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Mercury emission inventory enhancement for the coal sector

PROF LESLEY SLOSS

June 2024

Improving data quality and applicability in the coal sector

Using emission factors to estimate emissions

Improving data

Focussing on the important differences

Thanks to the US Department of State, the International Centre for Sustainable Carbon, BCRC-Asia, and the Indonesian Government for this project of work

Full report freely available from www. sustainable-carbon.org

Vietnam has ratified the Minamata Convention on Mercury

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MINAMATA CONVENTION ON MERCURY

"EACH PARTY SHALL ESTABLISH, AS SOON AS PRACTICABLE AND NO LATER THAN FIVE YEARS AFTER THE DATE OF ENTRY INTO FORCE OF THE CONVENTION FOR IT, AND MAINTAIN THEREAFTER, AN INVENTORY OF EMISSIONS FROM RELEVANT SOURCES"

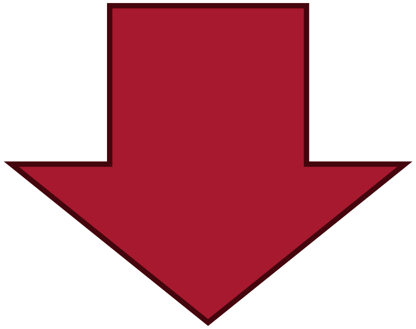
A PARTY WITH RELEVANT SOURCES SHALL TAKE MEASURES TO CONTROL EMISSIONS AND MAY PREPARE A NATIONAL PLAN SETTING OUT THE MEASURES TO BE TAKEN TO CONTROL EMISSIONS AND ITS EXPECTED TARGETS, GOALS AND OUTCOMES

Creating an emission inventory

A detailed approach

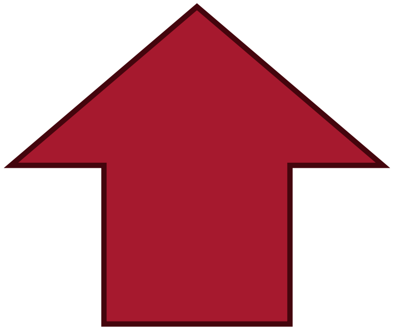
Most inventories are produced using a “top-down” approach:

Total coal burned x emission factor x retention factor



A far more appropriate approach is “bottom-up”:

Data for each unit x specific emission factor x specific retention factor



Emission factors for coal

EMISSION = EF x RF x AV

Approach	Emission Factor, EF Relates to the mercury content of the coal	Retention factor, RF Subtracts mercury that ends up in ash etc	EF x RF Estimates the amount of mercury released per unit of coal fired	Activity value Multiplies to cover all coal used in each source	Comments
UNEP Toolkit*	Generic – 0.05 g/kg	Generic - minus 10%	0.045 g/kg	Coal burn, t	Assumes all plants and coals are identical. Targets busier units, often unfairly
2017 UNEP Project	Coal analyses Results averaged across the fleet	iPOG# model of generic national plant	Convert to g/TJ Applies to all plants and takes average plant efficiency into account	Coal burn, t	EF and RF are now more accurate for the national coal fleet BUT still assumes all plants and coals are identical
Advanced projects (eg Indonesia)	Coal analysis on a unit-by-unit basis	iPOG analysis on a unit-by-unit basis	Unit-specific emission factor	Unit-specific plant activity	Produces a unit-specific emission estimate

* https://web.unep.org/globalmercurypartnership/mercury-emissions-coal-fired-power-plants-indonesia
# https://web.unep.org/globalmercurypartnership/interactive-process-optimization-guidance-ipog%E2%84%A2

Plant sampling for EF and RF

SAMPLES TAKEN AT PLANTS IN INDONESIA

Coal

Ash

Stack

- Sampling of coal as delivered and as fed into the boiler
- Coal samples from numerous mines were analysed and results collated
- Monitoring and mass balances are challenging but are still more useful than generic emission factors

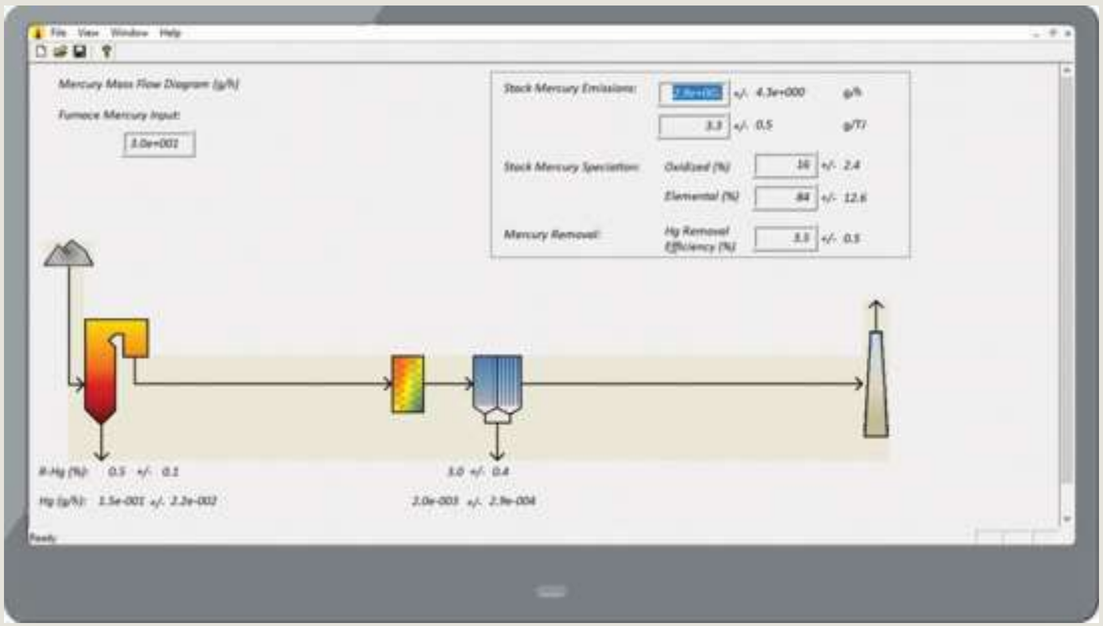
Creating the dataset

REAL DATA FROM PLANTS
MISSING DATA ESTIMATED THROUGH PROXY CALCULATIONS

Unit/plant details	Unit performance	Emission controls	Fuel quality
Unit and plant name	Operational load	Flue gas desulphurisation	Calorific value
Location	Utilisation/capacity factor	In boiler additives	Mercury content
Generating capacity	Specific energy consumption	NOx burners or SCR	Sulphur content
Certified operating and commissioning date	Annual coal consumption	PM controls	Chlorine content

Using the iPOG

INTERACTIVE PROCESS OPTIMISATION GUIDANCE TOOL



- Input unit-specific data
- RF estimated from plant configuration, coal chemistry and control technologies in place
- Results based on extrapolation and modelling of data from thousands of real data sets
- Used to focus on RELATIVE emission rates, not “actual”
- Image

Demonstration to follow

Creation of the dataset

LIVING DOCUMENT TO BE UPDATED REGULARLY
PROVENANCE OF DATA TO BE RECORDED

No	Power unit	2020	Capacity (MW)	2020	2020	Total electricity production/gross (MWh)*	Installed	2020 Purnomo			Annual operating hours (hour/year)		2020 Purnomo + Baruya	2020 Purnomo + Baruya	2020 Purnomo + Baruya	Stack Mercury Emission				
	Power unit	WEPP UNIT NAME	Installed	Commissioning Date (WEPP)	Remaining life as of 2020 (40yr life)	Total electricity production/gross (MWh)*	Annual utilisation	Operational load	Fuel Consumption (ton/year)	Specific Fuel Consumption (ton/MWh)			coal mercury content	coal sulphur content	coal chlorine content	Check if iPOG?	Annual Hg Emission, coal input, kg	Hg Emission Intensity, g/MWh	Annual Hg Emission, iPOG prediction, kg	Remaining Plant Life Hg Emission, kg
No	Power unit	WEPP UNIT NAME	Installed	Commissioning Date (WEPP)	Remaining life as of 2020 (40yr life)	Total electricity production/gross (MWh)*	Annual utilisation	%	Fuel Consumption (ton/year)	Specific Fuel Consumption (ton/MW	hours/y	SOx control (WEPP)	ug/kg	%	%	Result (g/h)				
	PLTU Celukan Bawan	CELUKAN BAWANG	142	2015	35	274,827.00	22.09	89.20	150,000.00	0.546	7,970	SWFGD	44.6	0.19	0.023	2.4	6,690	24	360	12,600
	PLTU Celukan Bawan	CELUKAN BAWANG	142	2015	35	274,827.00	22.09	89.20	150,000.00	0.546	7,970	SWFGD	44.6	0.19	0.023	2.4	6,690	24	360	12,600
	PLTU Celukan Bawan	CELUKAN BAWANG	142	2015	35	274,827.00	22.09	89.20	150,000.00	0.546	7,970	SWFGD	44.6	0.19	0.023	2.4	6,690	24	360	12,600
	PLTU Paiton Unit 5	PAITON-II NO 1	610	2000	20	3,549,546.25	66.42	100.00	1,618,332	0.456	6,416	SWFGD	26	0.19	0.024	5.5	42,077	12	8,901	178,017
	PLTU Paiton Unit 6	PAITON-II NO 2	610	2000	20	3,549,546.25	66.42	100.00	1,618,332	0.456	6,699	SWFGD	26	0.19	0.024	5.5	42,077	12	8,901	178,017
	PLTU Paiton Unit 7	PAITON-I NO 1	615	1999	19	3,584,327.53	66.53	106.52	1,947,206	0.543	6,146	SWFGD	40.89	0.118	0.0078	12	79,621	22	23,366	443,963
	PLTU Paiton Unit 8	PAITON-I NO 2	615	1999	19	3,584,327.53	66.53	106.03	2,218,145	0.619	7,025	SWFGD	40.89	0.118	0.0078	14	90,700	25	31,054	590,027
	PLTU TJB Unit 1	TANJUNG JATI-B NC	710	2006	26	4,469,025.09	71.85	93.07	1,626,044	0.409	7,619	WLST	13.3	0.7	0.023	2.4	24,286	5	4,383	113,945
	PLTU TJB Unit 2	TANJUNG JATI-B NC	710	2006	26	4,879,123.00	78.45	93.07	1,944,636	0.399	8,215	WLST	13.3	0.7	0.023	2.3	25,864	5	4,473	116,289
	PLTU TJB Unit 3	TANJUNG JATI-B NC	721.8	2011	31	4,563,981.90	72.18	91.59	1,780,111	0.390	8,411	WLST	27.5	0.52	0.026	3.2	48,953	11	5,696	176,587
	PLTU TJB Unit 4	TANJUNG JATI-B NC	721.8	2012	32	4,201,636.40	66.45	91.59	1,679,439	0.400	7,807	WLST	27.5	0.52	0.026	3.4	46,185	11	5,710	182,723

Conclusions and comments

Minamata inventories

- The Convention requires at least a Level 1 calculation for coal sector emissions
- A Level 2 or 3 approach, (bottom-up, using more coal and plant-specific data) will make cost-effective compliance easier

Thank you

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Using enhanced data to rank sources and create a cost-effective targeting strategy

PROF LESLEY SLOSS

June 2024

Informed ranking of data

Informing a strategic approach to emission reduction

Requirements for coal plants

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Under the UN Minamata Convention

"New sources" must apply, within 5 years of ratification:

- BAT/BEP (best available technology/best environmental practice)

"Existing source" must apply, within ten years of ratification :

- A qualified goal
- Emission limit values
- BAT/BEP
- Multipollutant strategy
- "Alternative measures"

How to turn emission data into an emission reduction strategy

- Create an accurate emission inventory for the fleet, with as much plant-specific data as possible

- Rank the sources/units and focus on high-emitters and inefficient plants first

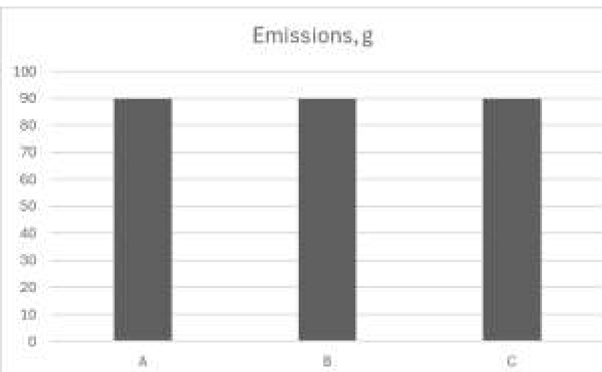
- Create policy or legislation which is appropriate – affordable and achievable – maximising “co-benefit” and multipollutant strategies

Changing the input

MOVING FROM ASSUMPTIONS TO REAL DATA

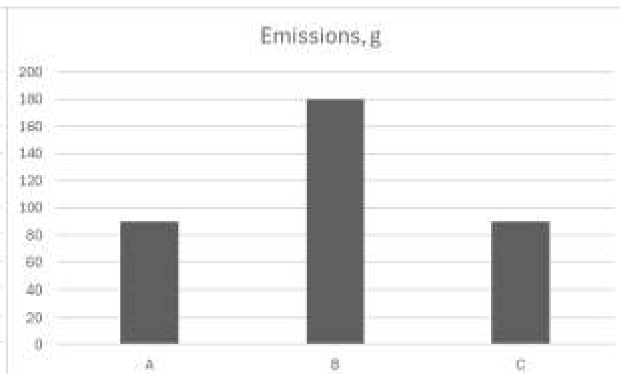
All plants are assumed equal

Plant	Emissions, g	EF, g/kg	RF, %	AV, t
A	90	1	10	100
B	90	1	10	100
C	90	1	10	100



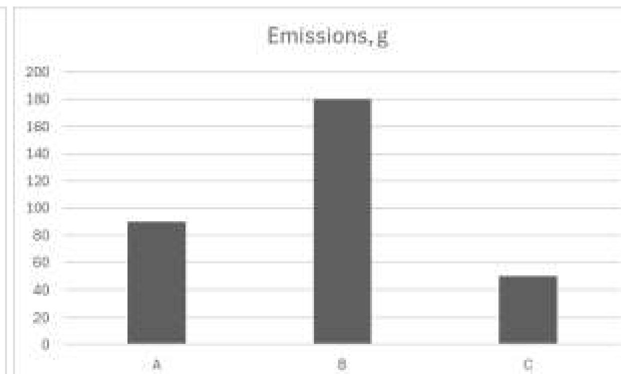
Plant B has higher mercury coal

Plant	Emissions, g	EF, g/kg	RF, %	AV, t
A	90	1	10	100
B	180	2	10	100
C	90	1	10	100



Plant C has higher ash retention

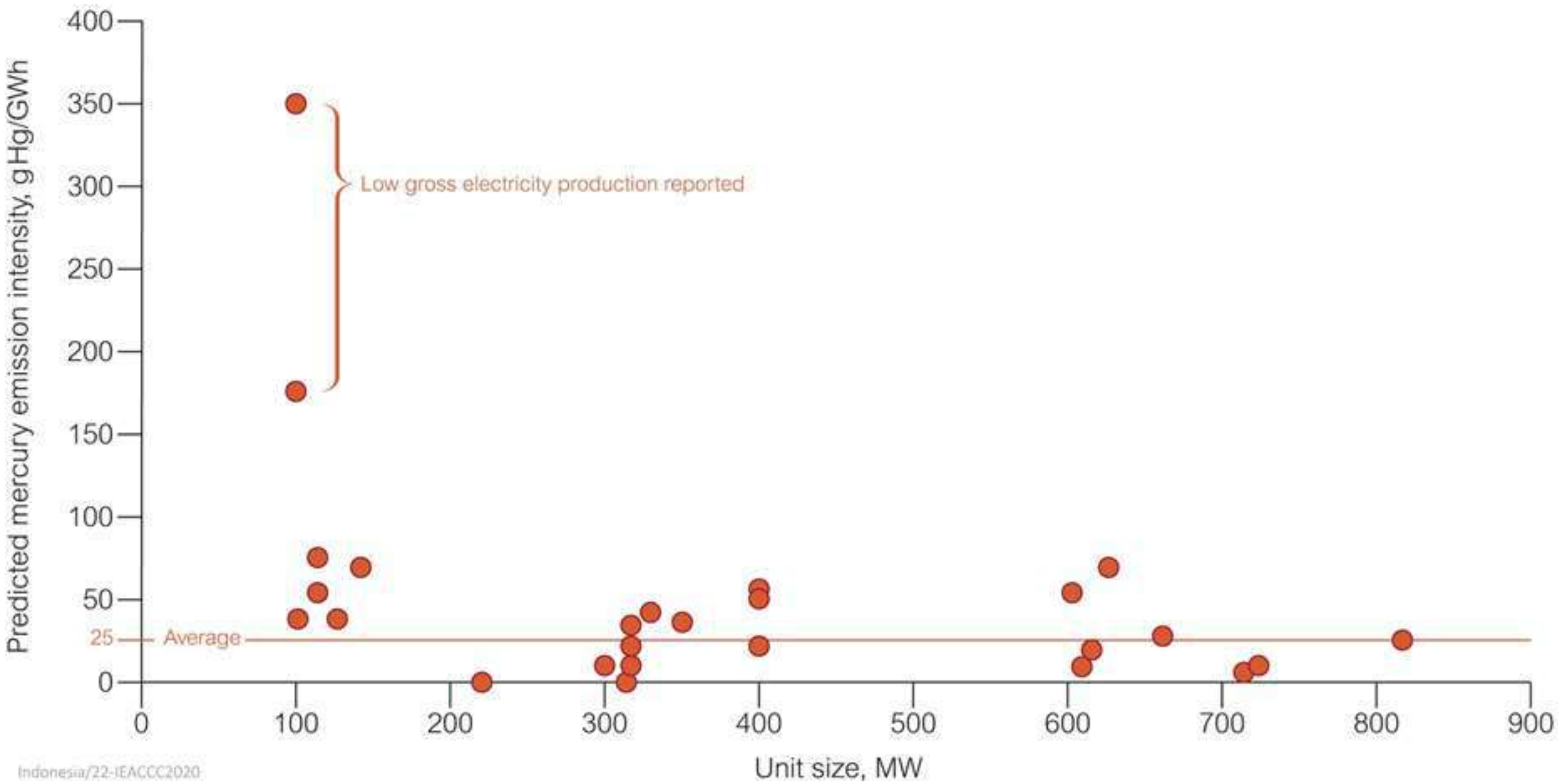
Plant	Emissions, g	EF, g/kg	RF, %	AV, t
A	90	1	10	100
B	180	2	10	100
C	50	1	50	100



The total coal burned is the same in all assumptions
All plants are NOT the same
Focus on plant efficiency by converting the emission factor to g Hg/GWh

Fleet emission intensity

Changing the emission factor from g/kg to g/GJ – Indonesian example

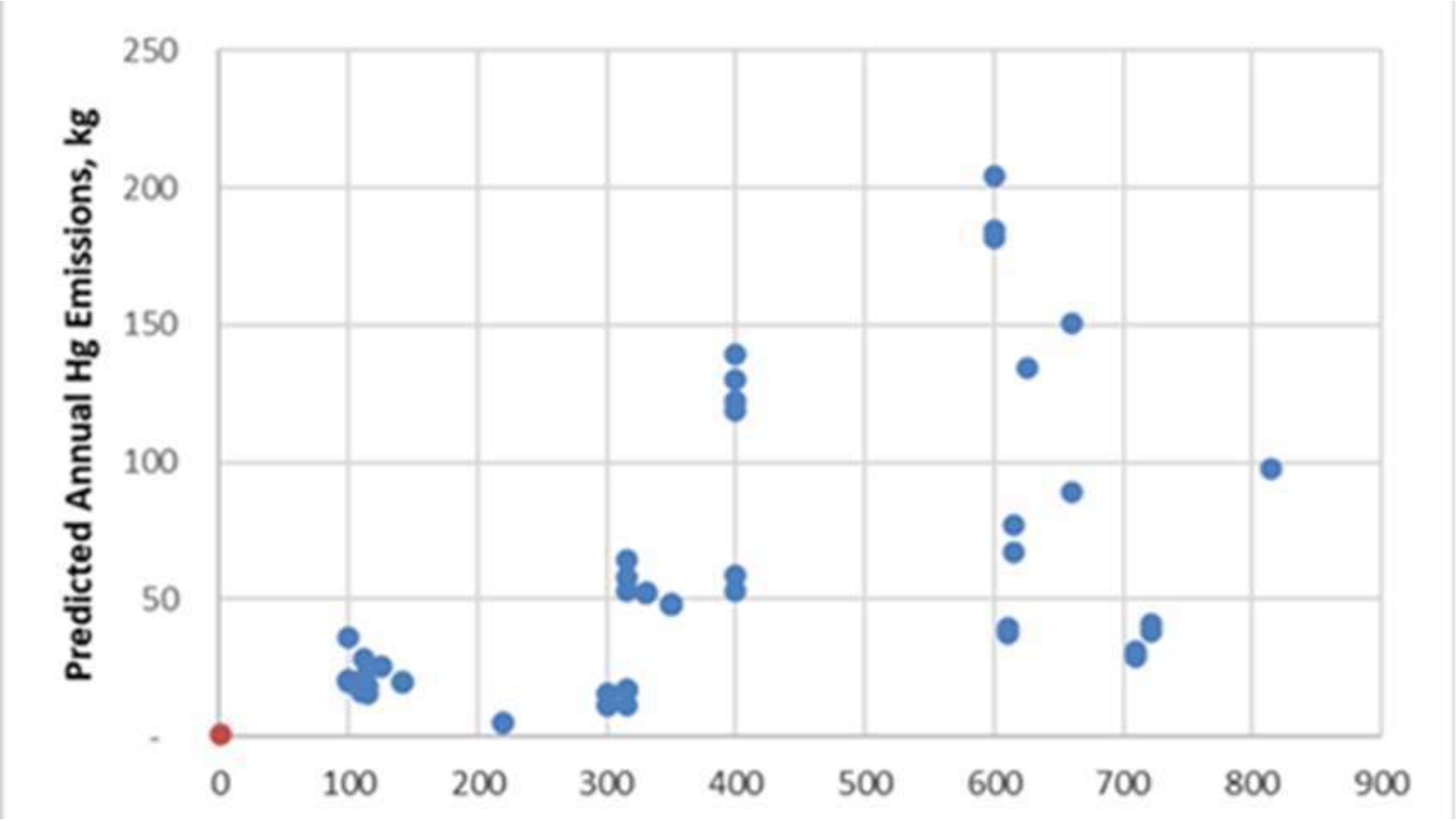


Amount of Hg (g) emitted per GWh of electricity produced – indication of "cleaner" burning plants.

No indication of size-related intensity of Hg emissions for units >100 MW

SOME UNITS EMIT AN ORDER OF MAGNITUDE MORE MERCURY PER GWh OF POWER PRODUCED THAN OTHERS

Predicted annual emissions from Indonesian coal plants



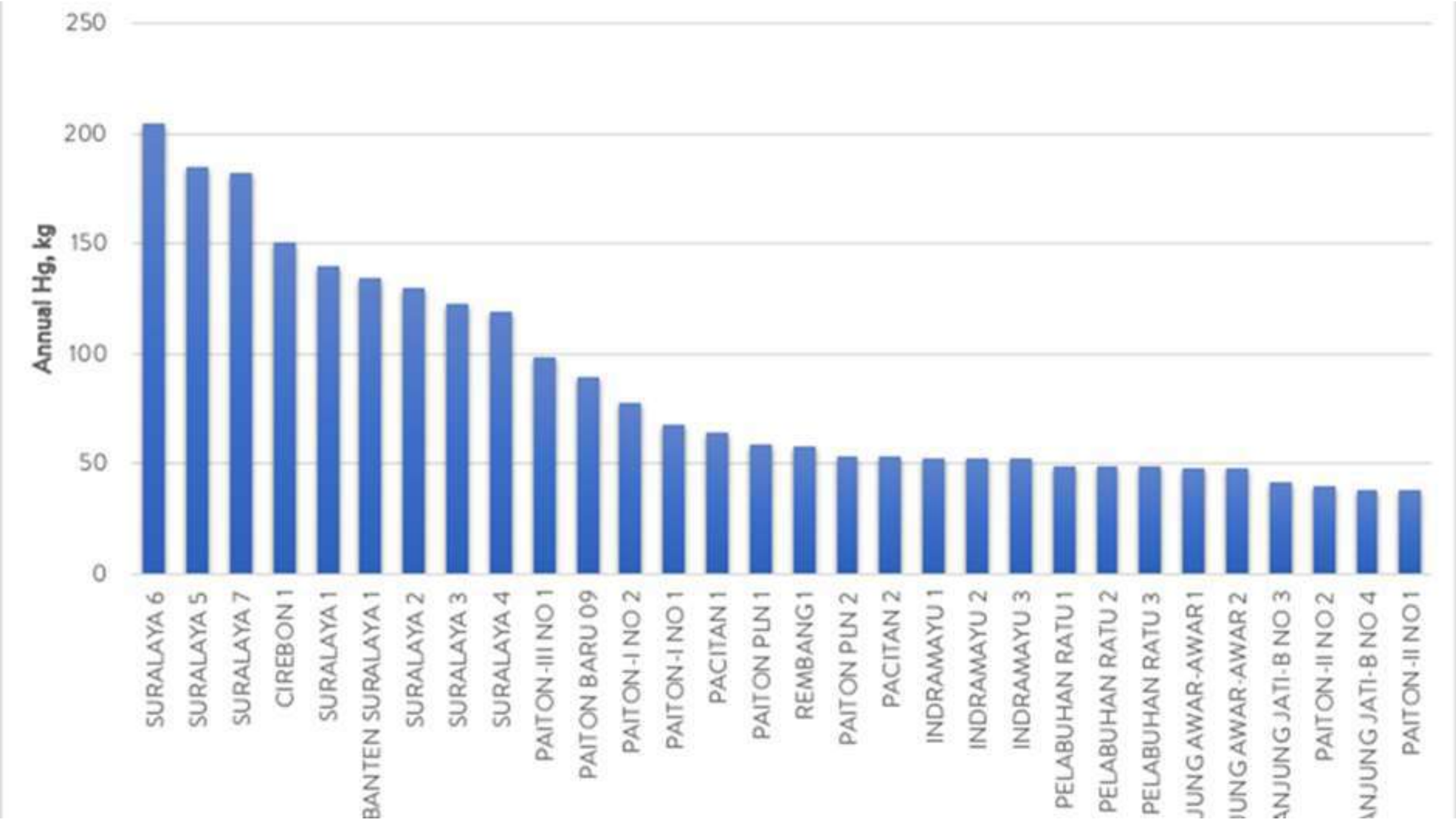
Bringing in plant lifetime

IMMEDIATELY BRINGS IN COST-EFFECTIVENESS

Current method	Add in capacity factor/remaining lifetime
Identifies plants which emitted the most mercury in the last operating year BUT assumes all plants are the same age	Removes older plants which will slow down or close soon. Allows focus for intervention on plants where control technologies may be effective in the long-term

Units which will emit >1t Hg over their remaining lifetime (Indonesia)

ASSUMING PLANTS RUN UNTIL THEY ARE 40 YEARS OLD



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The top 10 units in Indonesia (out of 111 units) emit around 50% of the total emissions from the entire fleet

Mercury emissions over remaining fleet lifetime

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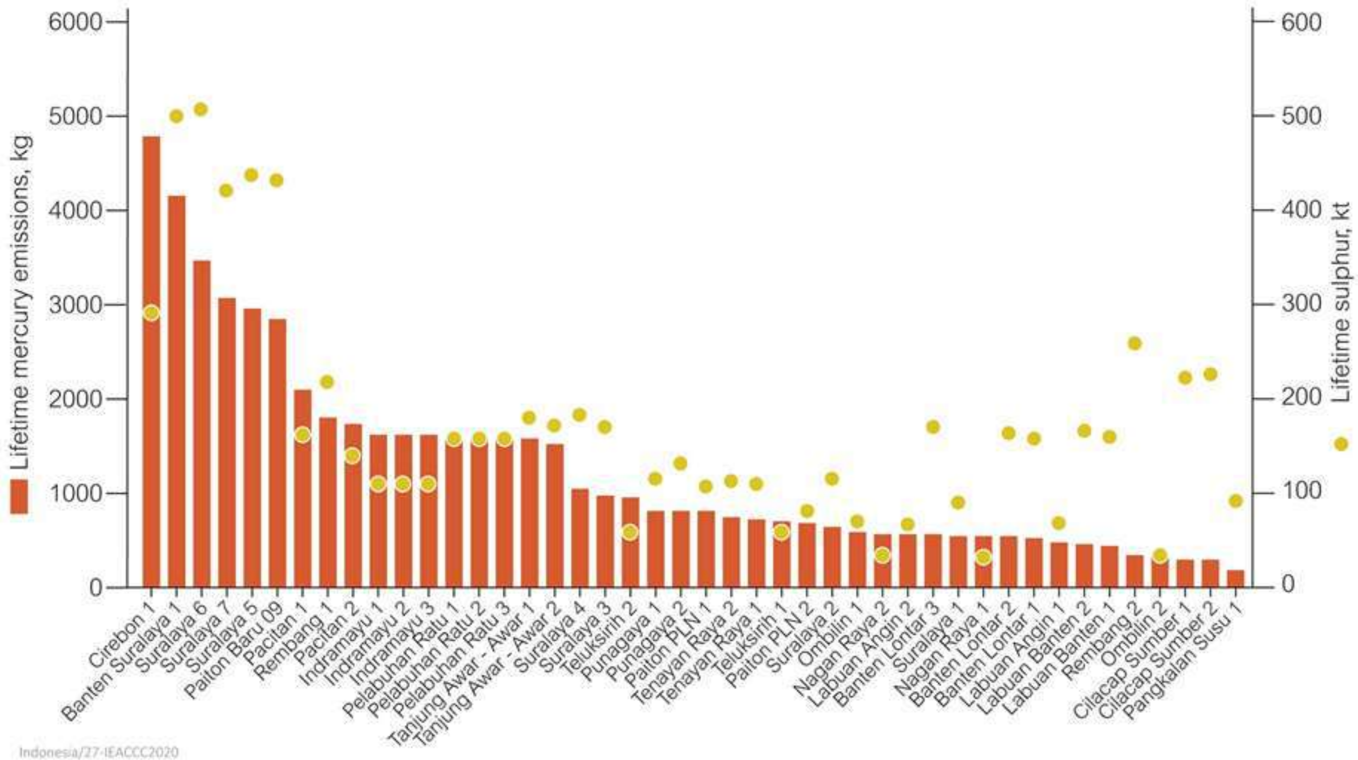

- Over 110 units analysed
- The top 10 units emit around 50% of the total emissions from the entire fleet

This provides valid science for an informed and strategic emission reduction strategy

Simple method to rank data

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TOP 10 UNITS >15 years old

UNIT NAME 1	UNIT NAME 2	CAPACITY MW	Remaining life as of 2020 (40yr life)	Operational load	Fuel Consumption (calculated)	Gross unit efficiency	SOx control (WEPP)	Coal Hg content	Coal S content	Coal Cl content	Annual Hg Emissions, coal input, kg	Hg Emissions Intensity, g/MWh	Annual Hg Emissions, iPOG prediction, kg	Remaining Plant Life Hg Emissions, kg	Total Score
PL	SU	4.0	2.0	5.0	3.0	4.0	5.0	4.0	5.0	3.0	5	4.0	5	4	53.0
PL	SU	4.0	2.0	5.0	3.0	4.0	5.0	4.0	5.0	3.0	5	4.0	5	4	53.0
PL	SU	4.0	2.0	5.0	3.0	4.0	5.0	4.0	5.0	3.0	5	4.0	5	4	53.0
PL	BA	4.0	3.0	5.0	3.0	4.0	5.0	4.0	5.0	3.0	4	3.0	4	5	52.0
PL	CI	4.0	3.0	5.0	3.0	4.0	5.0	3.0	2.0	3.0	5	3.0	5	5	50.0
PL	TE	1.0	4.0	5.0	1.0	5.0	5.0	5.0	2.0	5.0	3	5.0	3	2	46.0
PL	TE	1.0	4.0	5.0	1.0	5.0	5.0	5.0	2.0	5.0	3	5.0	3	2	46.0
PL	PA	2.0	3.0	5.0	3.0	4.0	5.0	4.0	3.0	2.0	4	2.0	4	4	45.0
PL	PA	2.0	3.0	5.0	3.0	4.0	5.0	4.0	3.0	2.0	4	2.0	4	4	45.0
PL	RE	2.0	3.0	5.0	3.0	2.0	5.0	3.0	3.0	5.0	4	2.0	4	4	45.0

Creating a reduction strategy for coal

BAT/BEP options

Maximising co-benefit

Two major forms of mercury

THE CHEMISTRY IS AFFECTED BY COAL TYPE, ASH CONTENT, CHLORINE CONTENT ETC – IT IS COMPLEX!

Oxidised mercury

- Soluble and sticky
- Easy to capture in solutions, ash or sorbents

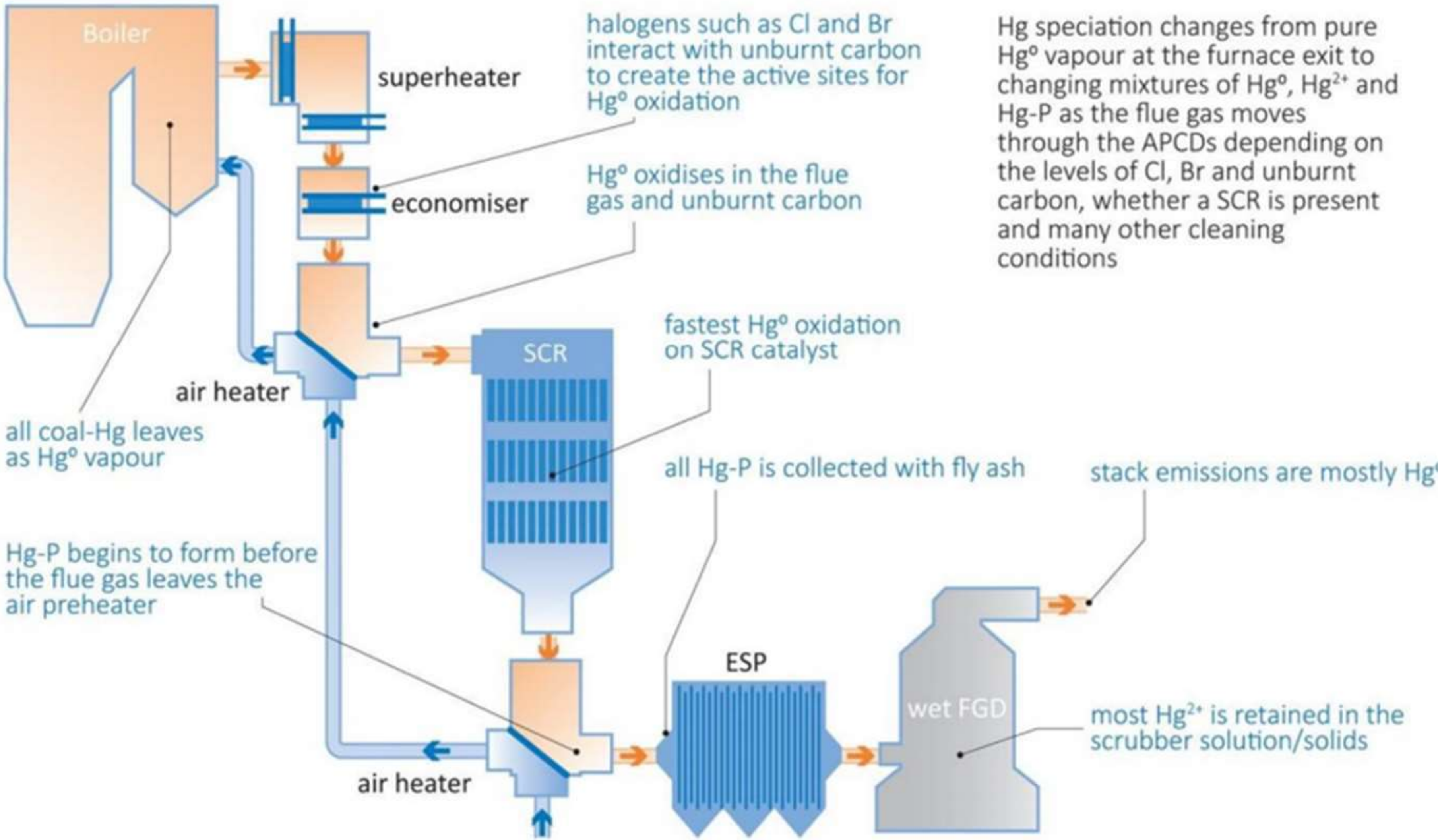
Hg2+

Elemental mercury

- Not soluble and not sticky
- Hard to capture
- Can be oxidised by chemicals such as chlorine and bromine

Hg0

Mercury flow through a coal plant



"Co-benefit effects"

MAXIMISING "FREE" MERCURY CONTROL

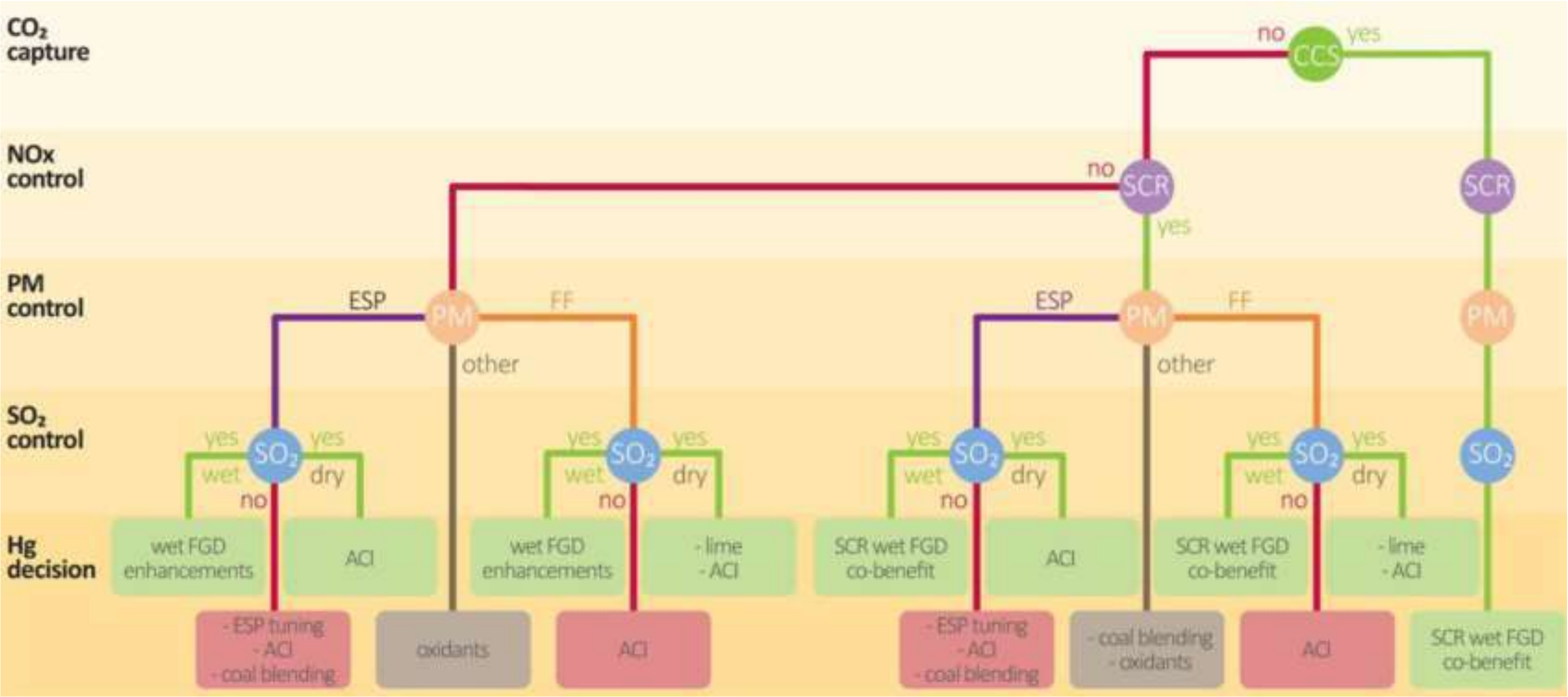
If you can control mercury, you can also control acid gases and particulates

and

if you control acid gases and particulates, you also control mercury

Flow chart for technology selection

INCLUDED IN THE UNEP BAT/BEP GUIDANCE FOR COAL



Coal cleaning* and blending

*CHEMICAL COAL CLEANING HAS YET TO PROVE COST-EFFECTIVE FOR MERCURY CONTROL

Selecting coal type

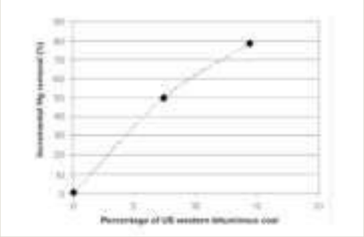
- US sub-bituminous coals tend to contain less chlorine and can be high in calcium
- Many US plants firing sub-bituminous coals found mercury reduction a challenge as most mercury is produced in the elemental form
- Oxidation with halogen addition was proven to work, but so was coal-blending

Blending

- Coal plants blend coals to maintain the characteristics required for efficient combustion
- Low-quality coals can be mixed with higher-quality coals to keep costs down
- Low sulphur coals can be mixed with high sulphur coals to keep emissions down
- Coal blending for emission control of anything other than sulphur is not a common strategy but theoretically it is possible

Strategic blending

- Study in a US plant firing sub-bituminous coal – mercury emissions remained high, even though the plant was fitted with a flue gas desulphurisation system
- Blending with bituminous coal helped to oxidise the mercury
- By blending in 15% bituminous coal in with the sub-bituminous coal, mercury emissions could be reduced by up to 80%



Co-firing biomass

- Most vegetation for co-firing will be low in mercury content. Reducing the mercury input in the total fuel will reduce the mercury input to the plant and thus reduce overall emissions
- The chlorine and ash contents of biomass can be higher than coal. This can help mercury oxidation and capture.

CW- chicken waste
TS – tobacco stalks
CR – coffee residue
WP – wood pellets

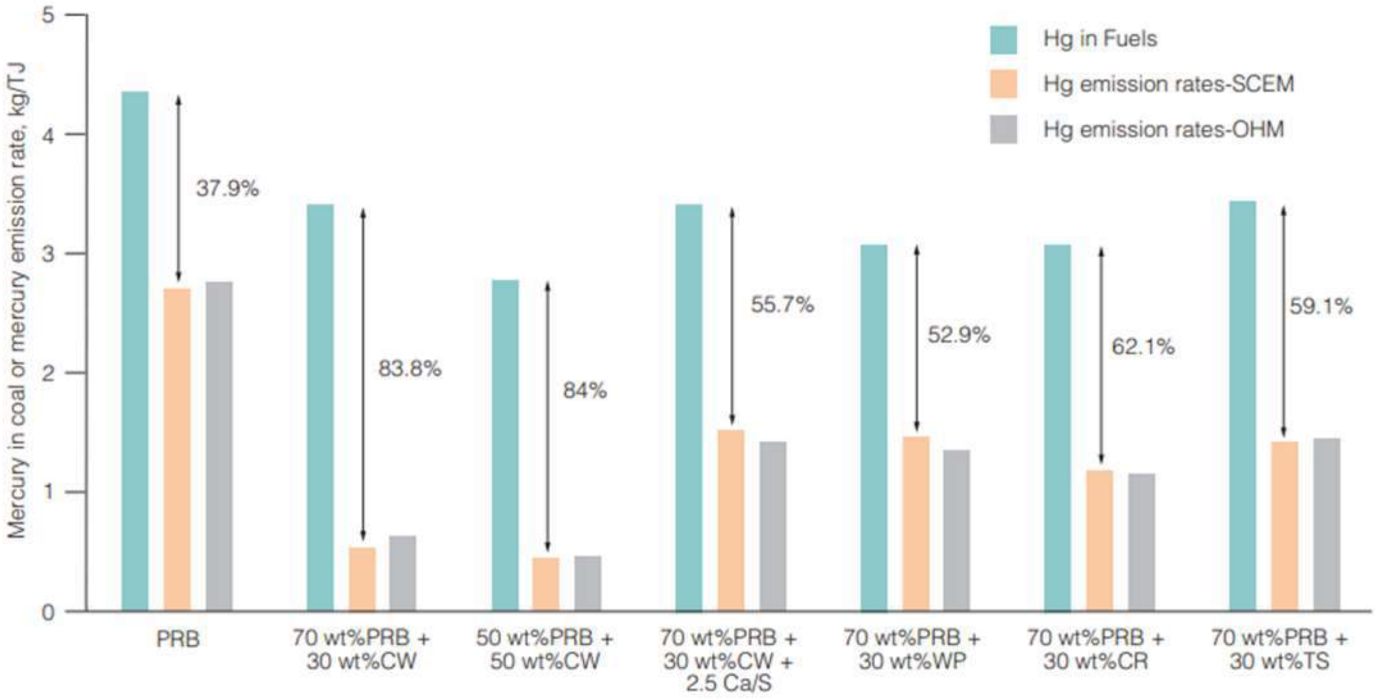


Figure 15 Variation of mercury emission during cofiring of subbituminous coal and biomass (Cao and others, 2008)

Particulate controls and mercury

VARIES WITH COAL AND PLAN TYPE

Particulate control systems can reduce PM emissions by >99.99%

Particulate control systems can capture mercury – oxidised mercury will stick to unburnt fly ash (sorbents can be added)

Mercury capture in ESP is generally lower (10-30%) than in fabric filters/baghouses (40-70%)

Emission values must be established for each site, due to potential variations in coal chemistry

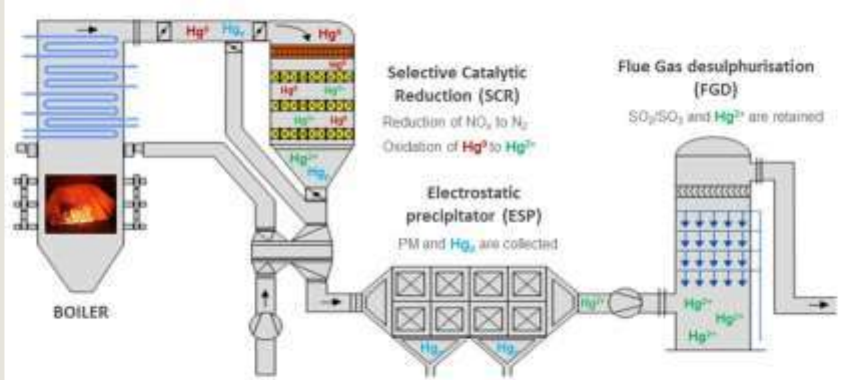
NOx controls and mercury

VARIES WITH COAL AND PLANT TYPE

NOx burners do not have a significant effect on mercury emissions

Selective catalytic reduction technologies fitted upstream of particulate controls can oxidise mercury and lead to increased mercury capture in the ash

BUT: Mercury can contaminate and shorten the life of catalysts.



https://www.jmsec.com/air-pollution-solutions/selective-catalytic-reduction-scr/scr-catalyst-for-hg-oxidation/

Sulphur controls and mercury

VARIES WITH COAL AND PLANT TYPE

IF mercury is in the oxidised form, it will be trapped in most FGD systems:

- Wet FGD systems will dissolve oxidised mercury
- Dry FGD systems will capture oxidised mercury in the dry sorbent
- Seawater FGD systems will dissolve oxidised mercury but may release it into the local water body

Mercury capture in any FGD system can be enhanced by converting elemental mercury to oxidised mercury by adding an oxidant such as bromine

Mercury reduction can be up to and even over 70% in an FGD system but is very site-specific.

Mercury-specific control options

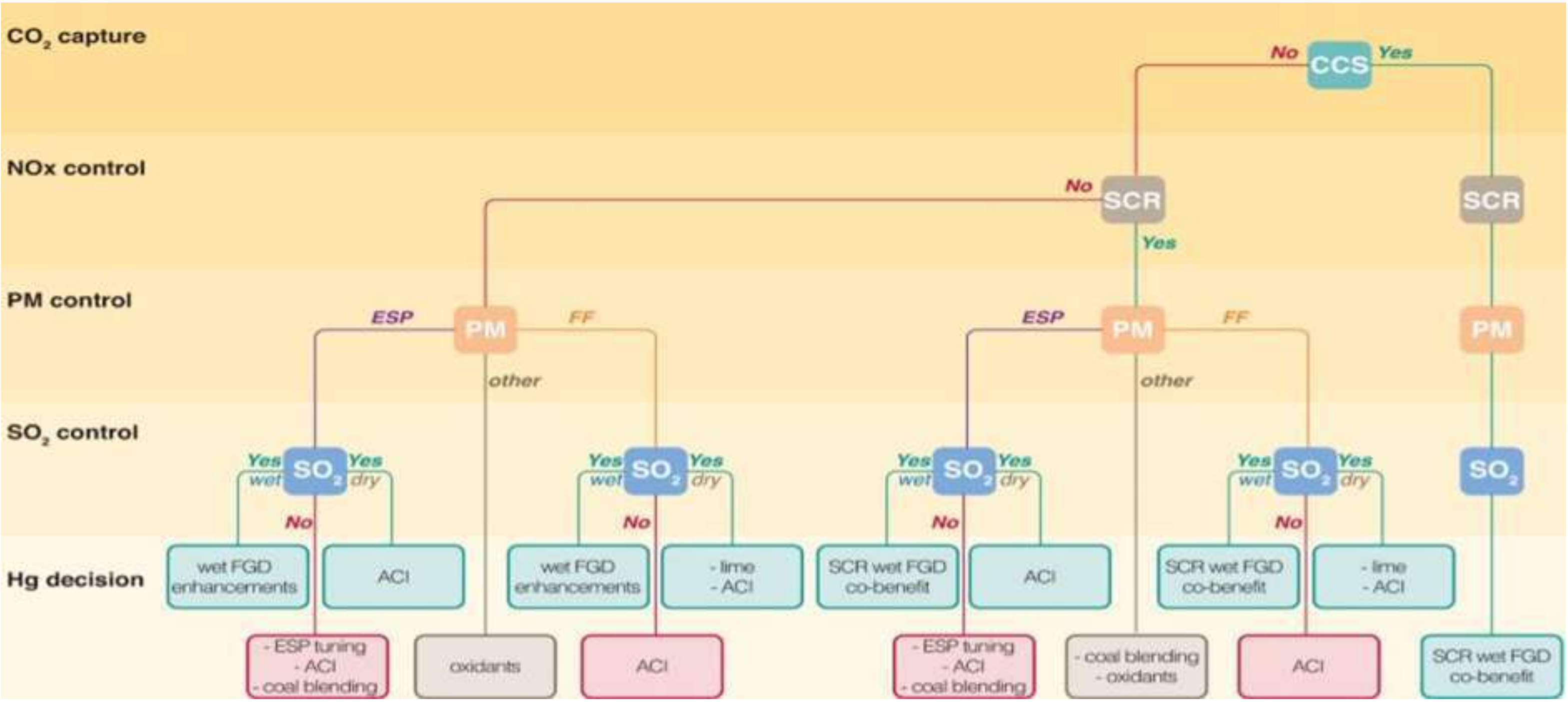
Many mercury-specific control systems have been developed and some are commercialised

Most plants see these systems as a “last-resort” to reducing emissions due to the cost

Table 7 Multi-pollutant control technologies

System	Format	Demonstration status	Marketed by
WESP	Wet ESP	Full scale at many plants	Various
COHPAC™	ESP plus fabric filter or pulse-jet fabric filter	1700 MW installed on coal plant and waste to energy incinerators	EPRI, via Babcock and Wilcox, Hamon Research-Cottrell
TOXECON™	Sorbent, and pulsed-jet fabric filter (COHPAC plus sorbent)	Fitted in 8 plants in USA	EPRI, via Babcock and Wilcox, Hamon Research-Cottrell
EFIC, electrostatic fabric integrated collector	Similar to COPAC with pulse-jet fabric filter	50 units currently in operation	China Fujian Longking
ESFF, ESP-FF hybrid system	Split level filters either integrated or separated	3 plants in China and 1 in India	Zheijian Feida Environmental Science and Technology Co
ECO™ Technology	Dielectric barrier discharge, ammonia based scrubber, and WESP	Slip-stream demonstration	Powerspan
ReACT™	Regenerative activated coke technology	Full scale – Isogo, Japan; Weston, USA; industrial plants in Germany	J-Power, Haldor Topsoe
SNOX™	Dry catalyst/reactors with ammonia addition	Full scale, Nordjyllandsvaerket, Denmark, plus industrial sites	Haldor Topsoe
SNRB™ (SOX-NOx-Rox-Box)	Alkali sorbent injection and high temperature fabric filter	Demonstration	Babcock and Wilcox
Airborne™ Process	Sodium bicarbonate injection with wet sodium scrubbing and oxidation	Pilot and small scale	Airborne Clean Energy
Neustream™ Technology	Dual-alkali FGD with upstream ozone injection	Pilot scale	Neumann Systems Group
Gore mercury and SO_2 control modules	Passive, modular, fixed absorption media modules	2100 MW installed in coal-fired power plants in the USA and demonstration pilots in European plants	Gore
Skymine™ Process	Electrochemical sodium hydroxide scrubbing	Pilot scale	Skyonic Corporation
Tri-Mer™	Modular ceramic catalyst and oxidant units	Pilot scale	Tri-Mer

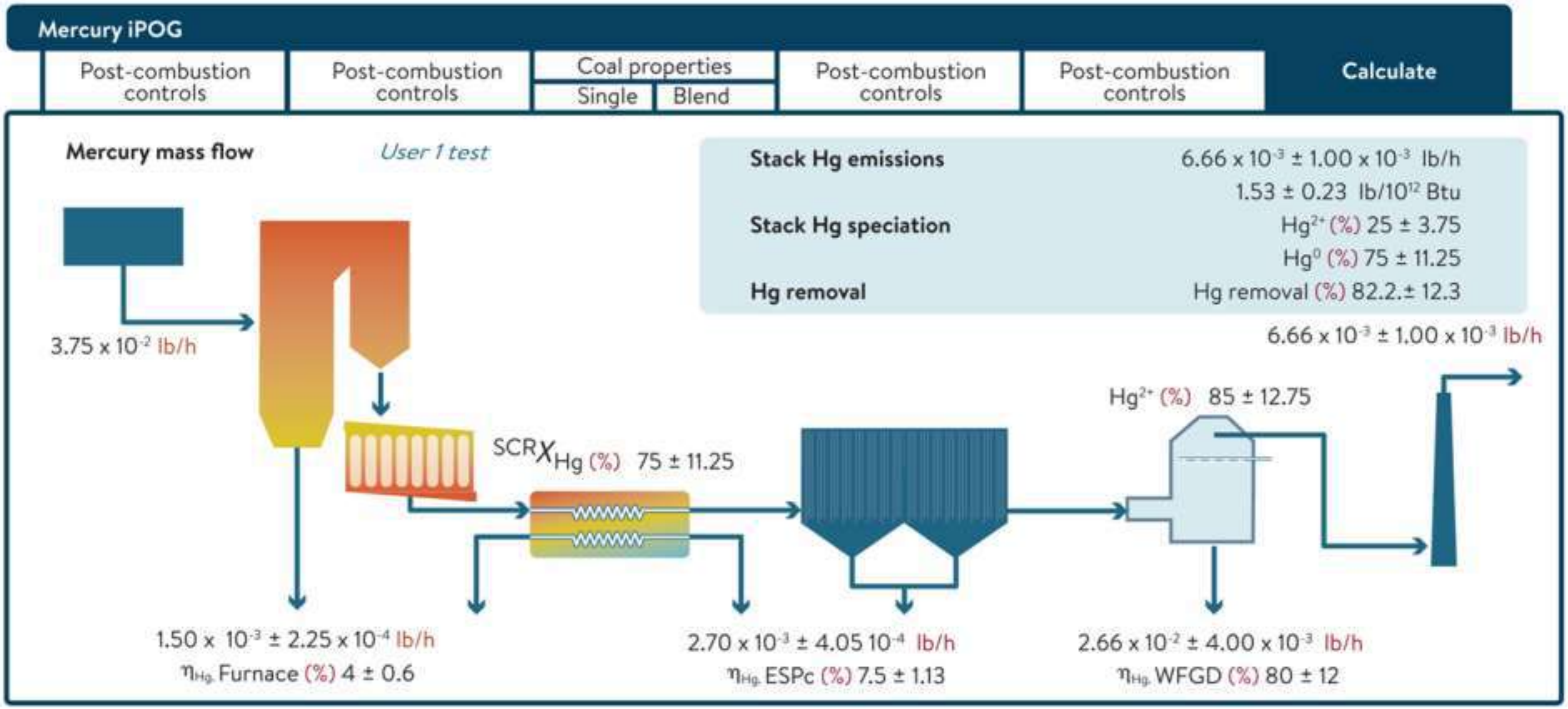
Decision tree



This is a simple flow diagram which allows the user to work through the BAT/BEP (best available technology/best environmental practice) to choose an option which will work best with different plant configurations.

Using the iPOG as a predictor

THE IPOG CAN HELP DETERMINE THE APPROACHES MOST LIKELY TO SUCCEED



Conclusions

Information and data = power

- The Minamata convention only requires a total sectoral inventory. However, an enhanced inventory could inform a significantly more cost-effective reduction strategy
- Creating an enhanced inventory takes time but, once established can simply be updated annually to monitor trends in emissions
- Use a ranking approach, considering plant-specific factors including remaining operating lifetime, to determine where action will achieve the greatest results
- It is possible and even likely that acting on a few plants could achieve faster and more cost-effective emission reduction than a blanket requirement for action across all plants

Thank you

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UN environment programme

MINAMATA CONVENTION ON MERCURY

Funded by the European Union

MERCURY FROM THE NON-FERROUS SECTOR

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Sydney, Australia

Co-lead UN Environment Mercury in Coal Combustion Partnership

Image: https://www.mining.com/wp-content/themes/miningdotcom/images/favicon/apple-icon-57x57.png

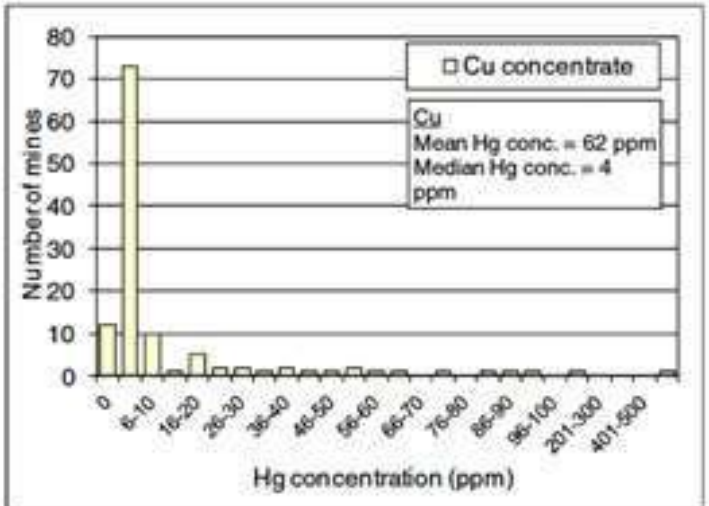
Non Ferrous Metals in Article 8 Minamata Convention

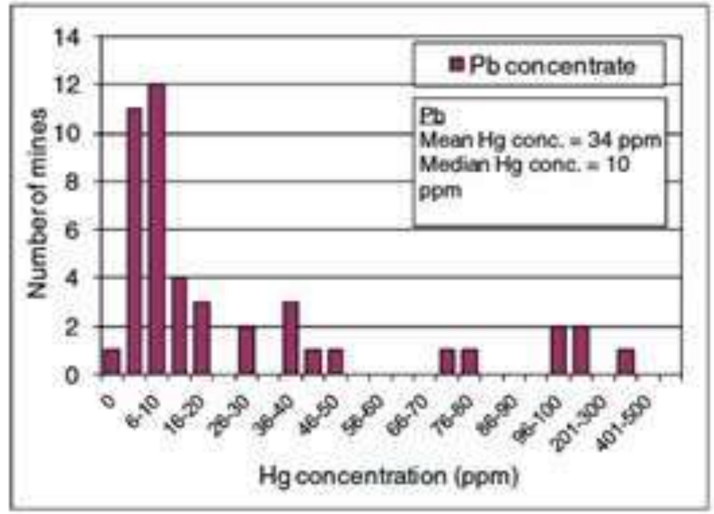
- Smelting and Roasting only
- Metals:
  - Copper
  - Lead
  - Zinc
  - Industrial Gold

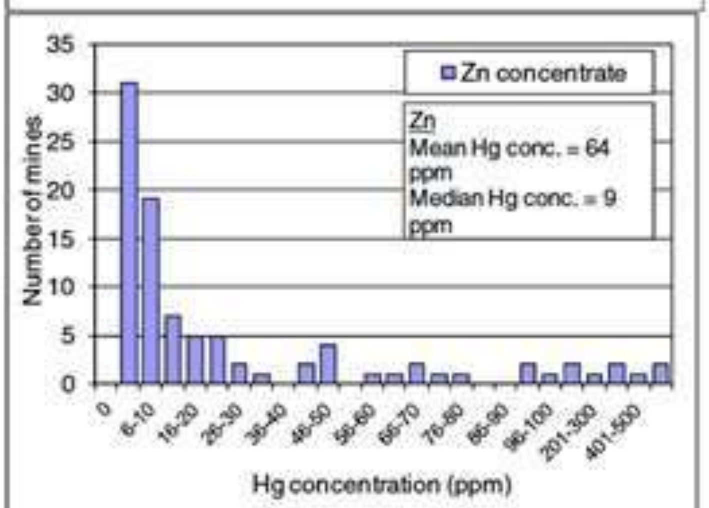
TABLE 1: ESTIMATED QUANTITIES OF MERCURY EMITTED TO AIR FROM ANTHROPOGENIC SOURCES IN 2015, BY DIFFERENT SECTORS (UNEP 2019A)

Sector	Mercury Emissions (range), tonnes	Sector % of total
Artisanal and small-scale gold mining (ASGM)	838 (675-1000)	37.7
Biomass burning (domestic, industrial and power plant)	51.9 (44.3-62.1)	2.33
Cement production (raw materials and fuel, excluding coal)	233 (117-782)	10.5
Chlor-alkali production (mercury process)	15.1 (12.2-18.3)	0.68
Non-ferrous metal production (primary Al, Cu, Pb, Zn)	228 (154-338)	10.3
Large-scale gold production	84.5 (72.3-97.4)	3.8
Mercury production	13.8	0.62
Stationary combustion of coal (domestic/residential, transportation)	55.8 (36.7-69.4)	2.51
Stationary combustion of coal (power plants)	292 (255-346)	13.1
Vinyl-chloride monomer (mercury catalyst)	58.2 (28.0-88.8)	2.6
Waste (incineration and other emissions from all waste streams)	162 (129-255)	7.3
Total	**2220 (2000-2820)**	

Mercury variability in ores







Number of mines and the reported Hg concentrations in

a) Cu concentrates
b) Pb concentrates
c) Zn concentrates

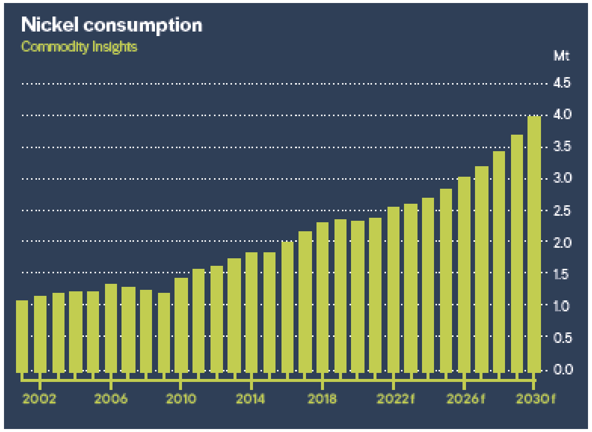
High Temperature Processing releases Hg

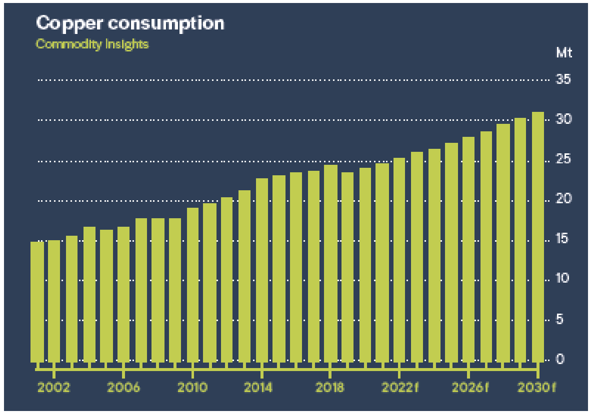
Non-ferrous metal sector in Vietnam (based on MIA, 2016)

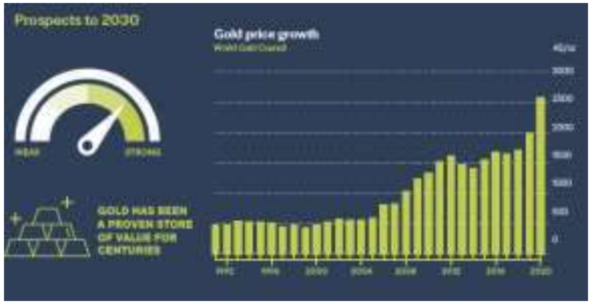
Toolkit Chapter	Source	
5.2.3	Zinc extraction and initial processing	Y
5.2.4	Copper extraction and initial processing	Y
5.2.5	Lead extraction and initial processing	Y
5.2.6	Gold extraction and initial processing by methods other than mercury amalgamation	Y
5.2.7	Aluminium extraction and initial processing	Y

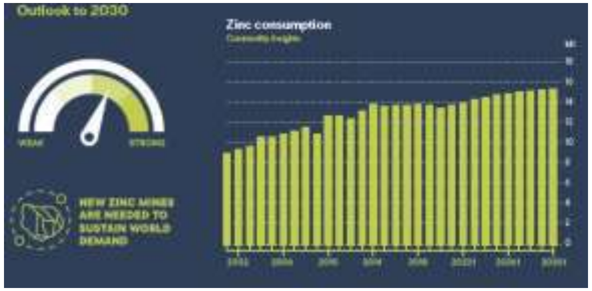
Vietnam has “significant quantities of copper, gold, tin, lead, zinc, gem stones, nickel, industrial and non-ferrous metals, clay and phosphate” (Reuters)

Non Ferrous Metals – Strong Growth









Emission Estimation

Tools for inventory development

UNEP Mercury Toolkit

https://www.unep.org/topics/chemicals-and-pollution-action/pollution-and-health/heavy-metals/mercury/mercury-inventory

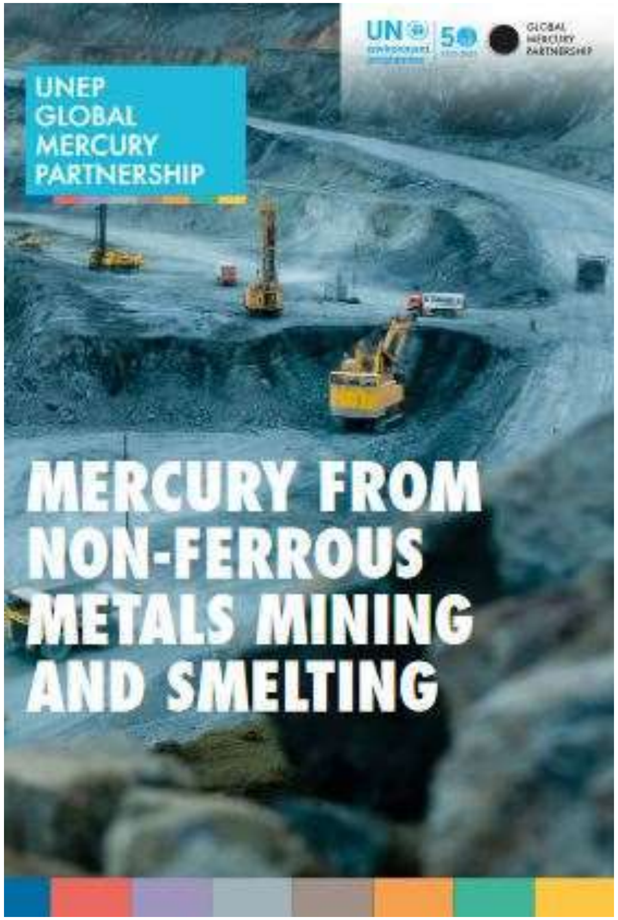
Inventory Level 1 (IL1)

- a simplified model - easy to use; useful for first-time inventories
- less reading to get started, less data, calculations are fully automatic, and it includes in-cell guidance within the spreadsheet
- uses national activity rate data
- assess mercury controls (BAT/BEP)

Tools for Inventory Development

Inventory Level 2 (IL2)

- a detailed mercury inventory tool
- all factors adjustable to national or local conditions.
- default estimation factors are pre-entered
- requires more reading and experience
- high level of accuracy, provided that the data needed for this are available



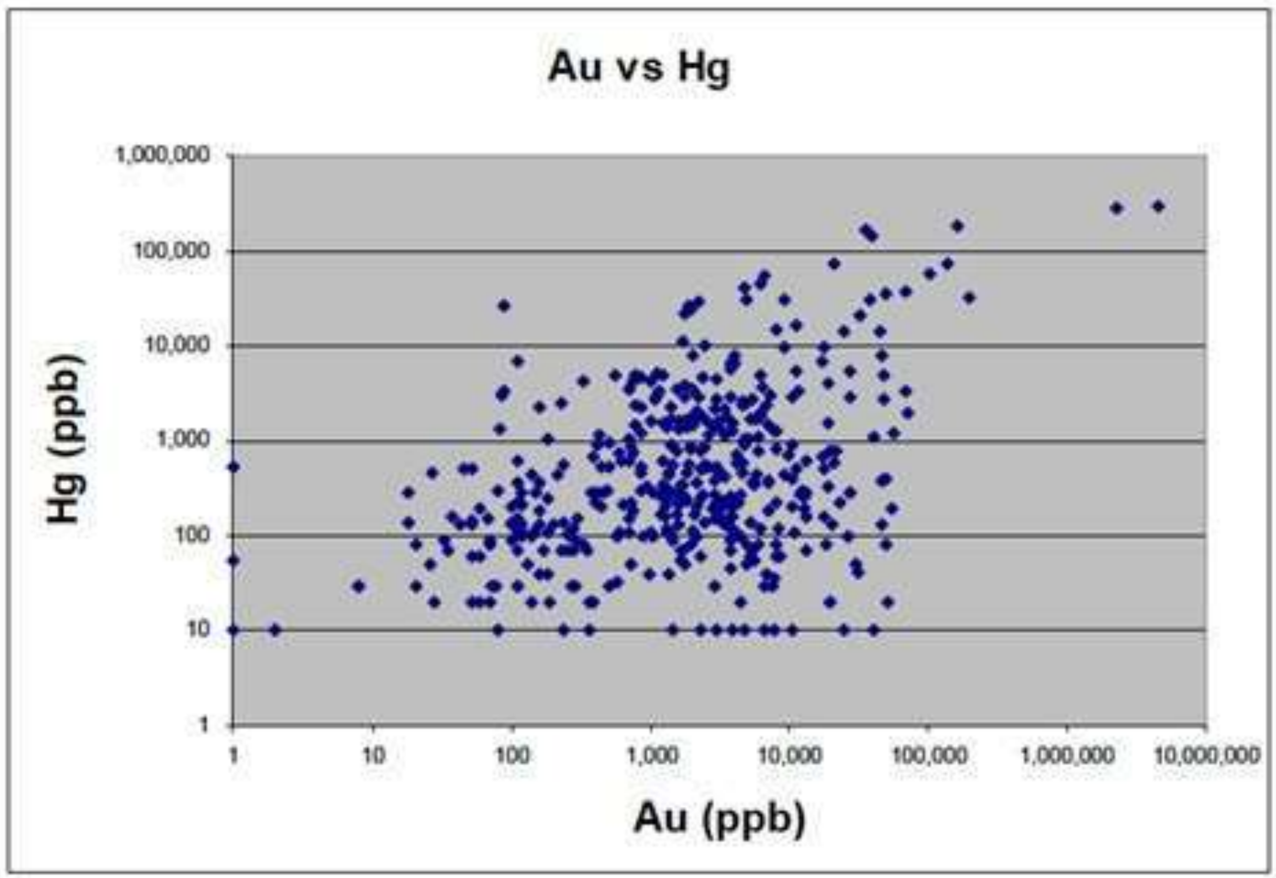
Other resources – Study Report on Non Ferrous Metals

Identified uncertainties and knowledge gaps

- Hg content in ores and concentrates, at plant and country level
- Hg air emissions test data
- Hg concentrations in reject material
- Hg distributions between emissions and other releases
- Activity data (amounts of ores and concentrates processed)
- Effects of pollution control technologies, incl. on distribution of Hg between emissions to air, and capture in solid and liquid waste
- Additional quantitative information on how mercury deports to emissions and releases to air, land, water, waste and by-products

DATA REQUIRED FOR BETTER EMISSION ESTIMATES

Mercury concentrations as a function of gold concentrations; samples from the Kalgoorlie deposit (Eviron 2006)



Improving emissions estimations

Improved data (mercury in ore and concentrates, activity data, control technologies and their effectiveness,…)

Individual plant data (often a large task)

Prospects for future development of mineral resources ?

Mine production of copper in concentrates (Cu content) and smelter and refinery copper production all increased by approximately 9% in 2021 (USGS, 2022)

Better understanding of ore characteristics

Gold is typically recovered from ores containing only traces of the metal - main challenge is concentrating

- Techiques:
  - Cyanide leaching; gold must be available for leaching
  - Mercury amalgamation – largely now only used in ASGM
  - Refractory ores – hard to leach ultra-fine mercury; requires pre-treatment (roasting, oxidation, …)

Reducing mercury emissions

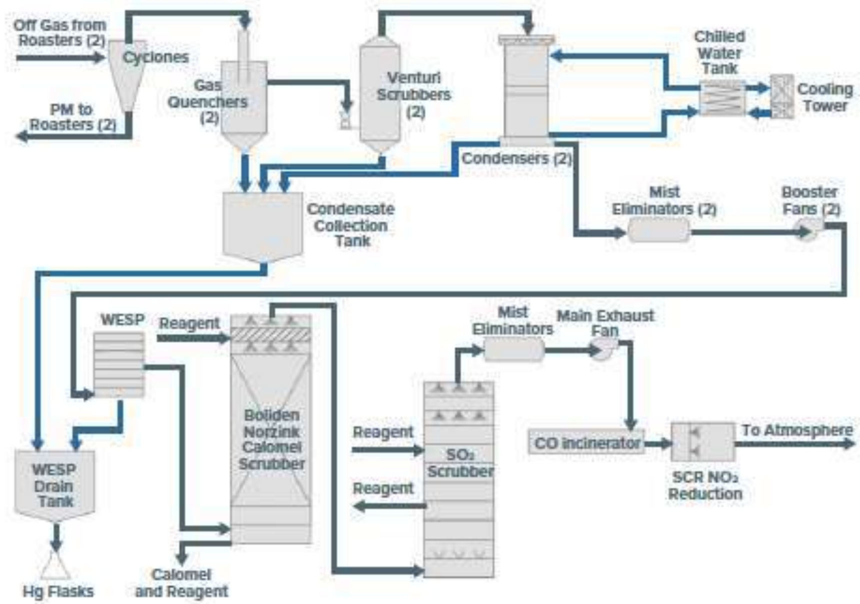
BAT/BEP Reduction of Hg emissions

- Boliden-Norzink process
  - $Hg + HgCl_2 \rightarrow Hg_2Cl_2$ (calomel)
- Selenium filter
  - $Se + Hg \rightarrow SeHg$
- Activated carbon
- Co-benefits of air pollution abatement technologies
  - Particulate matter, SO_2, NO_x

Case Study: Nevada Gold Plant

- Controls employed:

- Cyclone separation
- Gas Quench
- Venturi gas scrubbing
- Gas condenser
- Wet electrostatic precipitator (ESP)
- Calomel scrubber



Mercury Removal Technology	Process Conditions	Advantages	Disadvantages
Carbon Filter beds	Efficiency = 99%	• Effectively removes mercury chloride	• Untreated carbon ineffective in removing elemental mercury
Fixed activated carbon filter beds	Efficiency = 90%	• Sulfur-impregnated activated carbon is commercially available • Removes Hg^0 and other species • Low potential for leaching of mercury from spent carbon	• Spent carbon requires disposal in landfill
Activated carbon injection	Efficiency = 90-95%	• Sulfur-impregnated activated carbon is commercially available • Removes Hg^0 and other species • Low potential for leaching of mercury from spent carbon	• Spent carbon requires disposal in landfill
Lime/limestone scrubbing	Efficiency = 10-84%	• Effective for water soluble species	• Ineffective for elemental mercury • Wastewater requires treatment prior to disposal
Selenium filters	Efficiency = 99.6% Max Hg_{IN} = 9 mg/m^3 Max Hg_{OUT} = 40 µg/m^3	• Successful installation at metallurgical plants	• Limited inlet mercury concentration • Ineffective for species other than elemental mercury • Spent filter requires disposal in landfill
Boliden-Norzink process	Efficiency = 99% Max Hg_{IN} = 5-80 mg/m^3 Max Hg_{OUT} = 20-50 µg/m^3	• Widely demonstrated • Mercury removed as marketable product	• Removes only elemental mercury • Complicated flowsheet • Chlorine gas handling

Introduction: Minamata Convention on Mercury, Article 8, emissions inventories

Workshop to enhance inventories and strategies under Article 8 of the Minamata Convention in Vietnam, 10 June 2024

Alexander Romanov, UNEP-GEF Chemicals and Waste Unit (alexander.romanov@un.org)
on behalf of the Secretariat of the Minamata Convention on Mercury

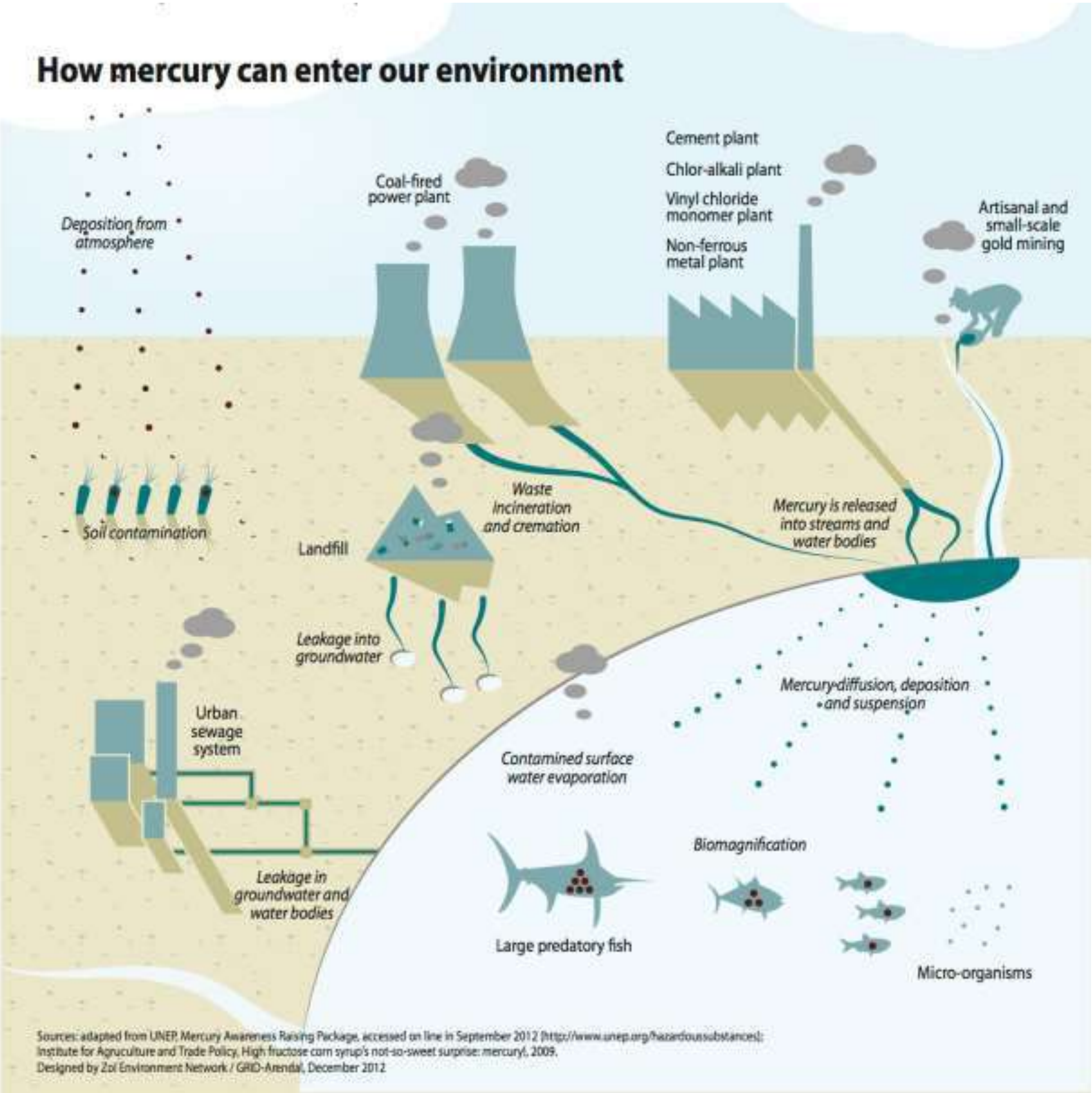
Funded by the European Union

Mercury around us

Mercury mine in Idrija, Slovenia, 1679, by Johann Weikhard von Valvasor (1641-1693). Wikimedia Commons. Public domain.

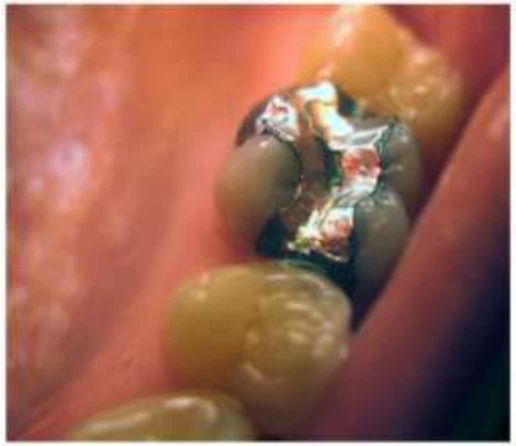
The Print sourced from:
Science for Environment Policy (2017) *Tackling mercury pollution in the EU and worldwide.* In-depth Report 15 produced for the European Commission, DG Environment by the Science Communication Unit, UWE, Bristol. Available at: http://ec.europa.eu/science-environment-policy

Mercury around us



Cinnabar on Dolomite. JJ Harrison, 2009. CC-BY-SA 3.0 Unported https://commons.wikimedia.org/wiki/File:Cinnabar_on_Dolomite.jpg

Clinical mecury thermometer, Menchi, 2005, Wikimedia Commons. CC-BY-SA 3.0 Unported.

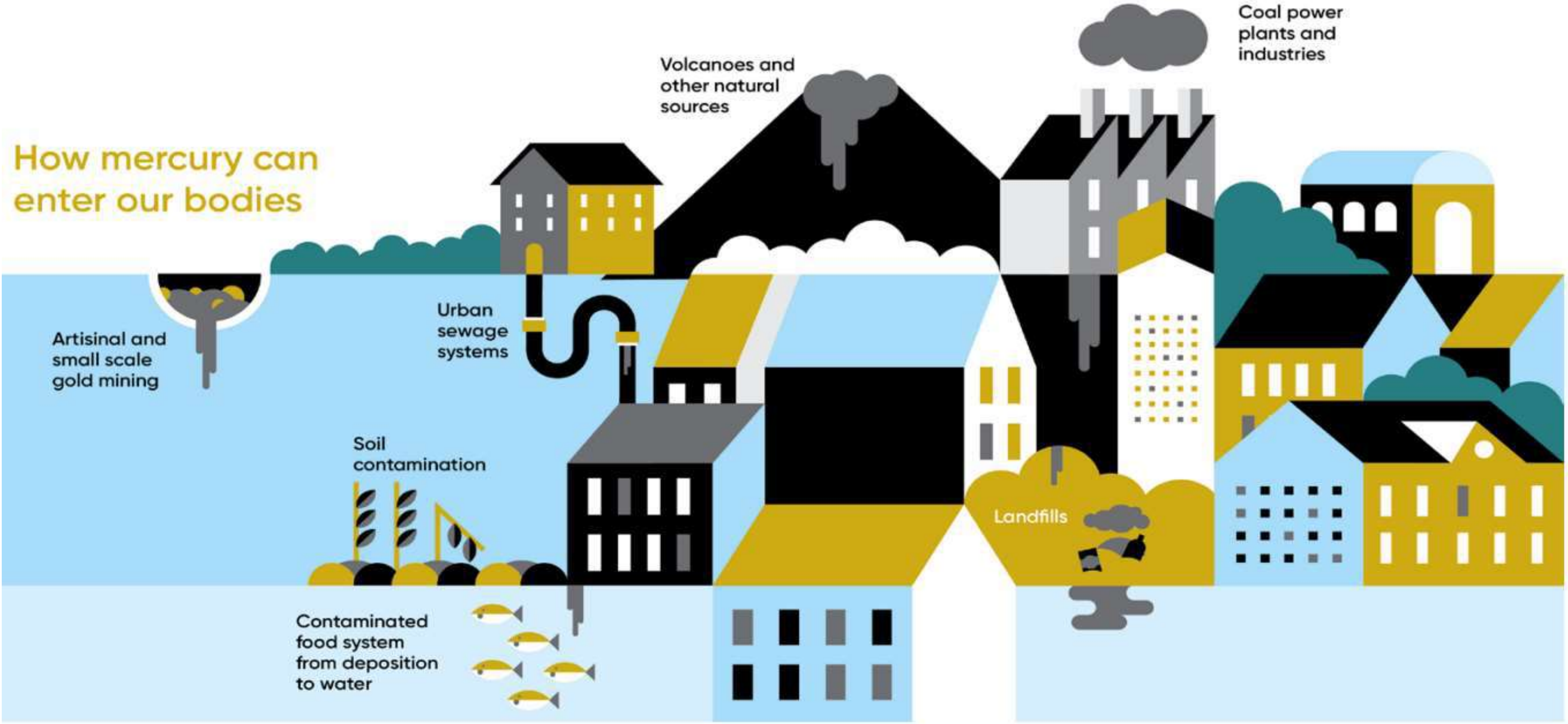


Mercury filling on first molar, shown upsidedown. Kauzio, 2009, Wikimedia Commons.

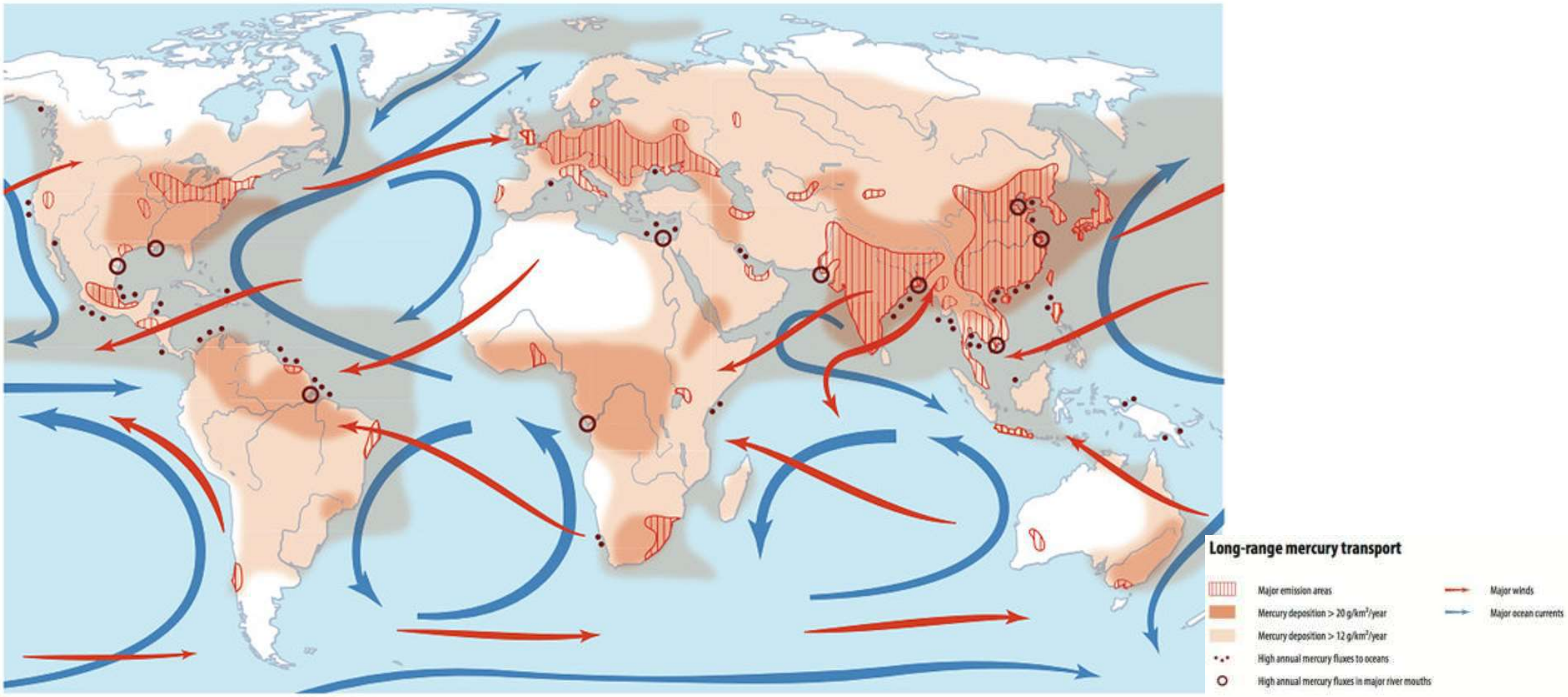
Li-ion battery from a laptop computer. Kristoferb, 2010. CC BY-SA 3.0 Wikimedia Commons.

Science for Environment Policy (2017) *Tackling mercury pollution in the EU and worldwide.* In-depth Report 15 produced for the European Commission, DG Environment by the Science Communication Unit, UWE, Bristol. Available at: http://ec.europa.eu/science-environment-policy

Mercury around us



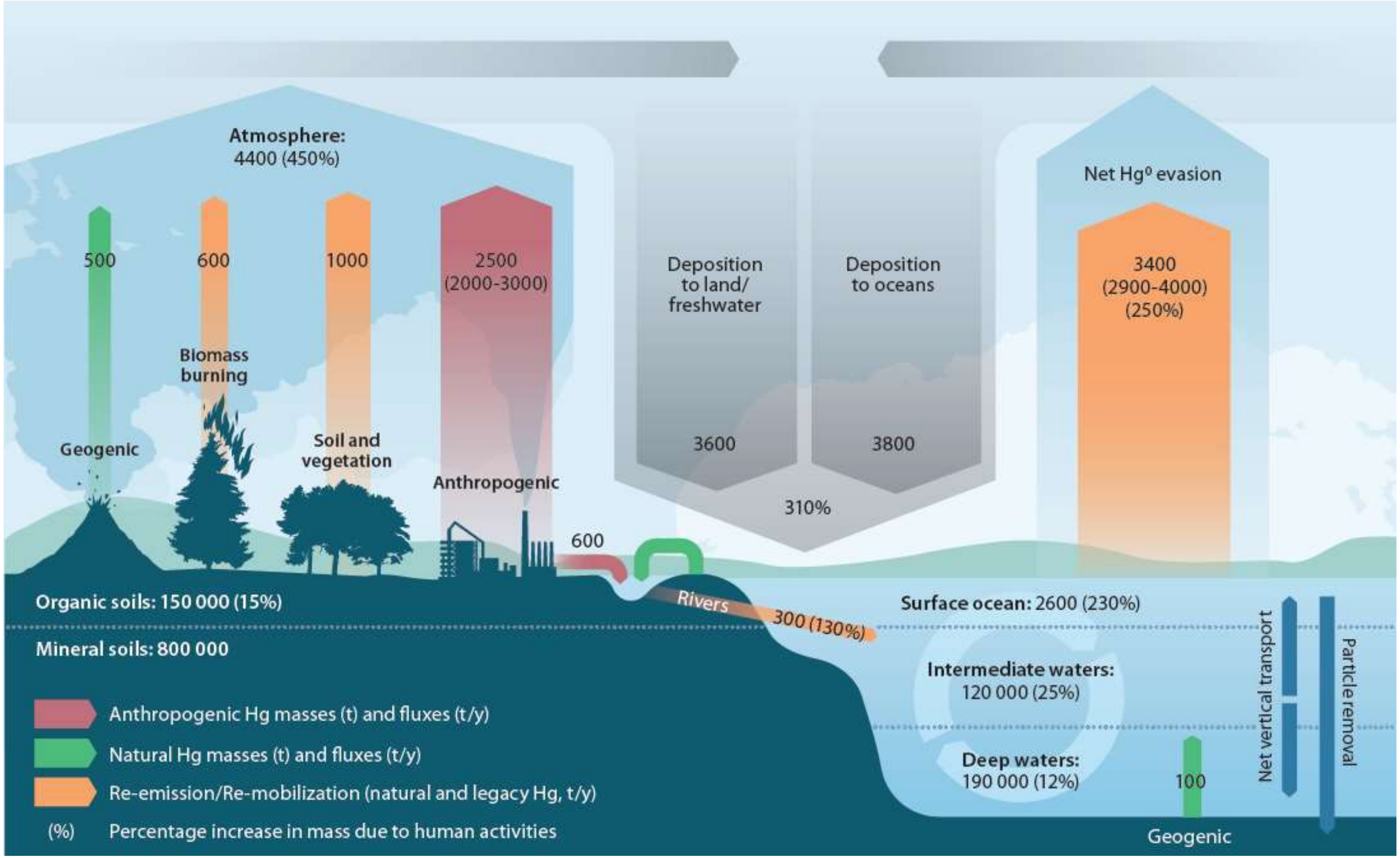
Mercury – pollutant of the global concern



Source: Adapted from AMAP/UNEP 2008, Technical Background Report to the Global Atmospheric Mercury Assessment; UNEP, Global Mercury Assessment 2013: Sources, Emissions, Releases and Environmental Transport, 2013
Designed by Zoi Environment Network / GRID-Arendal, December 2012

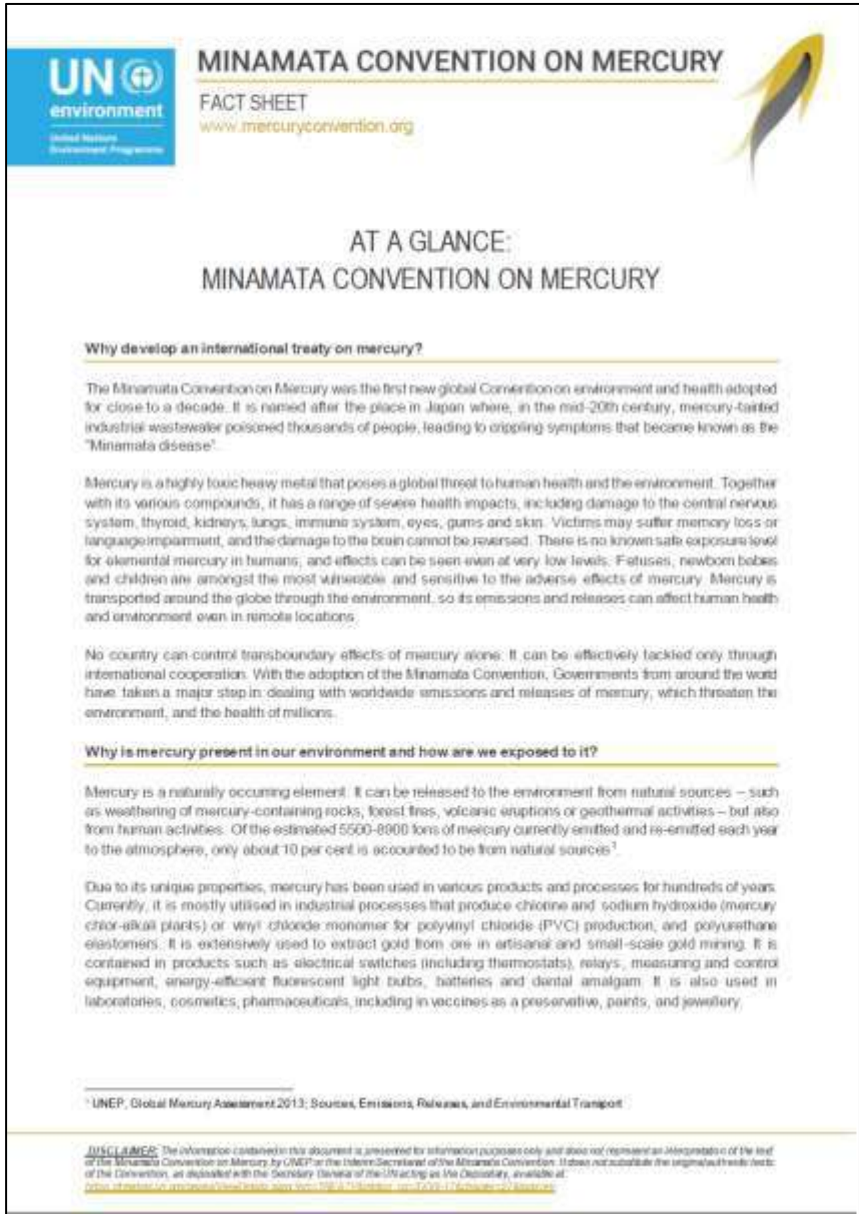
GMA 2018 - Update on global Hg pools and cycles

MINAMATA CONVENTION ON MERCURY



Minamata Convention on Mercury

- Objective: to **protect the human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds**.
- Adopted in October 2013, entered into force in August 2017.
- Mercury is a chemical of global concern owing to its:
  - ➢ Long-range atmospheric transport,
  - ➢ Persistence in the environment once anthropogenically introduced,
  - ➢ Ability to bioaccumulate in ecosystems, and
  - ➢ Significant negative effects and human health and the environment.
- Recognizes the lessons of Minamata Disease, in particular the serious health and environmental effects from mercury pollution.



UN environment

MINAMATA CONVENTION ON MERCURY

FACT SHEET

www.mercuryconvention.org

AT A GLANCE:
MINAMATA CONVENTION ON MERCURY

Why develop an international treaty on mercury?

The Minamata Convention on Mercury was the first new global Convention on environment and health adopted for close to a decade. It is named after the place in Japan where, in the mid-20th century, mercury-tainted industrial wastewater poisoned thousands of people, leading to crippling symptoms that became known as the "Minamata disease".

Mercury is a highly toxic heavy metal that poses a global threat to human health and the environment. Together with its various compounds, it has a range of severe health impacts, including damage to the central nervous system, thyroid, kidneys, lungs, immune system, eyes, gums and skin. Victims may suffer memory loss or language impairment, and the damage to the brain cannot be reversed. There is no known safe exposure level for elemental mercury in humans, and effects can be seen even at very low levels. Fetuses, newborn babies and children are amongst the most vulnerable and sensitive to the adverse effects of mercury. Mercury is transported around the globe through the environment, so its emissions and releases can affect human health and environment even in remote locations.

No country can control transboundary effects of mercury alone. It can be effectively tackled only through international cooperation. With the adoption of the Minamata Convention, Governments from around the world have taken a major step in dealing with worldwide emissions and releases of mercury, which threaten the environment, and the health of millions.

Why is mercury present in our environment and how are we exposed to it?

Mercury is a naturally occurring element. It can be released to the environment from natural sources – such as weathering of mercury-containing rocks, forest fires, volcanic eruptions or geothermal activities – but also from human activities. Of the estimated 5500-8900 tons of mercury currently emitted and re-emitted each year to the atmosphere, only about 10 per cent is accounted to be from natural sources[1].

Due to its unique properties, mercury has been used in various products and processes for hundreds of years. Currently, it is mostly utilised in industrial processes that produce chlorine and sodium hydroxide (mercury chlor-alkali plants) or vinyl chloride monomer for polyvinyl chloride (PVC) production, and polyurethane elastomers. It is extensively used to extract gold from ore in artisanal and small-scale gold mining. It is contained in products such as electrical switches (including thermostats), relays, measuring and control equipment, energy-efficient fluorescent light bulbs, batteries and dental amalgam. It is also used in laboratories, cosmetics, pharmaceuticals, including in vaccines as a preservative, paints, and jewellery.

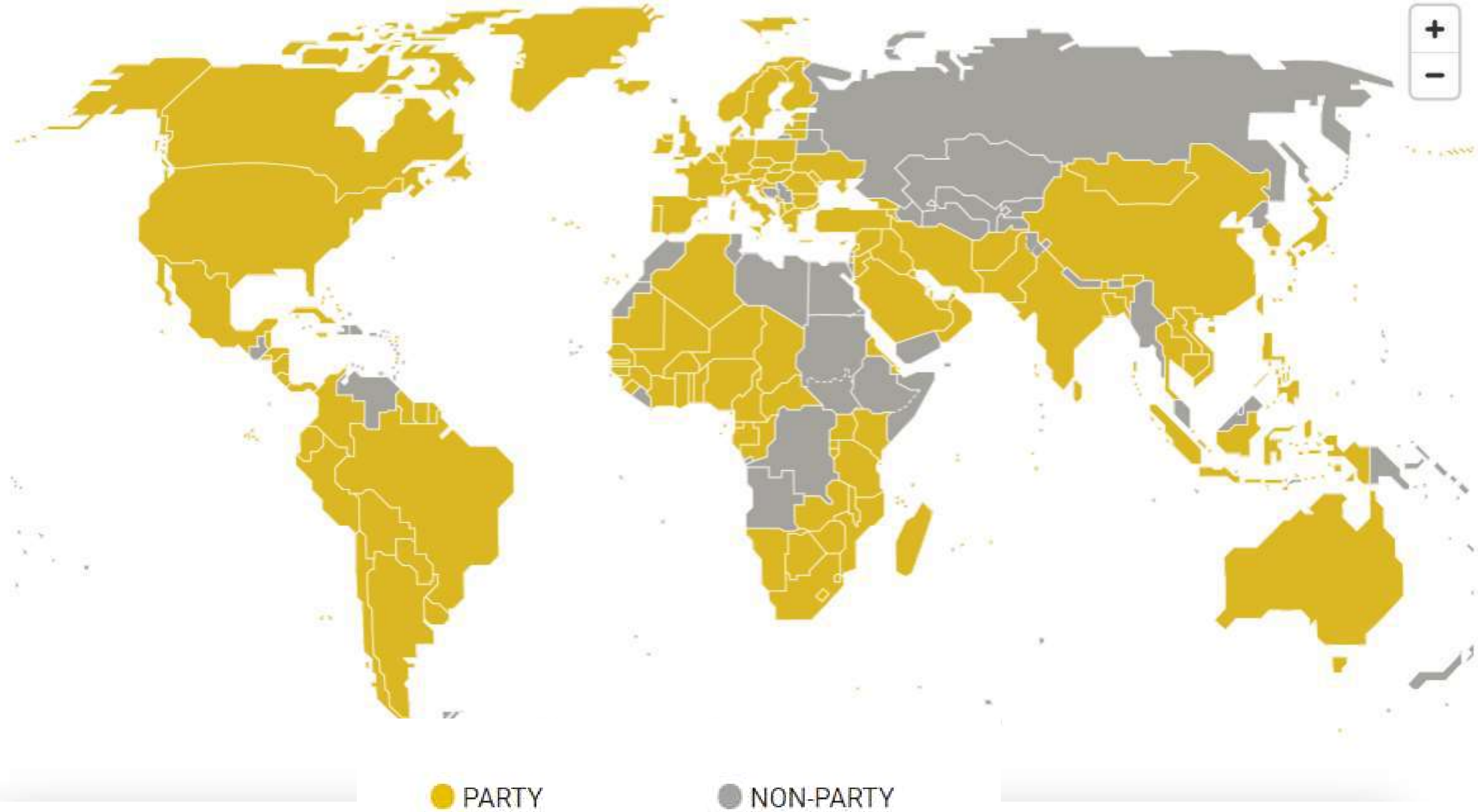
[1] UNEP, Global Mercury Assessment 2013: Sources, Emissions, Releases, and Environmental Transport

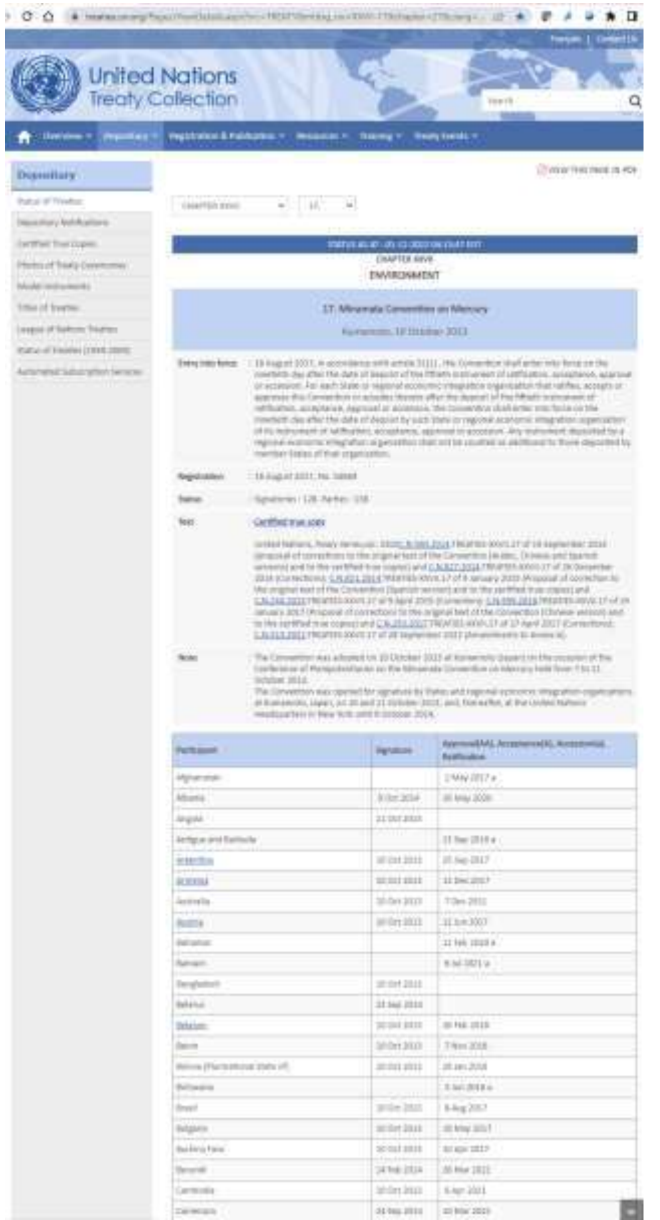
DISCLAIMER: The information contained in this document is presented for information purposes only and does not represent an interpretation of the text of the Minamata Convention on Mercury by UNEP or the Interim Secretariat of the Minamata Convention. It does not substitute the original authentic texts of the Convention, as deposited with the Secretary General of the UN acting as the Depositary, available at:

See [Minamata Convention at a Glance]

Parties to the Minamata Convention

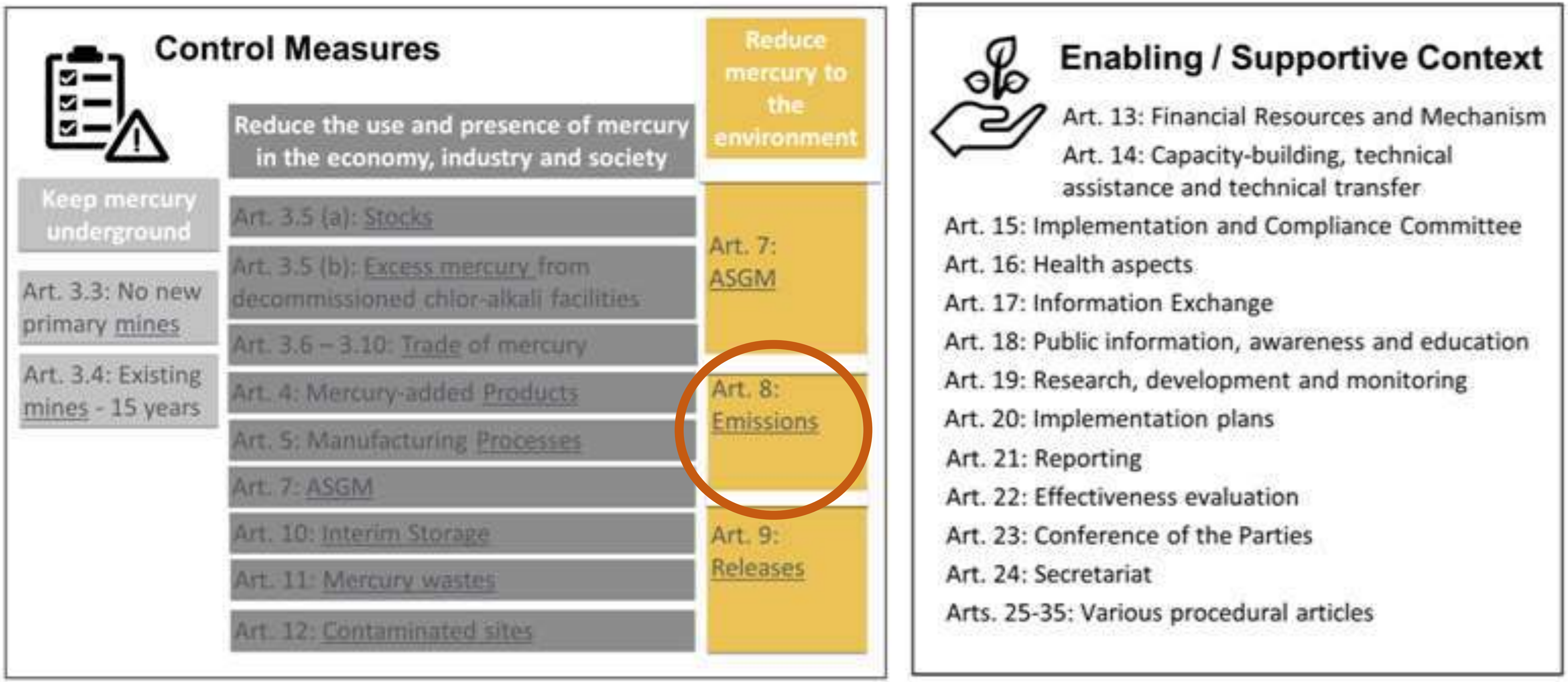
- 148 parties as of May 2024





For most recent list of parties, see [UN Treaties Section website]()

Control measures and support measures

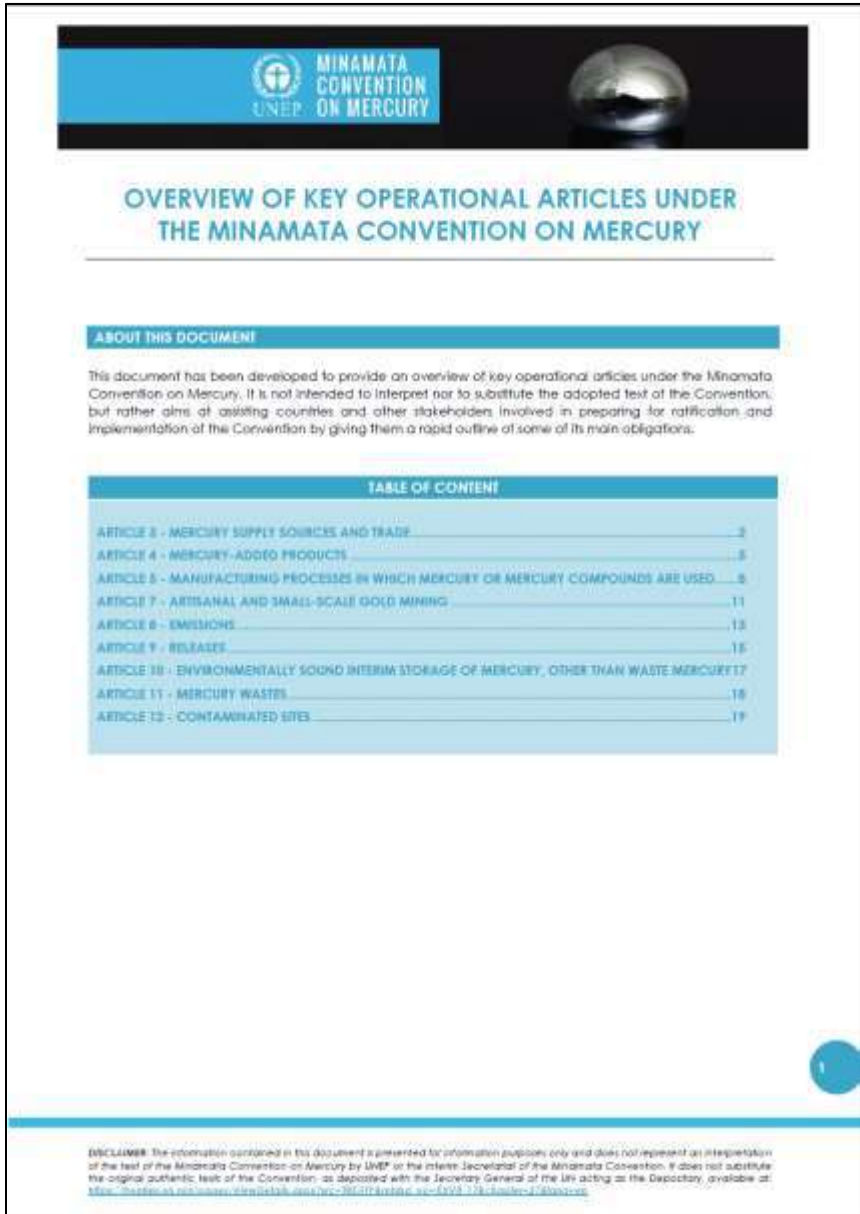


Major obligations of the parties to the Minamata Convention

MINAMATA CONVENTION ON MERCURY

- Article 3: Not allow new mercury mines and close old ones in 15 years
- Article 3: Only export mercury with written consent of importing countries
- Article 4: Phase out listed mercury-added products by 2020 (2025 for newly-added product categories.
- Article 4: Take measures to phase down dental amalgam
- Article 5: Phase out listed mercury-using processes by 2018 or 2025, and take measures to restrict other listed processes
- Article 7: Develop and implement national action plans on artisanal and small-scale gold mining in 3 years
- Article 8: Take measures on new emission sources in 5 years and existing sources in 10 years. Establish emission inventory in 5 years
- Article 9: Identify relevant sources and take measures. Establish release inventory in 5 years
- Article 10: Take measures on interim storage
- Article 11: Manage mercury waste in an environmentally sound manner
- Article 12: Endeavour to develop strategies
- Article 21: Report on the implementation of the Convention

See Overview of Key Operational Articles


UNEP MINAMATA CONVENTION ON MERCURY

OVERVIEW OF KEY OPERATIONAL ARTICLES UNDER THE MINAMATA CONVENTION ON MERCURY

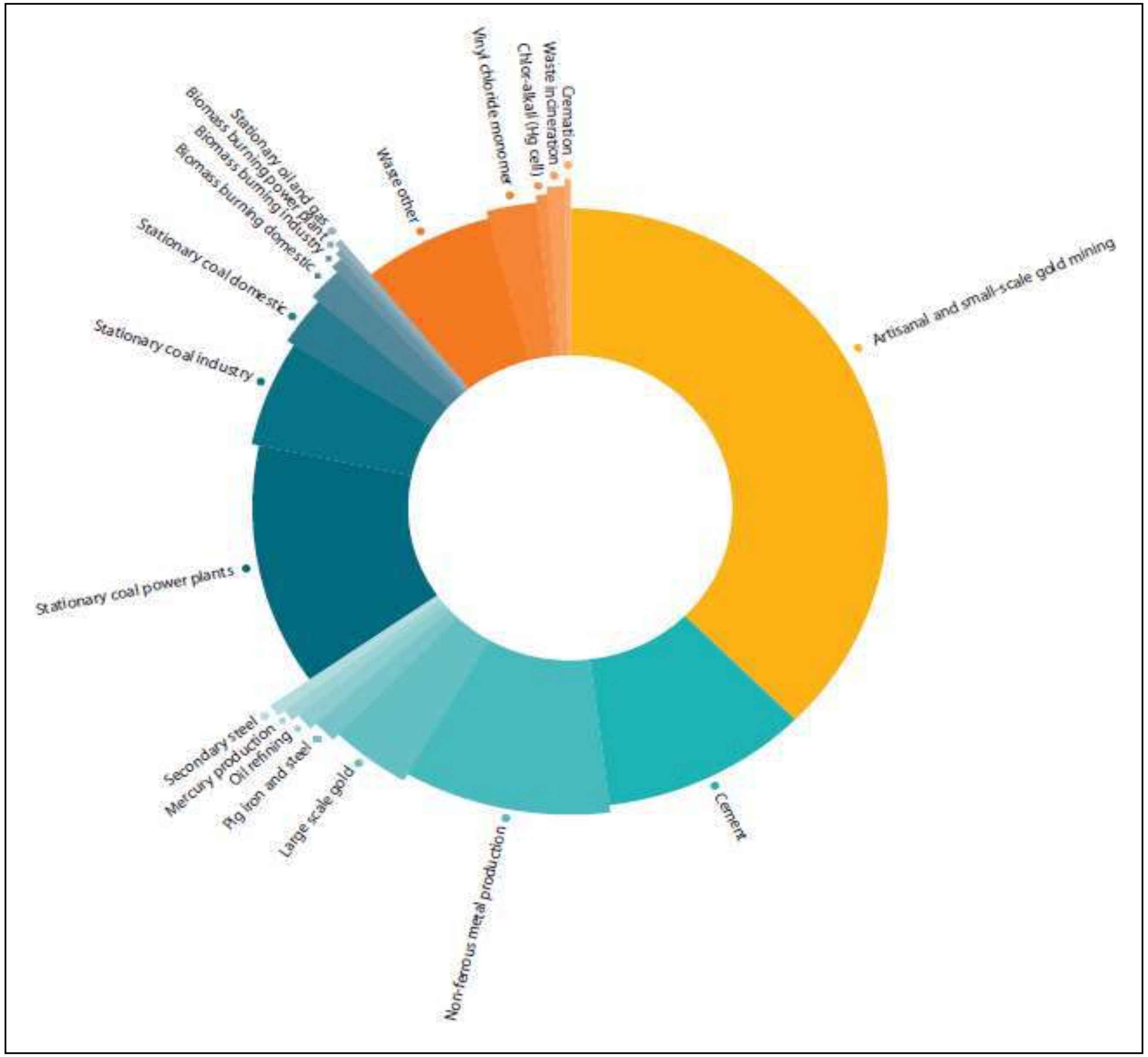
ABOUT THIS DOCUMENT

This document has been developed to provide an overview of key operational articles under the Minamata Convention on Mercury. It is not intended to interpret nor to substitute the adopted text of the Convention, but rather aims at assisting countries and other stakeholders involved in preparing for ratification and implementation of the Convention by giving them a rapid outline of some of its main obligations.

TABLE OF CONTENT

Global Mercury Assessment 2018

- The predominant source sector is artisanal and small-scale gold mining (about 38%).
- It is followed by stationary combustion of coal (about 21%), non-ferrous metal production (about 15%) and cement production (about 11%).



Article 8 of the Minamata Convention

MINAMATA CONVENTION ON MERCURY

- Controls the emissions of total mercury to air from the following sources listed in Annex D:
  - Coal-fired power plants
  - Coal-fired industrial boilers
  - Smelting and roasting processes used in the production of non-ferrous metals (lead, zinc, copper and industrial gold)
  - Waste incineration facilities
  - Cement clinker production facilities.
- Parties with relevant sources shall take measures to control emissions and may prepare a national plan, which is to be submitted **within 4 years after the entry into force** if prepared.
- For **new sources**, each Party shall require the use of BAT/BEP to control and reduce emissions, as soon as practicable but **no later than 5 years after the date of entry into force**.
- For **existing sources**, each Party shall include in any national plan, and shall implement, one or more of the following measures, as soon as practicable but **no more than 10 years after the date of entry into force**:
  - A quantified goal
  - Emission limit values
  - The use of BAT/BEP
  - A multi-pollutant control strategy that would deliver co-benefits
  - Alternative measures to reduce emissions from relevant sources
- Each Party shall establish, as soon as practicable and no later than **5 years after the date of entry into force** of the Convention for it, and maintain thereafter, an **inventory of emissions from relevant sources**.

Guidance under Article 8 of the Minamata Convention

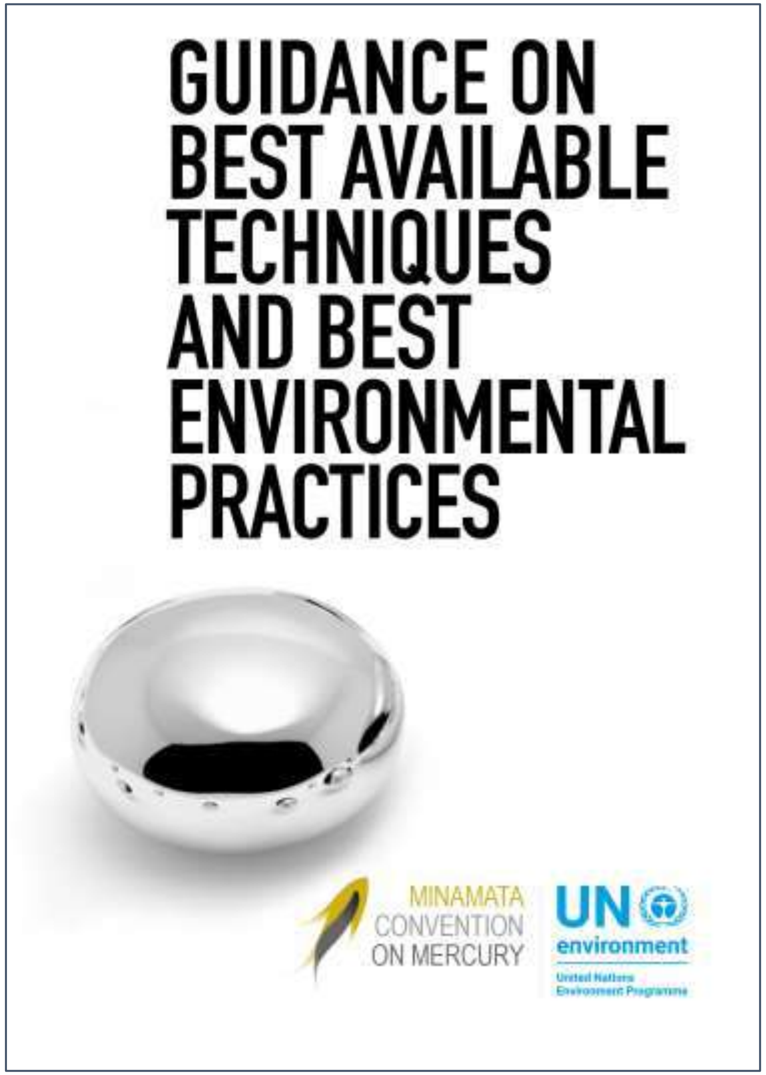
MINAMATA CONVENTION ON MERCURY

▶ Decision MC-1/4

- Adopted the guidance on BAT/BEP and on support for parties in implementing the measures
- Recognized that some of the measures described in the guidance may not be available to all parties for technical or economic reasons,
- Requested parties with experience in using such guidance to provide the secretariat with information on that experience, and the secretariat to compile such information and to update the guidance as necessary.

▶ Decision MC-1/16

- Adopted the guidance on criteria that parties may develop to identify emission sources, and on the methodology for emission inventories.



UNEP's Toolkit for identification and quantification of mercury releases

MINAMATA CONVENTION ON MERCURY

- UNEP's *Toolkit for identification and quantification of mercury releases* –aka UNEP Mercury *Toolkit* – is intended to assist countries to identify and quantify the sources of mercury emissions and releases, set priorities and reduction targets, enhance international co-operation, knowledge sharing, and **enable targeted technical assistance**.

- Inventories from countries contribute to the Global Mercury Assessment, the hub of the scientific knowledge of worldwide mercury emissions and releases.

- The Toolkit provides clear guidance on different stages of inventory development: identifying mercury sources, quantifying the consumption and calculating the final emissions and releases.

- The Toolkit includes detailed manual, calculation spreadsheet and a standard template for reporting.

- The Toolkit is one of the methods recommended in guidance from the Minamata Convention on preparing inventories of emissions pursuant to Article 8.

UNEP's Toolkit for identification and quantification of mercury releases

MINAMATA CONVENTION ON MERCURY

Inventory Level 1 (IL1) – simplified model based on default factors, requires national sectoral activity rate data; useful for first-time inventories, yet less accuracy of emission/release estimates should be expected

Inventory Level 2 (IL2) – detailed mercury inventory tool, all emission/release factors can be adjusted to national/local conditions (default factors are included), requires detailed national sectoral data to fully reflect mercury cycles

Inventory Level 3 (IL3) - integrates all mercury sources into their entire mass flow through and out of society to the environment linking different mercury sources and provides increased accuracy in estimations; most data- and expertise-intensive

+ Excel calculations sheets for Level 1, Level 2, and Level 3 inventories

Source: https://www.unep.org/topics/chemicals-and-pollution-action/pollution-and-health/heavy-metals/mercury/mercury-inventory

UNEP's Toolkit for identification and quantification of mercury releases (examples)

MINAMATA CONVENTION ON MERCURY

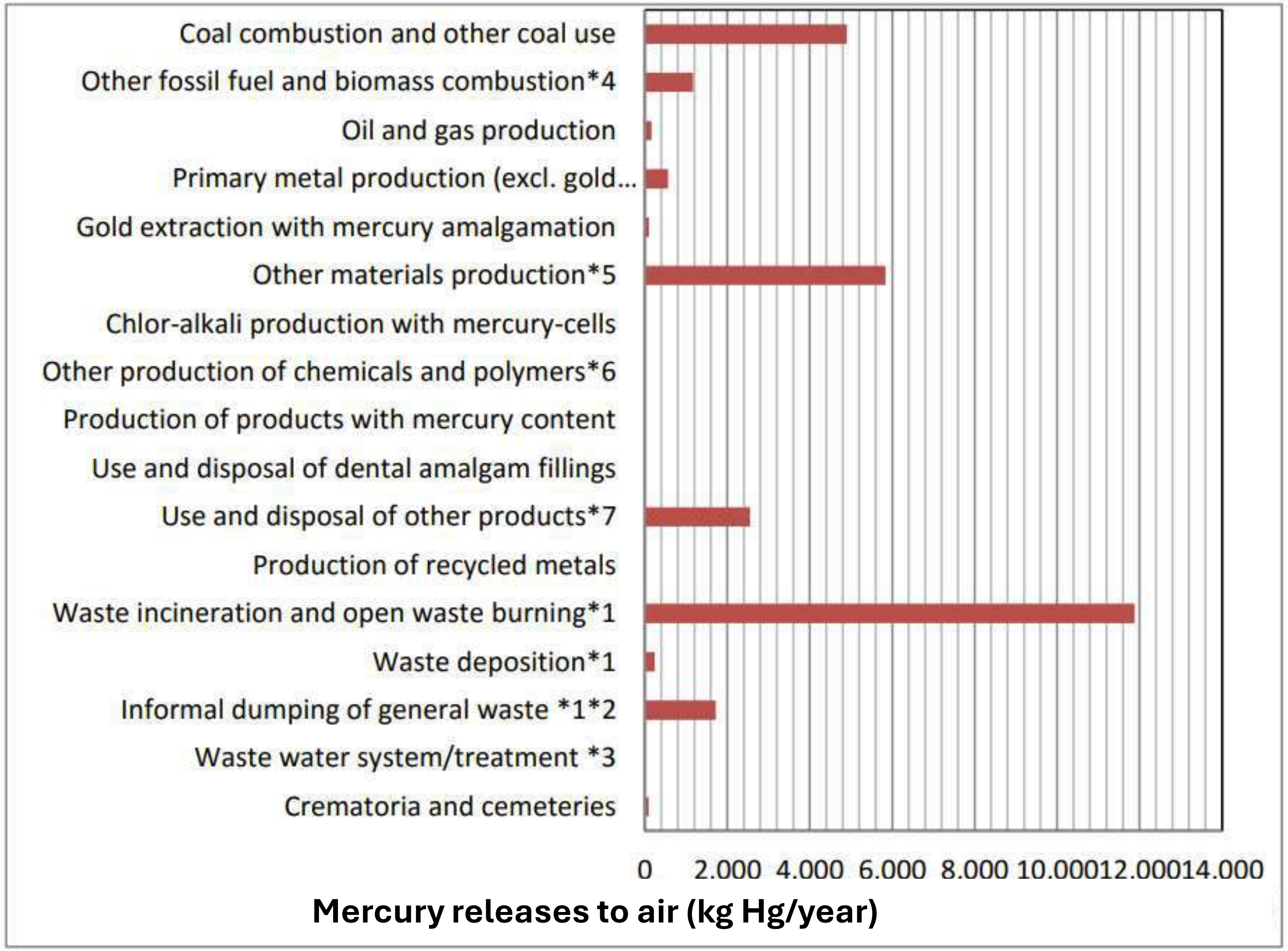
Minamata Initial Assessment Report for Vietnam (2017)

Summary of mercury emissions and releases

No.	Mercury sources (sectors/fields)	Total emissions kg Hg/year	Proportion (%)
1	Energy consumption	6,541	13.3
2	Fuel production	1,041	2.1
3	Crude metal production	4,259	8.7
4	Production of other crude materials	7,783	16
5	Producing of containing-mercury products	504	1
6	Use and disposal of products containing mercury	9,606	19.6
7	Waste incineration	12,383	25.2
8	Waste burying and wastewater treatment	5,440	11.1
9	Cremation and burial	1,565	3
	Total	**49,131**	**100**

List of priority sources identified in the MIA Vietnam report

No.	Mercury sources	Order by priority
1.1	Coal combustion in large power plants	High
2.1	Oil refinery /extraction and processing of natural gas	Medium
3.1	Metallurgy (tin, zinc, copper) from refined ore	Medium
3.2	Gold production by method using mercury amalgams	High
4.1	Cement production	High
5.1	Production of lamps containing mercury (fluorescent lamps, compacts and others)	High
6.1	Use and disposal of dental amalgam containing mercury	Medium
6.2	Thermometer	High
6.3	Circuit breakers/switches and relays containing mercury	High
6.4	Use and disposal of mercury containing lamps	Medium
7.1	Incineration of waste in incineration plants	High

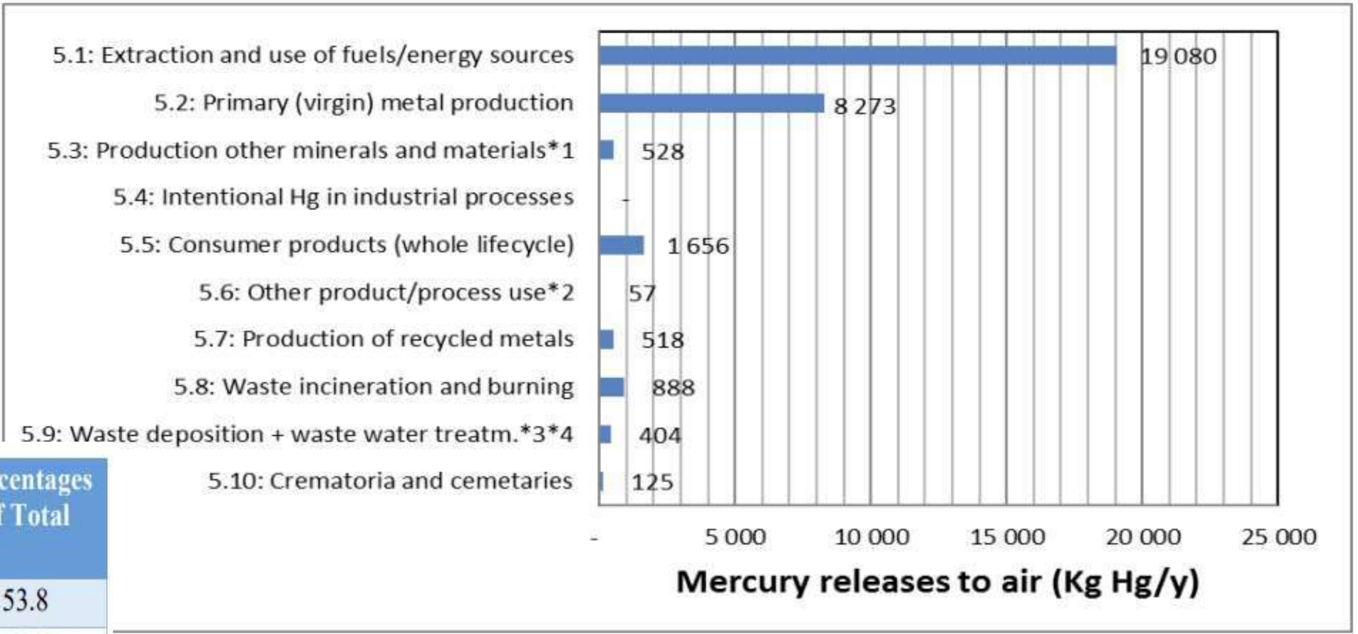


https://minamataconvention.org/sites/default/files/documents/minamata_initial_assessment/Viet-Nam-MIA-2016.pdf

UNEP's Toolkit for identification and quantification of mercury releases (examples)

MINAMATA CONVENTION ON MERCURY

Minamata Initial Assessment Report for South Africa (2021)

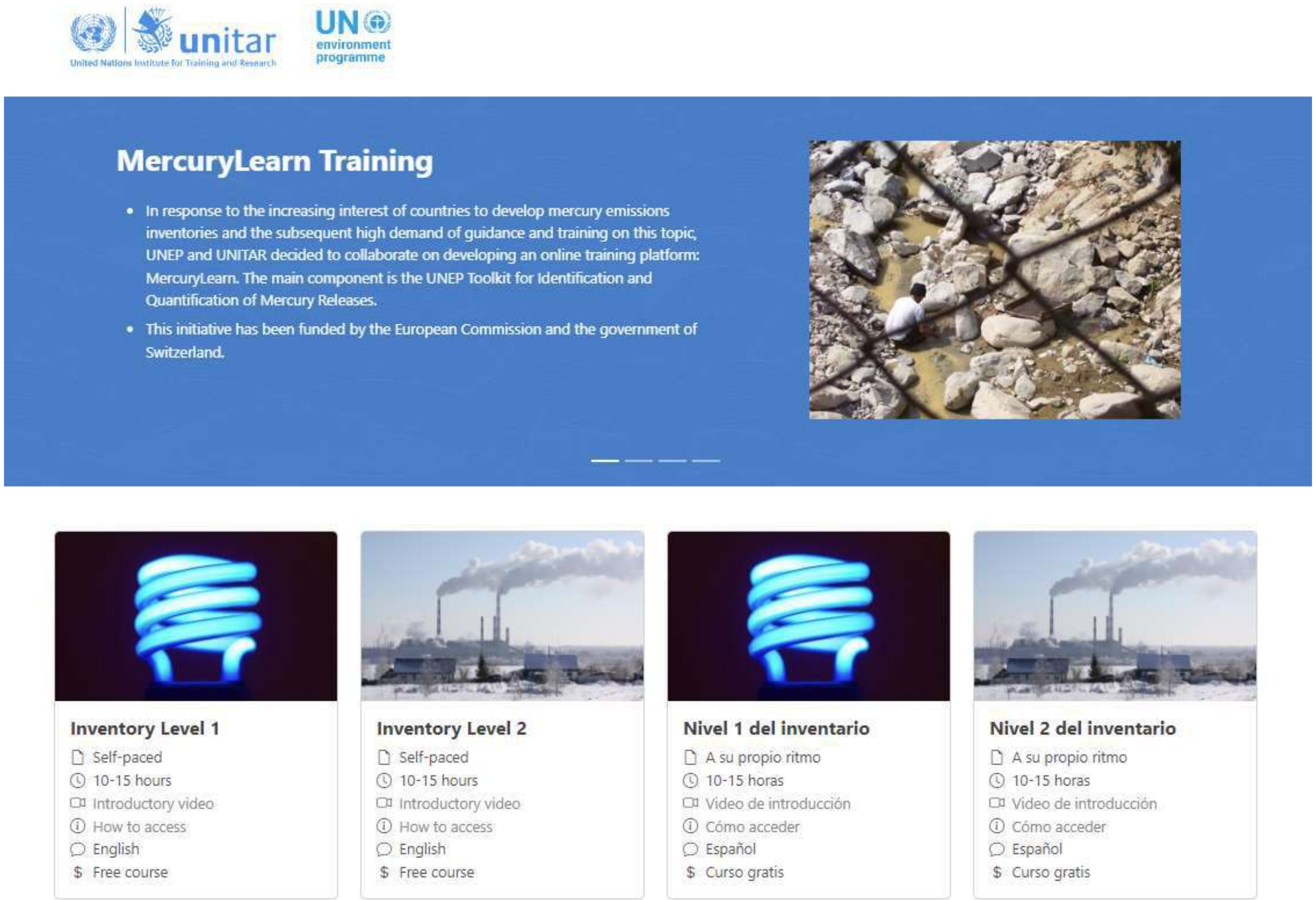


Category	Source category	Calculated. Hg input to society(Kg/y)	Percentages of Total
5.1	Extraction and use of fuels/energy sources	38080	53.8
5.2	Primary (virgin) metal production	12894	18.2
5.3	Production of other minerals and materials with mercury impurities	803	1.1
5.4	Intentional use of mercury in industrial processes	0	0.0
5.5	Consumer products with intentional use of mercury	11726	16.6
5.6	Other intentional product/process use	4346	6.1
5.7	Production of recycled metals ("secondary" metal production)	1594	2.3
5.8	Waste incineration*3	905	1.3
5.9	Waste deposition/landfilling and wastewater treatment	408	0.6
5.10	Crematoria and cemeteries	1250	1.8

https://minamataconvention.org/sites/default/files/documents/minamata_initial_assessment/South_Africa-MIA-2021-EN.pdf

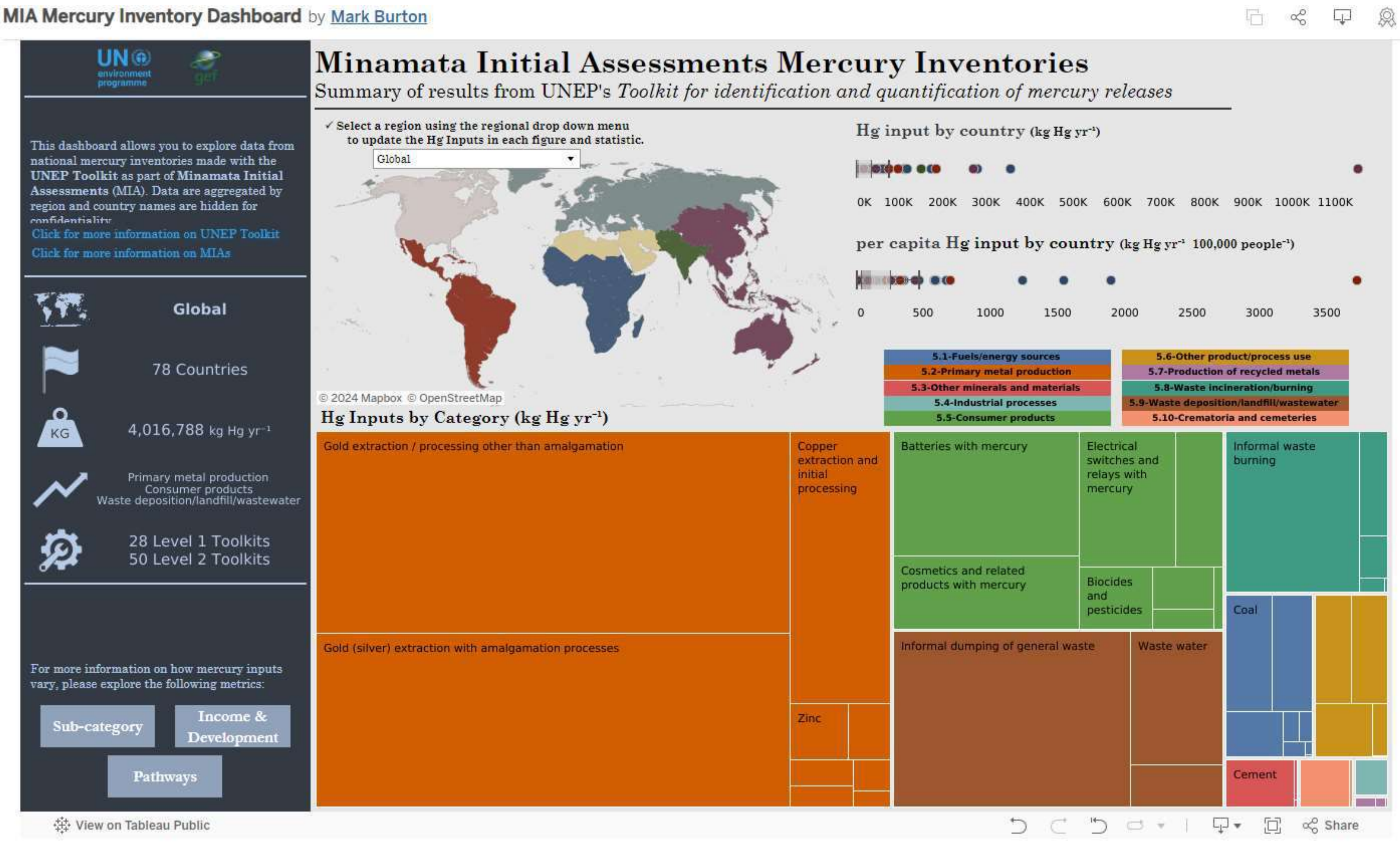
UNEP's Toolkit for identification and quantification of mercury releases

MINAMATA CONVENTION ON MERCURY



- https://mercurylearn.unitar.org/
- **Online training modules on the UNEP's Toolkit for identification and quantification of mercury releases Inventory Level 1 and 2**
- **Self-paced, available in English and Spanish**

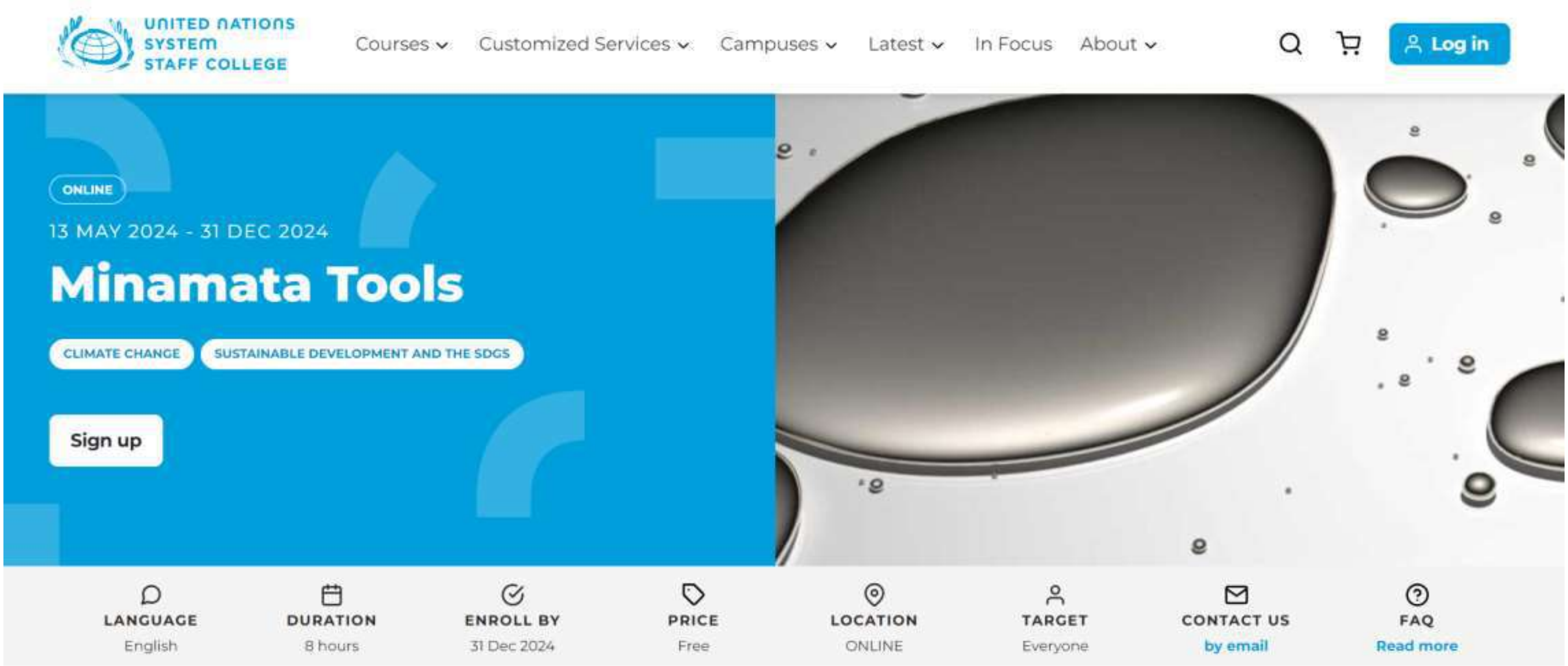
Minamata Convention Initial Assessments



https://public.tableau.com/app/profile/mark.burton.bri/viz/MIAMercuryInventoryDashboard/Main_Dashboard?publish=yes

Minamata (training) Tools

MINAMATA CONVENTION ON MERCURY



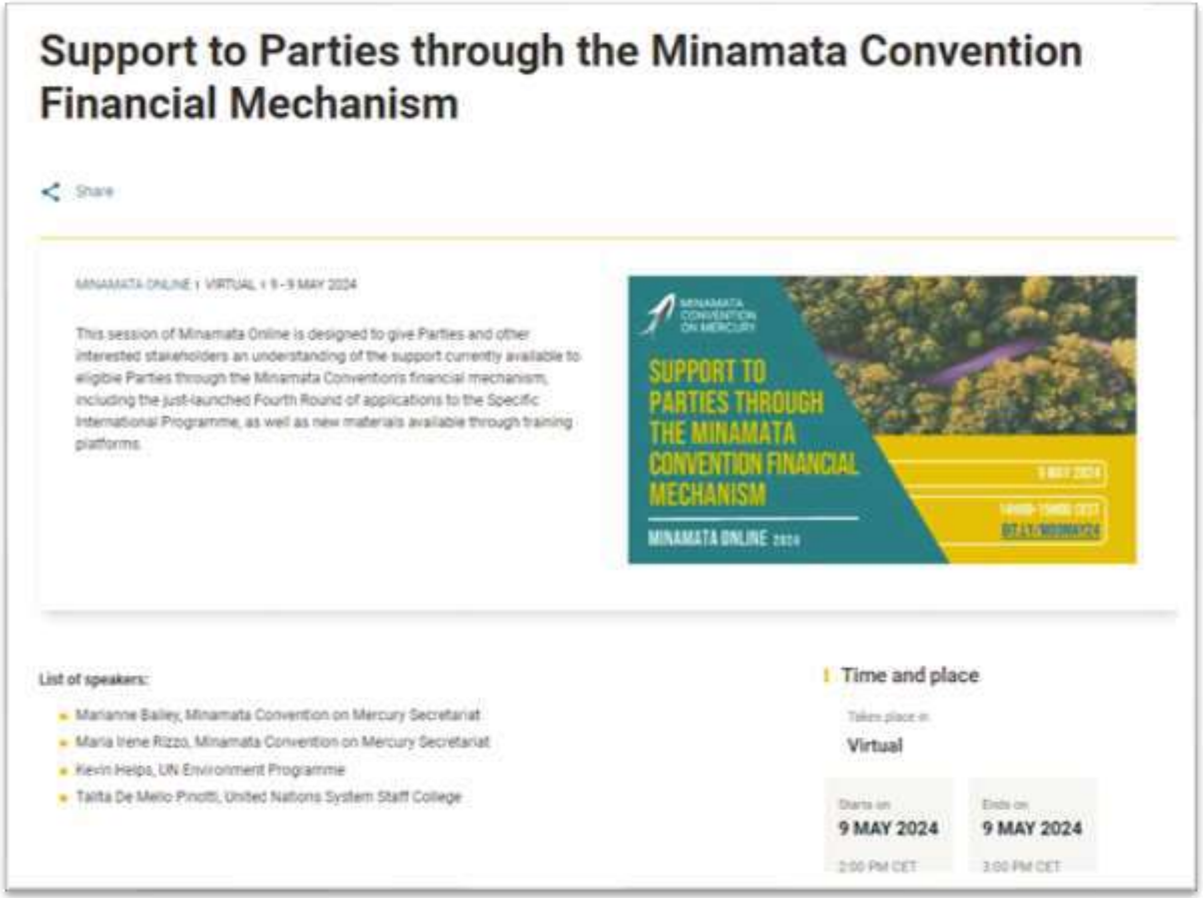
Funded by the European Union

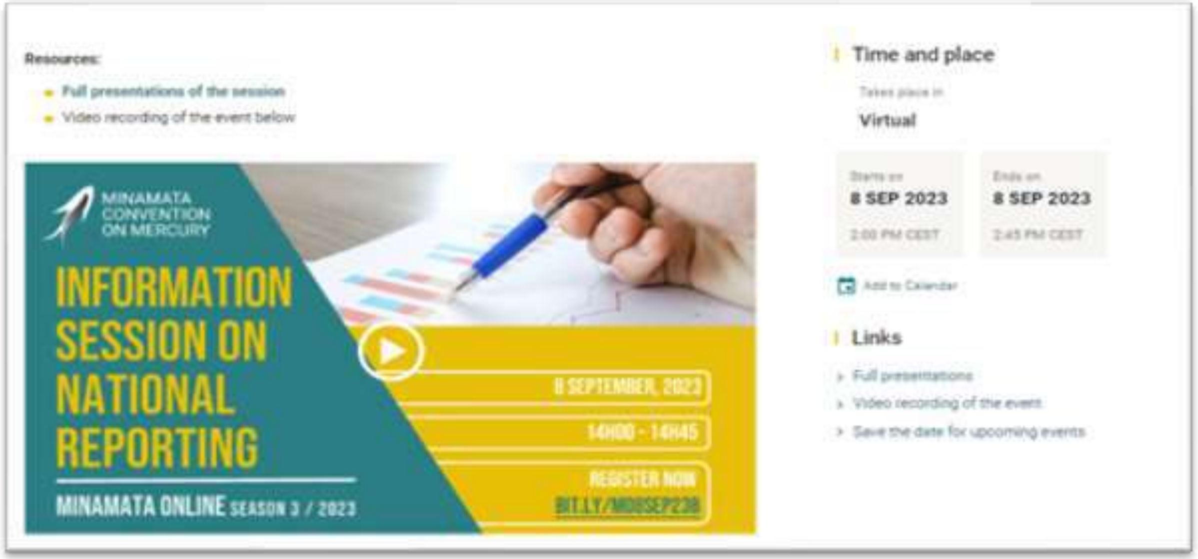
Developed with the generous support of the European Union as part of project "Support to the capacity-building and technical assistance programme of the Secretariat of the Minamata Convention on Mercury"

► https://www.unssc.org/courses/minamata-tools-0

Minamata Online

Minamata Online series of virtual webinars on various topics related to the Minamata Convention on mercury since 2020





https://minamataconvention.org/en/meetings/upcoming-list-view?field_event_type_target_id=287

MINAMATA CONVENTION ON MERCURY

Thank you for your attention

Secretariat of the Minamata Convention on Mercury
United Nations Environment Programme
11-13, Chemin des Anémones - 1219 Châtelaine, Switzerland

WEB: https://minamataconvention.org/
MAIL: MEA-MinamataSecretariat@un.org
TWITTER: @minamataMEA
#MakeMercuryHistory

Using Inventory Data and Planned Policies to Inform Future Emission Scenarios in Vietnam

MACQUARIE University SYDNEY · AUSTRALIA

One-day working event on inventory production and compliance strategies for the Vietnam Coal fleet under the Minamata Convention

10 June 2024

Project Outcomes

OUTCOME 1:

Comprehensive coal sectoral analysis

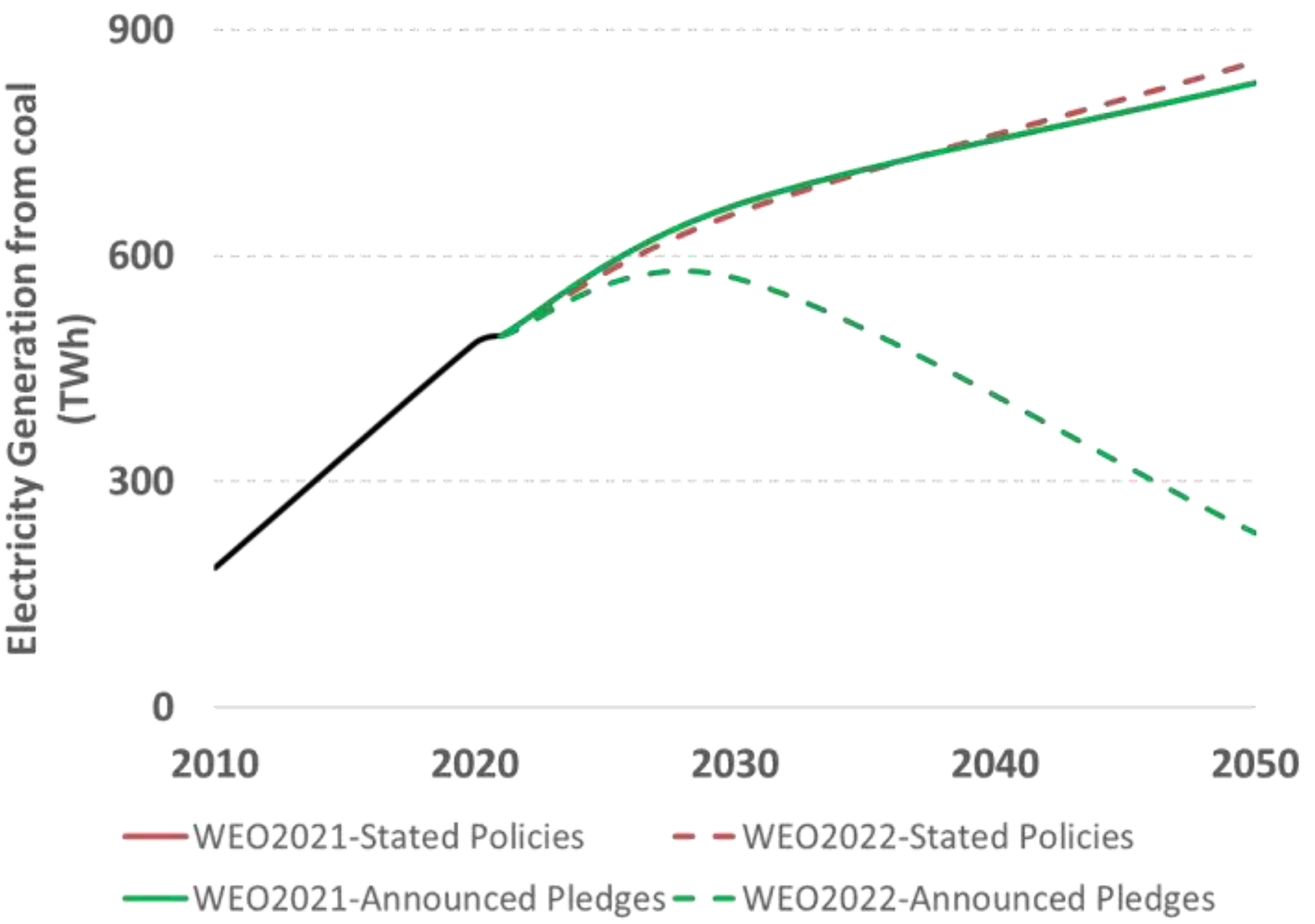
Activities

- Review scientific data on mercury emissions from CFPPs
- Evaluate the impact of commitments and targets by UN Conventions on Hg/GHG/POP emissions from the coal sector
- Potential mercury reduction figures & scenarios from CFPPs produced
  - ➢ Expand to Coal-Fired Industrial Boilers (CFIB)

Electricity Generation from Coal – SE Asia

IEA WORLD ENERGY OUTLOOK 2022/23

- Rapid economic growth in SE Asia
  - Increased energy demand
- Continued increase in coal-fired power generation and new projects in SE Asia during a time of increased international pressures to phase-out coal globally.
- Heightened announced pledges in cleaner energy development in SE Asia comparing WEO2021 and WEO2022 report

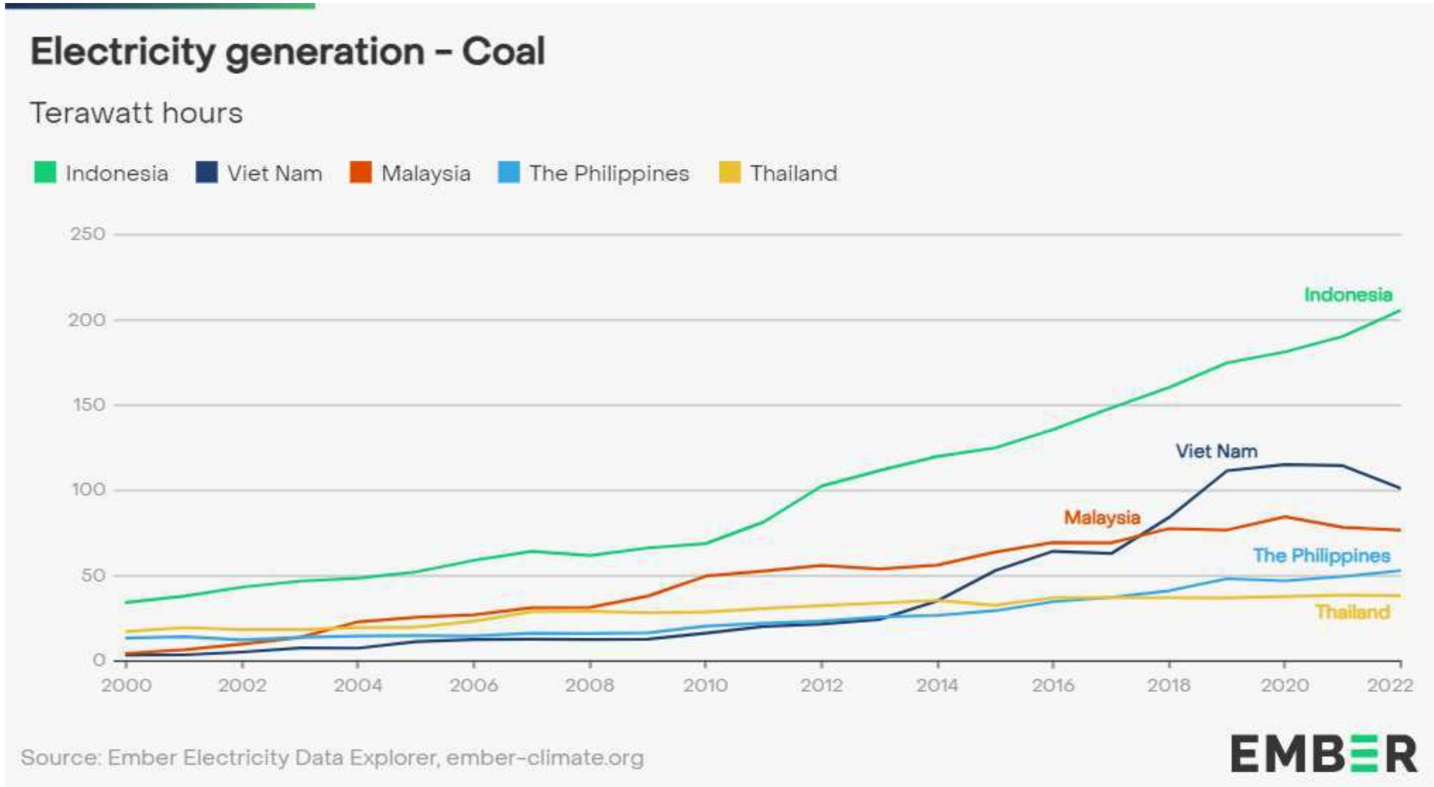


Vietnam Electricity Generation from Coal

IN CONTEXT WITH OTHER ASEAN COUNTRIES

EMBER Electricity Data Explorer

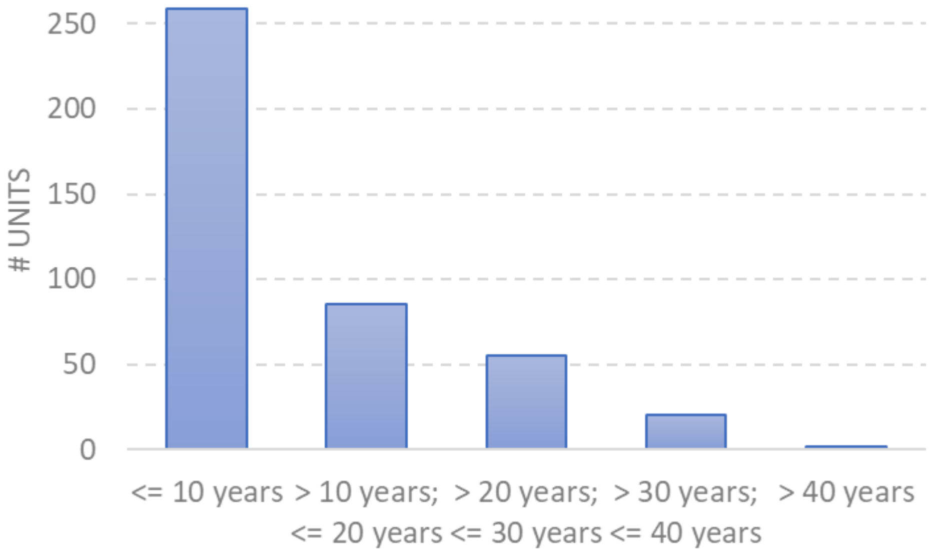
https://ember-climate.org/data/data-tools/data-explorer/



Global Energy Monitor
Global Coal Plant Tracker database

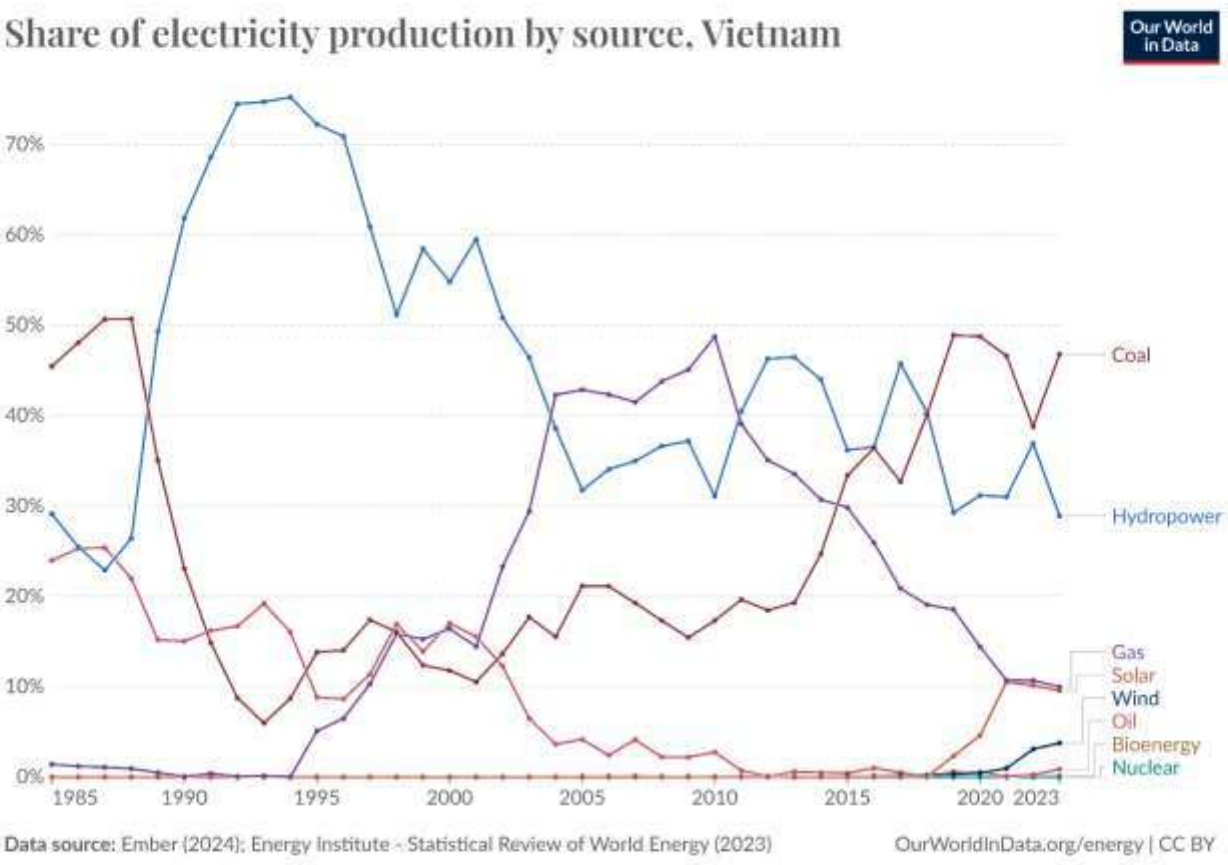
https://globalenergymonitor.org/projects/global-coal-plant-tracker/

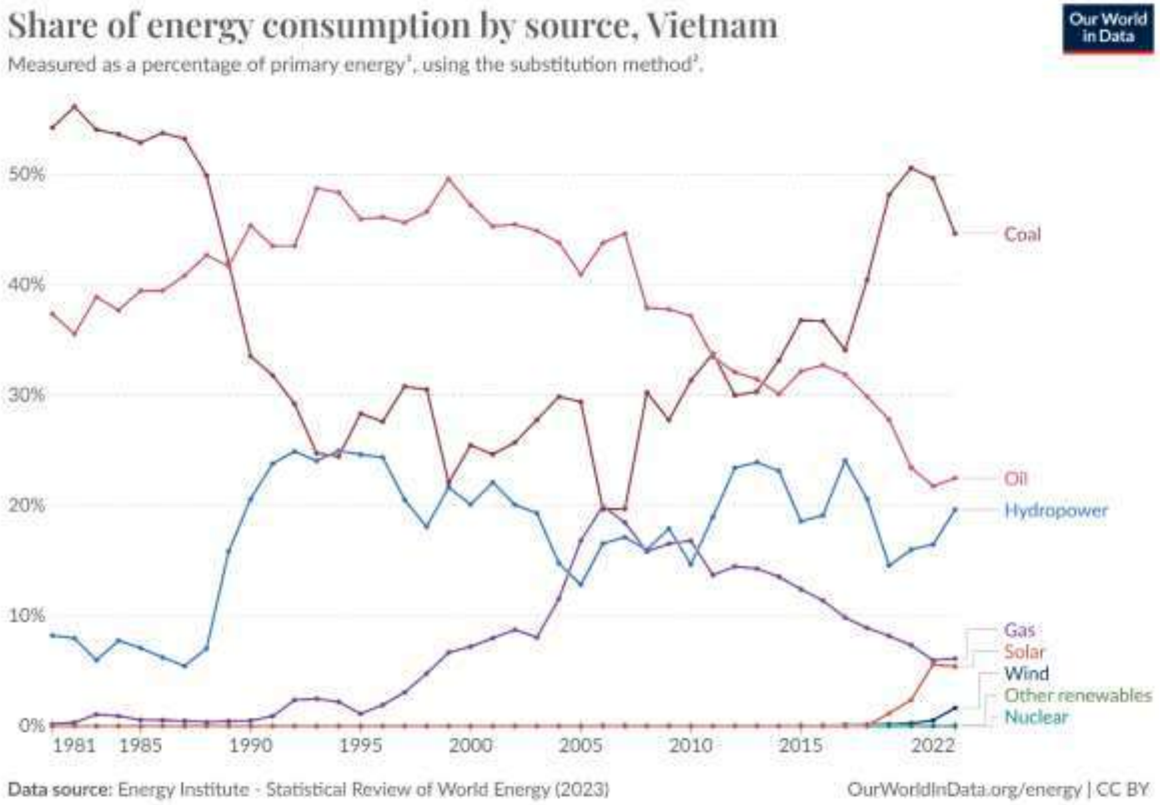
- Young CFPP fleet in Indonesia, Vietnam, Malaysia, Philippines and Thailand combined



Vietnam Electricity and Primary Energy Mix

HTTPS://OURWORLDINDATA.ORG/ENERGY/COUNTRY/VIETNAM





1. **Primary energy**: Primary energy is the energy available as resources – such as the fuels burnt in power plants – before it has been transformed. This relates to the coal before it has been burned, the uranium, or the barrels of oil. Primary energy includes energy that the end user needs, in the form of electricity, transport and heating, plus inefficiencies and energy that is lost when raw resources are transformed into a usable form. You can read more on the different ways of measuring energy in our article.

2. **Substitution method**: The 'substitution method' is used by researchers to correct primary energy consumption for efficiency losses experienced by fossil fuels. It tries to adjust non-fossil energy sources to the inputs that would be needed if it was generated from fossil fuels. It assumes that wind and solar electricity is as inefficient as coal or gas. To do this, energy generation from non-fossil sources are divided by a standard 'thermal efficiency factor' – typically around 0.4 Nuclear power is also adjusted despite it also experiencing thermal losses in a power plant. Since it's reported in terms of electricity output, we need to do this adjustment to calculate its equivalent input value. You can read more about this adjustment in our article.

Vietnam’s Energy Future

MACQUARIE University SYDNEY · AUSTRALIA

WITH REFERENCE THE PDP-VII

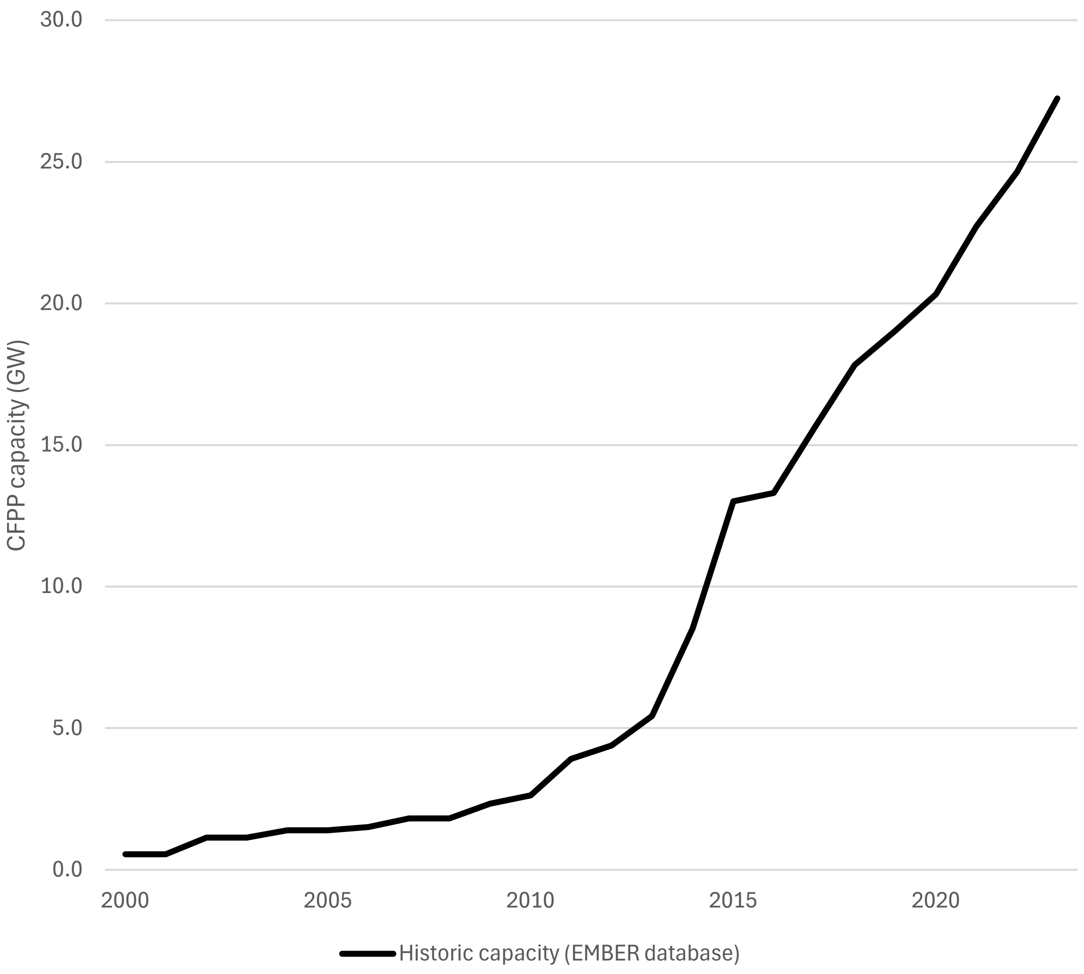
- In December 2022, Vietnam became the third country to agree on a JETP with its International Partners Group (IPG).
  - Initial USD 15.5 billion investment up to the period of 2026 to 2028 towards reaching energy transition targets.
  - Vietnam’s reported annual investment needed - USD 8 to 14 billion per year up to 2030
    - Expansion of the national grid system & develop new power generation infrastructure.

- Eighth Power Development Plan (PDP-VIII) - released in May 2023
  - Total CFPP capacity of 30.1 GW is expected to be reached by 2030
  - Cessation of all CFPPs by 2050 through either retirement and/or repurposing with biomass and ammonia fuel sources.

- The application and feasibility of biomass/ammonia co-firing for Vietnam’s CFPP fleet, along with the development of cost-effective battery storage and transmission improvements for renewable energy sources are thus priority areas to be explored for the country.

Vietnam Coal-Fired Power Plants

LARGE INCREASE SINCE 2015 – EST. 7,6GW (2023)



CFPP capacity – 2023
27 GW operating
7.9 GW under development

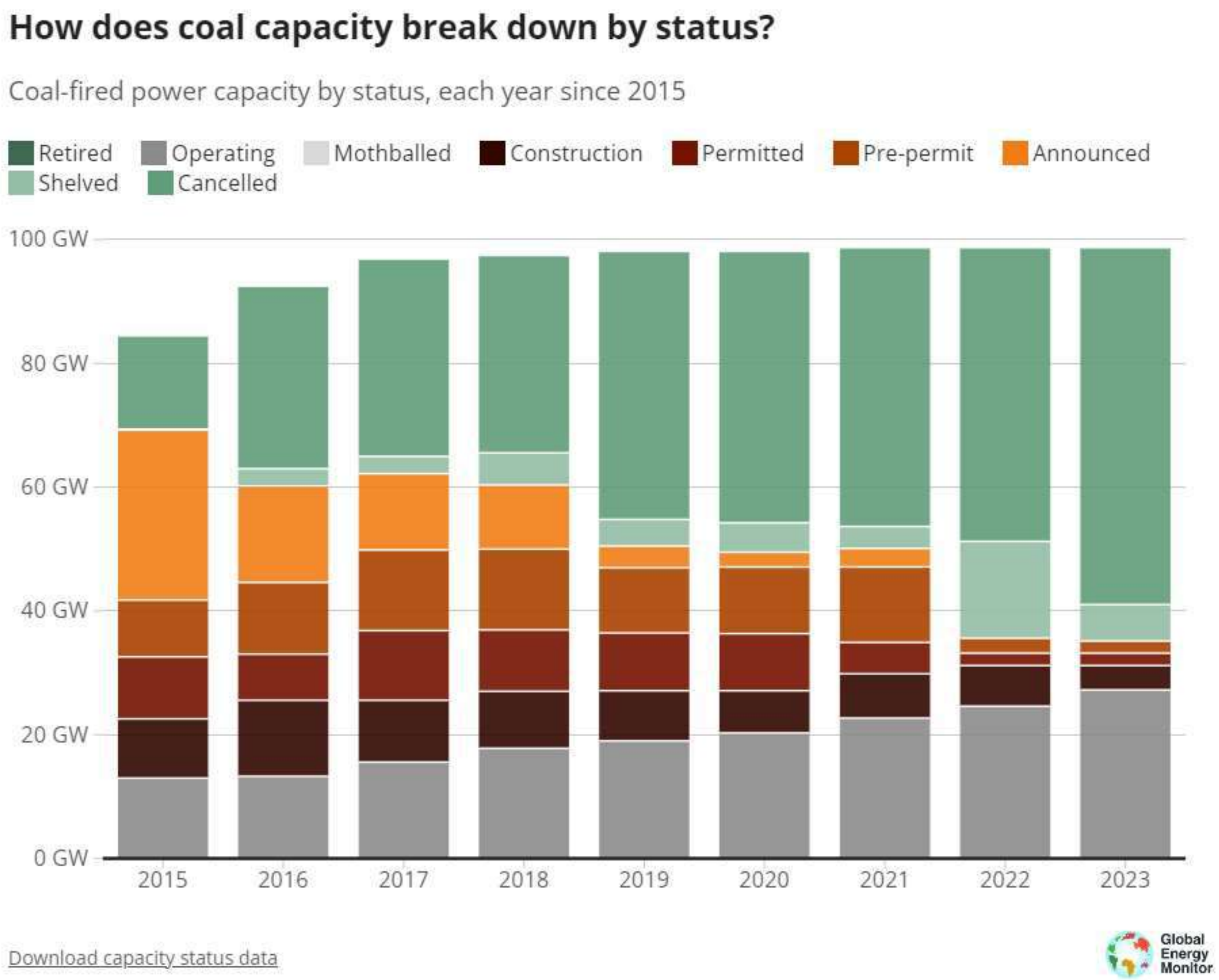
Coal consumption in power plants (MIA 2016):

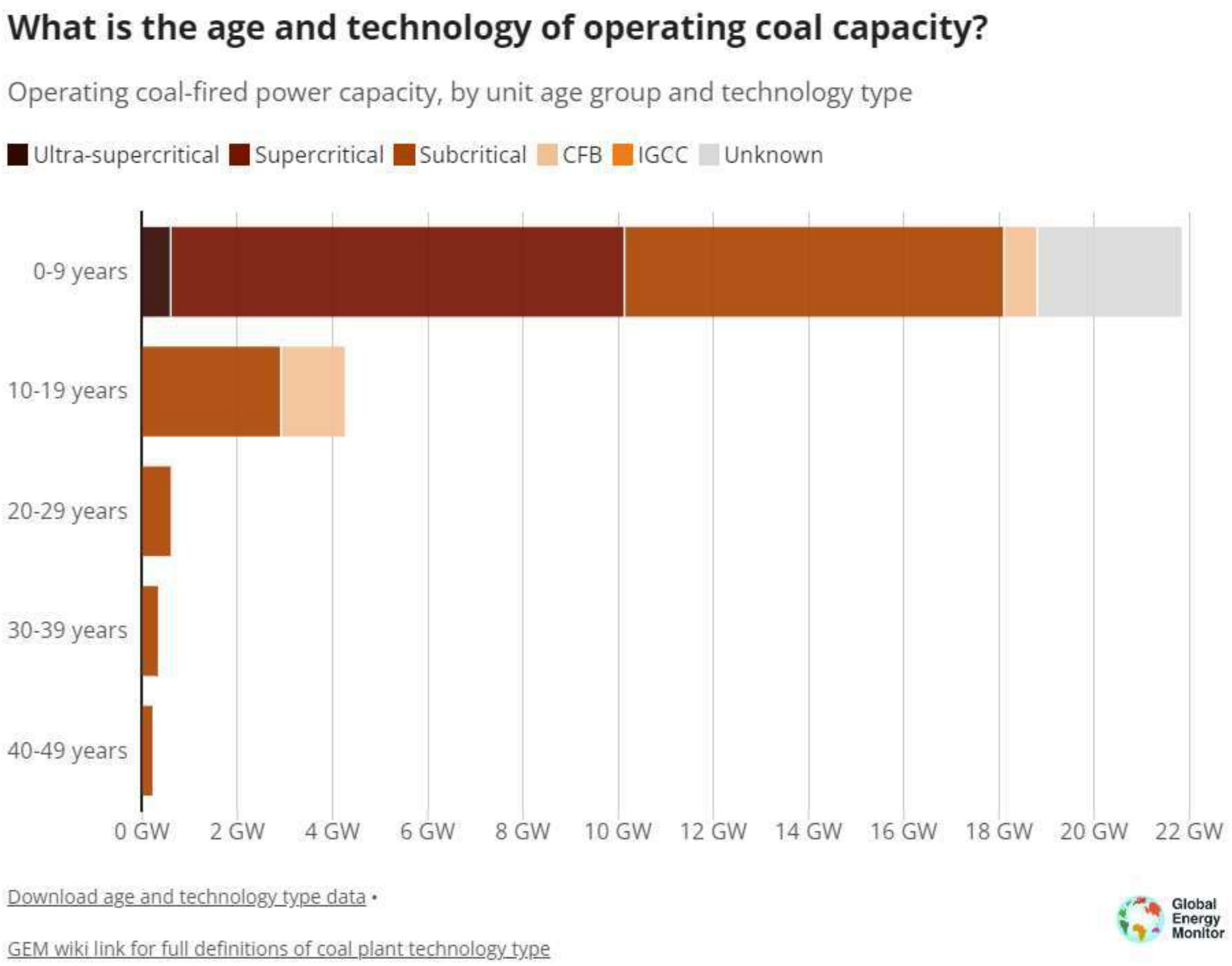
26.4 million tonnes / year

* Coal type influence mercury removal efficiency as mentioned in Minamata toolkit & POG

Global Energy Monitor – Global Coal Plant Tracker database – Vietnam profile

HTTPS://GLOBALENERGYMONITOR.ORG/PROJECTS/GLOBAL-COAL-PLANT-TRACKER/

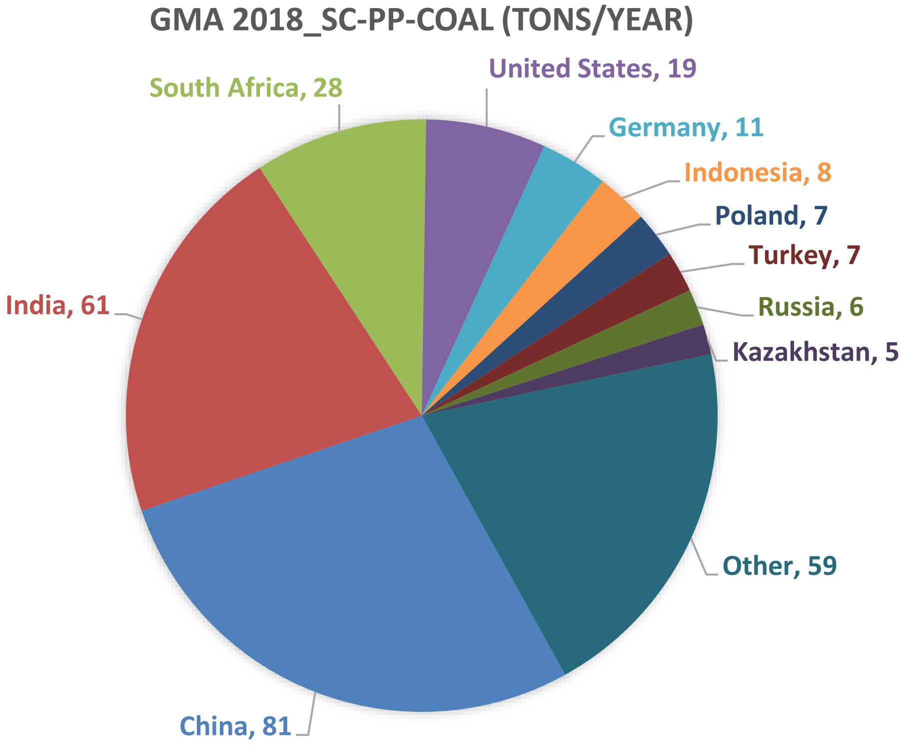




Global Mercury Assessment 2018

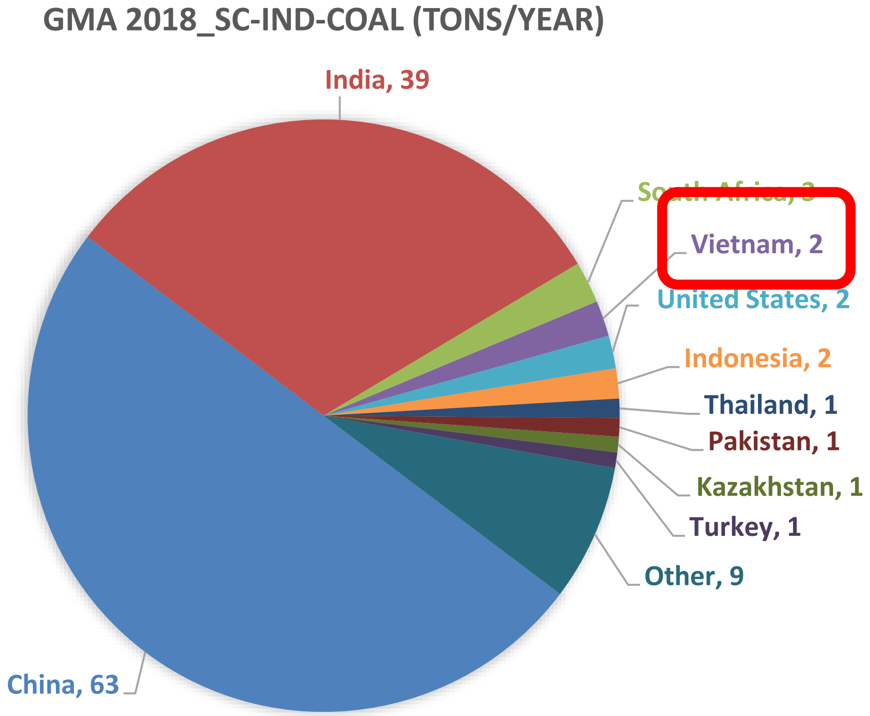
VIETNAM IN THE GLOBAL CONTEXT

Stationary Combustion of Coal at Power Plants
292 tons/year



China, India & South Africa = 47% - 59% global coverage
Vietnam average emission estimate = 2.65 tonnes per year

Stationary Combustion of Coal at Industrial Boilers
126 tons/year



China & India = 73% - 83% global coverage

Vietnam Minamata Initial Assessment 2016

MCM RATIFICATION – DECEMBER 2020

Table 3-1 Summary of mercury releases

Source category	Estimated Hg releases, standard estimates, Kg Hg/y					
	Air	Water	Land	By-products and impurities	General waste	Sector specific waste treatment /disposal
Energy consumption						
Coal combustion in large power plants	3,484.8	0.0	0.0	0.0	0.0	475.2
Other coal uses	1,413.3	0.0	0.0	0.0	0.0	0.0
Combustion/use of petroleum coke and heavy oil	-	-	-	-	-	-
Combustion/use of diesel, gasoil, petroleum, kerosene	75.4	0.0	0.0	0.0	0.0	0.0
Biomass fired power and heat production	996.9	0.0	0.0	0.0	0.0	0.0
Use of gas in pipelines (consumption)	-	-	-	-	-	-
Production of electrical and thermal energy from biomass	90.0	0.0	0.0	0.0	0.0	0.0
Charcoal combustion	5.8	0.0	0.0	0.0	0.0	0.0

CFPPs:

Emission to air:

- 3,5 tonnes / year

Mercury release to water at CFPPs through seawater FGD technologies?

GMA 2018

	Sum of Emission estimate, kg	Sum of Low range estimate, kg	Sum of High range estimate, kg
CEM	5770.9	2038.3	30421.4
SC-IND-coal	2447.5	1321.6	5833.2
SC-PP-coal	2651.7	1431.9	10928.6
Grand Total	10870.1	4791.9	47183.2

Methodology – CFPP emissions

BASELINE DATA FROM THE GLOBAL ENERGY MONITOR

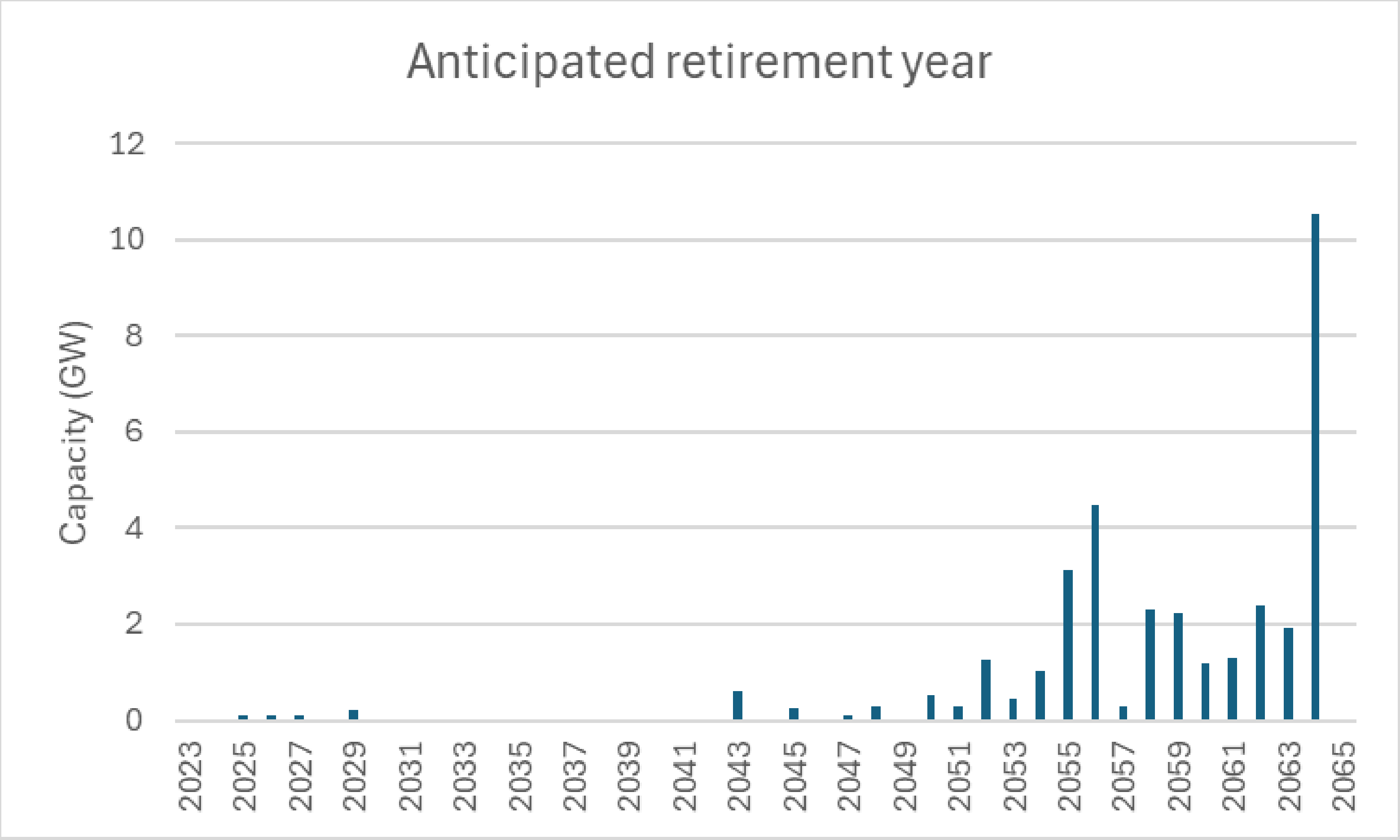
https://globalenergymonitor.org/projects/global-coal-plant-tracker/

https://globalenergymonitor.org/projects/global-coal-plant-tracker/methodology/

Country- & Unit-level information
- Capacity (MW)
- Start/Planned retirement year
- Combustion technology
- Coal type
- Heat rate (Btu/kWh) - https://www.gem.w
- Capacity factor - Global average from Inte
- Remaining plant lifetime

E.g., Heat Rate
– Vietnam CFPP units

Low – 7,528 Btu / kWh
High – 12,618 Btu / kWh



Methodology – CFPP emissions

BASELINE DATA FROM THE GLOBAL ENERGY MONITOR

<u>Assumptions/uncertainties</u>

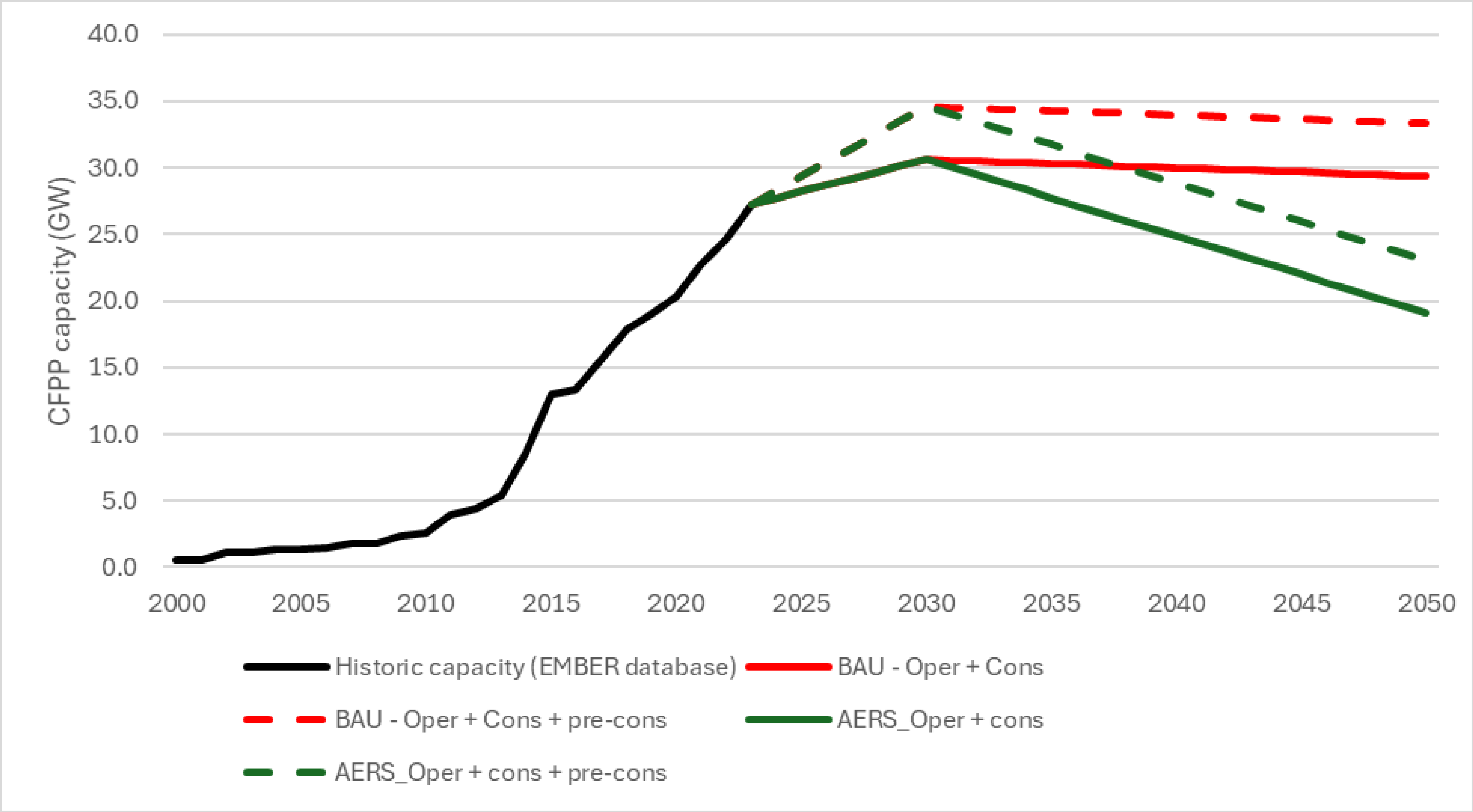
- Default 40-year plant life expectancy
- New project start year (where not indicated) – operational by 2030
- Mercury emissions
  - Defined APCD configurations on unit level limited
    - Assumption – **<u>ESP + FGD</u>** for all existing and new builds (construction/pre-construction)
  - Unit-level capacity factors
  - Unit-level GCV (kJ/kg coal) – average levels per coal type based on Annex 28 of the Stockholm Convention Toolkit

GCV (kJ/kg coal)	Av
Bituminous	29300
Subbituminous	14500
Anthracite	30667
Lignite	8583
Unknown	25000
Waste coal	25000

Stockholm Convention Annex 28 averages

  - Mercury coal input factor – 0.15 mg/kg – Default input factor & also used in Pakistan's MIA
  - Limitations: Additions of mercury-specific controls, Br additions, coal washing, Hg speciation, Cl content, coal blending/co-firing

CFPP capacity outlook - Vietnam



Business-as-usual (BAU)

2023: 27,2GW
2030: 30.6 - 34.6GW
2050: 29.4 - 33.3GW

10-year early retirement (AERS)* All subcritical CFPP units

2030: 30.6 – 34.6GW
2050: 19.1 – 23.1GW

Methodology – Mercury Emissions Estimate (UNEP toolkit)

MACQUARIE University SYDNEY · AUSTRALIA

Mercury emission (kg/year) = Coal consumption * IF * ((100-RF)/100)

HRV / GCV * CAP * CF * 9.24E03

Vietnam CFPPs (2023) = 54.6 million tonnes / year

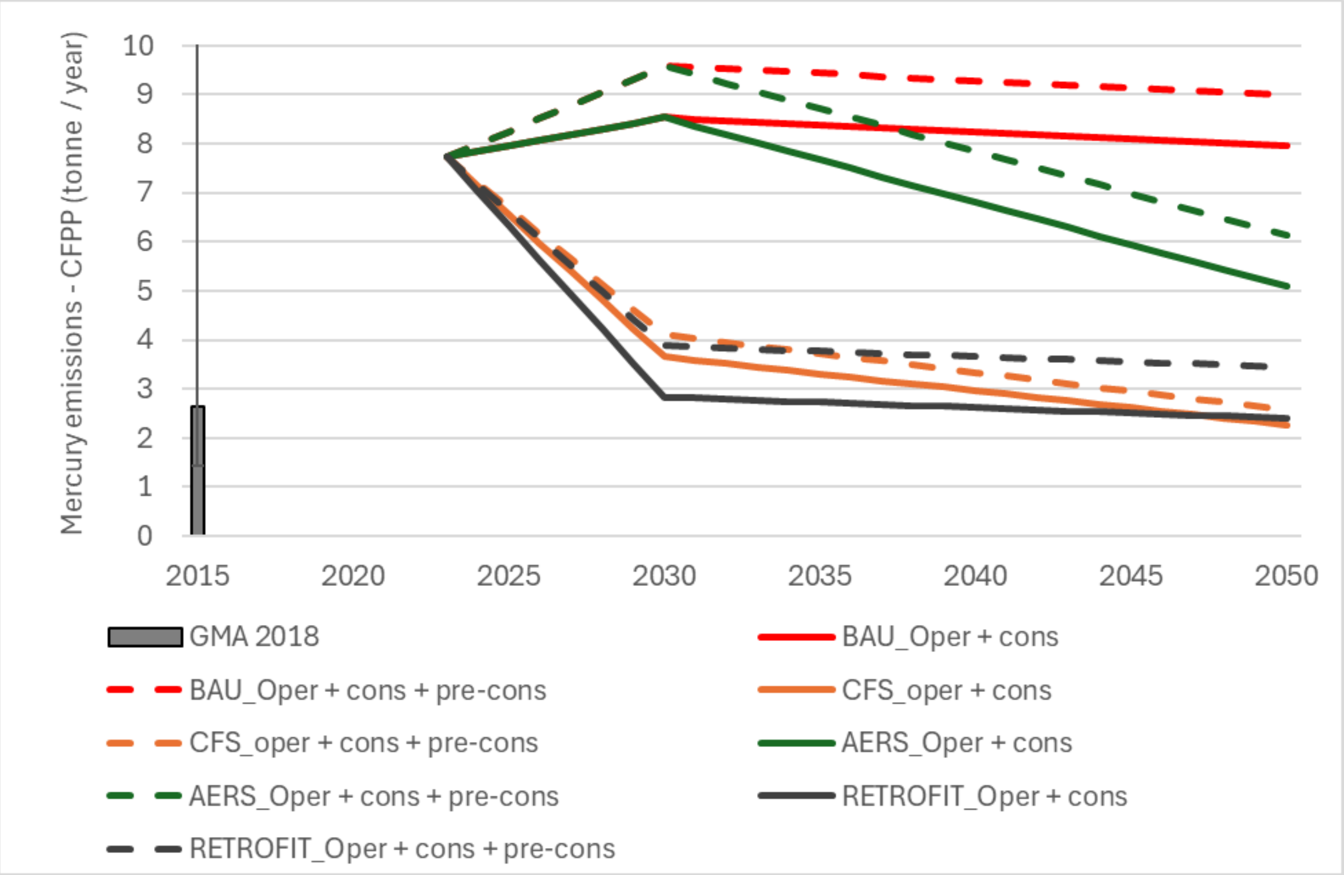
Mercury input factor by country (mg/kg) - USGS default		
China	0,17	Liu et al., 2019
India	0,22	India country profile (
Indonesia	0,06	BCRC-SEA, 2017
Vietnam	0,28	UNEP, 2017
Philippines	0,08	USGS
Thailand	0,14	USGS
Malaysia	0,08	USGS
South Africa	0,21	https://link.springer.c
REMAINING WORLD	0,15	USGS
Australia	0,08	USGS
United States	0,13	https://pubs.usgs.gov

Table 5-11 Mercury retention rates and application profile developed by UNEP/AMAP (2012).

	Intermediate mercury retention rates, %, by coal type		Degree of application (%) by country group *1				
Air pollution controls	Hard coal (anthracite, bituminous)	Brown coal (sub-bituminous, lignite)	1	2	3	4	5
Industrial use (combustion):							
Level 0: None	0.0	0.0			25	50	75
Level 1: Particulate matter simple APC: ESP/PS/CYC	25.0	5.0	25	25	50	50	25
Level 2: Particulate matter (FF)	50.0	50.0	25	50	25		
Level 3: Efficient APC: PM+SDA/wFGD	50.0	30.0	25	25			
Level 4: Very efficient APC: PM+FGD+SCR	90.0	20.0	25				
Level 5: Mercury specific	97.0	75.0					
Other coal combustion:							
Level 0: None	0.0	0.0	50	50	100	100	100
Level 1: Particulate matter simple APC: ESP/PS/CYC	25.0	5.0	50	50			

CFPP Mercury Emissions

2023 estimate – 7,7 tonnes / year



BAU – Business as Usual

AERS – Early Retirement

- All subcritical CFPPs retire 10 years earlier

CFS (Capacity factor scenario)

- 2024 – 0.53 (default global average)
- 2030 – 0.3
- 2050 – 0.2

More alternative energy resources (e.g., RE, nuclear, etc)

RETROFIT scenario

RETROFIT scenario criteria	
Unit remaining lifetime >=	20
Original APCD configuration	ESP + FGD
New APCD configuration	ESP + FGD + SCR
Unit status to retrofit	Operating
Retrofit by	2030

Project Outcomes

<u>**Activities**</u>

- Synthesis of results from completed & ongoing CFPP projects
- Selection criteria: Future projects based on highest impact potential
  - Guidance on where to support large scale projects – Training/Capacity-Building
- Assist public and private sectors in their decision-making processes

OUTCOME 2:

STRATEGY FOR THE COAL SECTOR'S EMISSIONS REDUCTION CONTRIBUTION TO STOCKHOLM AND MINAMATA CONVENTIONS

Thank you

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Inventory enhancement for coal using the UNEP toolkit and the iPOG

Workshop to enhance inventories and strategies under Article 8 of the Minamata Convention in Vietnam

Hanoi, Vietnam

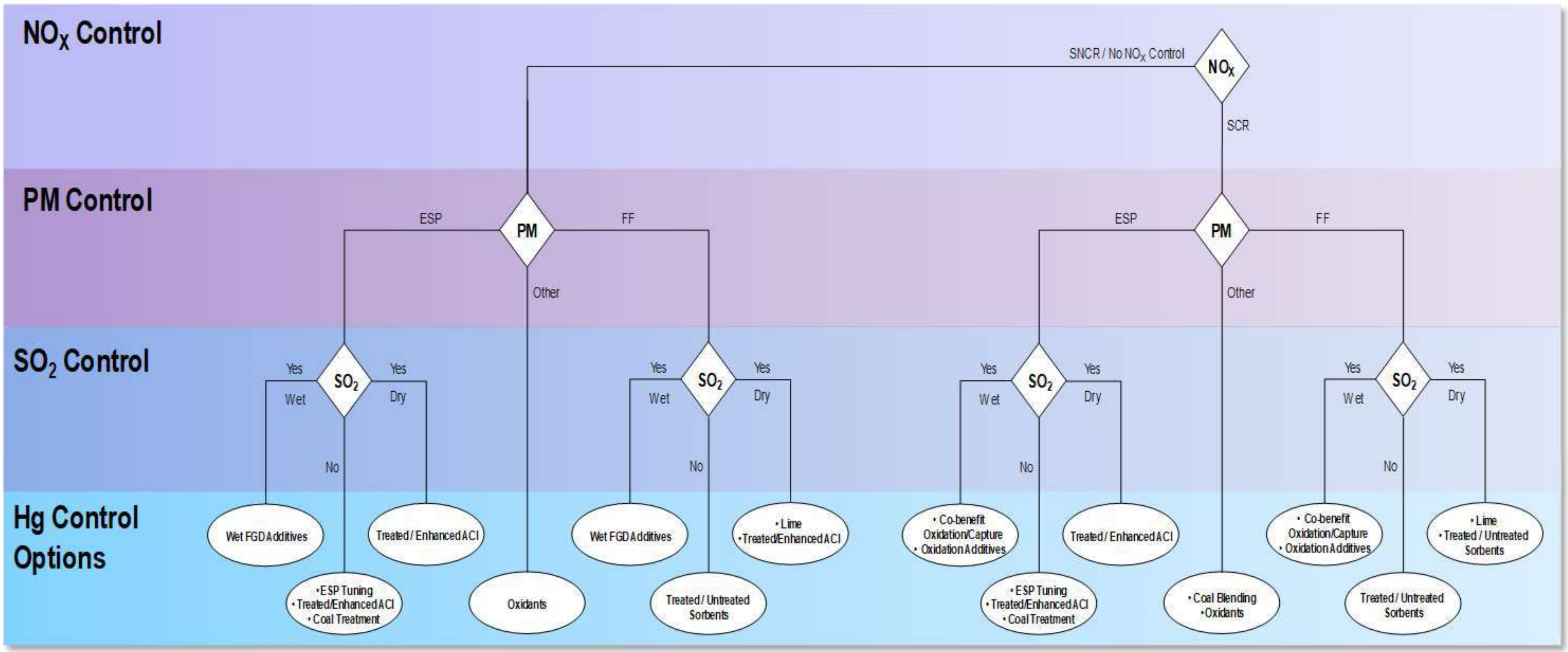
Hotel du Parc 10th June 2024

Wojciech Jozewicz, PhD

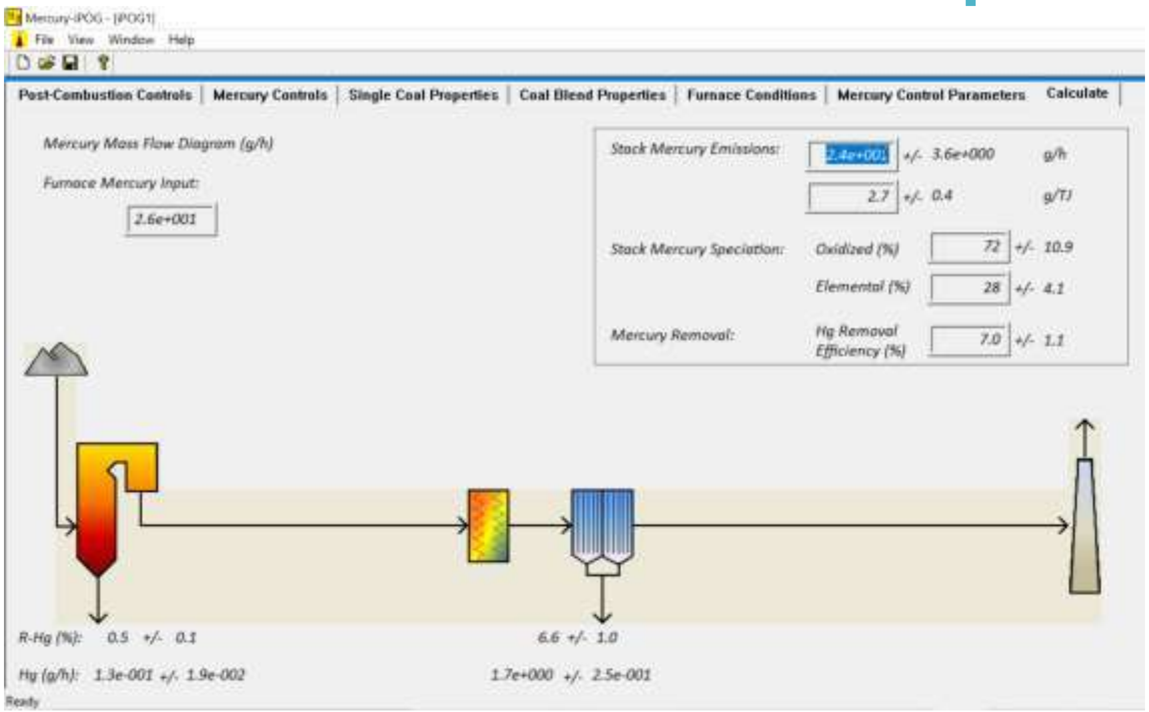
Background

- iPOG is an interactive application for UNEP's POG
- Developed for UNEP Coal Partnership by Niksa Associates
- Tool to help determine approaches to Hg emission control and rank them for individual coal-fired units
- Tradeoffs were made to only include basic inputs at the expense of quantitative accuracy
- Allows for addition of flue gas cleaning approaches and systems according to BAT/BEP
  - Improved fuel quality and blending
  - PM, SO_2, and NO_X control systems for co-benefit
  - Dedicated Hg control technology
- Follows "Decision Tree" logic from the POG

iPOG "Decision Tree" Structure



iPOG Calculations Tab - Example

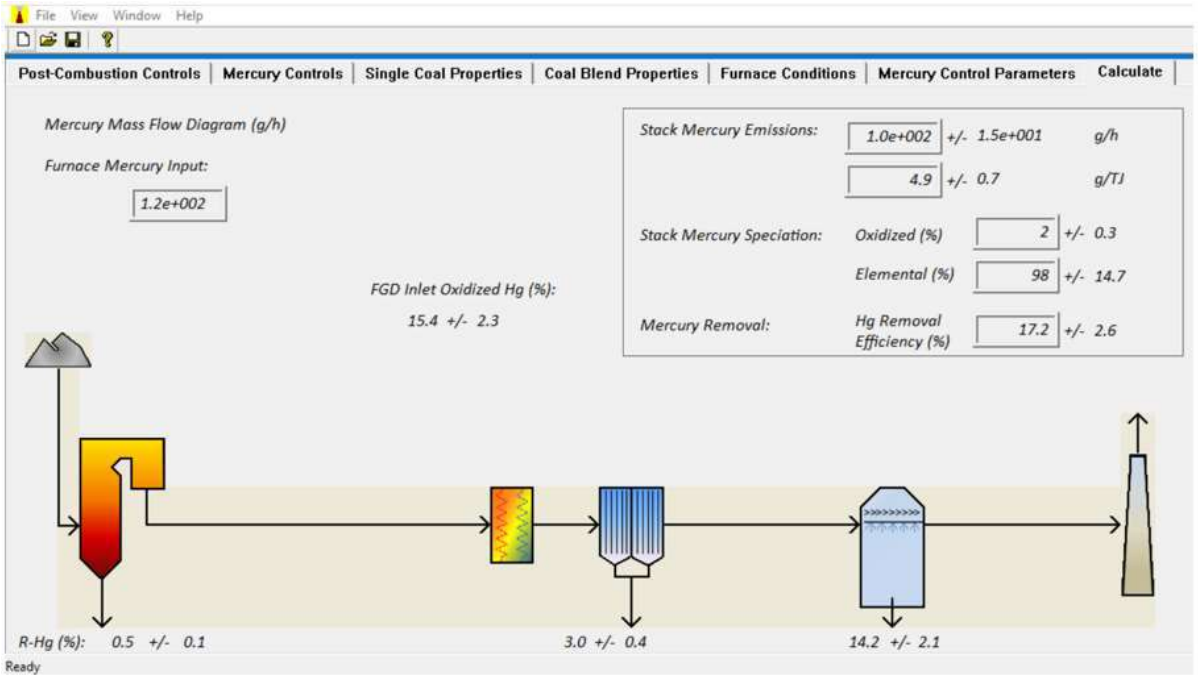


- Final tab to initiate calculations sequence
- In this example: older but well-controlled 500 MW, wall-fired boiler, burning low-S coal, cold-side ESP
- Essentially no Hg removal predicted (<10%)
- Estimated Hg emissions of 24 g/h or up to about 0.2 ton Hg/year

Data Quality Very Important

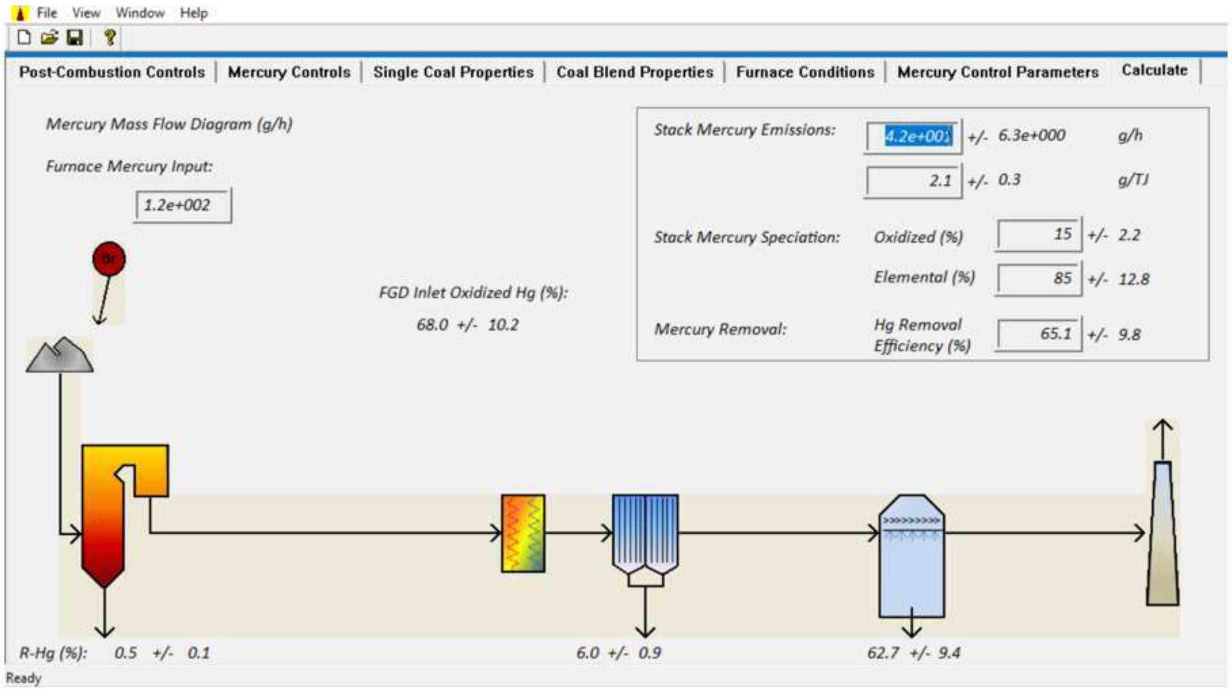
- Stakeholders should ensure that any missing data are obtained directly from the plant considered for the project rather than by the proxy calculations
- Unit details: generating capacity, commissioning date, planned retirement
- Unit performance: operational load, utilization, gross efficiency, coal consumption, LOI
- Coal quality: calorific value, ash-S-Hg-Cl content
- Emissions controls: PM, FGD, Hg controls
- Quality data in – Quality results out!

Unit with Wet FGD



- 800 MW unit with ESP and wet FGD
- Only about 17% Hg removal; emissions 98% of Hg0 and 2% of Hg++
- More mercury removal could be accomplished with more efficient Hg0 oxidation

Strategy for Improvement



- Over 65% removal with addition of 250 ppm of Br to coal
- Some other options
  - Activated carbon injection upstream of the ESP
  - SCR- expensive

Another Strategy

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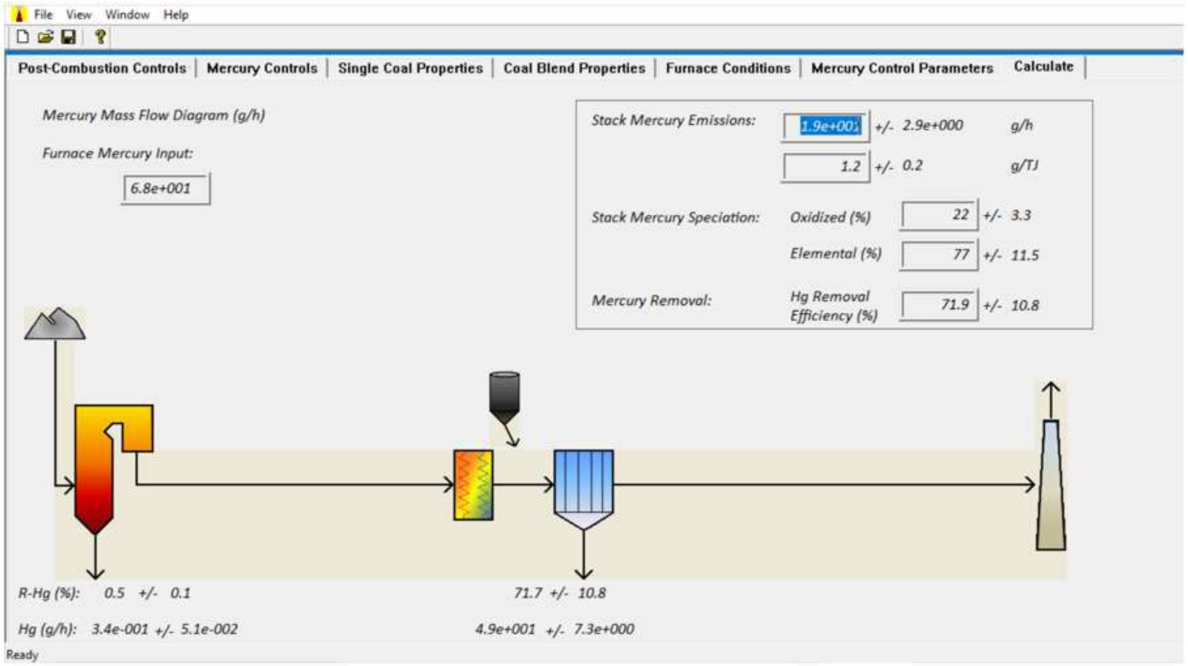

- Addition of 0.02 g/m3 of activated carbon upstream of the baghouse increases Hg removal to 72%

Rapid Development

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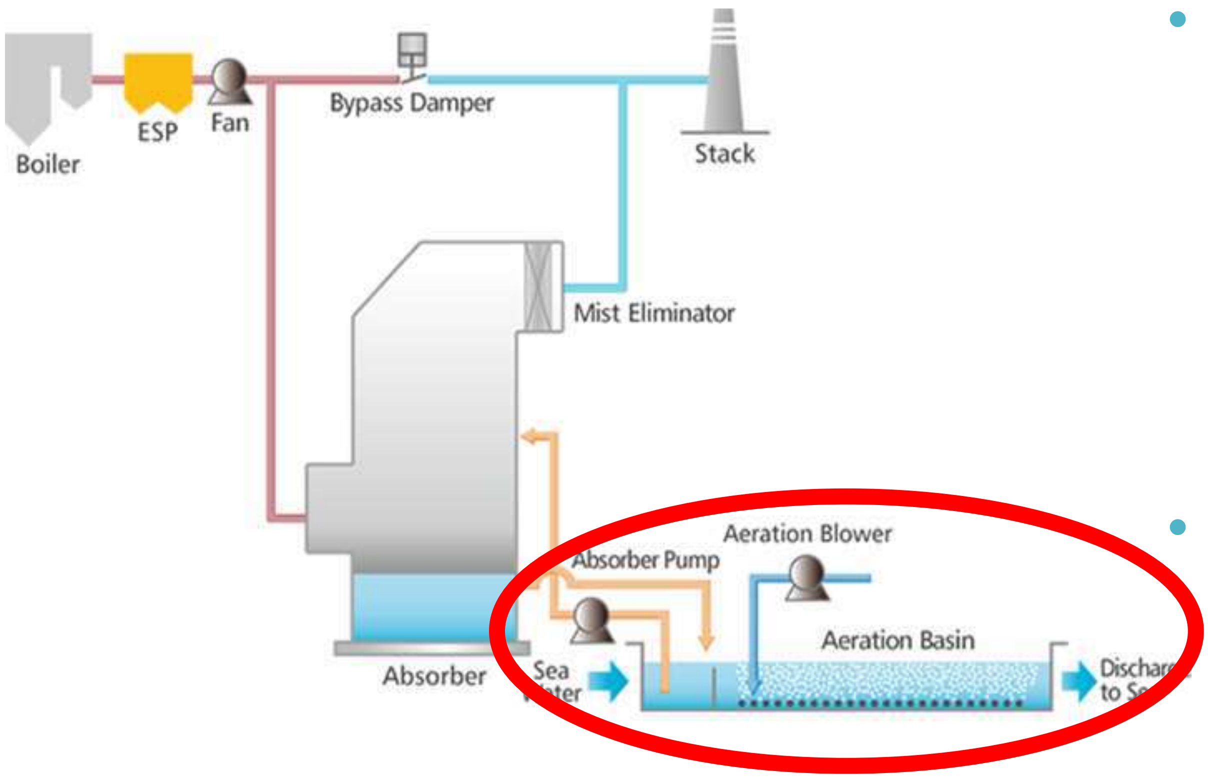
- Projections of 97 million tons of coal used and 48 GW coal power installed by 2025
- Duyen Hai 1 and Vinh Tan 2 plants installed seawater FGD for SO_2 and SCR system with ammonia and nitrogen oxides (NOx) emission control
- Environmental impact

https://www.gem.wiki/

Seawater FGD



From: ICSC 2023

- Back in 2010, Alstom alone reported more than 90 units corresponding to about 30 GW capacity
- How many today?

From: https://www.alstom.com/

Seawater FGD vs. WFGD

- SWFGD designed for SO_2 control
  - similar capture to that in WFGD
  - about 20-30% lower capex
  - lower opex- no sorbent purchased
  - no land transport of coal
- SWFGD can provide up to ~85% Hg removal
  - similar Hg chemistry to WFGD
  - waste handling different

Seawater FGD – Potential Issues

- Hg re-emission may occur in the scrubber
- Effluent aerated to convert sulfites to sulfates - Hg^0 may be released into the air
- Specialized Hg-focused treatment of "spent" seawater needed to prevent releases into oceans
- Precipitation and separation/capture of Hg
- Sulfurized activated carbon may be used for removing Hg^{++}

https://www.fossilconsulting.com/

Plant with a Seawater FGD

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- About 65% Hg removal measured
- Stack emissions mostly Hg^0
- Seawater Hg enhancement

Type of sample	Mercury concentrations as dry weight (Mean±SD)			
	Plant 1 (5 cycles)	Plant 2[a] (5 cycles)		
		Unit 6	Unit 10	Unit 13
Feed coal (µg/kg)	59.90±12.10	132.52±8.46	114.97 ± 14.28	124.43 ± 10.09
Sea water-In (µg/L)[b]	0.004±0.002			
Limestone (µg/kg)[c]		75.19±30.45	48.95 ± 8.40	54.65 ± 10.45
Bottom ash (µg/kg)	1.21±0.50	8.27±11.18	18.43 ± 23.62	7.50 ± 5.66
Fly ash (µg/kg)	47.59±17.22	22.37±3.60	18.39 ± 5.16	34.74 ± 12.00
Sea water-Out (µg/kg)[b]	0.09±0.02			
Gypsum (µg/kg)[c]		168.92±38.92	140.69 ± 8.79	165.98 ± 45.91
Stack gas (µg /m^3)	0.69±0.39	7.99±3.94	9.90 ± 1.98	5.22 ± 2.62
-particulate (µg /m^3)	0.07±0.14	0.01±0.01	0.03±0.05	0.02±0.02
-oxidized Hg (µg /m^3)	0.01±0.003	0.45±0.30	0.20±0.20	0.15±0.15
-Vapor Hg (µg /m^3)	0.61±0.34	7.52±3.88	9.67±2.04	5.04±2.54

Summary

- Limited information on FGD or seawater FGD
- Performance strategies available to improve Hg performance
- Limited information available on handling of effluent from SWFGD, fate of mercury

- However,
  - Growth projected for power demand
  - Ambitious renewable energy goals

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Thank you!