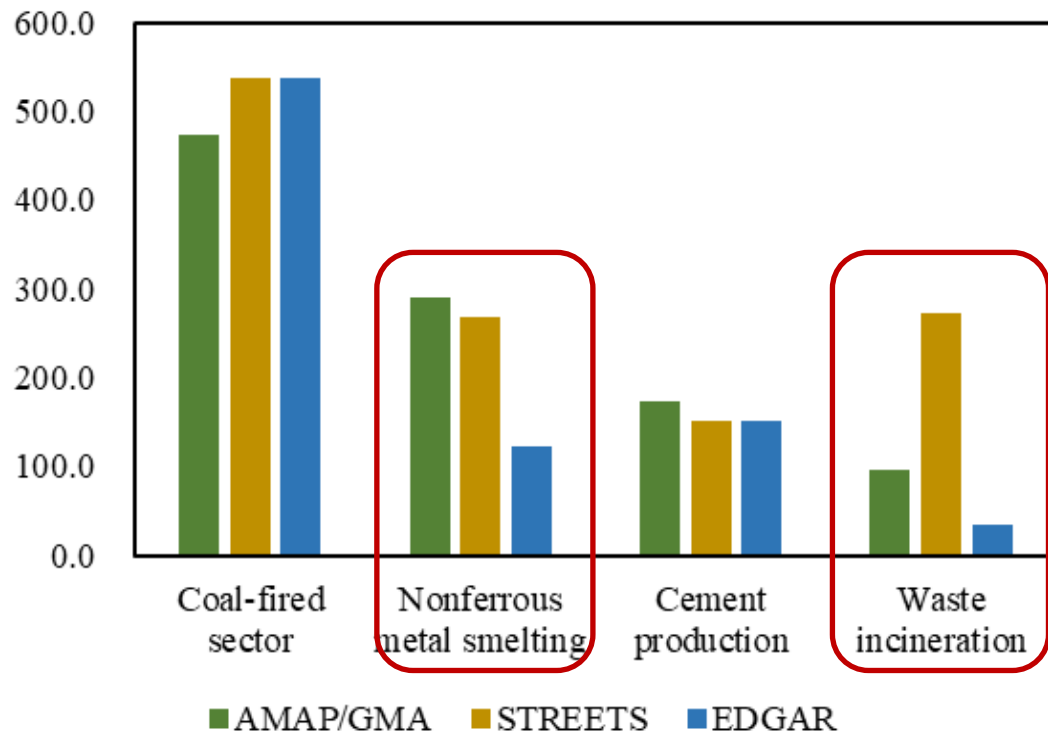
- AMAP/UN Environment
- Zhang et al. (2016)
- Streets et al. (2019)
- Streets et al. (2011)
- Pirrone et al. (1996)
- Pirrone et al. (2010)
- Muntean et al. (2018)
- Streets et al. (2011)
- Pirrone et al. (1996)
- Zhu et al. (2020)
- Pirrone et al. (2010)
- Nriagu et al. (1998)
- Pacyna et al. (2001)
- Streets et al. (2019)
- Streets et al. (2011)
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- Pirrone et al. (1996)
- Pirrone et al. (2010)
- Pacyna et al. (2016)

**Differences: 600 tons**

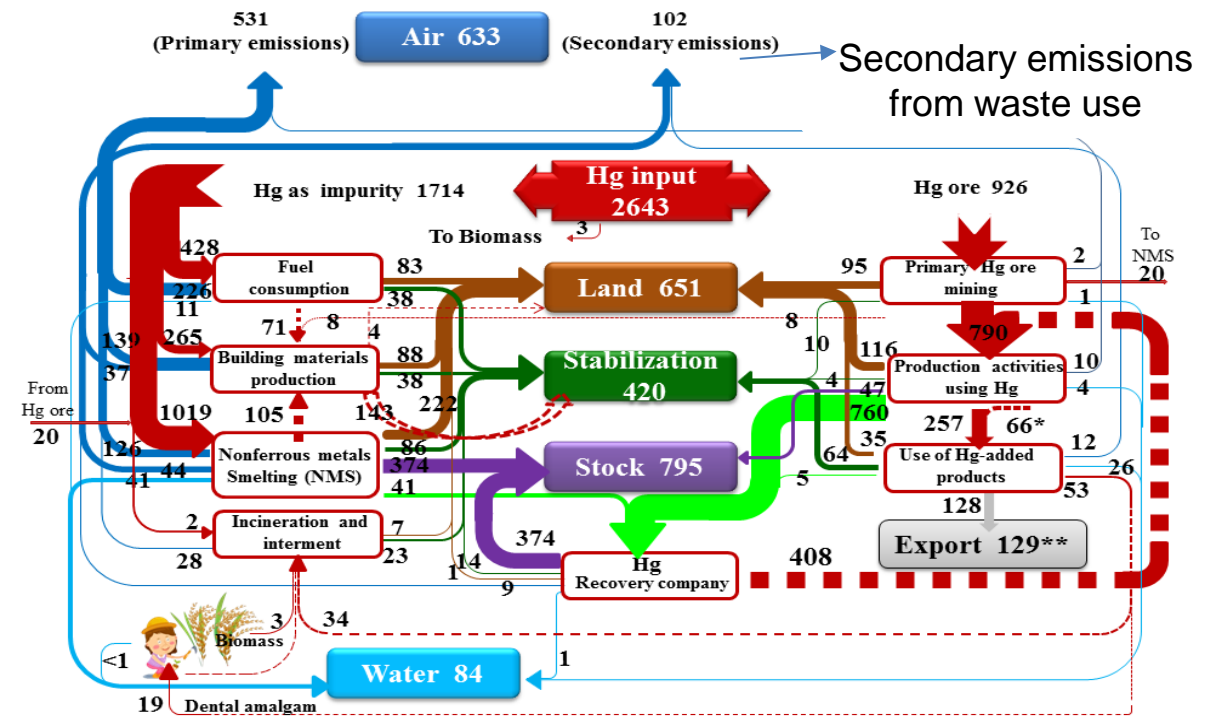
**The uncertainty is high**

# Hg flow analysis may better reflect the effectiveness

The uncertainty of Hg emissions from sectors which involve waste disposal is much higher. Ignoring the links between production activities and waste disposal will potentially overlook secondary atmospheric Hg emissions.



Hg emissions from key industries in different studies (2010)



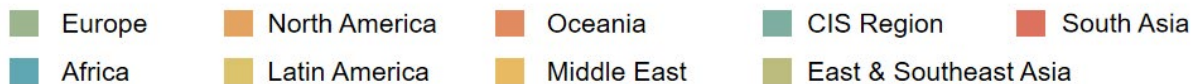
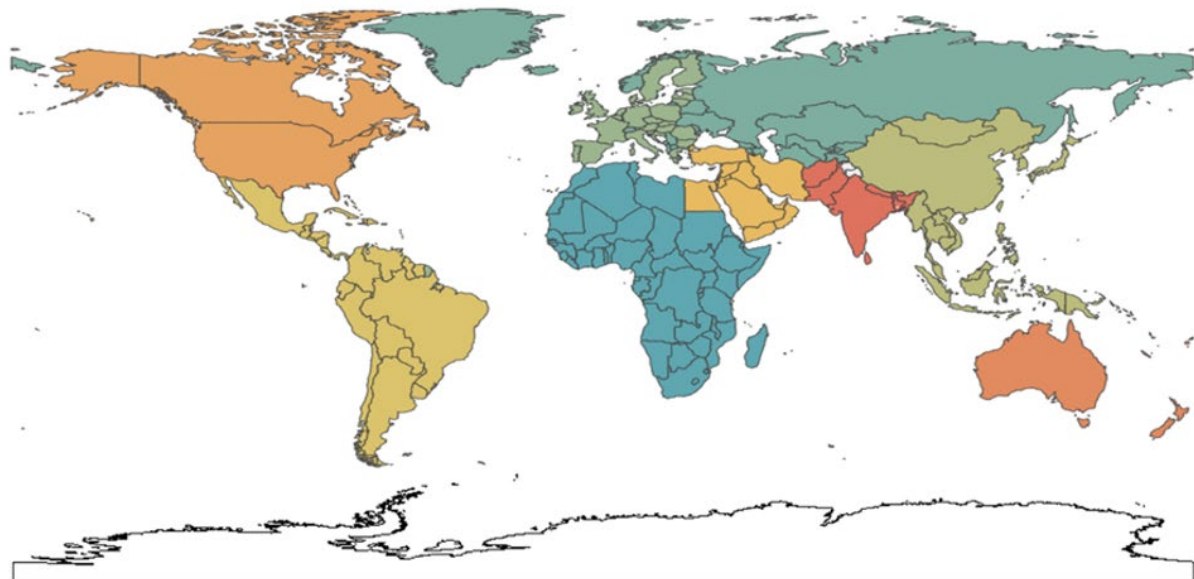
Mercury flows in China and global drivers (Hui et al., ES&T, 2017)

# Global mercury flow analysis

## ➤ Research scope and study period (2017-2022)

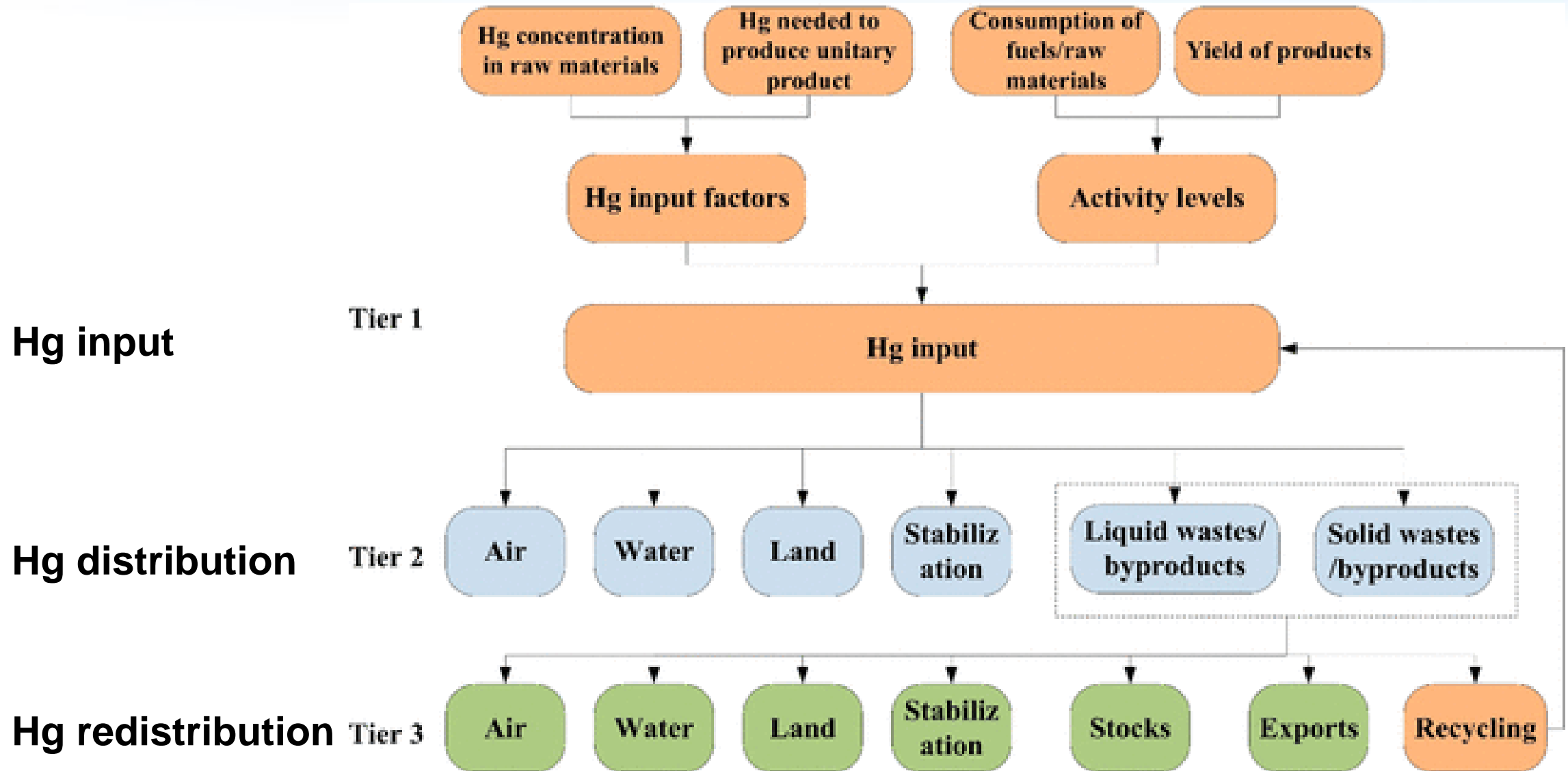
**227 countries, 9 regions in the world**

**Sectors: 29**



Sectors	Sectors
Coal-fired power plants	Leading smelting
Coal-fired industrial boilers	Zinc smelting
Other coal combustion	Copper smelting
Stationary oil combustion	Large-scale gold production
Gas combustion	Aluminum production
Biomass fuel combustion	Cement production
Municipal solid waste incineration	Coking
Municipal solid waste landfill	Iron and steel production
Primary Hg mining	Battery production
Hg Recovery	Sphygmomanometer production
Artisanal and small-scale gold mining	Thermometer production
Caustic soda production	Dental production
Chlor-alkali process	Fluorescent lamp production
Hg catalyst production	Hg-containing electronic devices production
	Other Hg-containing equipment production

# Conceptual model for mercury flow analysis



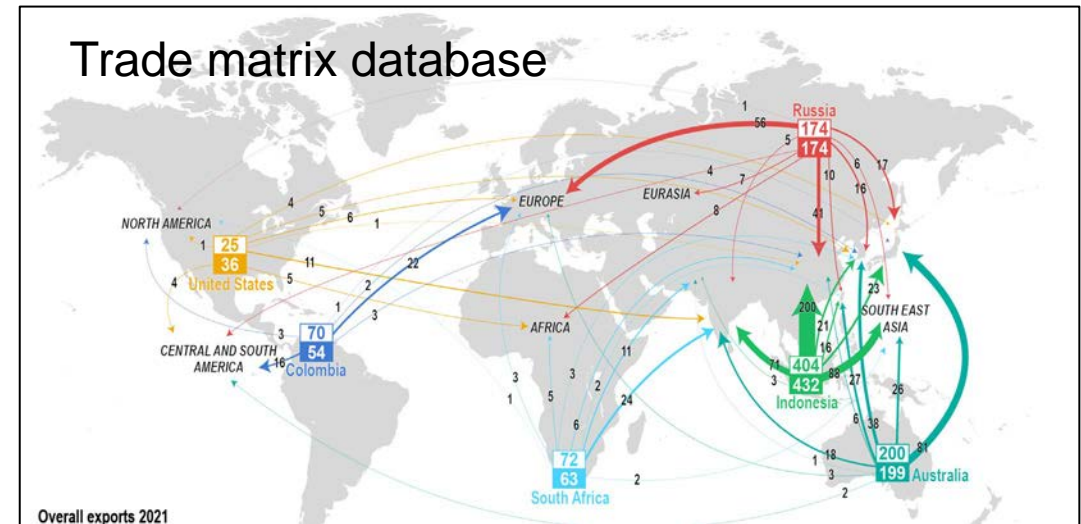
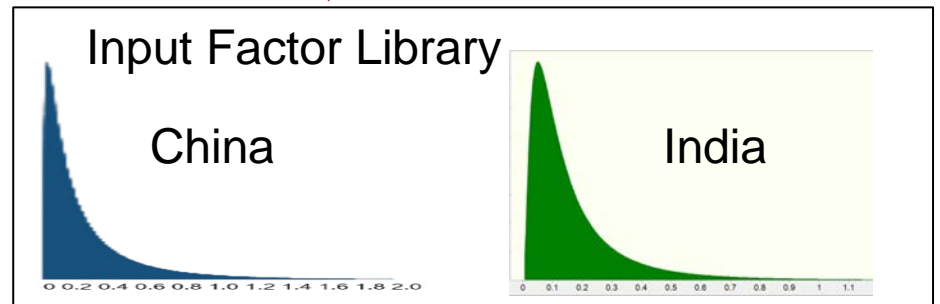
# Global mercury flow analysis

## Tier 1: Hg input

$$I_i = \sum_k [(A_{i,k} - \sum_{j \neq i} B_{i,j,k}) \times C_{i,k} + \sum_{j \neq i} (B_{i,j,k} \times C_{j,k})]$$

Activity level in 2017-2022

Sector	Consumption/ Production	Activity level						unit
		2017	2018	2019	2020	2021	2022	
Coal-fired power plants	Coal consumption	5.1	5.2	5.2	4.8	5.2	5.3	Gt
Coal-fired industry boilers	Coal consumption	0.6	0.6	0.6	0.6	0.7	0.7	Gt
Pb smelting	Mineral lead	4.0	4.2	4.8	5.3	5.2	5.8	Mt
	Production							
Zn smelting	Mineral zinc	13.0	12.5	12.7	12.8	13.0	13.4	Mt
	Production							
Cu smelting	Mineral copper	18.0	18.6	17.8	18.6	19.1	19.4	Mt
	Production							
Large-scale gold smelting	Gold production	3260	3310	3270	3030	2989	2911	t
Cement production	Cement production	3.9	3.8	4.0	4.0	4.4	4.1	Gt
Waste incineration	Amount of waste incinerated	2.7	2.7	2.8	2.8	3.0	3.1	Gt



# Global mercury flow analysis

## Tier 2: Hg distribution during production or combustion process

### Application rates and distribution factors

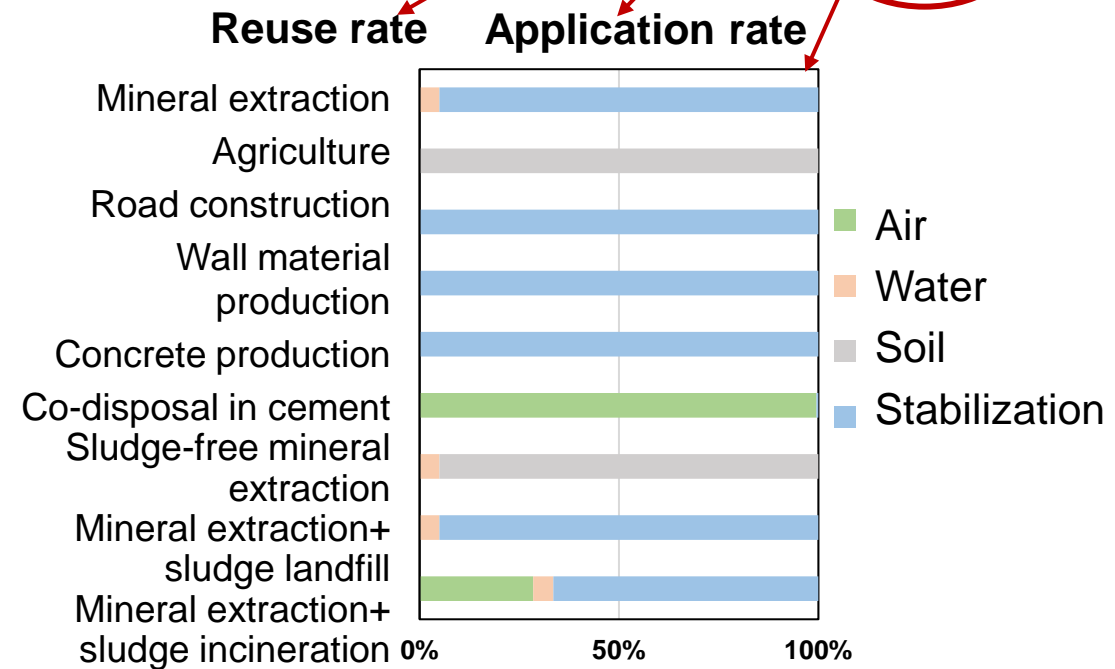
$$RM_{i,j,k} = \sum_e \sum_m \sum_n I_{i,j} \times T_{i,j,e} \times Q_{i,j,m,n} \times df_{i,j,n,k}$$

Air pollution control devices (APCDs)	Application rates (%)								Distribution factors (%)			
	AUS	BRA	CAN	CHN	EU	JPN	KOR	USA	Air	Fly ash	Gyp sum	Clin ker
Shaft kiln/rotary kiln	0	0	0	2	1	0	0	3	38	57	0	5
Dry-process precalciner+FF	100	100	38	8	61	85	0	82	94	0	0	6
Dry-process precalciner+FF+WFGD	0	0	40	0	23	9	100	9	69	0	25	6
Dry-process precalciner+FF+SCR+WFGD	0	0	0	6	1	1	0	1	54	0	40	6
Dry-process precalciner+FF+SCR/SNCR	0	0	23	84	15	5	0	5	94	0	0	6

## Tier 3: Hg re-distribution during waste disposal process

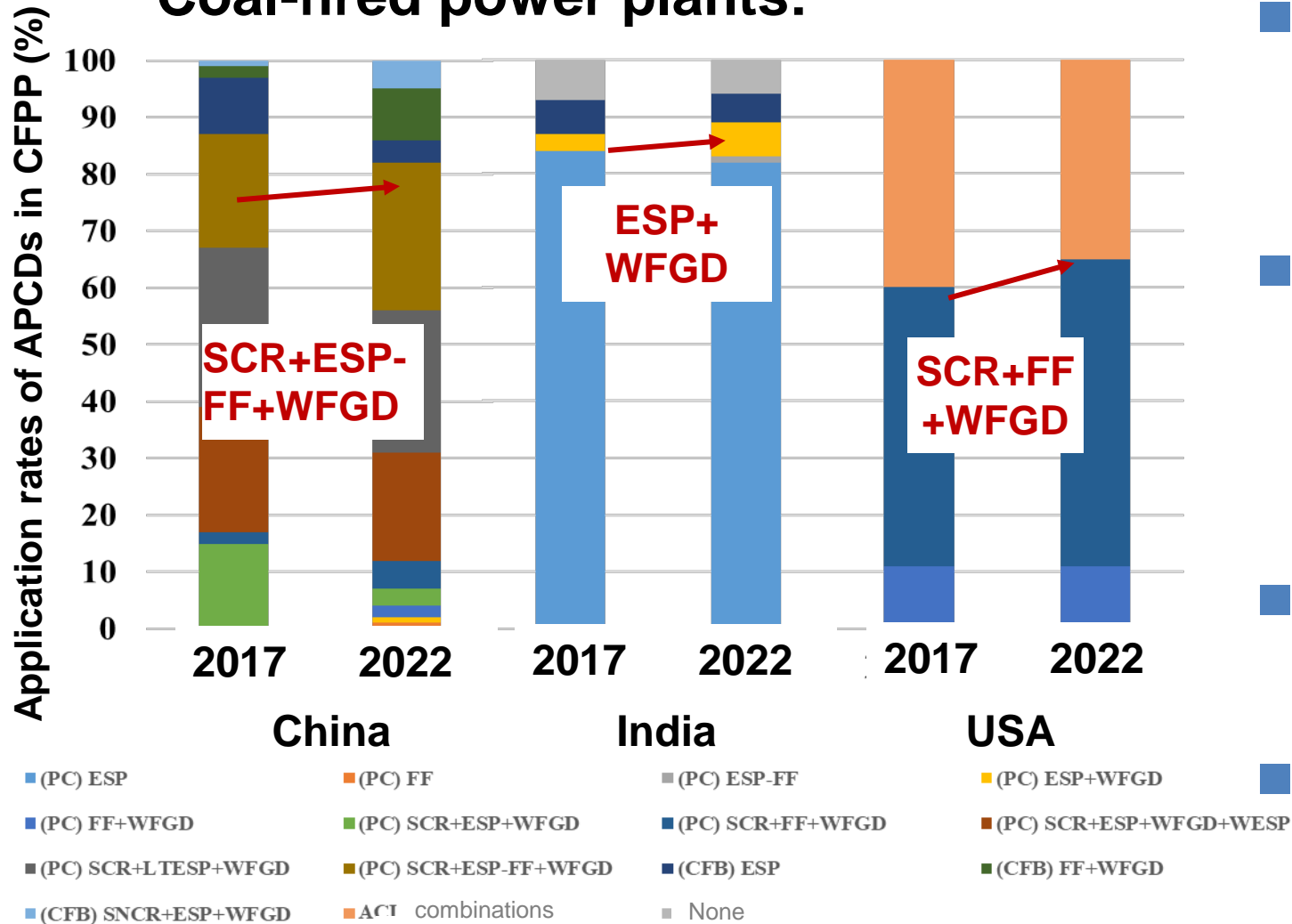
### Global-scale re-distribution module

$$r - RM_{i,j,q} = \sum_h RM_{i,j,k} \times \alpha_{i,j,k} \times \beta_{i,j,h,k} \times df_{i,j,h,q}$$



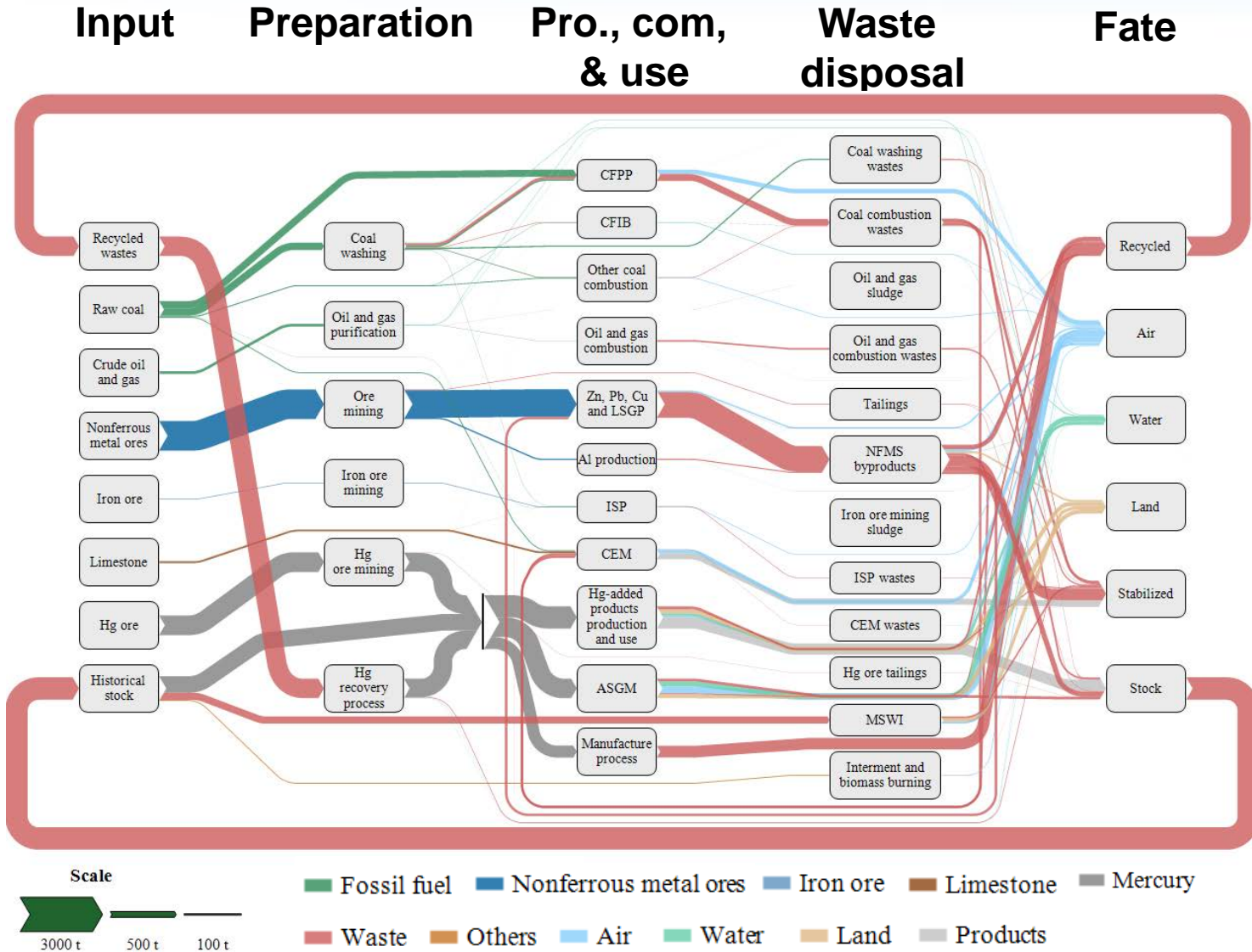
# Changes of air pollution control techniques, 2017-2022

## Coal-fired power plants:



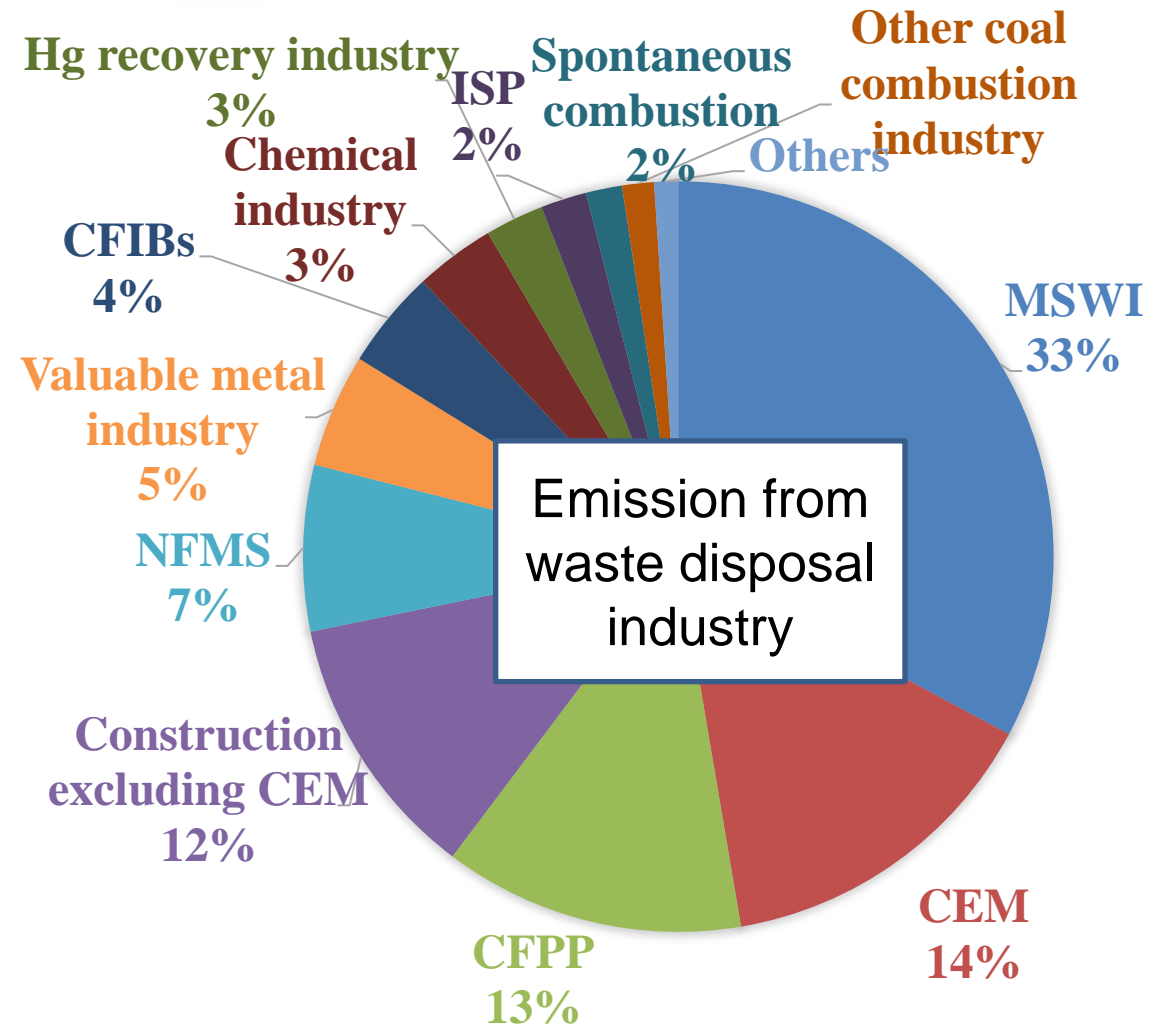
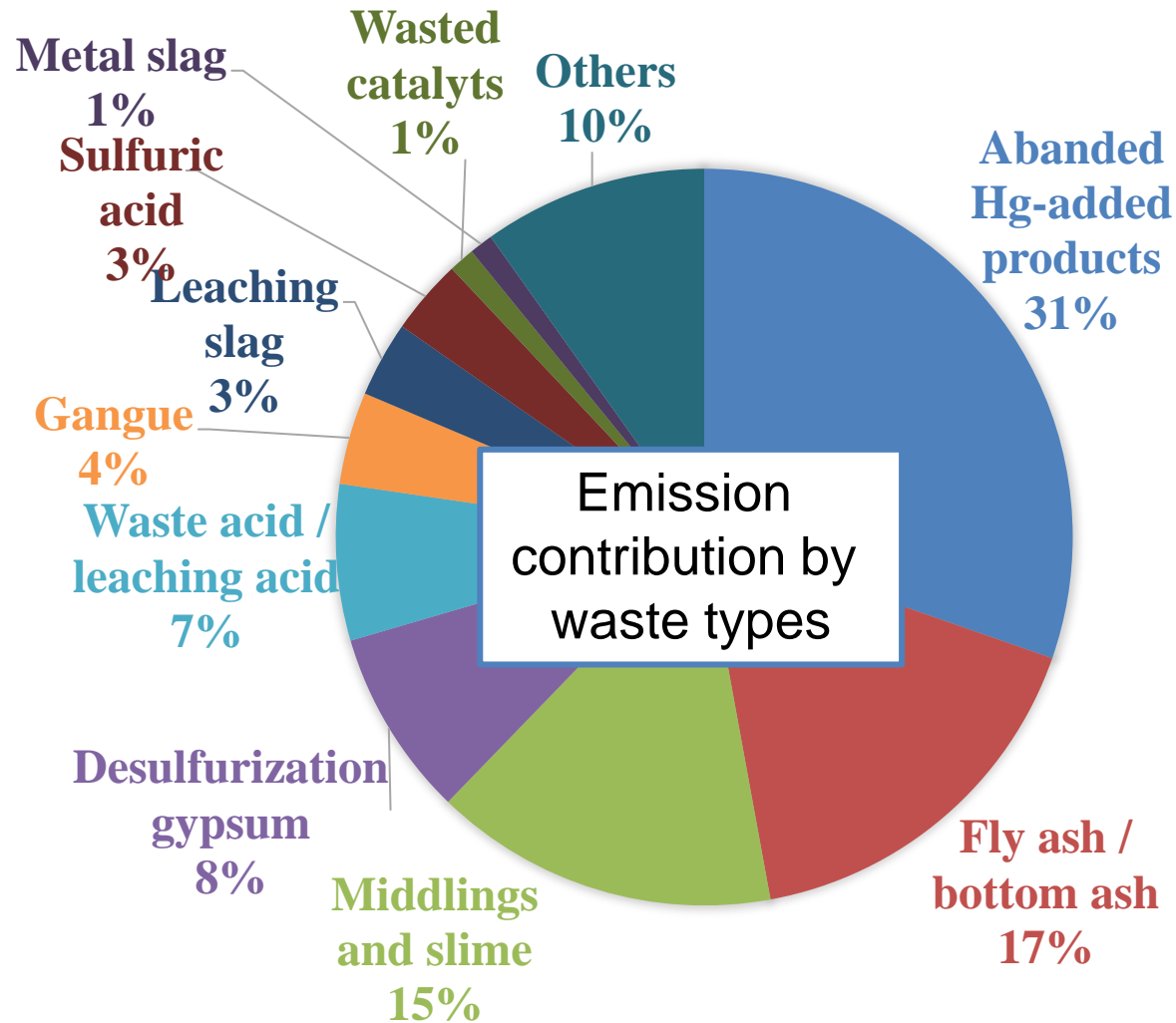
- Changes of pollution control techniques were considered for countries.
- The application rate of ultra-low emission (ULE) technique in China's CFPPs has increased from 70% in 2017 to 94% in 2022.
- Slightly growth of WFGD use in India CFPPs was observed (3%).
- The CFPPs in the US apply more SCR+FF+WFGD in 2022.

# Global mercury flows in 2017



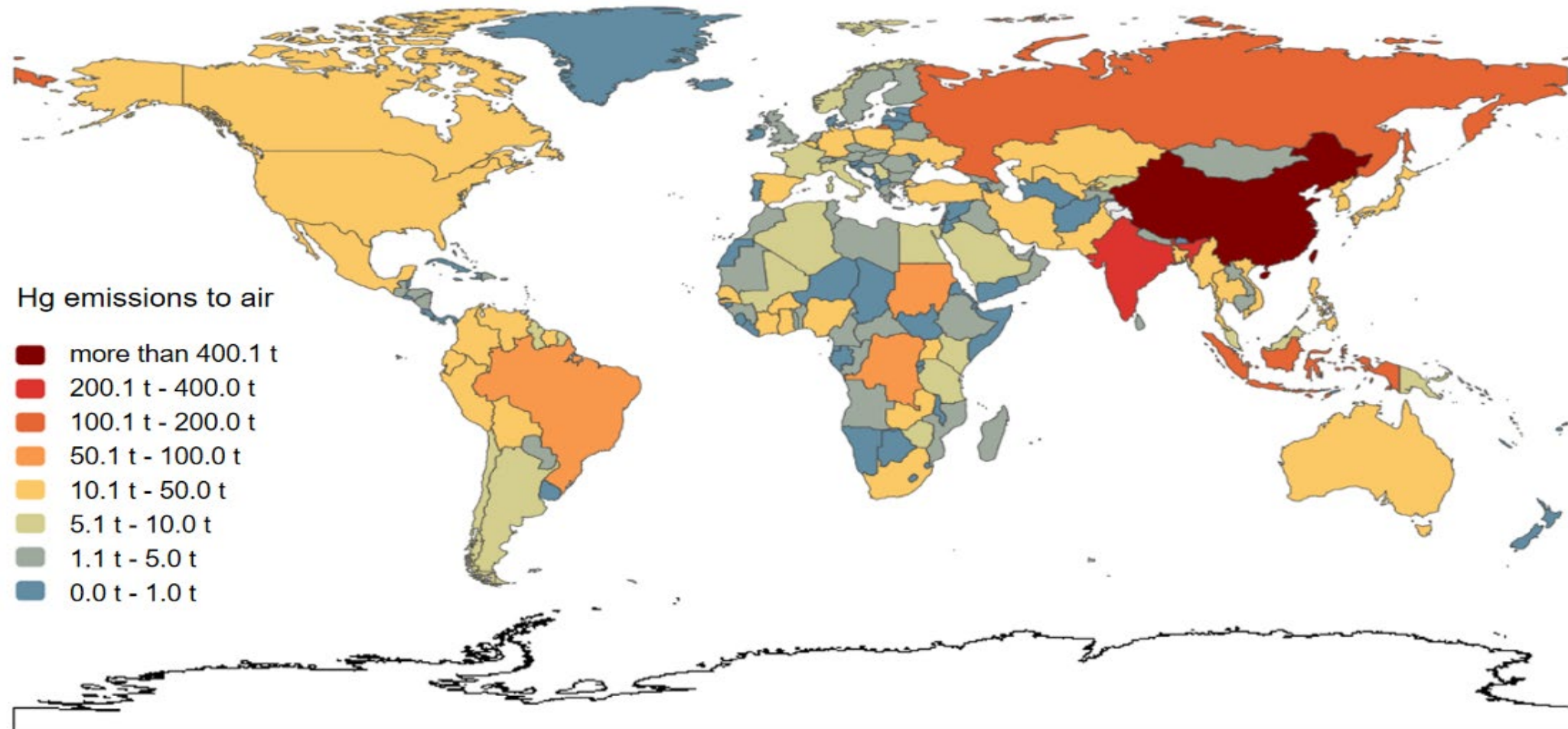
- In 2017, the global Hg input was 9600 t, with 45% from historical stock and recycled wastes.
- Hg releases to air, water and land were 2305 t, 952 t and 1379 t, respectively, accounting for 45% of total Hg in the fates.
- Approximately 20% of the total input of Hg was stabilized.
- The rest was either stock in the society as wastes/products or recycled.

# Waste disposal contributes to 30% of Hg emissions



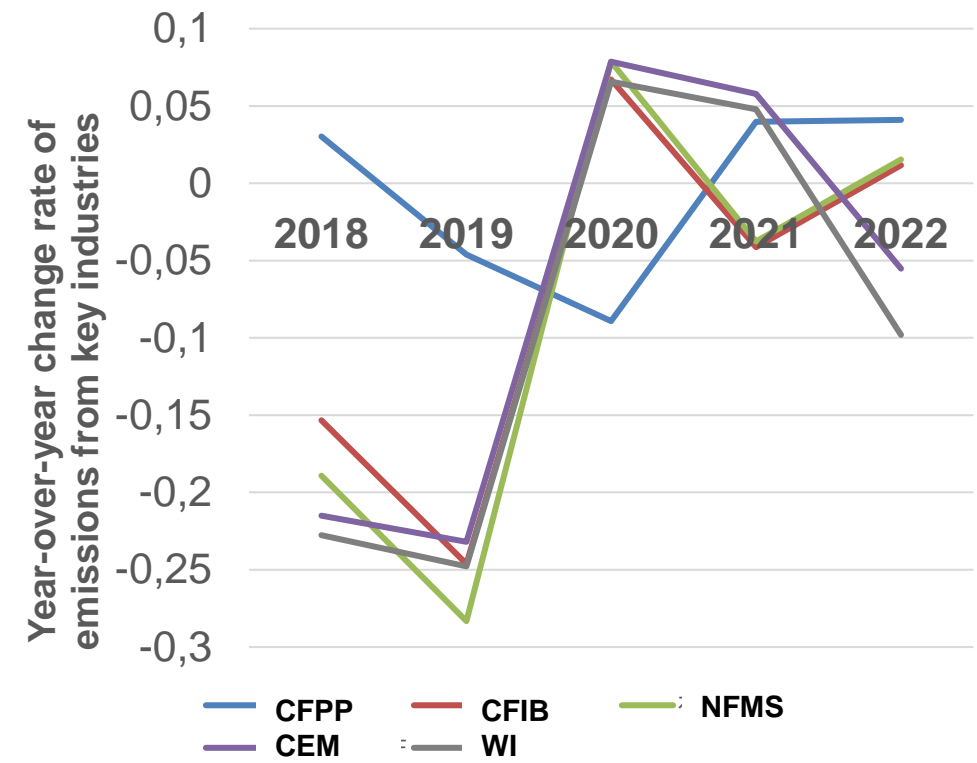
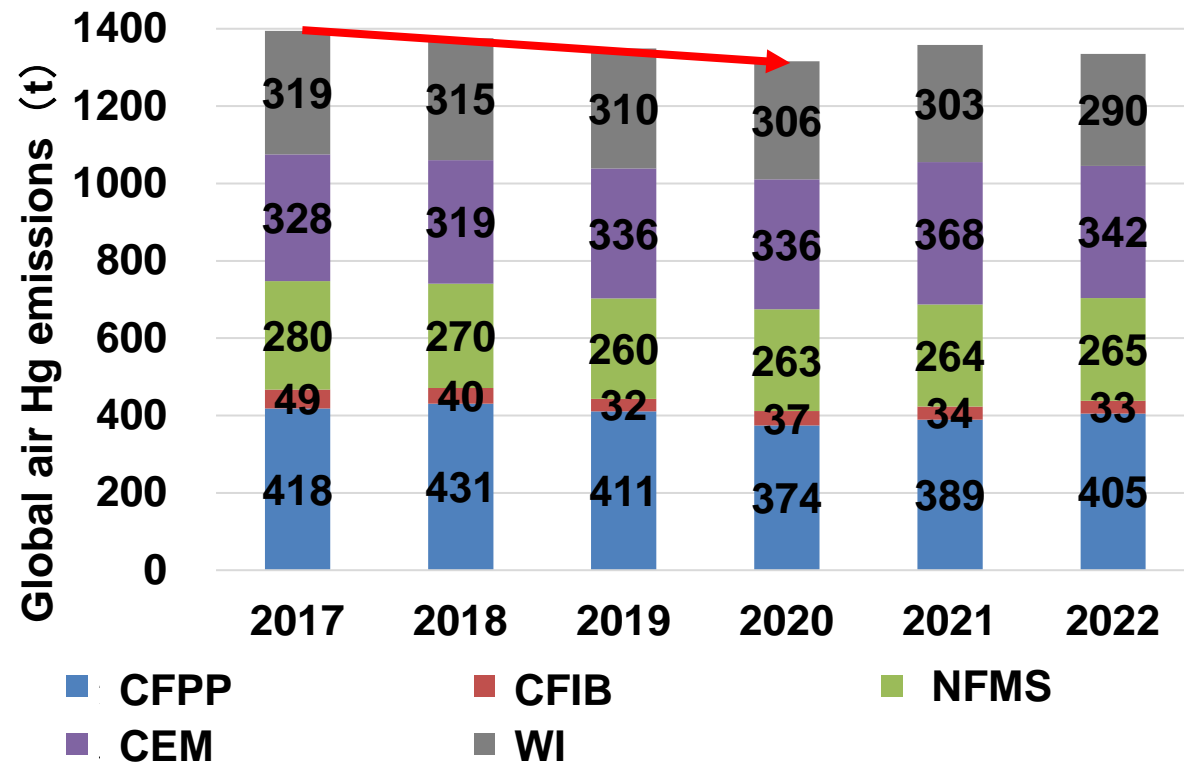
# Atmospheric Hg emissions by country in 2017

China, India and Indonesia emitted 1100 t Hg to air, 47% of global emissions.



# Trends of Hg emissions from relevant sources

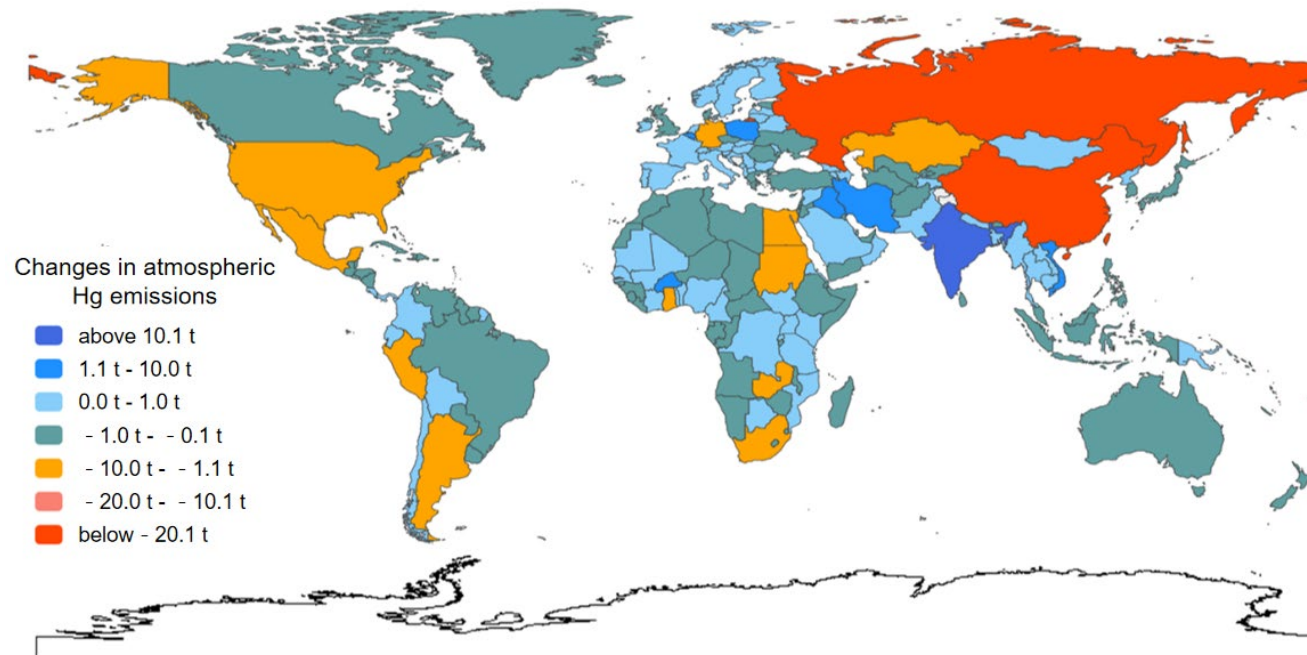
Hg emissions decreased from 1394 t in 2017 to 1316 t in 2020, then rebounded to 1335 t in 2022. Trends in emission varied significantly by sector; Emissions from other four sectors declined, except for cement production.



CFPP-coal-fired power plants; CFIB-coal-fired industrial boiler; CEM-cement clinker; NFMS- non-ferrous metal smelting; WI - waste incineration

# Trends of Hg emission from relevant sources by country

- The air Hg emissions in China and Russia reduced by 34 and 26 tons during 2017-2022, while that in India and Viet Nam increased by 15 and 9 tons, respectively.
- **China accounts for 48% of the global atmospheric Hg emission reductions.**



Emission change of 5 key sectors by country, 2017-2022 (t)



Top 10 countries for Hg emission changes in the five major sectors (t)

# Key drivers of Hg emission changes: method

A decomposition analysis was conducted to analyze the effect of 6 drivers, the **End-of-pipe control**  $HI_{i,j}$ , **Raw material control**  $C_{i,j}$ , **Industry structure**  $S_{i,j}$ , **Resource intensity**  $EI_{i,j}$ , **Economic level**  $E_i$  and **Population**  $P_i$  on Hg emissions:

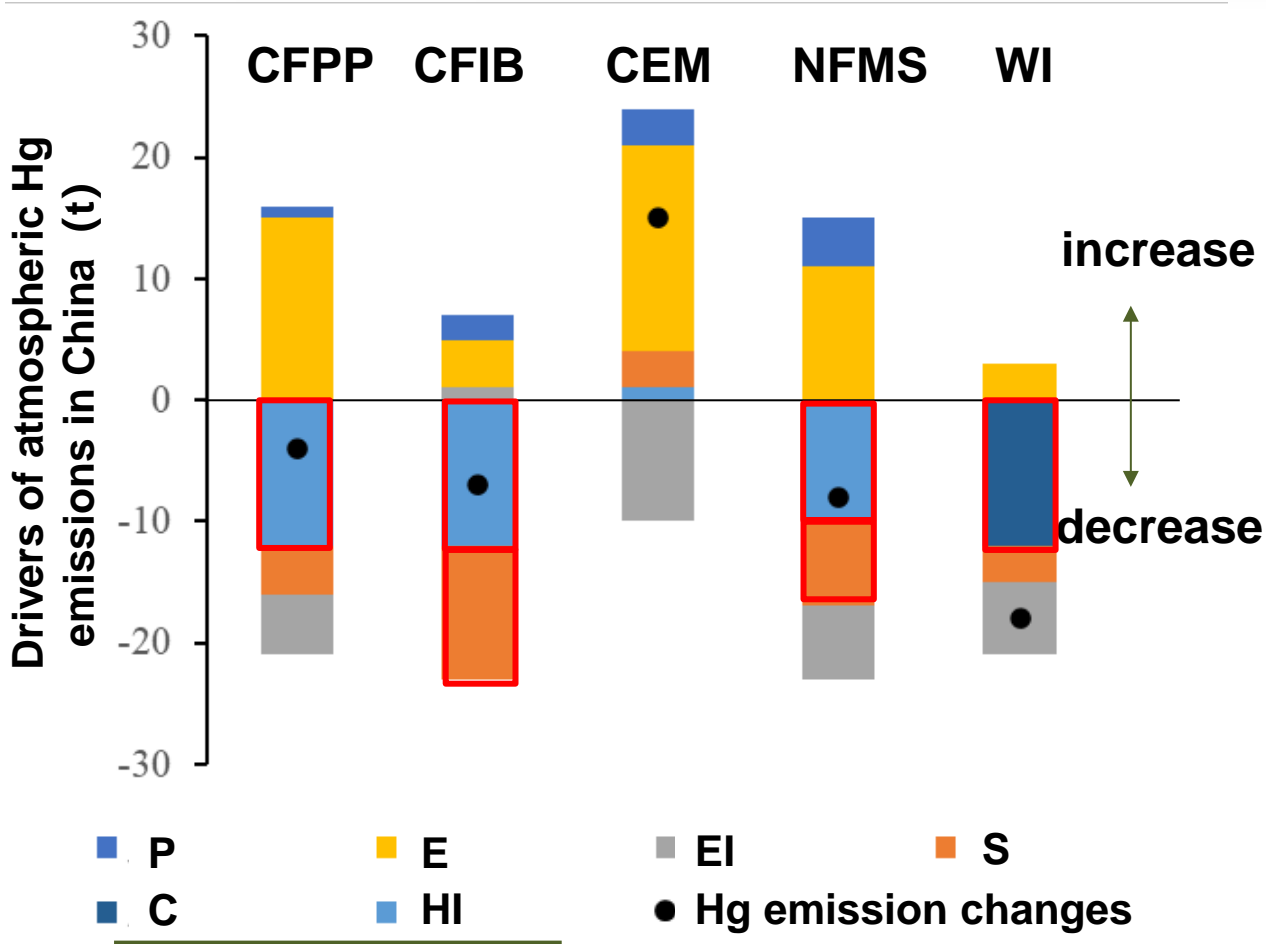
$$E_{Hg_{i,j}} = \frac{E_{Hg_{i,j}}}{I_{i,j}} \times \frac{I_{i,j}}{ATOT_{i,j}} \times \frac{ATOT_{i,j}}{GDP_{i,j}} \times \frac{GDP_i}{P_i} \times P_i = HI_{i,j} \times (C_{i,j} \times \alpha_{i,j} \times \theta_{i,j}) \times EI_{i,j} \times E_i \times P_i$$
$$= HI_{i,j} \times C_{i,j} \times S_{i,j} \times EI_{i,j} \times E_i \times P_i$$

$E_{Hg_{i,j}}$ : atmospheric Hg emissions of sector  $j$  in country  $i$ ;  $I_{i,j}$ : Hg input of sector  $j$  in country  $i$ ;  $ATOT_{i,j}$ : final production or waste of sector  $j$  in country  $i$ ;  $GDP_i$ : Gross Domestic Product of country  $i$ ;  $P_i$ : population of country  $i$ ;  $\alpha_{i,j}$ : production efficiency of sector  $j$  in country  $i$ ;  $\theta_{i,j}$ : industry structure parameters of sector  $j$  in country  $i$ .

# Key drivers of Hg emission changes: method

Sector	End-of-pipe control, $HI$	Raw material control, $C_{i,j}$	Industry structure, $S_{i,j}$	Resource intensity, $EI$	Economy, $E$	Population, $P$
CFPP	End-of-pipe control measures	Hg content of raw materials due to international trade	Coal replacement and energy efficiency improvement	Electricity generation per GDP	GDP per capita	Population
CFIB				Heat supply per GDP		
CEM			Waste substitution and energy saving	Clinker production per GDP		
NFMS			Recycled metals increase	Metals production per GDP		
WI		Reflecting Hg-added product control effect	Waste incineration technologies	Waste generation per GDP		

# Drivers of Hg emission change: China

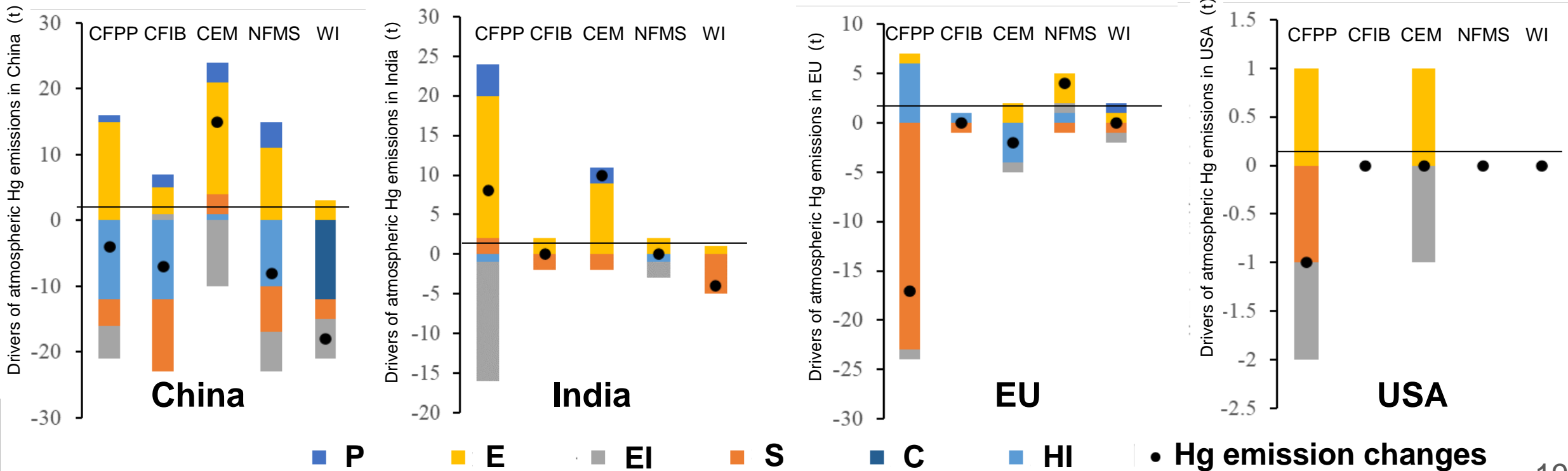


Effectiveness of the Convention

- The end-of-pipe control (HI) drove half of the emission reductions in CFPP, CFIB, and NFMS.
- Clean energy transition and metal recycle (S) resulted in 50% and 30% of the emission reduction in CFIB and NFMS.
- Limitation of Hg-added products (C) contributed 60% of the Hg emission reduction from waste incinerator.
- GDP growth is the key driver of Hg emission increase.

# Drivers of country-specific Hg emission change

- In India, effects of end-of-pipe control measures were limited, which is insufficient to offset the increase due to rapid economic growth.
- Clean energy transition and energy efficiency improvement in the EU and USA were key drivers of Hg reduction.



# Summary and implications

- In 2017, the global atmospheric Hg emissions, and Hg releases to water and land were 2305 t, 952 t and 1379 t, respectively.
- Waste disposal and utilization is a significant driver of global Hg flow and re-distribution. A holistic perspective is needed to ensure the success of Minamata Convention on Mercury.
- The global atmospheric Hg emission from five relevant source categories decreased from 1394 t in 2017 to 1335 t in 2022, with China accounted for approximately 48% of the total Hg reductions.
- Mercury emissions from coal combustion, non-ferrous metal smelting, and waste incineration decreased by 73 tons, while that from cement clinkers increased by 14 tons.
- Climate change mitigation measures were important drivers of Hg emission reduction, as well as clean air actions.

# Summary and implications

**Mercury control should consider synergistic management with related conventions such as UN Framework Convention on Climate Change and the Basel Convention.**

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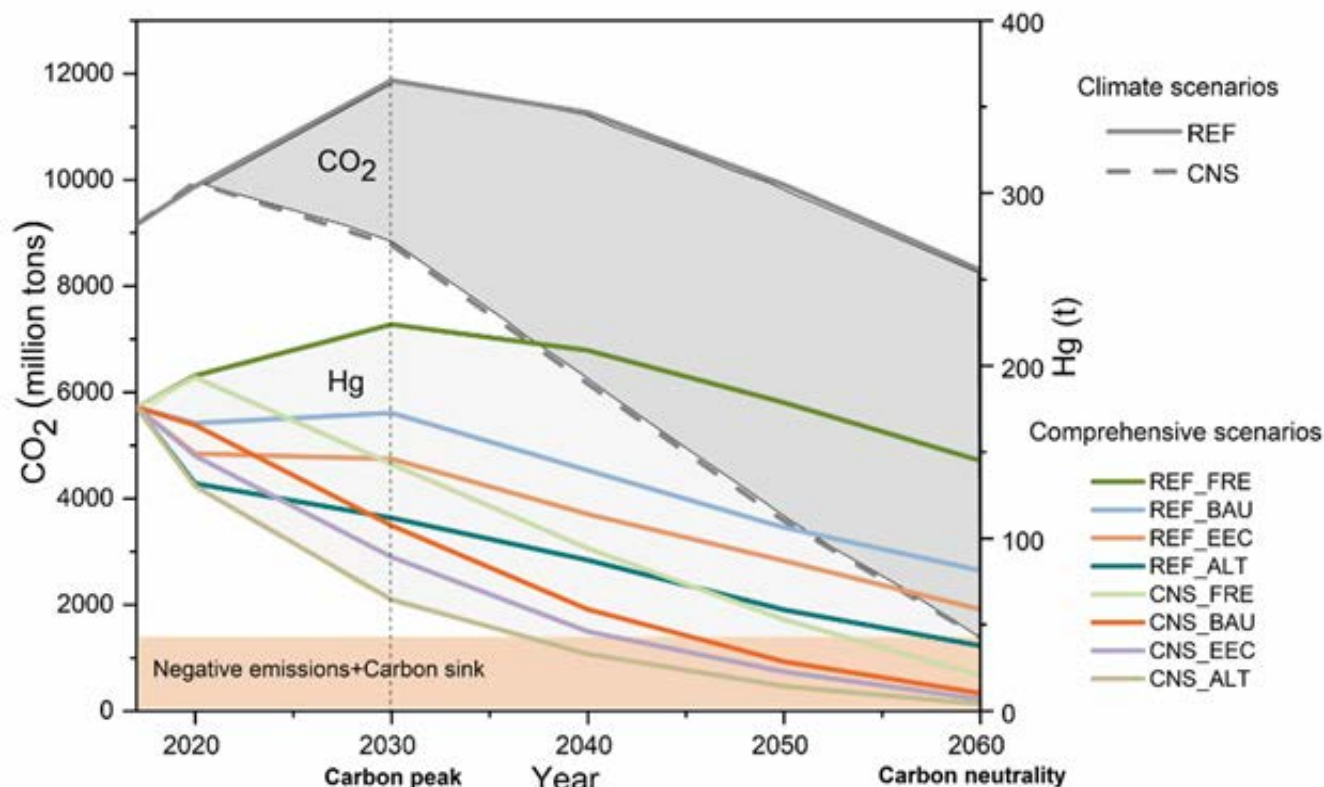
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**Carbon neutrality and clean air acts can enable China to meet the Minamata Convention goals with substantial cost savings**

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- **Carbon neutral strategies will enhance near-zero emission of Hg in 2060**
- **Climate and clean air targets can save 384 million CNY in Hg reduction in 2060**



**Thanks for your attention!**  
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