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S1 – GAINS sectors and activities

Table S1. List of sector-activity combinations in GAINS which are associated with mercury emissions.

Aggregated category	Category	Associated subsectors	Associated activity
Artisanal and small-scale gold production			
ASGM	Small-scale and artisanal gold production		
		Small-scale artisanal gold production	NOF
Combustion			
COMB_IND	Industrial combustion		
		Combustion in boilers (transformation sector, chemical industry, paper/pulp production, other sectors [>50 MWth, <50 MWth]), Other combustion	OS1, OS2, BC, DC, HC, GSL, HF, LPG, MD
COMB_POWER	Power Plants		
		Power & district heat plants with internal combustion engines	GSL, HF, MD
		Power and district heat plants (Existing/new, <50 MWth/ >50 MWth)	OS1, OS2, BC, DC, HC, GSL, HF, MD
		Integrated Gasification Combined Cycle (IGCC) plants	OS1, OS2, BC, HC, HF
		Modern power plants (coal: ultra- and supercritical)	OS1, BC, HC
		Power plants combined with carbon capture and storage (modern / IGCC)	OS1, BC, HC
COMB_OTHER			
	Combustion conversion		
		Fuel production: combustion (grate firing, fluidized bed, pulverized coal)	OS1, OS2, BC, DC, HC, GSL, HF, LPG, MD
	Domestic combustion		
		Combustion for residential, commercial, services, agriculture purposes;	OS1, GSL, HF, LPG, MD
		Residential/commercial combustion in fireplaces, kerosene lamps, boilers (<40 kW / <1 MW, <50 MW), open pit fires, cooking stoves, heating stoves	OS1, BC, DC, HC, GSL
Industrial Processes			
GOLD	Gold production		
		Large-scale gold production	NOF
NFME	Non-ferrous metal production		
		Non-ferrous metals production; primary and secondary (Pb, Zn, Cu, Ni,...)	NOF
CEM	Cement production		
		Cement production	NOF
IND_PROC	Other industrial processes		
		Primary Aluminum production	NOF
		Iron and steel production (Coke ovens, basic oxygen furnace, electric arc furnace, pig iron production in blast furnace, open hearth furnace,	NOF
		Bricks production	NOF

		Chlorine and caustic soda production by electrolysis using mercury cells	NOF
		Fertilizer production	NOF
		Glass production	NOF
		Lime production	NOF
		Paper pulp mills	NOF
		Crude oil and other products (input to petroleum refineries)	NOF
OTHER			
	Transport		
		Other transport (non-road, agriculture and forestry, civil aviation, mobile sources in construction and industry, inland waterways, off-road with 4-stroke engines, off-road with 2-stroke engines, rail)	GSL, LPG, MD, BC, DC, HC
		Maritime (large/medium vessels)	HF, MD
		Road transport (buses, trucks, motorcycles / mopeds / cars with 2-stroke engines, light duty vehicles with 4-stroke engines, others)	GSL, LPB, MD
	Waste		
		Industrial waste from industry	NOF
		Municipal solid waste (non-recycled fraction, rural/urban)	NOF
	Others		
		Non-energy use of fuels	HF
		Other Hg emissions not included separately in GAINS and statistical differences	NOF
		Share of population cremated annually	NOF

Table S2. Full list of activities connected to Hg emissions in GAINS.

Activity	Parent activity	Long name
ARD	OS1	Agricultural residuals - direct use
BC1		Brown coal/lignite grade 1
BC2		Brown coal/lignite grade 2 (also peat)
BMG	OS1	Biomass gasification
CHCOA	OS1	Charcoal
DC		Derived coal (coke, briquettes)
DNG	OS1	Dung
FWD	OS1	Fuelwood direct
GSL		Gasoline and other light fractions of oil (includes kerosene)
HC1		Hard coal, grade 1
HC2		Hard coal, grade 2
HC3		Hard coal, grade 3
HF		Heavy fuel oil
LPG		Liquefied petroleum gas
MD		Medium distillates (diesel, light fuel oil)
NOF		No fuel use
OS1		Biomass fuels
OS2		Other biomass and waste fuels

S2 – Mercury control technologies and their removal efficiencies in GAINS

Table S3. Abbreviations used in GAINS for Hg control technologies.

Abbreviation	Description
BAN	Ban of sector (small-scale gold mining, chlor-alkali production using Hg cells)
CYC_REM	Cyclone - remaining capacity
ESP1	Electrostatic precipitator - 1 field
ESP2	Electrostatic precipitator - 2 fields
FFSINJ	Sorbent injection before an additional fabric/baghouse filter
HED	High-efficiency deduster
LHGCO	Low-mercury coal or halide(Br, Cl)-treated coal in the power sector
LHGCO_PM	Combination of LHGCO and particulate matter control with ESP1, ESP2 or HED
LHGCO_PM_FGD	Combination of LHGCO and FF_FGD
LHGCO_REM	LHGCO, applied in absence of other particulate matter control or desulfurization technologies.
MINE_GP	Good practice in mining (ASGM)
PM_FGD	Particulate matter control (ESP1, ESP2, HED)- combined with flue gas desulphurization
PM_REM	Electrostatic precipitator (ESP1, ESP2, HED) - remaining capacity without overlap from other pollutant controls
PMSINJ	Sorbent injection before an existing electrostatic precipitation (ESP1, ESP2, HED)
PR_AP	Acid plant equipped with mercury removal process (e.g. Boliden-Norzink), applied in industrial processes
PRF_GP1	Good practice: ind.process - stage 1; (for cement, lime production: 10\% of operating time in dust shuttling mode)
PRF_GP2	Good practice: ind.process - stage 2; (for cement, lime production: 20\% of operating time in dust shuttling mode)
SINJ	Sorbent injection in the power sector, combined with particulate matter control via electrostatic precipitation (ESP1, ESP2, HED)
SPC	Sorbent polymer catalyst modules
STH_GP	Good practice in storage & handling
SWD_COMP	Managed solid waste disposal sites, compressed without cover
SWD_COVER	Managed solid waste disposal sites, compressed with cover, no gas recovery
TREAT_INC_ENE	Mixed waste incineration with energy recovery
WSCR_B_REM	Wet scrubber - remaining capacity

Table S4. Control technologies and their removal efficiencies for combustion sectors.

COMBUSTION Technology	Activity	Removal efficiency [%]			Speciated stack emissions			Reference
		Hg ⁰	Hg ^{II}	Hg _p	Hg ⁰	Hg ^{II}	Hg _p	
FFSINJ	HC	97	91	99.98	0.82	0.16	0.02	iPOG, GMA'18
	BC	88	82	99.98	0.735	0.245	0.02	iPOG, GMA'18, Feeley et al. (2009)
	OS2	88	82	99.98	0.735	0.245	0.02	UBA-DE 2021/2
PMSINJ	HC	87	84	99.98	0.4	0.59	0.01	iPOG, Feeley et al. (2009), Wilcox (2014)
	BC	67	62	99.98	0.71	0.28	0.01	iPOG, Feeley et al. (2009)
	OS2	67	62	99.98	0.71	0.28	0.01	like PMSINJ, brown coal
LHGCO_PM_FGD	HC	74.8	99.3	99.98	0.72	0.26	0.02	iPOG, Giang et al. (2015), UBA2021/2
	BC	67.1	96.5	99.98	0.8	0.19	0.01	iPOG, Giang et al. (2015), UBA2021/2
LHGCO_PM	HC	79	-90	99.98	0.15	0.85	0	iPOG, Giang et al. (2015), GMA'18
	BC	79	-90	99.98	0.46	0.53	0.01	iPOG, Giang et al. (2015)
LHGCO_REM	HC	30	30	30	0.42	0.56	0.02	UBA-DE 2021/2, iPOG
	BC	20	20	20	0.43	0.5	0.07	UBA-DE 2021/2, iPOG
PM_FGD	HC	64	99	99.98	0.72	0.27	0.01	Li et al. (2020), iPOG, Giang et al. (2015), Liu et al. (2018), Pacyna et al. (2010), GMA'18, Cui et al. (2018), Cheng et al. (2009)
	HF	64	99	99.98	0.72	0.27	0.01	like PM_FGD, HC
	BC	53	95	99.98	0.8	0.12	0.08	Li et al. (2020), iPOG, Liu et al. (2018), Giang et al. (2015), GMA'18
	OS2	53	95	99.98	0.8	0.12	0.08	like PM_FGD, BC
PM_REM	HC	35	55	97	0.51	0.47	0.02	Cheng et al. (2009), Cui et al. (2018), Giang et al. (2015), iPOG, Li et al. (2020), Liu et al. (2018), GMA'18, Zhang (2016)
	HF	35	55	97	0.51	0.47	0.02	like PM_REM, hard coal
	OS2	25	45	97	0.59	0.4	0.01	like PM_REM, brown coal
	BC	25	45	97	0.59	0.4	0.01	Giang et al. (2015), iPOG, Li et al. (2020), GMA'18, Zhang (2016)
WSCR_B_REM	HC	10	40	85	0.71	0.29	0	Pacyna et al. (2010), iPOG
CYC_REM	HC	0	0	70	0.6	0.3	0.1	GAINS default
	OS2	0	0	70	0.2	0.6	0.2	GAINS default
ESP1	DC, OS1	15	30	95	0.5	0.4	0.1	GAINS default
ESP2	DC, OS1	15	30	99	0.5	0.4	0.1	GAINS default
HED	DC, OS1	30	50	99.9	0.5	0.4	0.1	GAINS default

BC ... Brown coal, DC ... Derived coal, HC ... Hard coal, HF ... Heavy fuel oil, OS1 ... Biomass, OS2 ... Waste

GMA'18 ... AMAP/UNEP (2019)

iPOG ... Niksa Energy Associates LLC (2011). iPOG speciation results were generated with the following characteristics: Coal: 1 wt-% sulphur. Furnace: 750 MWe, 100% operating load, 32% gross efficiency, 3.5% O2 economizer, 0.75% LOI, 25% bottom ash.

Table S5. Control technologies and their removal efficiencies for industrial processes.

INDUSTRY Technology	Removal efficiency [%]			Stack emissions			References
	Hg ⁰	Hg ^{II}	Hg _p	Hg ⁰	Hg ^{II}	Hg _p	
FFSINJ	91	86	99.98	0.8	0.15	0.05	Pacyna et al. (2010), Dehoust et al. (2021b), GMA'18
PMSINJ	87	84	99.98	0.71	0.28	0.01	Wu et al. (2018)
PR_AP	91	99.98	99.98	0.8	0.12	0.08	Wu et al. (2018); Pacyna et al. (2010), Dehoust et al. (2021b), GMA'18
PM_FGD	53	95	99.98	0.8	0.12	0.08	Wu et al. (2018), GMA'18
PM_REM	35	55	97	0.51	0.47	0.02	GMA'18, Wu et al. (2018); Pacyna et al. (2010); Wang et al. (2014), Dehoust et al. (2021a)
WSCR_B_REM	0	40	85	0.8	0.15	0.05	Pacyna et al. (2010), GAINS default
CYC_REM	0	0	70	0.8	0.15	0.05	GAINS default; Wu et al. (2018), Dehoust et al. (2021b), GMA'18
PR_GP1	20	20	20	0.8	0.15	0.05	Dehoust et al. (2021b), GMA'18
PR_GP2	40	40	40	0.8	0.15	0.05	Dehoust et al. (2021b), GMA'18
MINE_GP	50	50	50	0.8	0.15	0.05	generic estimate
STH_GP	70	70	70	0.8	0.15	0.05	generic estimate

GMA'18 ... AMAP/UNEP (2019)

Table S6. Control technologies and their removal efficiencies for waste sectors.

WASTE Technology	Removal efficiency [%]			Stack emissions			Reference
	Hg ⁰	Hg ^{II}	Hg _p	Hg ⁰	Hg ^{II}	Hg _p	
TREAT_INC_ENE	100	100	100	1	0	0	Emissions accounted for in waste incineration sectors (PP_EX_L, waste)
SWD_COMP	33	33	33	0.96	0.04	0	Lee et al. (2016); Han et al. (2017); Wang et al. (2021); Lindberg et al. (2005)
SWD_COVER	33	33	33	0.96	0.04	0	Lee et al. (2016); Han et al. (2017); Wang et al. (2021); Lindberg et al. (2005)

S3 – Details on applied mercury control strategies of the displayed scenarios

S3.1 – Mercury control strategies

Table S7. Hg-specific changes to the Current Legislation (CLE) control strategies were made in the following sectors, to better reflect current Hg emission limit values and policy.

	'CLE' NFME*	Cremation	Waste incineration	Additional controls in 'Mina': ASGM VCM, Hg mining
Africa				MINE_GP, BAN
Asia Pacific	PM_FGD → PR_AP			
China				-50%
India	PM_FGD → PR_AP			
Japan				
Southeast Asia				BAN
Central & South America	PM_FGD → PR_AP			MINE_GP, BAN
Brazil	PM_FGD → PR_AP			
Eurasia	PM_FGD → PR_AP			
Russia				BAN
Europe		FFSINJ	FFSINJ	
European Union	PM_FGD → PR_AP	FFSINJ	FFSINJ	
Middle East	PM_FGD → PR_AP			
North America	PM_FGD → PR_AP			
United States				

* Control technologies for large-scale gold production (GOLD) equal those for the NFME sector.

Table S8. Full control strategy of the Hg-MFR scenario in 2050. The full list of activities, sectors and technologies in GAINS can be found in the GAINS glossary: <https://gains.iiasa.ac.at/gains/GOD/abbreviations.info>

Sector	Activity	Technology	%
AU_LGP	NOF	PR_AP	100
AU_SGP	NOF	BAN	100
CON_COMB	DC	IN_HED	100
CON_COMB	HF	FFSINJ	100
CON_COMB	OS1	IN_HED	100
CON_COMB	OS2	FFSINJ	100
CON_COMB1	BC1	FFSINJ	100
CON_COMB1	BC2	FFSINJ	100
CON_COMB1	HC1	FFSINJ	100
CON_COMB1	HC2	FFSINJ	100
CON_COMB1	HC3	FFSINJ	100
CON_COMB2	BC1	FFSINJ	100
CON_COMB2	BC2	FFSINJ	100
CON_COMB2	HC1	FFSINJ	100
CON_COMB2	HC2	FFSINJ	100
CON_COMB2	HC3	FFSINJ	100
CON_COMB2	HC3	FFSINJ	100
CON_COMB3	BC1	FFSINJ	100
CON_COMB3	BC2	FFSINJ	100
CON_COMB3	HC1	FFSINJ	100
CON_COMB3	HC2	FFSINJ	100
CON_COMB3	HC3	FFSINJ	100
DOM	HF	GHDOM	100
DOM	MD	GHDOM	100
DOM_FPLACE	FWD	FP_NEW	100
DOM_LIGHT	GSL	LED	100
DOM_MB_A	BC1	MB_HED	100
DOM_MB_A	BC2	MB_HED	100
DOM_MB_A	DC	MB_HED	100
DOM_MB_A	FWD	MB_HED_F	100
DOM_MB_A	HC1	MB_HED	100

DOM_MB_A	HC2	MB_HED	100
DOM_MB_A	HC3	MB_HED	100
DOM_MB_M	BC1	MB_CYC	100
DOM_MB_M	BC2	MB_CYC	100
DOM_MB_M	DC	MB_CYC	100
DOM_MB_M	FWD	MB_HED_F	100
DOM_MB_M	HC1	MB_CYC	100
DOM_MB_M	HC2	MB_CYC	100
DOM_MB_M	HC3	MB_CYC	100
DOM_SHB_A	FWD	SHB_HED	100
DOM_SHB_M	BC1	SHB_NEW_C	100
DOM_SHB_M	DC	SHB_NEW_C	100
DOM_SHB_M	FWD	SHB_PLESP	100
DOM_SHB_M	HC1	SHB_NEW_C	100
DOM_SHB_M	HC2	SHB_NEW_C	100
DOM_SHB_M	HC3	SHB_NEW_C	100
DOM_STOVE_C	ARD	STV_NEW_B	100
DOM_STOVE_C	BC1	STV_NEW_C	100
DOM_STOVE_C	BC2	STV_NEW_C	100
DOM_STOVE_C	DC	STV_NEW_C	100
DOM_STOVE_C	DNG	STV_NEW_B	100
DOM_STOVE_C	FWD	STV_NEW_B	100
DOM_STOVE_C	HC1	STV_NEW_C	100
DOM_STOVE_C	HC2	STV_NEW_C	100
DOM_STOVE_C	HC3	STV_NEW_C	100
DOM_STOVE_H	ARD	STV_NEW_B	100
DOM_STOVE_H	BC1	STV_NEW_C	100
DOM_STOVE_H	BC2	STV_NEW_C	100
DOM_STOVE_H	DC	STV_NEW_C	100
DOM_STOVE_H	DNG	STV_NEW_B	100
DOM_STOVE_H	FWD	STV_PLESP	100

DOM_STOVE_H	HC1	STV_BRIQ	100
DOM_STOVE_H	HC2	STV_NEW_C	100
DOM_STOVE_H	HC3	STV_NEW_C	100
IN_BO_CHEM	BC1	FFSINJ	100
IN_BO_CHEM	BC2	FFSINJ	100
IN_BO_CHEM	HC1	FFSINJ	100
IN_BO_CHEM	HC2	FFSINJ	100
IN_BO_CHEM	HC3	FFSINJ	100
IN_BO_CHEM	HF	FFSINJ	100
IN_BO_CHEM	OS1	IN_HED	100
IN_BO_CHEM	OS2	FFSINJ	100
IN_BO_CON	BC1	FFSINJ	100
IN_BO_CON	BC2	FFSINJ	100
IN_BO_CON	HC1	FFSINJ	100
IN_BO_CON	HC2	FFSINJ	100
IN_BO_CON	HC3	FFSINJ	100
IN_BO_CON	HF	FFSINJ	100
IN_BO_CON	OS1	IN_HED	100
IN_BO_CON	OS2	FFSINJ	100
IN_BO_OTH	DC	IN_HED	100
IN_BO_OTH	HF	FFSINJ	100
IN_BO_OTH	OS1	IN_HED	100
IN_BO_OTH	OS2	FFSINJ	100
IN_BO_OTH_L	BC1	FFSINJ	100
IN_BO_OTH_L	BC2	FFSINJ	100
IN_BO_OTH_L	HC1	FFSINJ	100
IN_BO_OTH_L	HC2	FFSINJ	100
IN_BO_OTH_L	HC3	FFSINJ	100
IN_BO_OTH_S	BC1	FFSINJ	100
IN_BO_OTH_S	BC2	FFSINJ	100
IN_BO_OTH_S	HC1	FFSINJ	100

IN_BO_OTH_S	HC2	FFSINJ	100
IN_BO_OTH_S	HC3	FFSINJ	100
IN_BO_PAP	BC1	FFSINJ	100
IN_BO_PAP	BC2	FFSINJ	100
IN_BO_PAP	HC1	FFSINJ	100
IN_BO_PAP	HC2	FFSINJ	100
IN_BO_PAP	HC3	FFSINJ	100
IN_BO_PAP	HF	FFSINJ	100
IN_BO_PAP	OS1	IN_HED	100
IN_BO_PAP	OS2	FFSINJ	100
IN_OC	DC	IN_HED	100
IN_OC	HF	FFSINJ	100
IN_OC	OS1	IN_HED	100
IN_OC	OS2	FFSINJ	100
IN_OC1	BC1	FFSINJ	100
IN_OC1	BC2	FFSINJ	100
IN_OC1	HC1	FFSINJ	100
IN_OC1	HC2	FFSINJ	100
IN_OC1	HC3	FFSINJ	100
IN_OC2	BC1	FFSINJ	100
IN_OC2	BC2	FFSINJ	100
IN_OC2	HC1	FFSINJ	100
IN_OC2	HC2	FFSINJ	100
IN_OC2	HC3	FFSINJ	100
IN_OC3	BC1	FFSINJ	100
IN_OC3	BC2	FFSINJ	100
IN_OC3	HC1	FFSINJ	100
IN_OC3	HC2	FFSINJ	100
IN_OC3	HC3	FFSINJ	100
INW_OTH	NOF	INDOTH_INC	0
INW_OTH	NOF	INDOTH_INC_ENE	100
INW_OTH	NOF	UNC_BURN	0
MSW_RUR_OTH	NOF	SWD_COMP	0

MSW_RUR_OTH	NOF	SWD_COVER	0
MSW_RUR_OTH	NOF	SWD_FLA	0
MSW_RUR_OTH	NOF	SWD_UNM_HIGH	0
MSW_RUR_OTH	NOF	SWD_UNM_LOW	0
MSW_RUR_OTH	NOF	SWD_USE	0
MSW_RUR_OTH	NOF	TREAT_INC	0
MSW_RUR_OTH	NOF	TREAT_INC_ENE	100
MSW_RUR_OTH	NOF	UNC_BURN	0
MSW_URB_OTH	NOF	SWD_COMP	0
MSW_URB_OTH	NOF	SWD_COVER	0
MSW_URB_OTH	NOF	SWD_FLA	0
MSW_URB_OTH	NOF	SWD_UNM_HIGH	0
MSW_URB_OTH	NOF	SWD_UNM_LOW	0
MSW_URB_OTH	NOF	SWD_USE	0
MSW_URB_OTH	NOF	TREAT_INC	0
MSW_URB_OTH	NOF	TREAT_INC_ENE	100
MSW_URB_OTH	NOF	UNC_BURN	0
PP_ENG	HF	TIWEUV	17
PP_ENG	HF	TIWEUVI	83
PP_ENG	MD	TIWEUVI	100
PP_EX_L	BC1	FFSINJ	100
PP_EX_L	BC2	FFSINJ	100
PP_EX_L	HC1	FFSINJ	100
PP_EX_L	HC2	FFSINJ	100
PP_EX_L	HC3	FFSINJ	100
PP_EX_OTH	DC	HED	100
PP_EX_OTH	HF	PM_FGD	100
PP_EX_OTH	OS1	HED	100
PP_EX_OTH	OS2	CYC	22
PP_EX_OTH	OS2	FFSINJ	100
PP_EX_S	BC1	FFSINJ	100
PP_EX_S	BC2	FFSINJ	100
PP_EX_S	HC1	FFSINJ	100

PP_EX_S	HC2	FFSINJ	100
PP_EX_S	HC3	FFSINJ	100
PP_IGCC	BC1	FFSINJ	100
PP_IGCC	BC2	FFSINJ	100
PP_IGCC	HC1	FFSINJ	100
PP_IGCC	HC2	FFSINJ	100
PP_IGCC	HC3	FFSINJ	100
PP_IGCC	OS2	FFSINJ	100
PP_MOD	BC1	FFSINJ	100
PP_MOD	BC2	FFSINJ	100
PP_MOD	HC1	FFSINJ	100
PP_MOD	HC2	FFSINJ	100
PP_MOD	HC3	FFSINJ	100
PP_MOD_CCS	BC1	FFSINJ	100
PP_MOD_CCS	BC2	FFSINJ	100
PP_MOD_CCS	HC1	FFSINJ	100
PP_MOD_CCS	HC2	FFSINJ	100
PP_MOD_CCS	HC3	FFSINJ	100
PP_NEW	HF	PM_FGD	100
PP_NEW	OS1	HED	100
PP_NEW	OS2	FFSINJ	100
PP_NEW_L	BC1	FFSINJ	100
PP_NEW_L	BC2	FFSINJ	100
PP_NEW_L	HC1	FFSINJ	100
PP_NEW_L	HC2	FFSINJ	100
PP_NEW_L	HC3	FFSINJ	100
PR_ALPRIM	NOF	PM_REM	100
PR_BAOX	NOF	FFSINJ	100
PR_BRICK	NOF	TK_EOF	100
PR_CEM	NOF	FFSINJ	100
PR_COKE	NOF	FFSINJ	100
PR_CSP	NOF	BAN	100
PR_EARC	NOF	PR_HED	100

PR_FERT	NOF	PR_HED	100
PR_GLASS	NOF	FFSINJ	100
PR_HEARTH	NOF	FFSINJ	100
PR_LIME	NOF	FFSINJ	100
PR_OT_NFME	NOF	PR_AP	100
PR_PIGI	NOF	FFSINJ	100
PR_PULP	NOF	FFSINJ	100
PR_REF	NOF	FFSINJ	100
TRA_OT_AGR	GSL	LFEUVI	100
TRA_OT_AGR	LPG	LFEUII	100
TRA_OT_AGR	MD	CAGEUVI	100
TRA_OT_CNS	GSL	LFEUVI	100
TRA_OT_CNS	LPG	LFEUVI	100
TRA_OT_CNS	MD	CAGEUVI	100

TRA_OT_INW	GSL	LFEUVI	100
TRA_OT_INW	MD	TIWEUVI	100
TRA_OT_LB	GSL	LFEUVI	100
TRA_OT_LB	LPG	LFEUII	100
TRA_OT_LB	MD	HDEUVI	100
TRA_OT_LD2	GSL	MMO2III	100
TRA_OT_RAI	GSL	LFEUII	100
TRA_OT_RAI	MD	TIWEUVI	100
TRA_OTS_L	HF	STLHCM	30
TRA_OTS_L	HF	STLSCR	70
TRA_OTS_L	MD	STLSCR	100
TRA_OTS_M	MD	STMCM	100
TRA_RD_HDB	GSL	HDSEIII	100
TRA_RD_HDB	LPG	HDSEIII	100

TRA_RD_HDB	MD	HDEUVI	100
TRA_RD_HDT	GSL	HDSEIII	100
TRA_RD_HDT	LPG	HDSEIII	100
TRA_RD_HDT	MD	HDEUVI	100
TRA_RD_LD2	GSL	MMO2III	100
TRA_RD_LD4C	GSL	LFEUVI	100
TRA_RD_LD4C	LPG	LFEUVI	100
TRA_RD_LD4C	MD	MDEUVI	100
TRA_RD_LD4T	GSL	LFEUVI	100
TRA_RD_LD4T	LPG	LFEUVI	100
TRA_RD_LD4T	MD	MDEUVI	100
TRA_RD_M4	GSL	MOT4III	100
TRA_RD_OTH	GSL	OTHIII	100

S3.2 – PM and SO₂ control strategies

Historically, the power sector has been regulated with the most stringent emission limit values (e.g., ICSC 2019). Already in the CLE control strategy, some kind of particulate matter control is present for >98% of all installed capacity in the coal sector (industrial combustion, power plants) for all study years (2015-2050) (see Table S9). There are differences in the CLE and co-MFR control strategies in the PM removal efficiency of applied controls: The share of high efficiency dedusting (HED) is steadily increasing in both scenarios relative to the less efficient electrostatic precipitators (ESP1 and ESP2). For power plants, HED application reaches a peak application on 77% of total global capacity in all coal combustion sectors in the CLE scenario in 2050 but is applied on 98% of total capacity in the same year in the co-MFR control strategy. However, for the implementation of the Hg control strategy, the differences in Hg removal efficiency between ESP1, ESP2 and HED are not implemented in the GAINS model at the current time and all three technologies are summarized as ‘Particulate matter control’ (see Table S3). For SO₂ controls, the share of flue gas desulfurization devices (FGD), which have a Hg removal efficiency associated with them, climbs up to >90% in 2050 for the CLE scenarios but reaches >97% in the co-MFR scenario for coal power stations. For industrial combustion, the application rates are lower and more markedly different: 65% application of FGDs in 2050 in the CLE, and up to 87% in the co-MFR, globally. However, the reduction potential varies greatly between regions, especially in sectors and world regions (see Figure S3 in the SI) where stringent air control policies are not yet mandated. As a result, even on a global scale, only 12.5% reduction in Hg emissions can be seen in the power sector in 2050.

Table S9. Global average application rates of pollution control measures in selected sectors in %.

Control Strategy	Sector	Activity	Pollutant	Technology (long name)	Technology (abbreviation)	2015	2020	2025	2030	2035	2040	2045	2050
CLE, MINA	COMB_IND	Coal	PM2.5	Cyclone	CYC	1.28	0.67	0.62	0.62	0.62	0.62	0.61	0.6
CLE, MINA	COMB_IND	Coal	PM2.5	Electrostatic precipitator: 1 field	ESP1	74.46	70.11	73.58	75.43	78.8	80.62	81.94	82.77
CLE, MINA	COMB_IND	Coal	PM2.5	Electrostatic precipitator: 2 fields	ESP2	3.91	11.14	9.35	8.89	8.17	7.49	6.92	6.62
CLE, MINA	COMB_IND	Coal	PM2.5	High efficiency deduster	HED	3.52	7.06	9.1	10.92	9.35	8.45	7.89	7.53
CLE, MINA	COMB_IND	Coal	PM2.5	Wet scrubber	WSCRb	14.08	8.91	5.64	2.78	2.58	2.4	2.25	2.12
co-MFR	COMB_IND	Coal	PM2.5	Cyclone	CYC	n.a	n.a	2.76	1.64	0.78	0.14	0.14	0.13
co-MFR	COMB_IND	Coal	PM2.5	Electrostatic precipitator: 1 field	ESP1	n.a	n.a	58.03	42.44	26.59	9.65	10.19	10.95
co-MFR	COMB_IND	Coal	PM2.5	Electrostatic precipitator: 2 fields	ESP2	n.a	n.a	5.82	4.17	1.97	0.02	0	0
co-MFR	COMB_IND	Coal	PM2.5	High efficiency deduster	HED	n.a	n.a	27.28	48.69	67.97	87.78	87.42	86.8
co-MFR	COMB_IND	Coal	PM2.5	Wet scrubber	WSCRb	n.a	n.a	5.64	2.78	2.58	2.4	2.25	2.12
CLE, MINA	COMB_IND	Coal	SO ₂	Industry - wet flue gases desulphurisation	IWFGD	36.07	59.11	62.54	66.92	66.36	65.88	65.3	64.52
CLE, MINA	COMB_IND	Coal	SO ₂	In-furnace control - limestone injection	LINJ	23.65	13.49	13.65	12.83	11.86	11.14	10.6	10.17

CLE, MINA	COMB_IND	Coal	SO2	Low sulphur coal (0.6 %S)	LSCO	17.46	2.43	1.84	1.64	1.65	1.53	1.49	1.47
co-MFR	COMB_IND	Coal	SO2	Industry - wet flue gases desulphurisation	IWFGD	n.a	n.a	68.4	77.02	77.26	87.82	87.54	87.14
co-MFR	COMB_IND	Coal	SO2	In-furnace control - limestone injection	LINJ	n.a	n.a	12.51	10.56	14.29	7.39	7.41	7.41
co-MFR	COMB_IND	Coal	SO2	Low sulphur coal (0.6 %S)	LSCO	n.a	n.a	1.1	1.02	0.6	1.11	1.02	0.98
CLE, MINA	COMB_POWER	Coal	PM2.5	Cyclone	CYC	0.02	0	0	0	0	0	0	0
CLE, MINA	COMB_POWER	Coal	PM2.5	Electrostatic precipitator: 1 field	ESP1	21.36	15.64	5.3	4.1	4.41	4.47	4.71	4.8
CLE, MINA	COMB_POWER	Coal	PM2.5	Electrostatic precipitator: 2 fields	ESP2	34.75	19.24	18.17	11.43	12.84	14.01	15.12	16.1
CLE, MINA	COMB_POWER	Coal	PM2.5	High efficiency deduster	HED	43.87	64.89	76.06	83.83	81.89	80.37	78.58	77.05
CLE, MINA	COMB_POWER	Coal	PM2.5	Wet scrubber	WSCRb	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
co-MFR	COMB_POWER	Coal	PM2.5	Cyclone	CYC	n.a	n.a	0	0	0	n.a	n.a	n.a
co-MFR	COMB_POWER	Coal	PM2.5	Electrostatic precipitator: 1 field	ESP1	n.a	n.a	4.16	2.41	1.68	0.79	0.84	0.85
co-MFR	COMB_POWER	Coal	PM2.5	Electrostatic precipitator: 2 fields	ESP2	n.a	n.a	12.02	6.05	4.47	2.31	2.81	3.28
co-MFR	COMB_POWER	Coal	PM2.5	High efficiency deduster	HED	n.a	n.a	83.8	91.53	93.85	96.9	96.34	95.87
co-MFR	COMB_POWER	Coal	PM2.5	Wet scrubber	WSCRb	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
CLE, MINA	COMB_POWER	Coal	SO2	In-furnace control - limestone injection	LINJ	4.56	2.09	1.64	1.41	1.5	1.58	1.71	1.88
CLE, MINA	COMB_POWER	Coal	SO2	Low sulphur coke (0.6 %S)	LSCK	0.07	n.a	n.a	n.a	n.a	n.a	n.a	n.a
CLE, MINA	COMB_POWER	Coal	SO2	Low sulphur coal (0.6 %S)	LSCO	0.6	0.59	0.54	0.58	0.6	0.65	0.75	0.87
CLE, MINA	COMB_POWER	Coal	SO2	Wet flue gases desulphurisation (retrofitted)	PRWFGD	8.72	4.32	2.09	1.2	0.68	0.28	0.27	0.24

CLE, MINA	COMB_POWER	Coal	SO2	Wet flue gases desulphurisation	PWFGD	68.72	46.86	44.32	43.14	44.05	46.18	47.06	48.3
CLE, MINA	COMB_POWER	Coal	SO2	High efficiency flue gases desulphurisation	RFGD	1.56	34.91	44.36	49.06	48.05	45.7	43.96	41.82
co-MFR	COMB_POWER	Coal	SO2	In-furnace control - limestone injection	LINJ	n.a	n.a	1.48	1.04	1.49	0	0	0
co-MFR	COMB_POWER	Coal	SO2	Low sulphur coke (0.6 %S)	LSCK	n.a	n.a	0	0	0.01	0.01	0.01	0.01
co-MFR	COMB_POWER	Coal	SO2	Low sulphur coal (0.6 %S)	LSCO	n.a	n.a	0.02	0.18	0.18	0.18	0.21	0.24
co-MFR	COMB_POWER	Coal	SO2	Wet flue gases desulphurisation (retrofitted)	PRWFGD	n.a	n.a	2.09	1.2	0.68	0.28	0.27	0.24
co-MFR	COMB_POWER	Coal	SO2	Wet flue gases desulphurisation	PWFGD	n.a	n.a	39.76	33.33	43.85	8.4	8	8.04
co-MFR	COMB_POWER	Coal	SO2	High efficiency flue gases desulphurisation	RFGD	n.a	n.a	49.76	61.01	51.36	89.68	89.76	89.4

S4 – The No Control Scenario

To establish a theoretical maximum of yearly anthropogenic mercury emissions in the present scenarios, it is useful to compare the current legislation scenario to a hypothetical “no control” endpoint, conceptualized in the ‘No Control’ (BAS_NOC) scenario (plotted in the SI, Figure S1). This scenario assumes unabated emissions factors, as if no PM, SO₂ or Hg air pollution control were implemented (see Table 2). Comparing the No Control and Baseline (BAS_CLE) scenarios, the full extent of emissions reductions from current clean air policy becomes apparent, highlighting the co-benefits for Hg of already existing clean air policies and the impact of the CLE control strategy used in the Baseline scenario. In 2015, global emissions are 5273 t Hg in the No Control scenario, more than twice as high as in the Baseline (2321 t Hg). From Figures S2 and 3, it can be seen that the difference between No Control and the Baseline is larger than between the Baseline and the other, stricter control strategy scenarios (MINA, co-MFR, Hg-MFR), illustrating that already, more than 50% of potential unabated Hg emissions are avoided through clean air policy.

Most co-benefit reductions occur in the NFME sector: In 2015, NFME emissions alone would have been 2334 t/a without any APDCs in place, 6.7 times higher than in the Baseline, owing to the high unabated emission factors in this sector, the high Hg removal efficiency of co-benefit controls (in this case, acid plants), and the already high application rates of these technologies in the baseline control strategy. Other sectors which are significantly higher without emission controls than reported in 2015 include the power sector COMB_POWER (3.0 x higher), industrial combustion COMB_IND (2.7 x higher) and cement production (1.7 x higher), indicating that these sectors are already largely controlled through particulate filters and even desulfurization measures in many world regions. A more extensive discussion for the control strategy compared to a No Control scenario can be found in Amann et al. (2020).

Figure S1. No Control scenario (00_BAS_NOC), compared to all other control strategies on the baseline scenario. Refer to Tables 1 & 2 of the main text for details of the abbreviations in the legend.

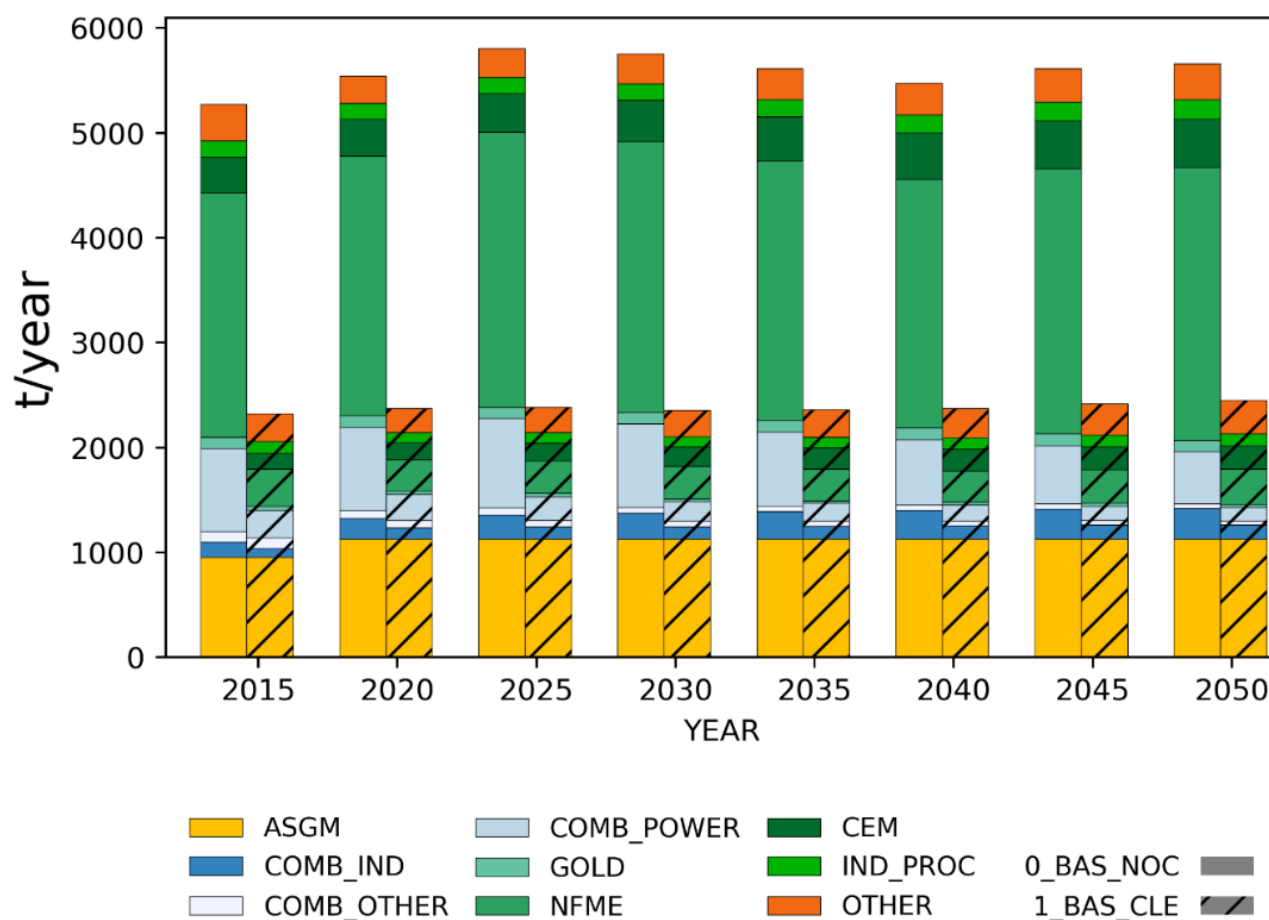


Table S10. Regional aggregation of countries and GAINS model regions (consistent with IEA (2022) regional grouping).

Region	Countries	GAINS regions
North America:	Canada, Mexico and United States	CANA_WHOL, MEXI_WHOL, USAM_ALAS, USAM_MAIN
Central and South America:	Argentina, Plurinational State of Bolivia (Bolivia), Brazil, Chile, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay, Bolivarian Republic of Venezuela (Venezuela), and other Central and South American countries and territories	ARGE_WHOL, BOLV_WHOL, BRAZ_WHOL, CHIL_WHOL, COLO_WHOL, CARB_WHOL, CEAM_WHOL, ECUA_WHOL, PARA_WHOL, PERU_WHOL, URUG_WHOL, VENE_WHOL
Europe:	European Union regional grouping and Albania, Belarus, Bosnia and Herzegovina, North Macedonia, Gibraltar, Iceland, Israel, Kosovo, Montenegro, Norway, Serbia, Switzerland, Republic of Moldova, Türkiye, Ukraine and United Kingdom.	European Union and ALBA_WHOL, BELA_WHOL, BOHE_WHOL, ICEL_WHOL, ISRA_WHOL, KOSO_WHOL, MACE_WHOL, MOLD_WHOL, MONT_WHOL, NORW_WHOL, SERB_WHOL, SWIT_WHOL, TURK_WHOL, UNKI_WHOL, UKRA_WHOL
European Union:	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain and Sweden	UST_WHOL, BELG_WHOL, BULG_WHOL, CROA_WHOL, CYPR_WHOL, CZRE_WHOL, DENM_WHOL, ESTO_WHOL, FINL_WHOL, FRAN_WHOL, GERM_WHOL, GREE_WHOL, HUNG_WHOL, IREL_WHOL, ITAL_WHOL, LATV_WHOL, LITH_WHOL, LUXE_WHOL, MALT_WHOL, NETH_WHOL, POLA_WHOL, PORT_WHOL, ROMA_WHOL, SKRE_WHOL, SLOV_WHOL, SPAI_WHOL, SWED_WHOL
Africa:	North Africa (Algeria, Egypt, Libya, Morocco and Tunisia) and sub-saharan Africa (Angola, Benin, Botswana, Cameroon, Republic of the Congo (Congo), Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Mauritius, Mozambique, Namibia, Niger, Nigeria, Senegal, South Africa, South Sudan, Sudan, United Republic of Tanzania (Tanzania), Togo, Zambia, Zimbabwe and other African countries	EAFR_WHOL, EGYP_WHOL, KENY_WHOL, NAFR_WHOL, NIGE_WHOL, RSAF_WHOL, TANZ_WHOL, WAFR_WHOL

Middle East:	Bahrain, Islamic Republic of Iran (Iran), Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic (Syria), United Arab Emirates and Yemen	IRAN_WHOL, SAAR_WHOL, MIDE_WHOL
Eurasia:	Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan, the Russian Federation (Russia)	ARME_WHOL, AZER_WHOL, GEOR_WHOL, KAZA_WHOL, KYRG_WHOL, RUSS_ASIA, RUSS_EURO, TAJI_WHOL, TKME_WHOL, UZBE_WHOL
Asia Pacific:	Southeast Asia regional grouping and Australia, Bangladesh, Democratic People's Republic of Korea (North Korea), India, Japan, Korea, Mongolia, Nepal, New Zealand, Pakistan, People's Republic of China (China), Sri Lanka, Chinese Taipei, and other Asia Pacific countries and territories.	Southeast Asia regional grouping and AFGH_WHOL, AUTR_WHOL, BANG_DHAK, BANG_REST, BHUT_WHOL, CHIN_ANHU, CHIN_BEIJ, CHIN_CHON, CHIN_FUJI, CHIN_GANS, CHIN_GUAD, CHIN_GUAX, CHIN_GUIZ, CHIN_HAIN, CHIN_HEBE, CHIN_HEIL, CHIN_HENA, CHIN_HONG, CHIN_HUBE, CHIN_HUNA, CHIN_JILI, CHIN_JINU, CHIN_JINX, CHIN_LIAO, CHIN_NEMO, CHIN_NINX, CHIN_QING, CHIN_SHAA, CHIN_SHAN, CHIN_SHND, CHIN_SHNX, CHIN_SICH, CHIN_TIAN, CHIN_TIBE, CHIN_XING, CHIN_YUNN, CHIN_ZHEJ, INDI_ANPR, INDI_ASSA, INDI_BENG, INDI_BIHA, INDI_CHHA, INDI_DELH, INDI_EHIM, INDI_GOA, INDI_GUJA, INDI_HARY, INDI_HIPR, INDI_JHAR, INDI_KARN, INDI_KERA, INDI_MAHA, INDI_MAPR, INDI_ORIS, INDI_PUNJ, INDI_RAJA, INDI_TAMI, INDI_UTAN, INDI_UTPR, INDI_WHIM, JAPA_CHSH, JAPA_CHUB, JAPA_HOTO, JAPA_KANT, JAPA_KINK, JAPA_KYOK, KORN_WHOL, KORS_NORT, KORS_PUSA, KORS_SEOI, KORS_SOUT, MONG_WHOL, NEPA_WHOL, NZEL_WHOL, PAKI_KARA, PAKI_NMWP, PAKI_PUNJ, PAKI_SIND, SRIL_WHOL, TAIW_WHOL
Southeast Asia:	Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam. These countries are all members of the Association of Southeast Asian Nations (ASEAN)	BRUN_WHOL, CAMB_WHOL, INDO_JAKA, INDO_JAVA, INDO_REST, INDO_SUMA, LAOS_WHOL, MALA_KUAL, MALA_PENM, MALA_SASA, MYAN_WHOL, PHIL_BVMI, , PHIL_LUZO, PHIL_MANI, SING_WHOL, THAI_BANG, THAI_CVAL, THAI_NEPL, THAI_NHIG, THAI_SPEN, VIET_NORT, VIET_SOUT

S6 – Monte Carlo Simulation to estimate uncertainties of unabated mercury emissions.

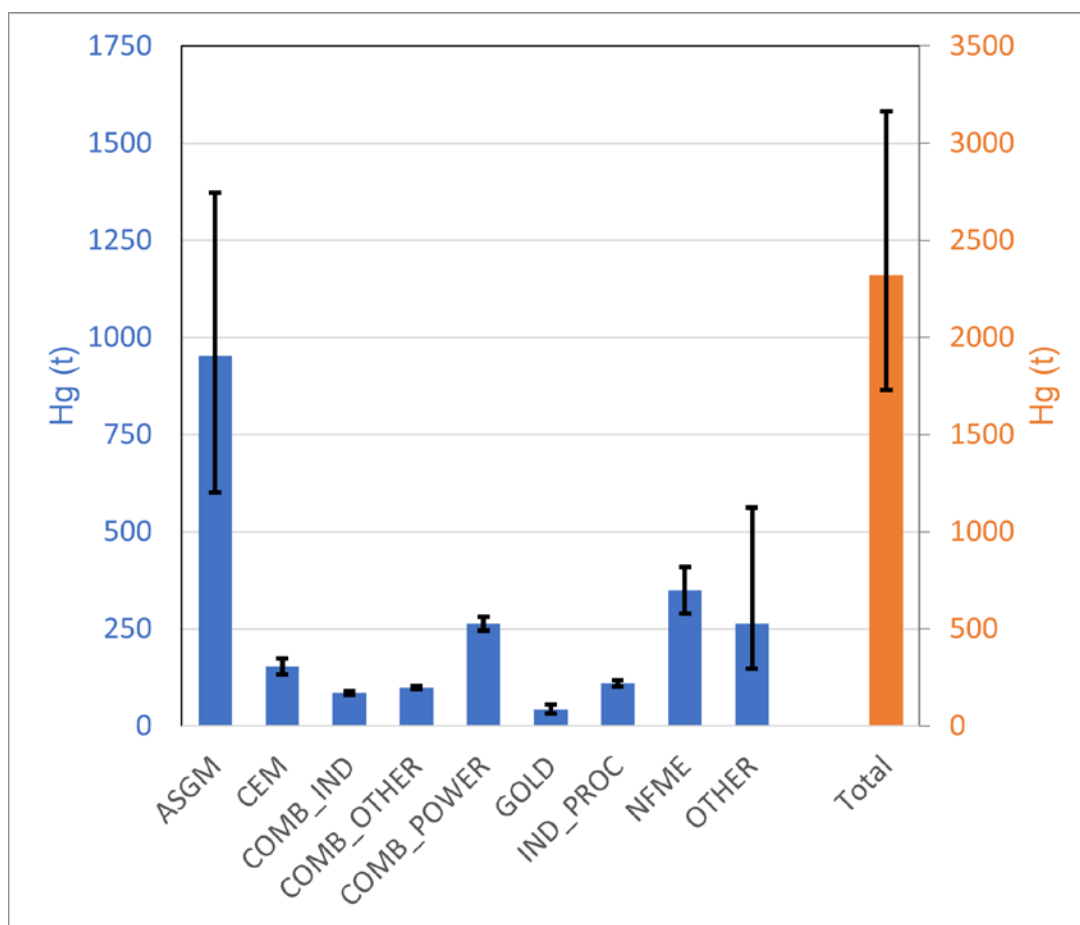
Table S11. Uncertainty estimations used as input to Monte Carlo Simulation. UEF ... Unabated Emission Factor. GMA'18 ... AMAP/UNEP (2019), Global Mercury Assessment 2018.

Sector		1 Standard Deviation	Distribution	Source
ACTIVITY DATA				
ASGM		$\pm 0.5 \times \text{activity}$	normal	GMA'18
CEM COMB_IND COMB_OTHER COMB_POWER GOLD IND_PROC NFME OTHER	EU27 North America USA Japan All others	$\pm 0.05 \times \text{activity}$ $\pm 0.1 \times \text{activity}$	normal	GMA'18
Waste		$\pm 0.2 \times \text{activity}$	normal	own estimate
UNABATED EMISSION FACTORS (UEF)				
Coal sectors COMB_IND COMB_OTHER COMB_POWER	All countries	$\pm 0.3 \times \text{UEF}$	normal	GMA'18
CEM GOLD IND_PROC NFME ASGM	All countries	$\pm 0.5 \times \text{UEF}$	normal	GMA'18
OTHER	All countries	$0.3 \times \text{UEF} - 3 \times \text{UEF}$	log-normal	GMA'18

Table S12. Global results of the Monte Carlo Simulation for 00_BAS_NOC after 10000 runs.

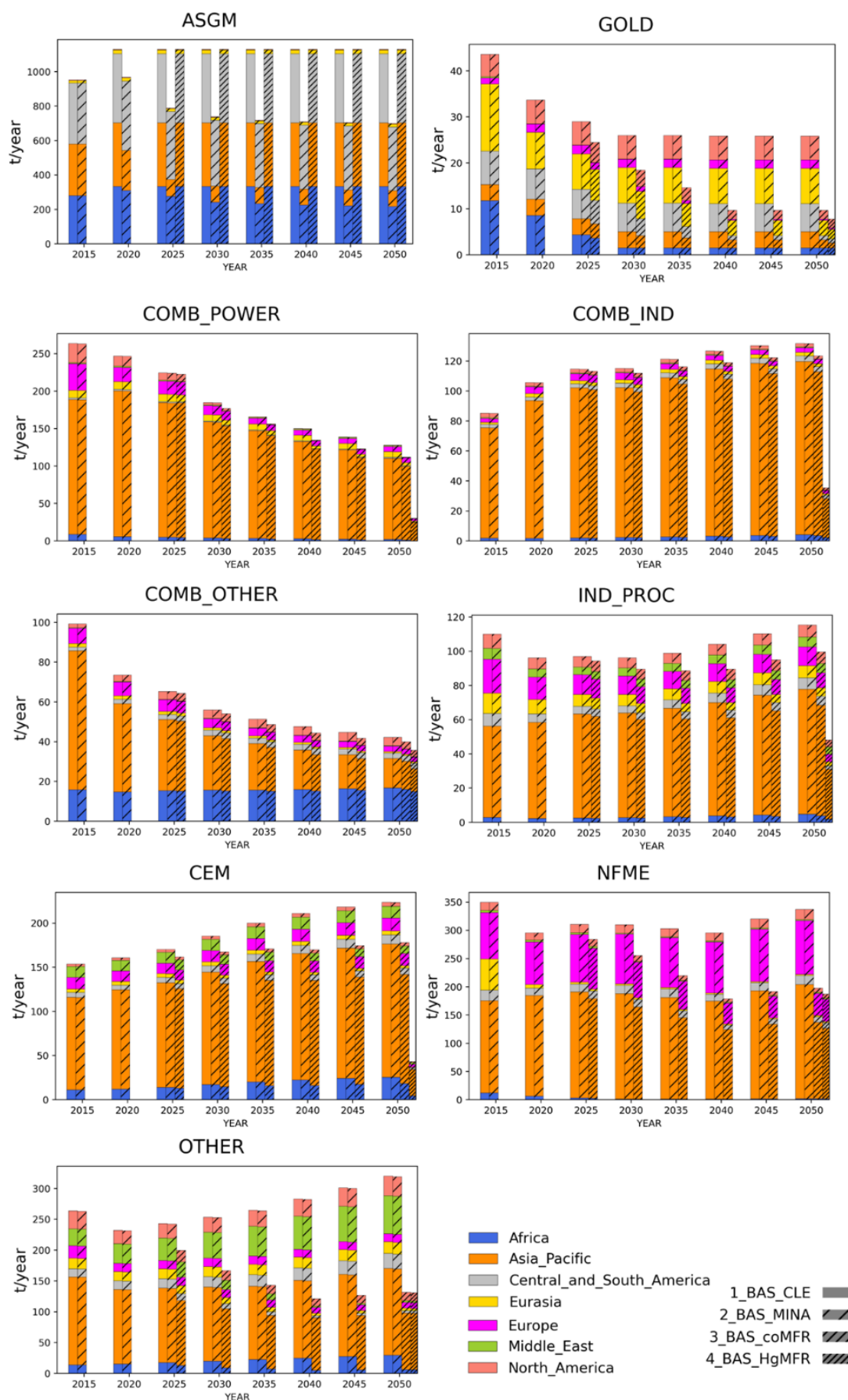
Sector	Mean simulated emissions (50 th percentile) in tons	Upper range estimate (95 th percentile) (t)	Lower range estimate (5 th percentile) (t)	GAINS emissions (t)	% error (lower)	% error (upper)
ASGM	951.34	1370.94	600.97	952.61	36.83	44.11
CEM	334.74	378.26	291.43	335.06	12.94	13.00
COMB_IND	141.87	149.26	134.61	141.86	5.12	5.21
COMB_OTHER	104.63	109.07	100.18	104.63	4.26	4.25
COMB_POWER	791.84	846.70	739.33	792.08	6.63	6.93
GOLD	103.03	128.88	77.55	103.12	24.73	25.10
IND_PROC	160.84	173.33	148.02	160.75	7.97	7.76
NFME	2333.95	2733.50	1930.90	2334.21	17.27	17.12
OTHER	353.74	753.37	199.18	352.08	43.69	112.97

Figure S2. Global Hg emissions in the Baseline scenario (01_BAS_CLE) in 2015. Error bars represent the range of 95% confidence interval.



S7 – Additional plots.

Figure S3: Global mercury emissions for the BAS activity pathway and all different Hg control strategies – by region.



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