

# Marginal damage costs for air pollutants and externalities from European industrial facilities

Updated assessment



European Environment Agency  
European Topic Centre  
Human health and the environment



# Estimating the external costs of industrial air pollution: Trends 2012-2021

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- Update of earlier reports
  - Costs of air pollution from European industrial facilities 2008–2017, EIONET Report ETC/ATNI 2020/04
  - Costs of air pollution from European industrial facilities 2008–2012, an updated assessment, EEA Technical Report 20/2014



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## Estimating the external costs of industrial air pollution: Trends 2012-2021

Technical note on the methodology and additional results from the EEA briefing 24/2023

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# Scope of the work (1/2)

- Three distinct assessments

- Marginal damage costs (MDCs) per tonne of pollutant and per country
- Sectoral adjustment factors for main air pollutants (exposure & PM ratio)
- Externalities of industrial facilities using E-PRTR (\*) emission data

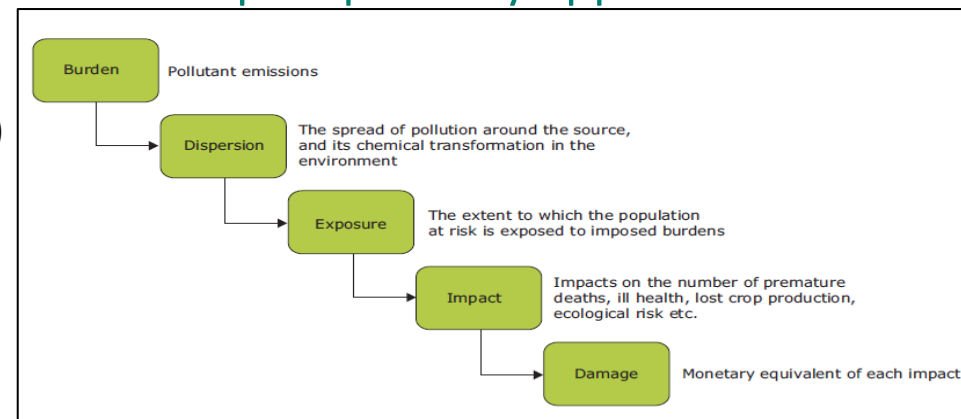
- Pollutants

- Main air pollutants:  $\text{NH}_3$ ,  $\text{NO}_x$ ,  $\text{SO}_2$ , NMVOCs,  $\text{PM}_{10}$ ,  $\text{PM}_{2.5}$
- Heavy metals: As, Cd, CrVI, Pb, Hg, Ni
- Organic pollutants: 1,3 Butadiene, benzene, formaldehyde, PAH (as BaP equiv.), dioxins and furans
- Greenhouse gases:  $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{N}_2\text{O}$

- Impacts

- Health: main air pollutants ( $\text{PM}_{2.5}$ ,  $\text{O}_3$ ,  $\text{NO}_2$ ), heavy metals, organic pollutants
- Crops and forests: main air pollutants ( $\text{O}_3$ )
- Building materials: main air pollutants ( $\text{NO}_x$ ,  $\text{SO}_2$ )
- Ecosystems: main air pollutants (eutrophication)

## Impact pathway approach



(\*) E-PRTR: European Pollutant Release and Transfer Register

# Scope of the work (2/2)

- **Countries**

- EEA38+UK wherever possible for MDCs
- EU27 for externalities

- **Damage**

- Impact of emission per tonne of pollutant from a particular country wherever it occurs ( $\approx$  damage in EEA38+UK)
- Impact occurring in the emitter country only

- **Period**

- Reference year 2019
  - SRMs based on 2019 emissions & meteorology
- For health impacts, MDCs are for the first time made year specific
  - Adapted for 2012-2021 by country specific population & mortality data (accounting for demographic change)
  - Adapted for 2012-2021 by income changes (growth rate calculated as 2-year average between the year n-1 and n+1)
  - Correction for inflation as in previous editions
- Externalities for 2012-2021



# Updated marginal damage costs

# Main air pollutants – calculation of MDCs

- Dispersion & exposure modelling
  - EMEP Source-Receptor-Matrices (SRMs)
  - Calculation of higher resolution Source-Receptor-Relationships (SRRs) for NO<sub>2</sub> using SHERPA model (JRC)
- Calculation of sectoral exposure adjustment factors for PM<sub>2.5</sub> and NO<sub>2</sub> precursors using SHERPA
  - Specific to each precursor, GNFR sector and country
  - Account for closeness of emission source to population and emission height
- Inclusion of PM<sub>10</sub>/PM<sub>2.5</sub> ratio adjustment factors
  - MDCs initially calculated for PM<sub>10</sub> ( SRMs, E-PRTR)
  - Health effects estimated for exposure to PM<sub>2.5</sub>
  - Account for the mass fraction of PM<sub>2.5</sub> in the PM<sub>10</sub> emitted
  - Specific to each GNFR sector and country
- Mortality & morbidity valuation updated as recommended by OECD (2012)
  - Correction for income changes and inflation
  - But no adjustment in space (equity)
- Response functions and valuation for health broadly consistent with the 3<sup>rd</sup> CAO (Klimont et al., 2022)



# Main air pollutants – health endpoints & valuation

- Health impacts from PM<sub>2.5</sub>, O<sub>3</sub> and NO<sub>2</sub>
- Unit costs (costs per life year, death, new incidence of illness, etc.) in 2019 in €<sub>2021</sub>

<b>Mortality</b>	
Value of a life year (VOLY) <sup>1</sup>	111,47
Value of statistical life (VSL) <sup>1</sup>	4.2 million
Infant Mortality	6.5 million
<b>Morbidity</b>	
Bronchitis in Children (age 6 -12)	420
Chronic Bronchitis in adults	75,1
Cardiovascular hospital admissions	6,95
Respiratory hospital admissions	5,65
Restricted activity days	154
Minor restricted activity day	57
Asthma symptom days in children (age 5-19 years)	59
Lost working days	183
Stroke (CVA)	115,532
Lung cancer	35,13
New incidence of asthma in children (age < 16 years)	8,157
Diabetes Mellitus Type2	24,957
Non-fatal myocardial infarction	39,517
Chronic Obstructive Pulmonary Disease (COPD)	75,127

## Two alternative aggregates

- Sum over all health impacts valuing premature mortality in terms of attributable deaths (=> “VSL”)
- Sum over all health impacts valuing premature mortality in terms of Years of Life Lost (=> “VOLY”)

# Main air pollutants - average European MDCs

- Damage costs in 2019 accounting for impacts on health, crops & forests, building materials and ecosystems (€/t)

Pollutant	Average European damage cost (€ <sub>2021</sub> per tonne) – EEA 38+UK	
	VOLY	VSL
NO <sub>x</sub>	15 353	42 953
SO <sub>2</sub>	16 212	38 345
PM <sub>10</sub>	51 482	141 145
PM <sub>2.5</sub>	86 490	237 123
NMVOC	1 844	4 480
NH <sub>3</sub>	18 991	52 268

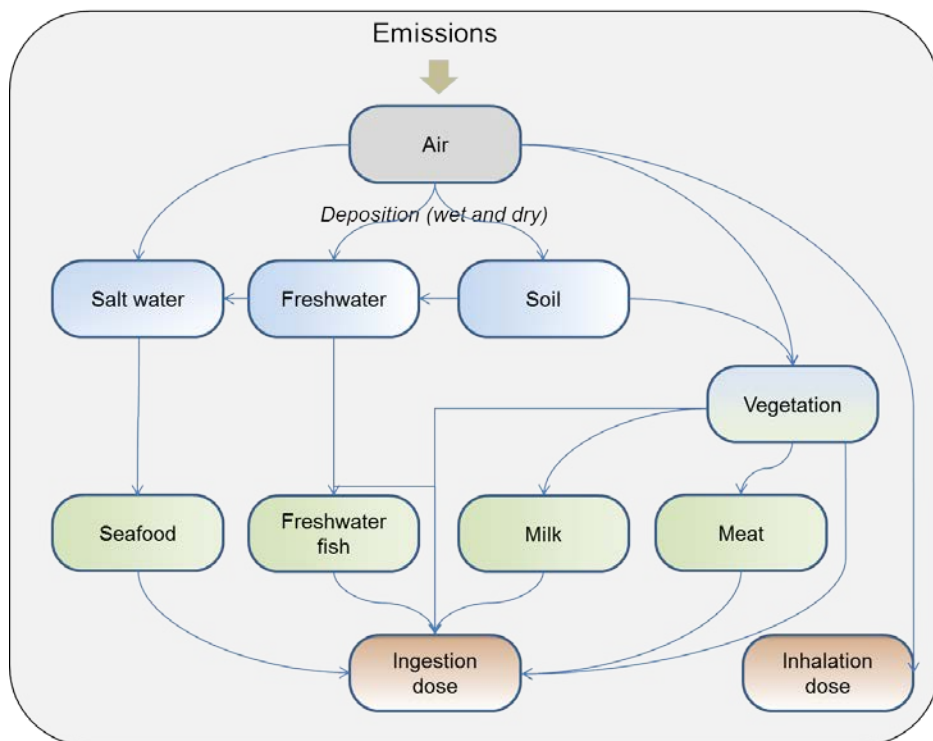
- Country specific MDCs available in the technical note

- Changes compared to ETC/ATNI 2020/04 due to
  - Updated population and health data
  - Updated source receptor matrices
  - Estimates adjusted to 2021 prices for inflation
  - Accounting for income changes & economic growth
  - Additional health endpoints



# Heavy metals and organic pollutants – calculation of MDCs

- Dispersion & exposure modelling
  - Uniform World methodology, environmental accumulation, transport in food & water, uptake via ingestion & inhalation
- Impact calculation using RiskPoll



Pollutant	Current study
<b>Arsenic (inorganic)*</b>	Non-cancer mortality, Cancer (fatal & non-fatal), Chronic bronchitis, IQ loss and diabetes
<b>Cadmium*</b>	All-cause mortality, Non-fatal cancers and Osteoporosis (hip fractures)
<b>Chromium (hexavalent, VI)†</b>	Cancer (fatal & non-fatal)
<b>Lead*</b>	All-cause mortality, IQ loss and Anaemia
<b>Mercury*</b>	Cardiovascular mortality and IQ loss
<b>Nickel†</b>	Cancer (fatal & non-fatal)
<b>1,3 Butadiene†</b>	Cancer (fatal & non-fatal)
<b>Benzene†</b>	Cancer (fatal & non-fatal)
<b>Dioxins/Furans (TCDD equiv.)*</b>	Cancer (fatal & non-fatal)
<b>Formaldehyde†</b>	Cancer (fatal & non-fatal)
<b>PAH (as BaP equiv.)†</b>	Cancer (fatal & non-fatal)

Human exposure route: (\*) Inhalation and Ingestion; (†) Inhalation only

# Heavy metals and organic pollutants – average European MDCs

- Marginal damage costs of heavy metals and organics for European emissions (€<sub>2021</sub> per kg pollutant emitted to air)

Pollutant	2019
Arsenic	10 328
Cadmium	253 058
Chromium VI	687
Lead	45 201
Mercury	16 755
Nickel	22.9
1,3 Butadiene	4.15
Benzene	0.889
Benzo(a)pyrene	1 435
Dioxins/Furans (TCDD equiv.)	132.6M
Formaldehyde	0.298

- Differences compared to to ETC/ATNI 2020/04 due to
  - Updated incidence and population data
  - Partly updated unit costs
  - Estimates adjusted to 2021 prices for inflation
  - Accounting for income growth
  - Results of Monte Carlo simulation considering the uncertainty distribution of all the input parameters of the impact calculation

# Greenhouse gases – Marginal abatement costs (MACs)

- Marginal abatement costs as a proxy for carbon valuation
  - Valuation for CO<sub>2</sub> from DG MOVE Handbook on the External Costs of Transport (EC, 2019)
  - Conversion of methane and nitrous oxide through factors for temperature change after 20 years (IPCC, 2014)
- Climate change avoidance costs in €/tCO<sub>2</sub> equivalent (€<sub>2021</sub>)

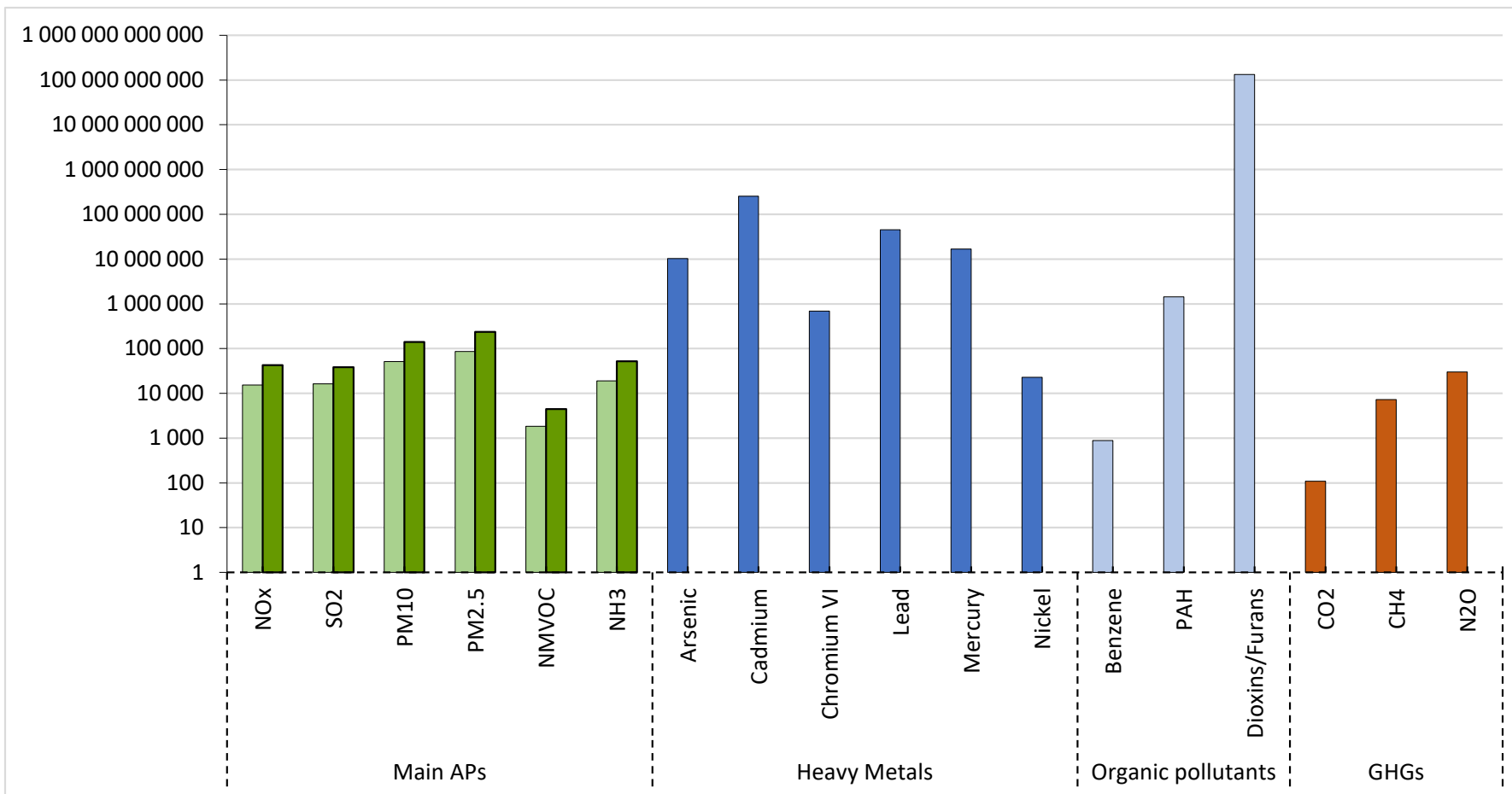
	Low	Central	High
Short and medium term, to 2030	65	109	206
Longer term (2040 to 2060)	170	293	543

- GWP and GTP for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O

Pollutant	GWP		GTP	
	Cumulative forcing over 20 years	Cumulative forcing over 100 years	Temperature change after 20 years	Temperature change after 100 years
CO <sub>2</sub>	1	1	1	1
CH <sub>4</sub>	84	28	67	4
N <sub>2</sub> O	264	265	277	234

# Average damage cost per tonne emitted, € (€<sub>2021</sub>)

Logarithmic scale!



European averages, except for greenhouse gases and mercury, for which they are global

# Updated externalities – a few general results

# Only a limited share of emissions reported to E-PRTR

- Number of reporting facilities (all pollutant groups)

Number of facilities reporting the selected air pollutant emissions									
2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
9 715	9 809	10 011	10 314	10 271	10 374	10 443	9 936	9 982	9 400

- Emissions reported EU27 countries to E-PRTR and EMEP in 2019

EU27 (*)	Emissions reported to E-PRTR (tonnes)	Aggregated total emissions reported to EMEP (tonnes)	% E-PRTR emissions of national totals
NOx	1 095 290	6 027 631	18%
SOx	797 438	1 622 096	49%
PM10	46 515	1 725 164	3%
NMVOG	253 771	6 257 282	4%
NH3	205 684	3 466 224	6%
As	14	69	21%
Cd	8	54	15%
Cr	43	290	15%
Hg	19	41	48%
Ni	83	426	19%
Pb	105	1 034	10%
Dioxins & furans	0,0004	0,0016	23%
PAH	28	703	4%
(*) excluding Lithuania and Slovakia			

⇒ Externalities calculated in this study do not represent the total damage costs caused by air pollution across Europe

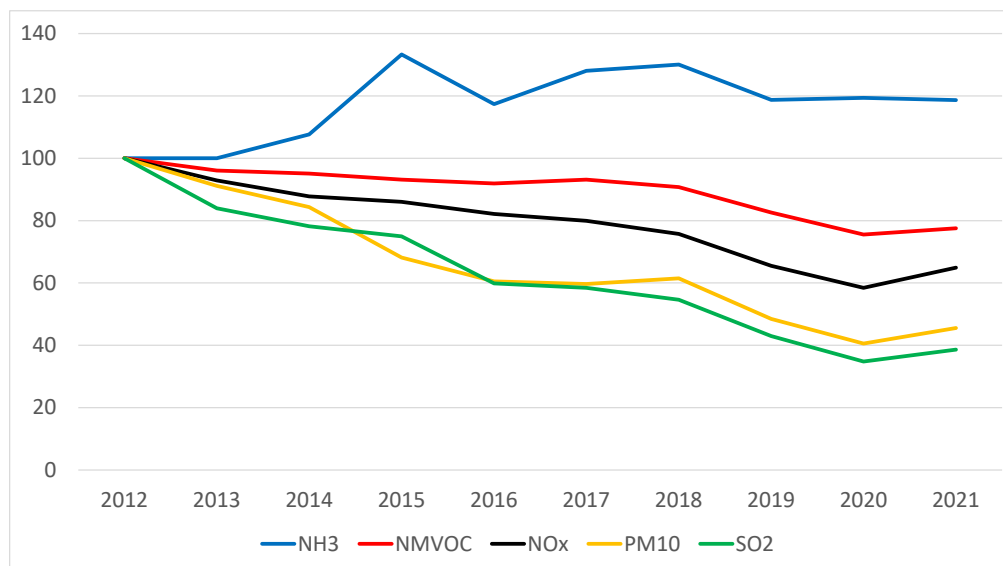
# Aggregated damage cost declines over the period

- Aggregated damage costs by pollutant groups from 2012 to 2021 (million €<sub>2021</sub>)

	Aggregated damage costs (million € <sub>2021</sub> )									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Main air pollutants (NH <sub>3</sub> , NO <sub>x</sub> , PM <sub>10</sub> , SO <sub>2</sub> , NMVOCs) VOLY	119 042	104 531	98 362	95 345	82 197	80 721	76 608	63 255	54 277	59 728
Main air pollutants (NH <sub>3</sub> , NO <sub>x</sub> , PM <sub>10</sub> , SO <sub>2</sub> , NMVOCs) VSL	329 152	291 050	274 609	277 302	237 010	238 591	226 419	186 285	173 111	193 056
Greenhouse gases (CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O)	193 641	187 188	183 596	181 747	180 129	180 852	174 949	157 898	137 567	150 657
Heavy metals (As, Cd, Cr, Hg, Ni, Pb)	13 803	13 055	13 179	11 553	14 041	14 493	13 395	10 140	8 039	8 924
Organic pollutants (benzene, dioxins and furans, PAHs)	66	143	141	147	140	154	99	60	52	69
<b>Sum VOLY</b>	<b>326 553</b>	<b>304 919</b>	<b>295 277</b>	<b>288 791</b>	<b>276 507</b>	<b>276 219</b>	<b>265 051</b>	<b>231 354</b>	<b>199 935</b>	<b>219 378</b>
<b>Sum VSL</b>	<b>536 663</b>	<b>491 437</b>	<b>471 524</b>	<b>470 749</b>	<b>431 320</b>	<b>434 089</b>	<b>414 862</b>	<b>354 383</b>	<b>318 769</b>	<b>352 707</b>

Main air pollutants: mortality valued by VOLY for low range and by VSL for high range

- Damage for main air pollutants from 2012 to 2021 (million €<sub>2019</sub>) – indicator VOLY for mortality



## Aggregated damage costs

- Dominated by costs from main air pollutants (VSL) and greenhouse gases

Reduction in damage in 2021 relative to 2012

- Main air pollutants: 50% VOLY (41% VSL)
- Greenhouse gases : 22%
- Heavy metals: 35%
- Organic pollutants: 5% (52% rel. to 2013)

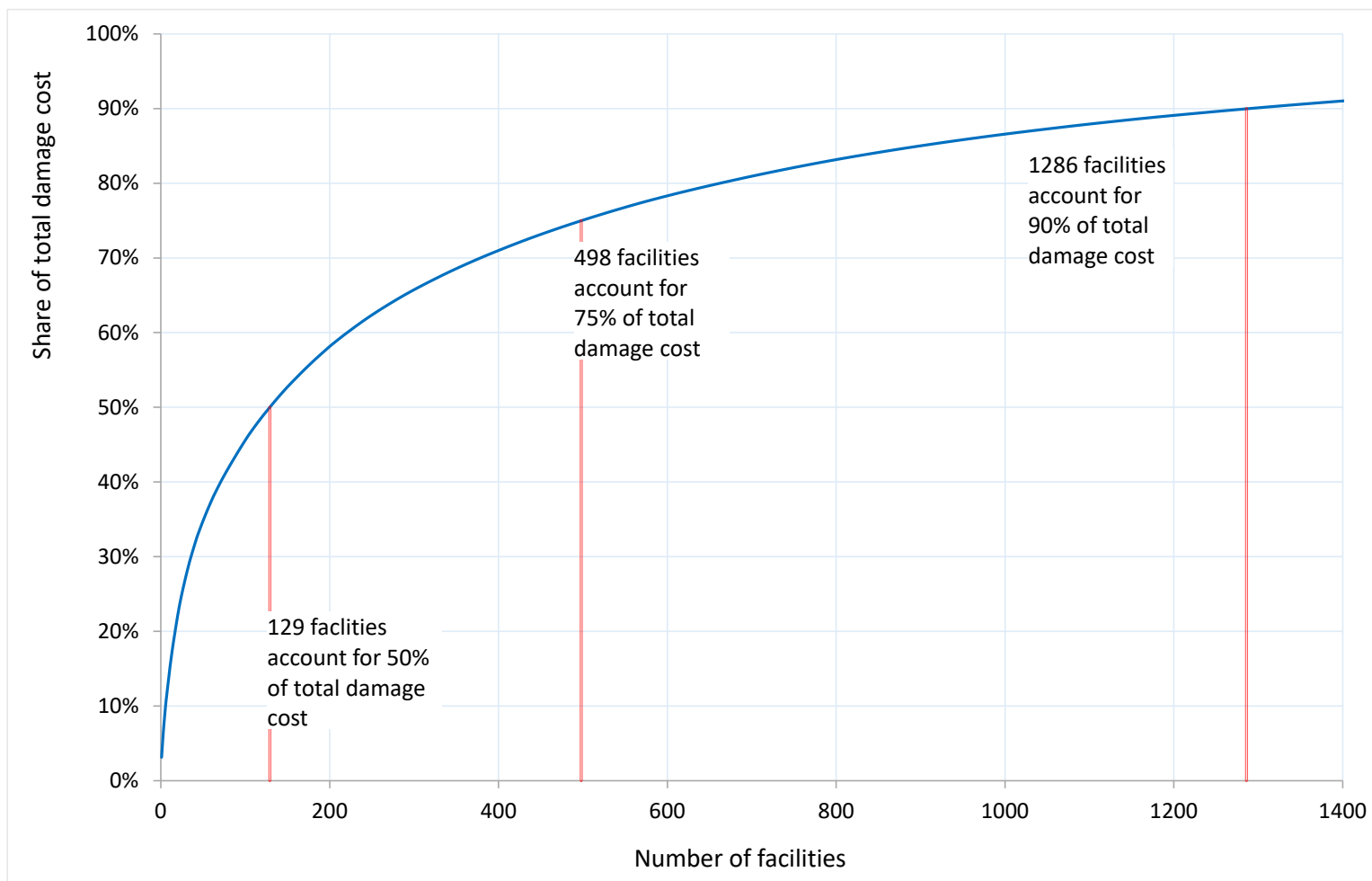
## Main air pollutants

- Reduction most important for SO<sub>2</sub> and PM<sub>10</sub>, followed by NO<sub>x</sub> and NMVOCs
- Damage related to NH<sub>3</sub> increased



# A small number of plant account for 50% of damage

- Cumulative distribution of the estimated damage costs from main air pollutants, 2021 – mortality valued using the VOLY indicator



Number of facilities accounting for 50% of damage in 2021:

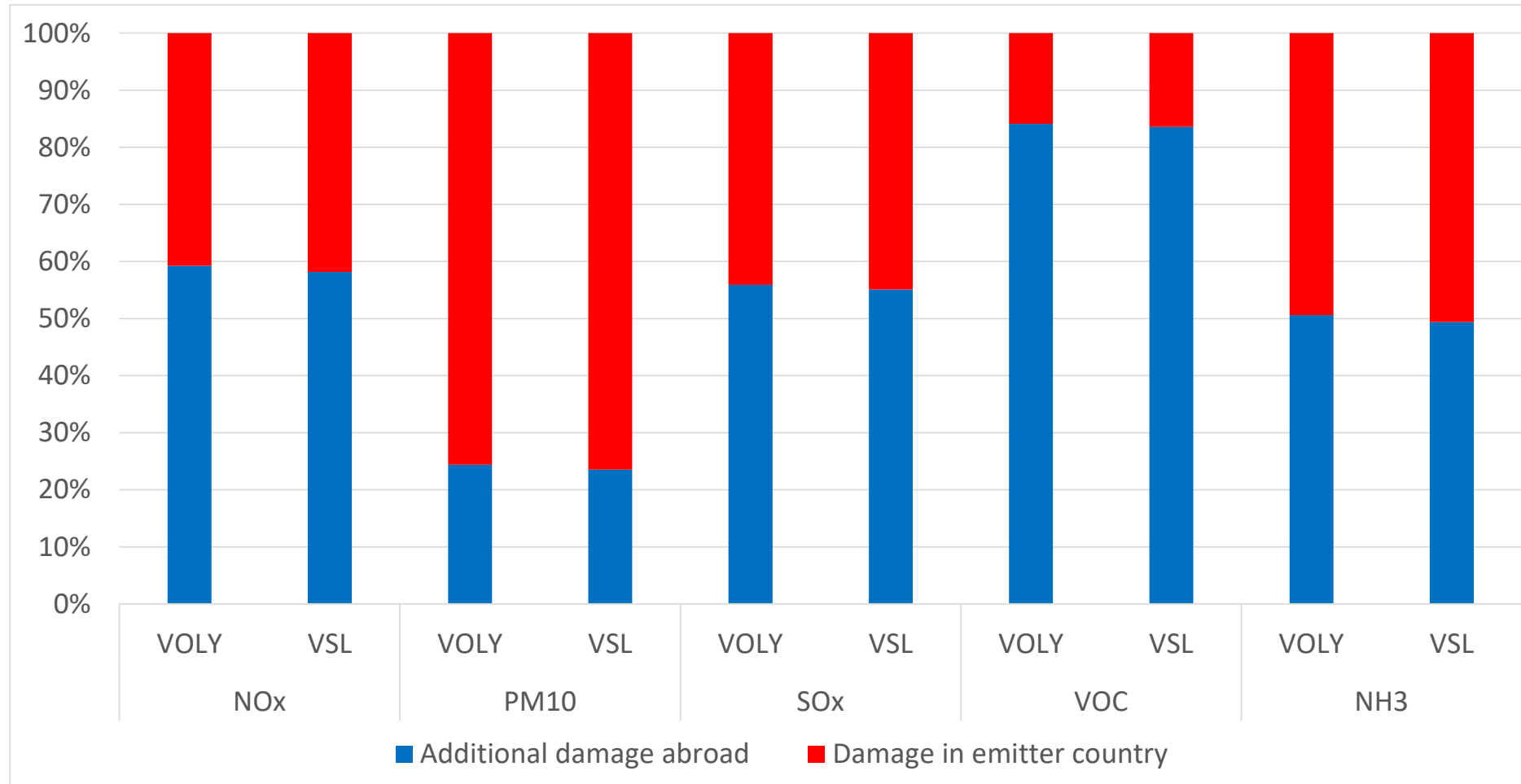
- Main APs: 129 (out of 8,140 reporting)
- GHGs: 170 (out of 2,745)
- Heavy metals: 19 (out of 528)
- Organic pollutants: 6 (out of 352)





# Neglecting transboundary impact ignores important share of damage

- Comparison between damage in emitter country and additional transboundary damage in % (example: health damage for PM<sub>2.5</sub> precursors in France)



# Conclusions and outlook

- Update of MDC calculation
  - Use of latest SRMs, new scientific findings, updated health endpoints and valuation, year-specific MDCs for health
- Further development of sectoral adjustment factors for all sectors and countries
- Externality results consistent with those of previous editions
  - Broad magnitude of numbers, performance of facilities relative to one another, and trends in terms of % reduction in damage over time, are relatively stable
- General consistency with Third Clean Air Outlook
  - exposure-response functions for, and monetisation of, health impacts from main air pollutants
- Priorities for further updates could be
  - Updating health endpoints and response functions (EMAPEC, HRAPIE II)
  - Use ozone flux indicator for crop & forest assessment (POD SRMs now available)
  - Use of 5-year meteorology averaged SRMs (as in GAINS)
  - Obtain production data to better account for the efficiency of production



# Thank you for your attention!

## EEA briefing 2024:

[The costs to health and the environment from industrial air pollution in Europe – 2024 update — European Environment Agency \(europa.eu\)](#)

## Technical note 2024:

[https://www.eea.europa.eu/publications/the-cost-to-health-and-the/technical-note\\_estimating-the-external-costs/view](#)

## Previous full report, ETC/ATNI 04/2020:

[https://www.eionet.europa.eu/etcs/etc-atni/products/etc-atni-reports/etc-atni-report-04-2020-costs-of-air-pollution-from-european-industrial-facilities-200820132017/@@download/file/ETC-ATNI\\_2020-4\\_Task-1222\\_FINAL\\_v2\\_17-08-2021.pdf](#)

