Universität Stuttgart
Institute of Energy Economics and the Rational Use of Energy
IER

ESPREME

EU 6th Framework Programme

DROPS –

Integrated Impact Assessment of Selected Heavy Metals and POPs at the European Level

Results from ESPREME and First Results from DROPS

Main contributors:

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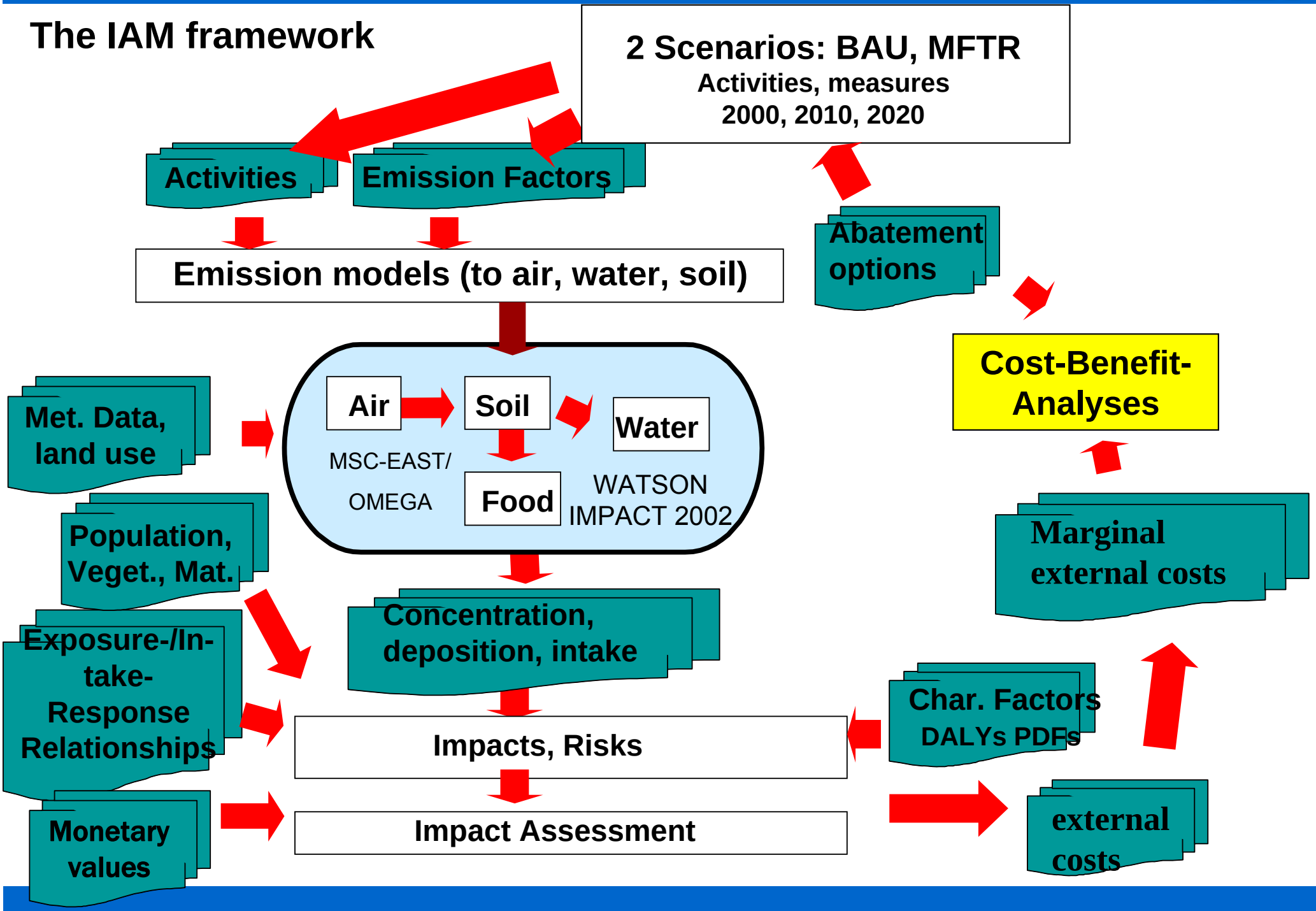
IOM Edinburgh, IVL Gothenburg

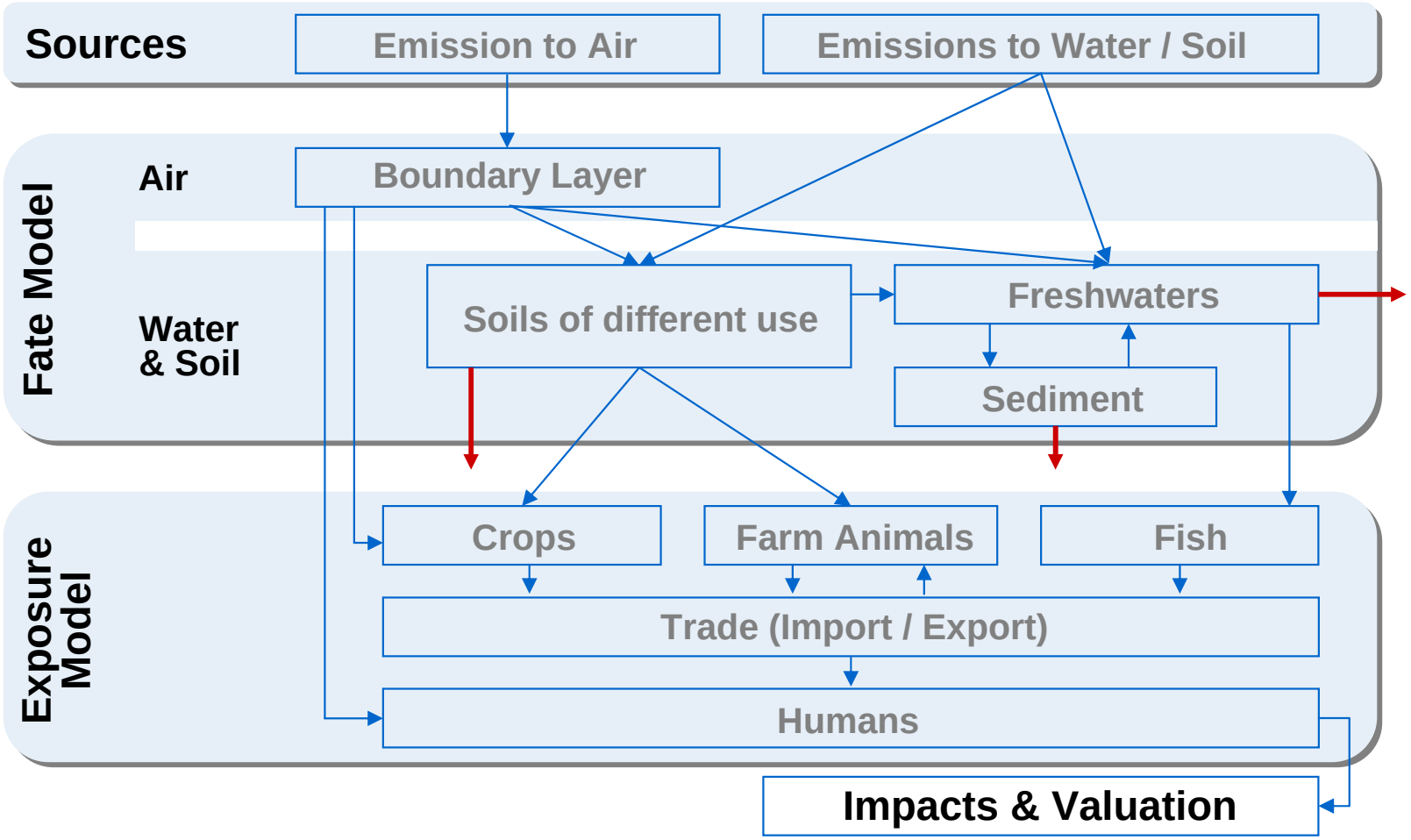
Task Force on Integrated Assessment Modelling, Madrid (Spain)

08th – 09th May 2008

The IAM framework



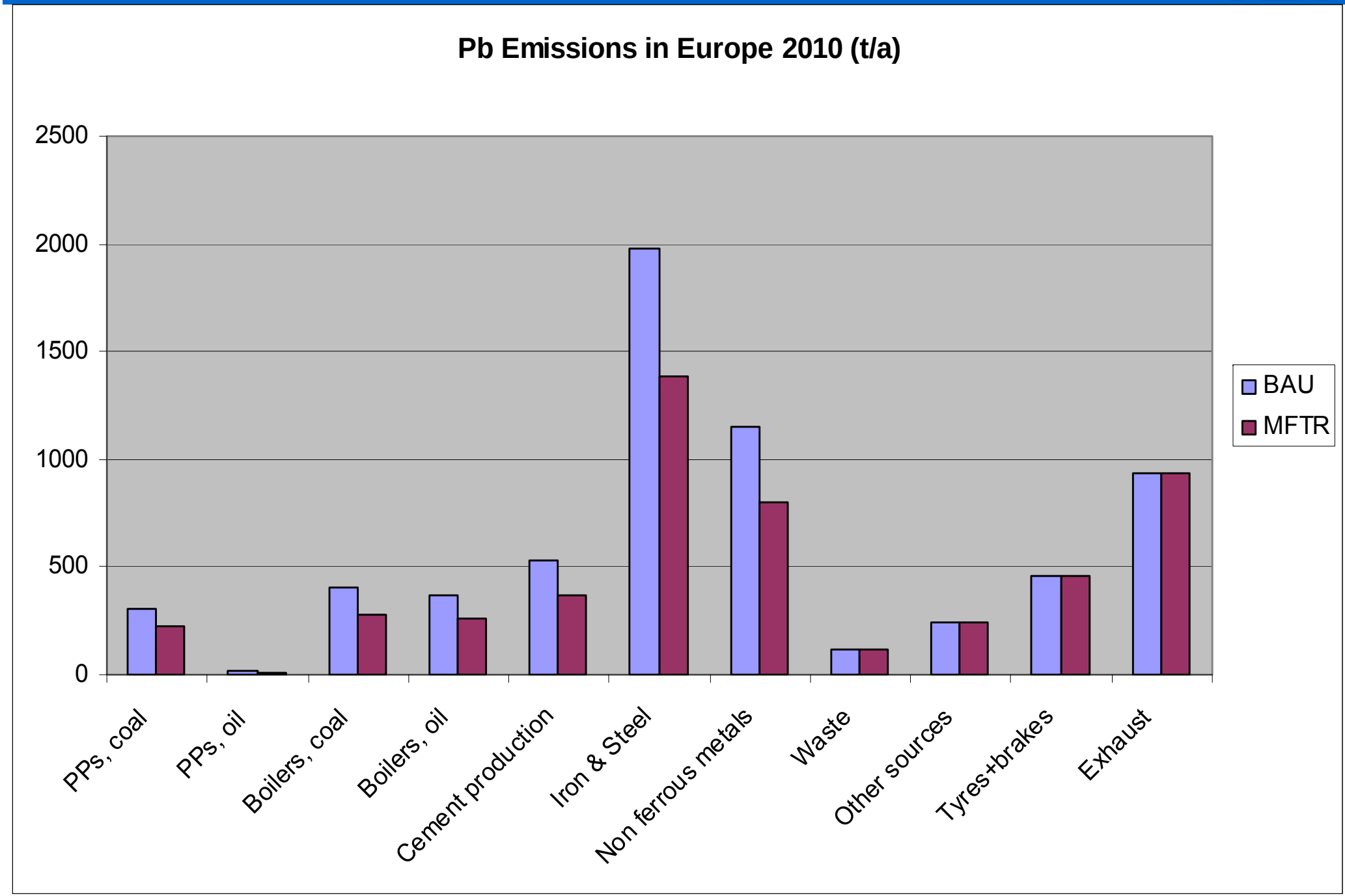
Soil and Water Model WATSON – Model Concept

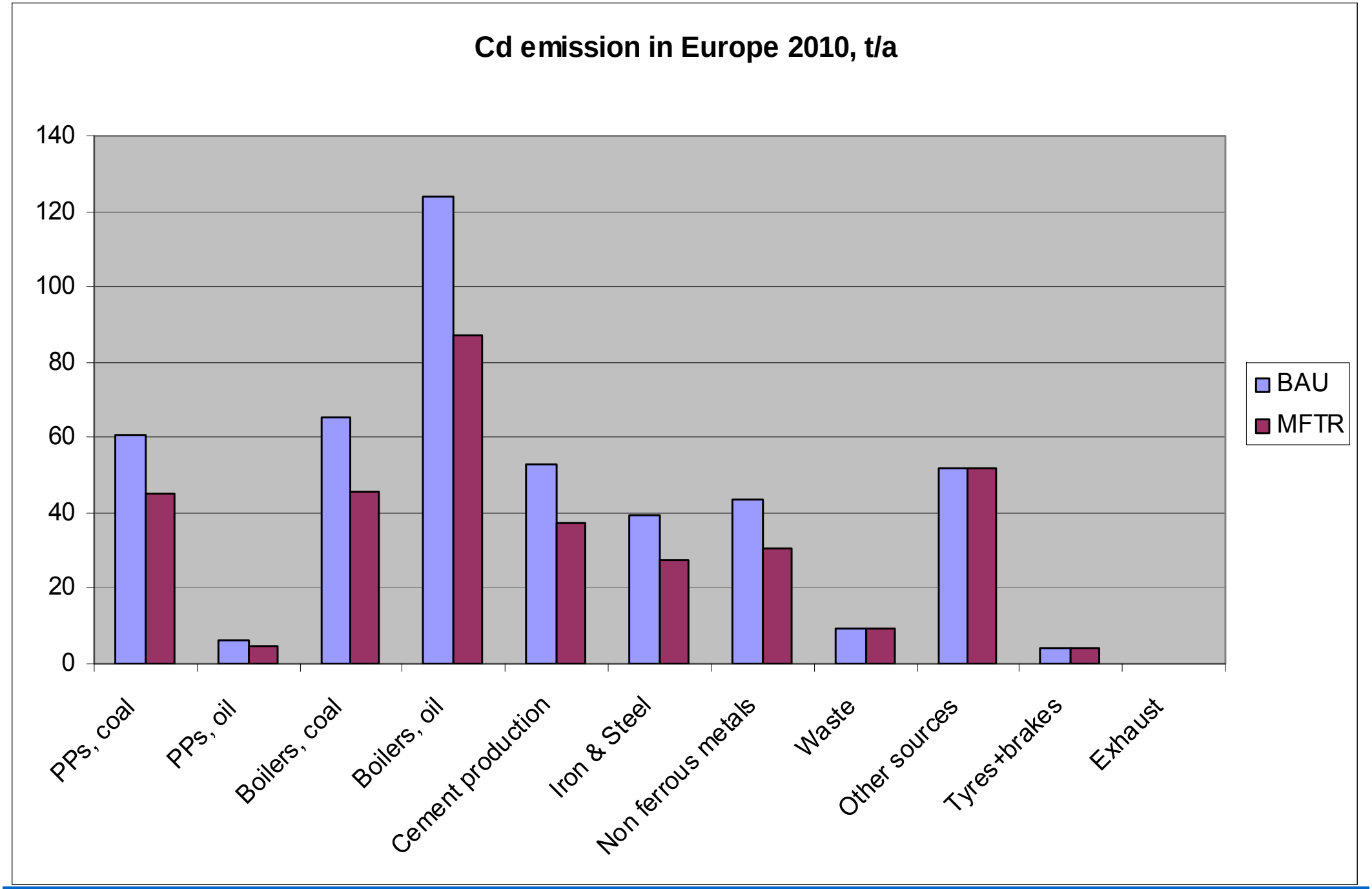


Scenario abatement measures (1)

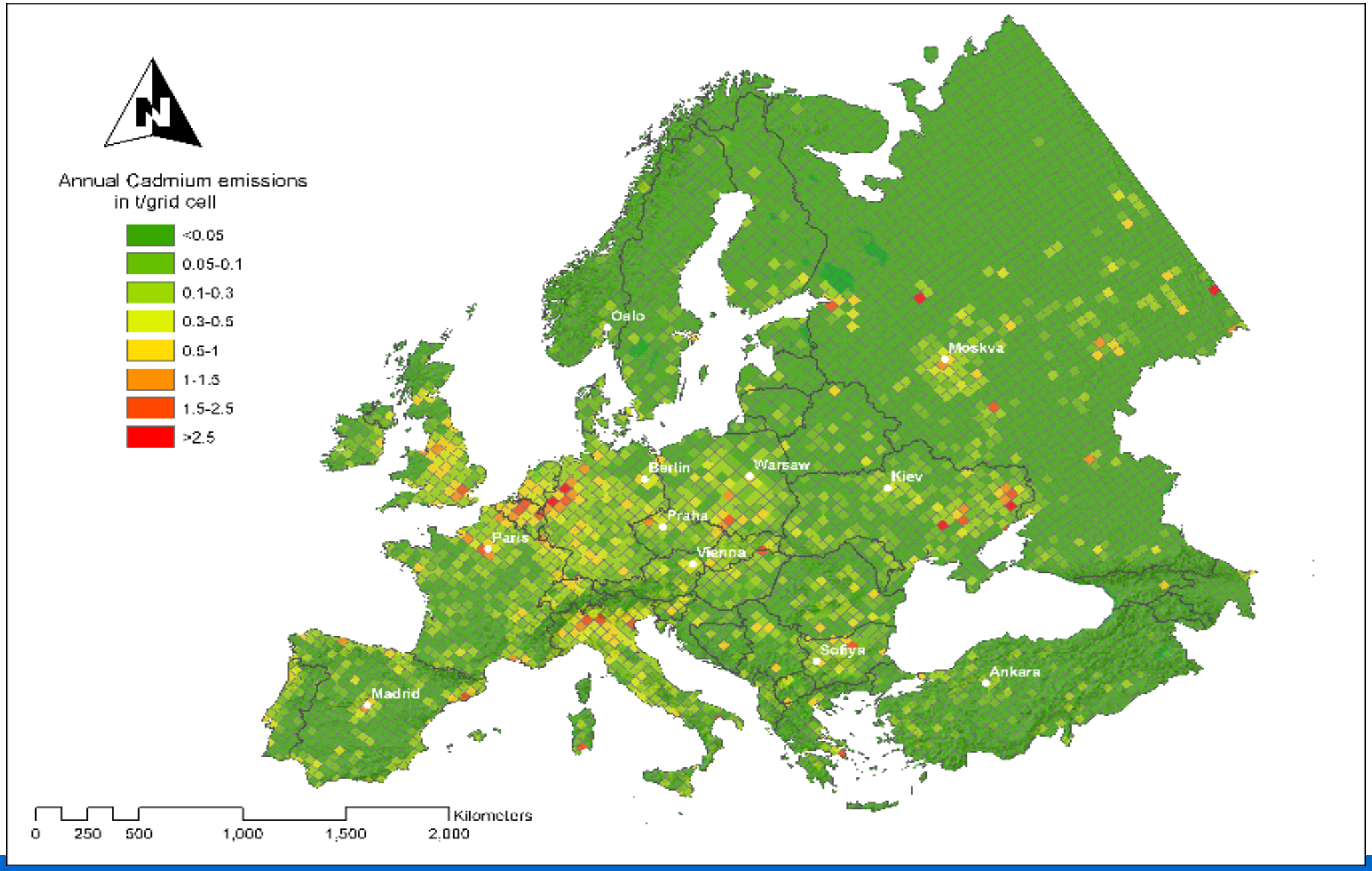
Sector	BAU 2010	BAU 2020	MFTR 2010	MFTR 2020
Large combustion plants	Dedusting: Fabric filters and electrostatic precipitator operated in combination with FGD	• Activated carbon filter • Sulphur-impregnated adsorbents • Selenium impregnated filters	Like BAU 2020	• Integrated gasification combined cycle (IGCC) • Supercritical polyvalent technologies • In 2020 50% participation in electricity generation by thermal method
Iron and steel production	• In sintering: Fine wet scrubbing systems or fabric filters with addition of lignite coke powder • In blast furnaces: Scrubbers or wet ESPs for BF treatment • In basic oxygen furnace: Dry ESPs or scrubbing for primary dedusting and fabric filters or ESPs for secondary dedusting	In sintering: Catalytic oxidation	• BAU 2010 and 2020 techniques in existing insatallations • Sorting of scrap	• New iron-marking techniques • Direct reduction and smelting reduction

Sector	BAU 2010	BAU 2020	MFTR 2010	MFTR 2020
Cement industry	Dedusting: fabric filters and electrostatic precipitators		Like BAU 2020	• All plants with techniques for heavy metals reduction • To 2010 activity decrease by 7% • To 2020 activity decrease by 29% (DEG)
Agriculture			• 80% reduction of sewage sludge applications on agricultural areas • 80% reduction of the use of basic slag for liming • 80% reduced amounts of heavy metals in the forage of cattle, pigs, poultry, sheep and goats • 80% reduced amount of nitrogen application to fields in countries outside the EU	
Chlor-alkali industry	Phase-out of mercury cell plants by 2010			
Road transport	Phase-out of leaded petrol in all countries except Russia, Belarus and Serbia-Montenegro (Directive 2003/17/EC for EU-countries)			

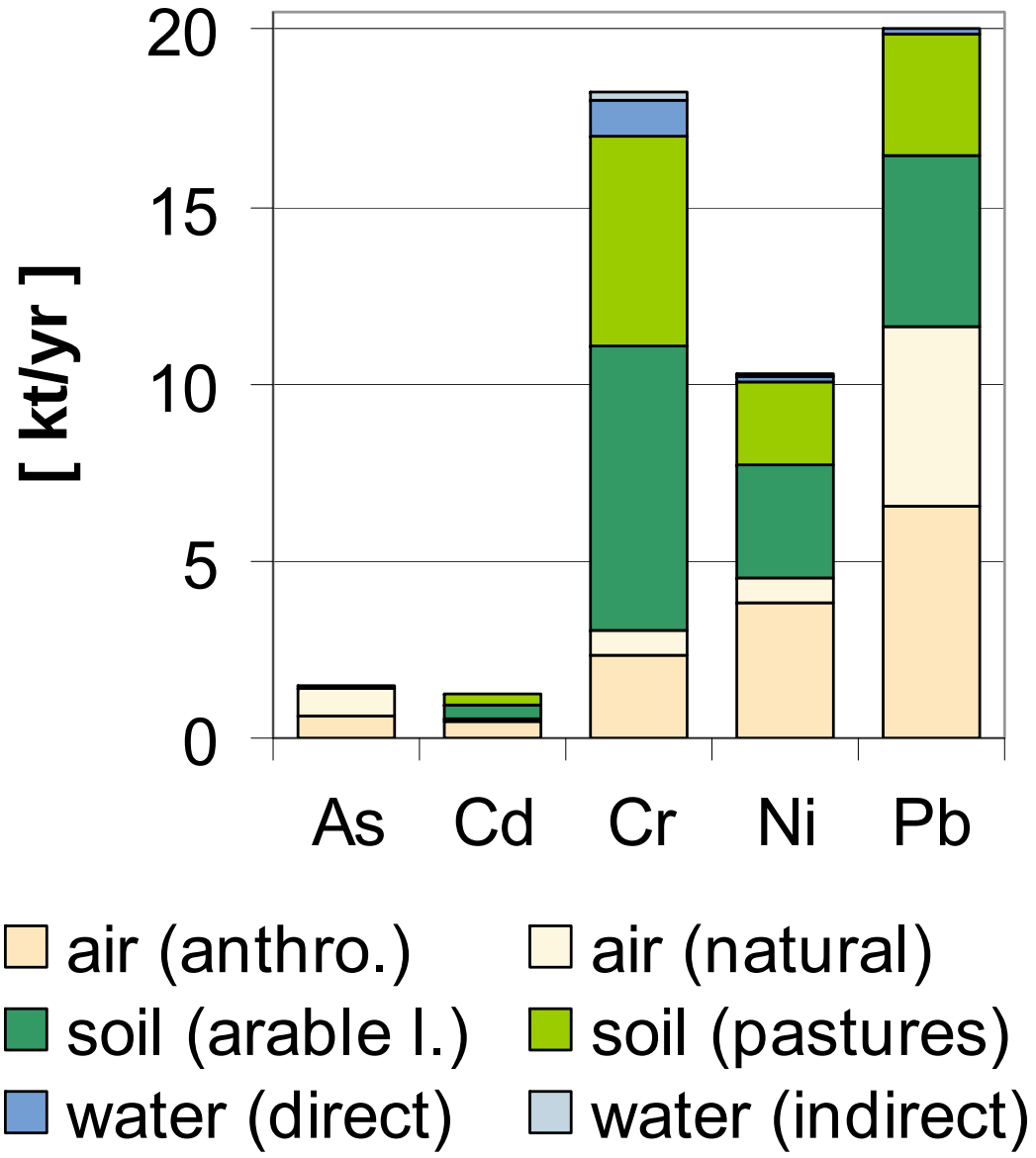

Pb Emissions in Europe 2010 (t/a)
2500
2000
1500
1000
500
0
BAU
MFTR
PPs, coal
PPs, oil
Boilers, coal
Boilers, oil
Cement production
Iron & Steel
Non ferrous metals
Waste
Other sources
Tyres+brakes
Exhaust


Cd emission in Europe 2010, t/a
140
120
100
80
60
40
20
0
BAU
MFTR
PPs, coal
PPs, oil
Boilers, coal
Boilers, oil
Cement production
Iron & Steel
Non ferrous metals
Waste
Other sources
Tyres+brakes
Exhaust

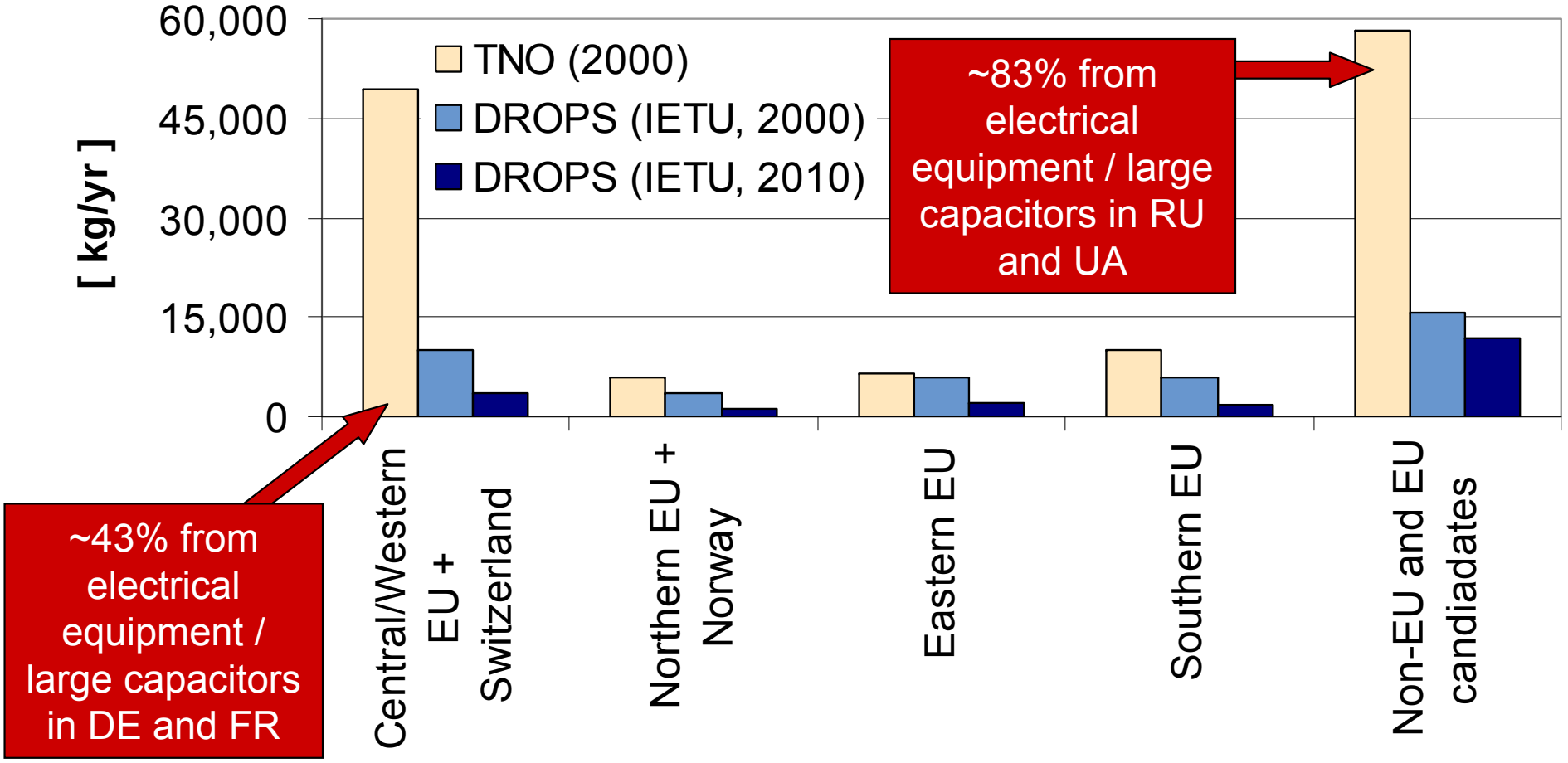
Cd Emissions – Spatial Distribution



HM Emissions into Air, Water and Soil, BAU 2010

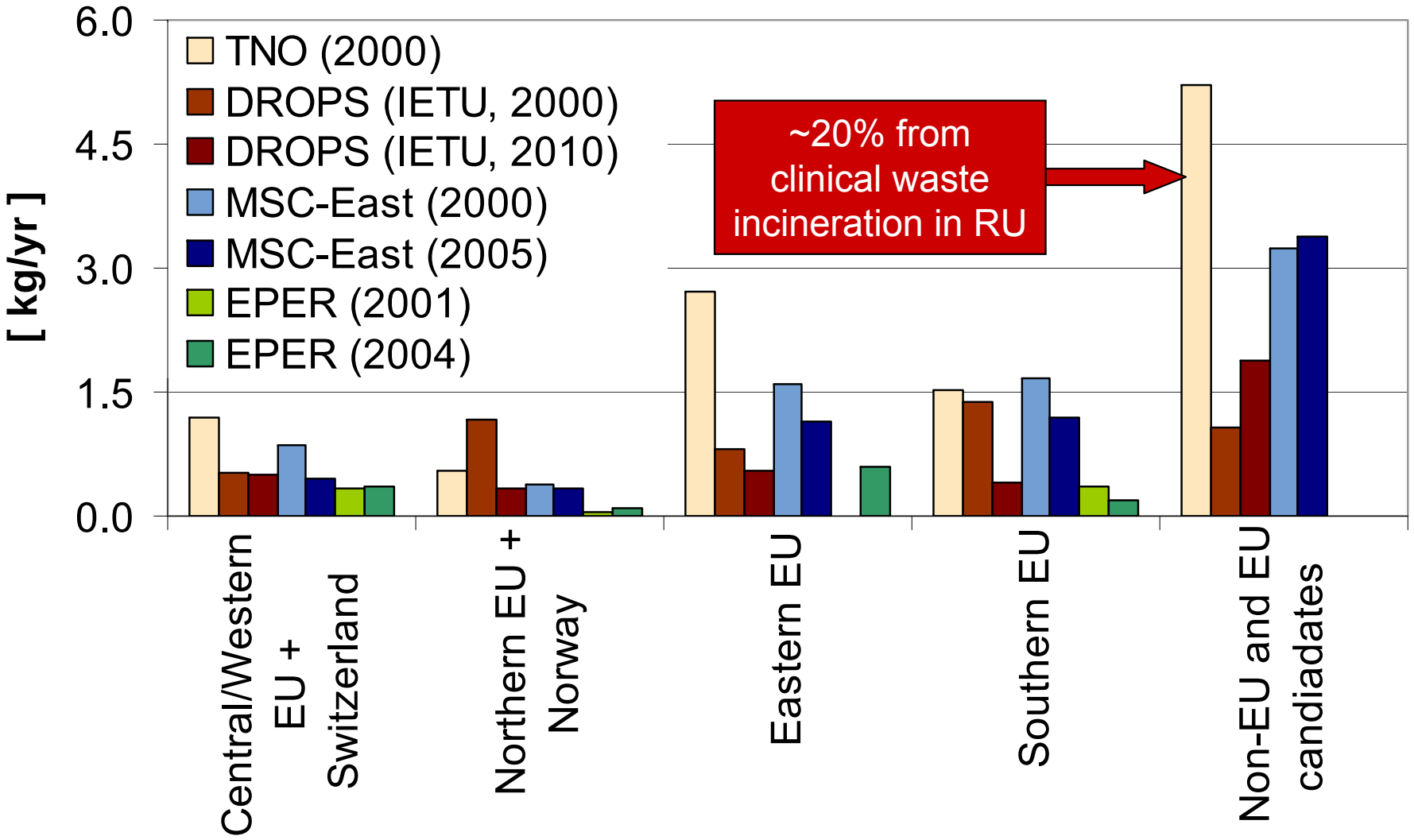


Comparison of PCB Air Emissions



- Further emission data: *Breivik K, Sweetman A, Pacyna JM and Jones KC, 2007. Towards a global historical emission inventory for selected PCB congeners - a mass balance approach. Science of the Total Environment 377 (2-3): 296-307.*

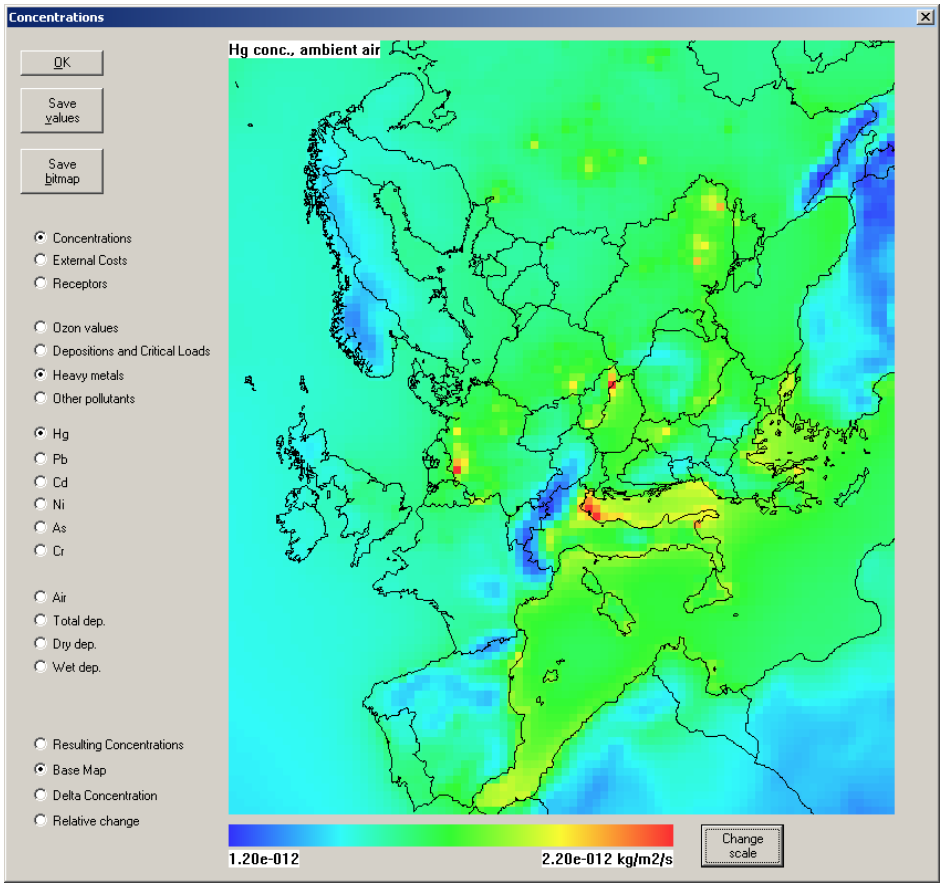
Comparison of PCDD/F Air Emissions



- EPER data only available for selected countries.

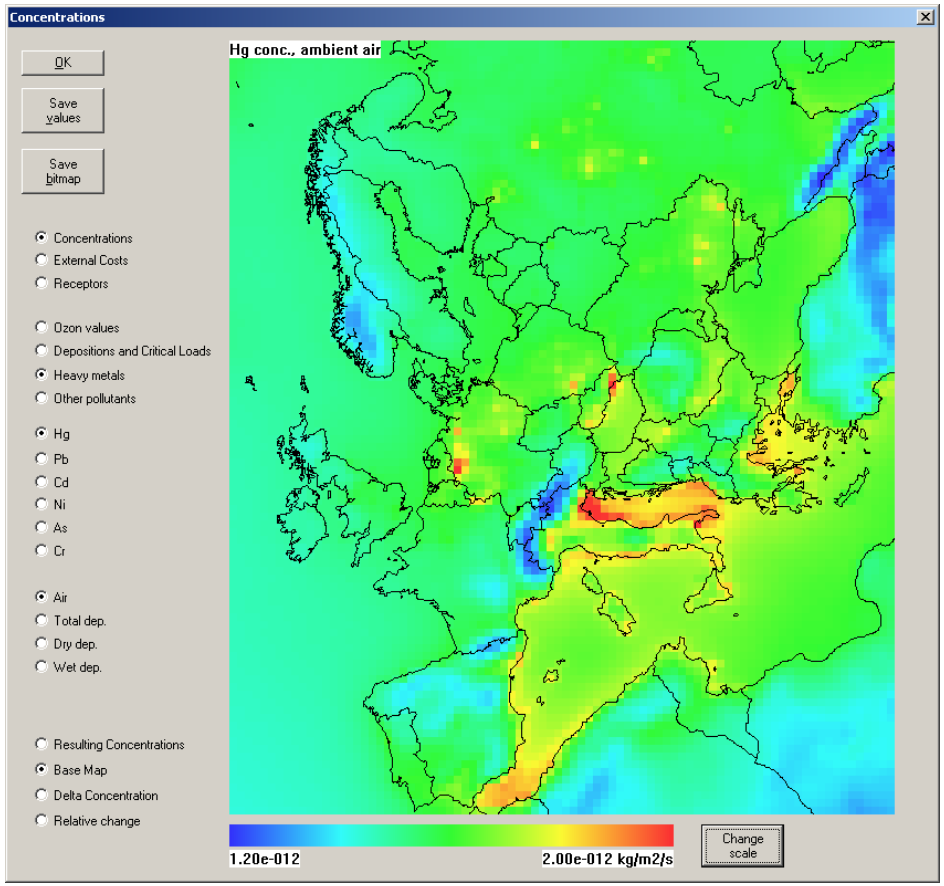
Average annual Hg concentration

BAU



Cell (100,60): 1.67 ng/m3

MFTR

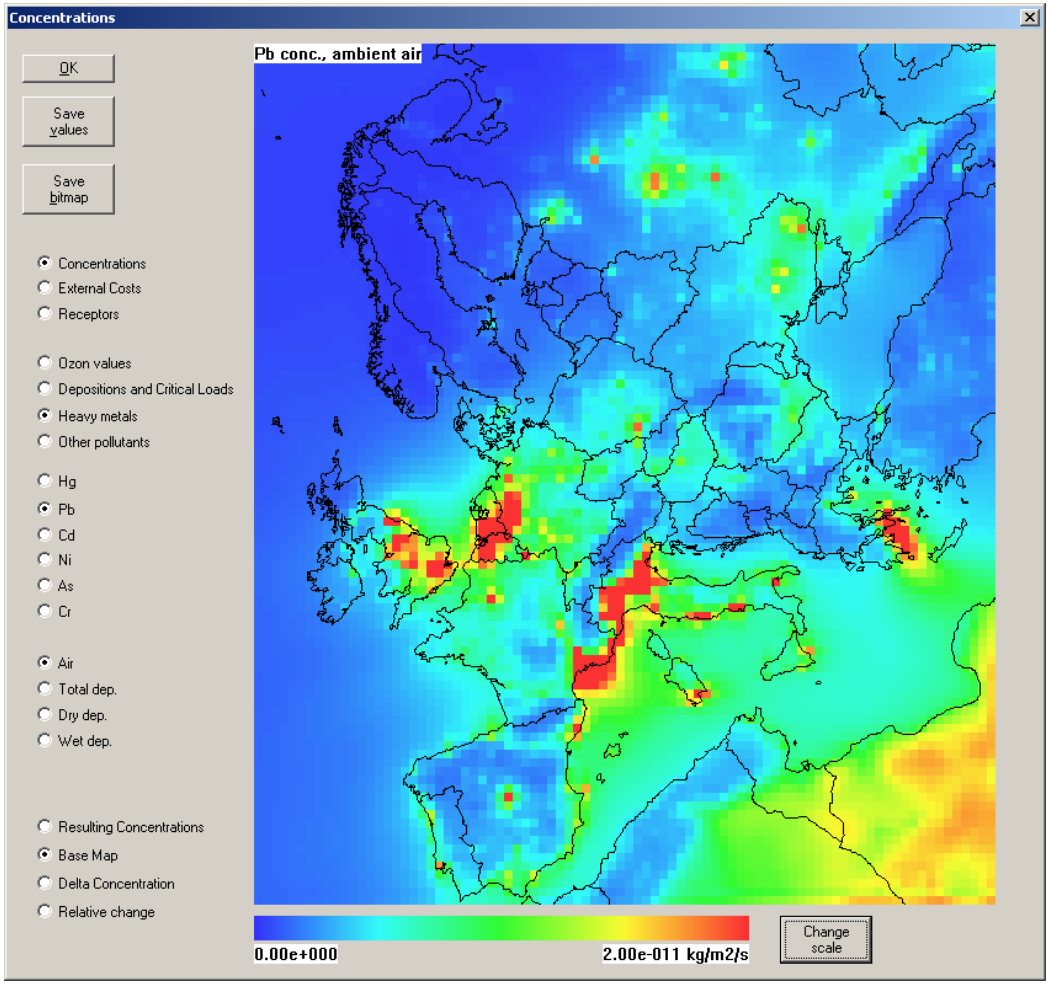


Cell (100,60): 1.64 ng/m3

Reduction is only 1.4 %

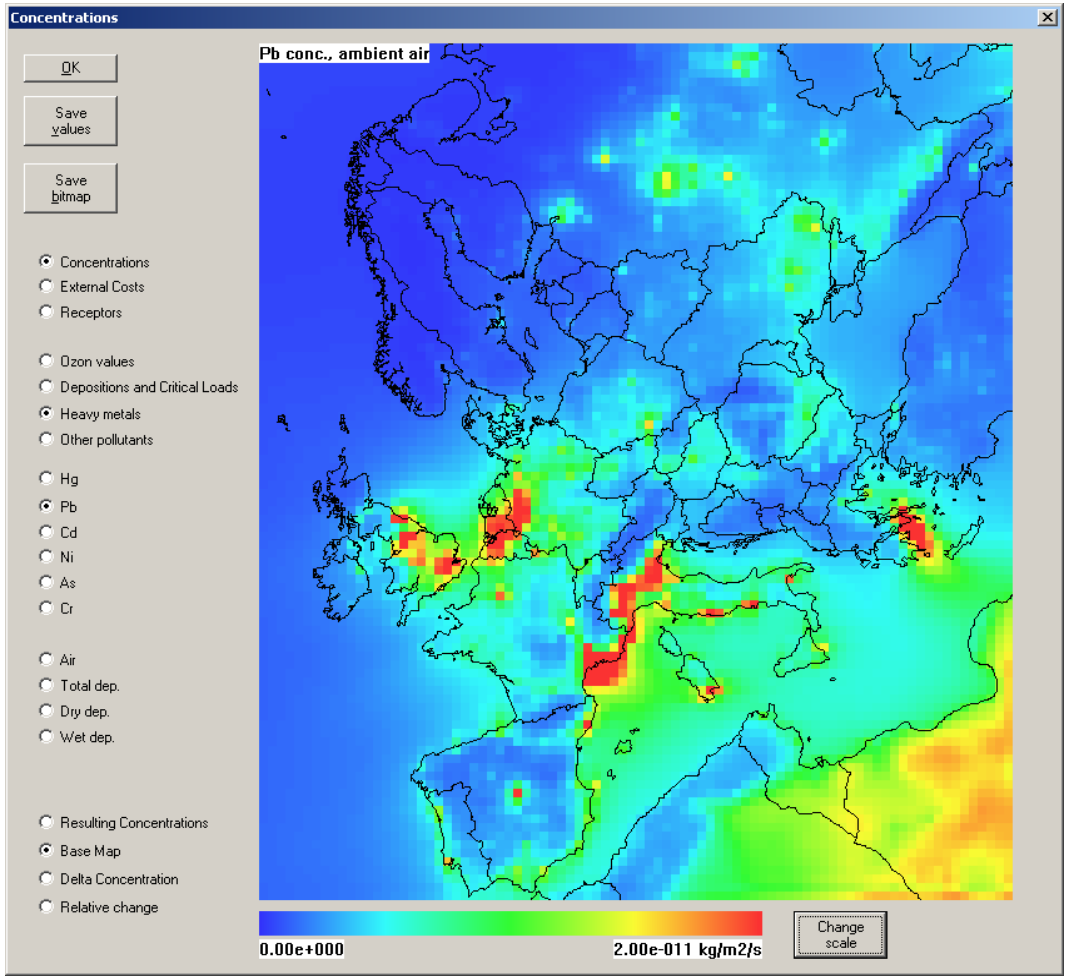
Average annual Pb concentration

BAU



Cell (100,60): 6.76 ng/m3

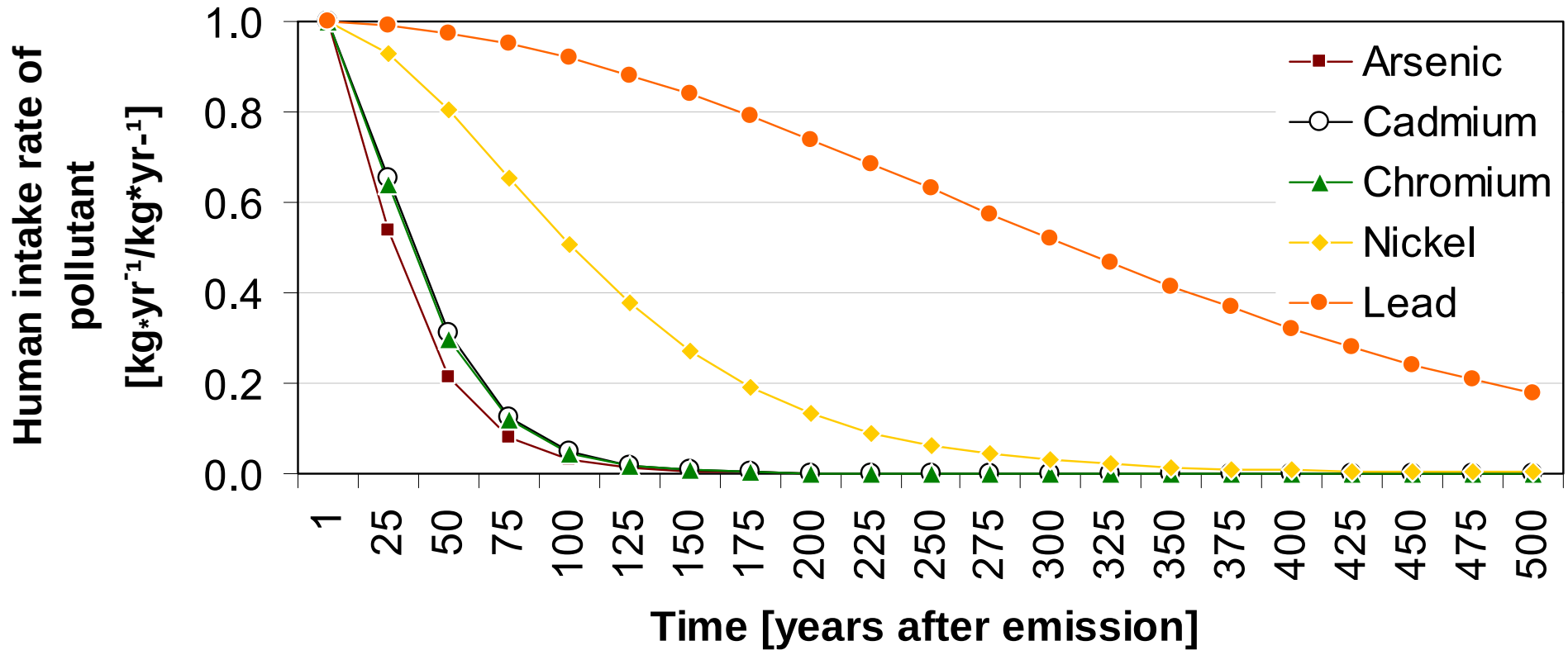
MFTR



Cell (100,60): 6.10 ng/m3

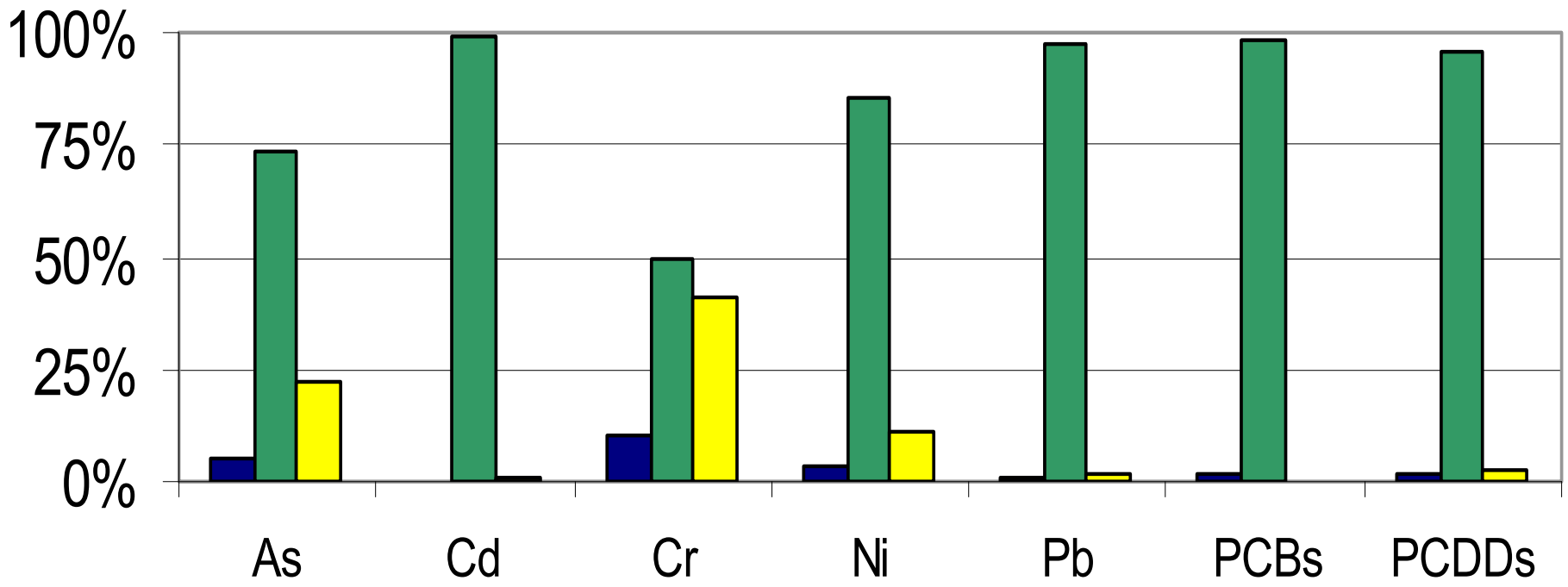
Time dependency of HM exposure

- Availability of HMs for ingestion exposure in Europe over 500 years



- Levels of arsenic, cadmium and chromium below 10% after less than 100 years while level of lead still is about 20% after 500 years.

Share of Intake Pathways



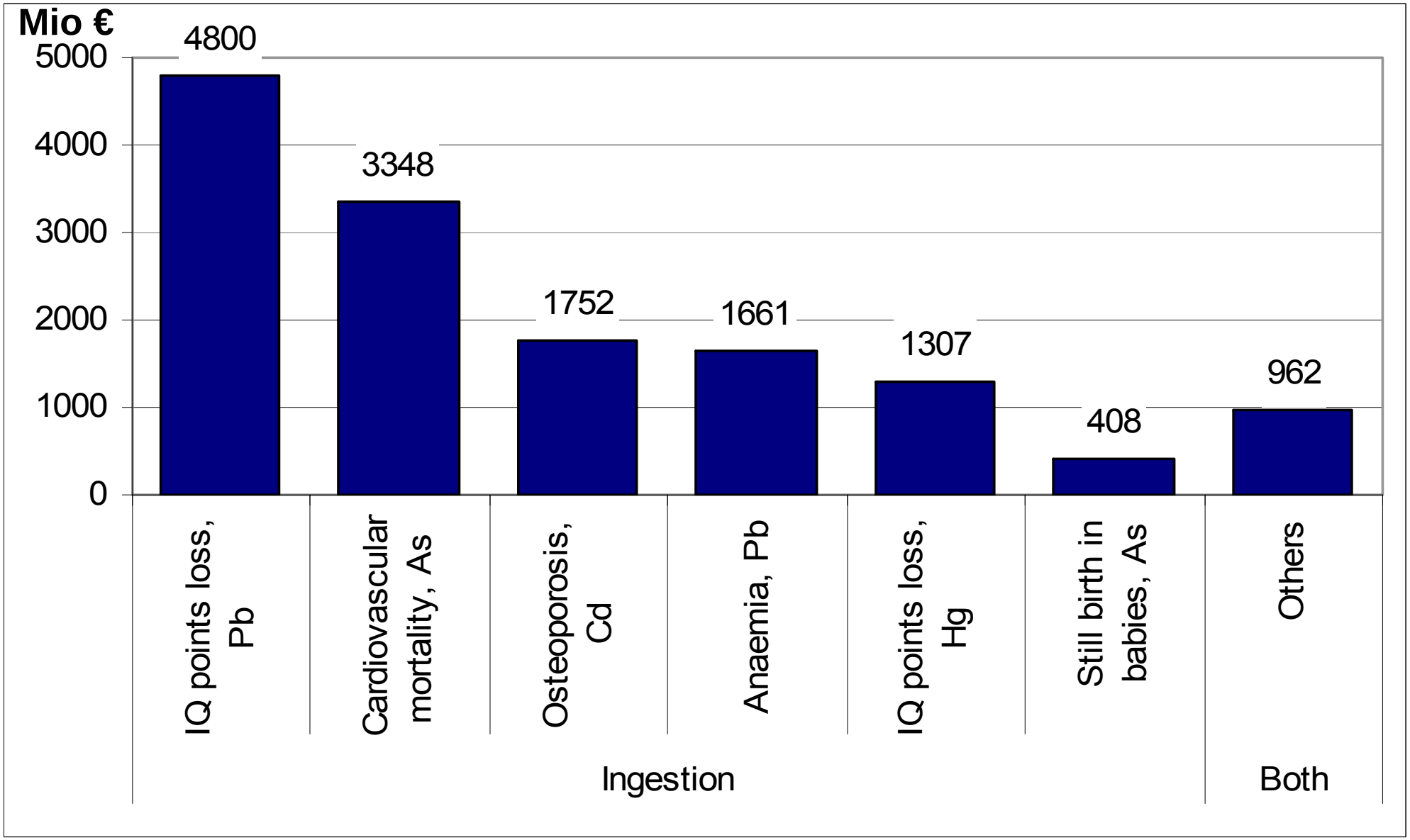
More reliable concentration-/intake-response functions

Pollutant	Exposure Pathway	Exposure [years]	Human Health End-point
As	Ingestion (Food/Water)	70	Bladder cancer
As	Inhalation	70	Bladder cancer
As	Inhalation	70	Lung cancer
As	Ingestion (Food/Water)	70	Skin cancer
As	Inhalation	70	Skin cancer
As	Ingestion (Food/Water)	1	Still birth
As	Inhalation	1	Still birth
Cd	Inhalation	70	Total cancer, 85% fatal
Cr(VI)	Inhalation	70	Lung cancer
methyl Hg	Ingestion (Food/Water)	1	IQ-Points loss in children
Ni	Inhalation	70	Lung cancer
Pb	Ingestion (Food/Water)	1	IQ-Points loss in children
Pb	Inhalation	1	IQ-Points loss in children
PCBs	Ingestion (Food/Water)	70	Total cancer, 50% fatal
PCBs	Inhalation	70	Total cancer, 50% fatal
PCDDs	Ingestion (Food)	70	Total cancer, 50% fatal

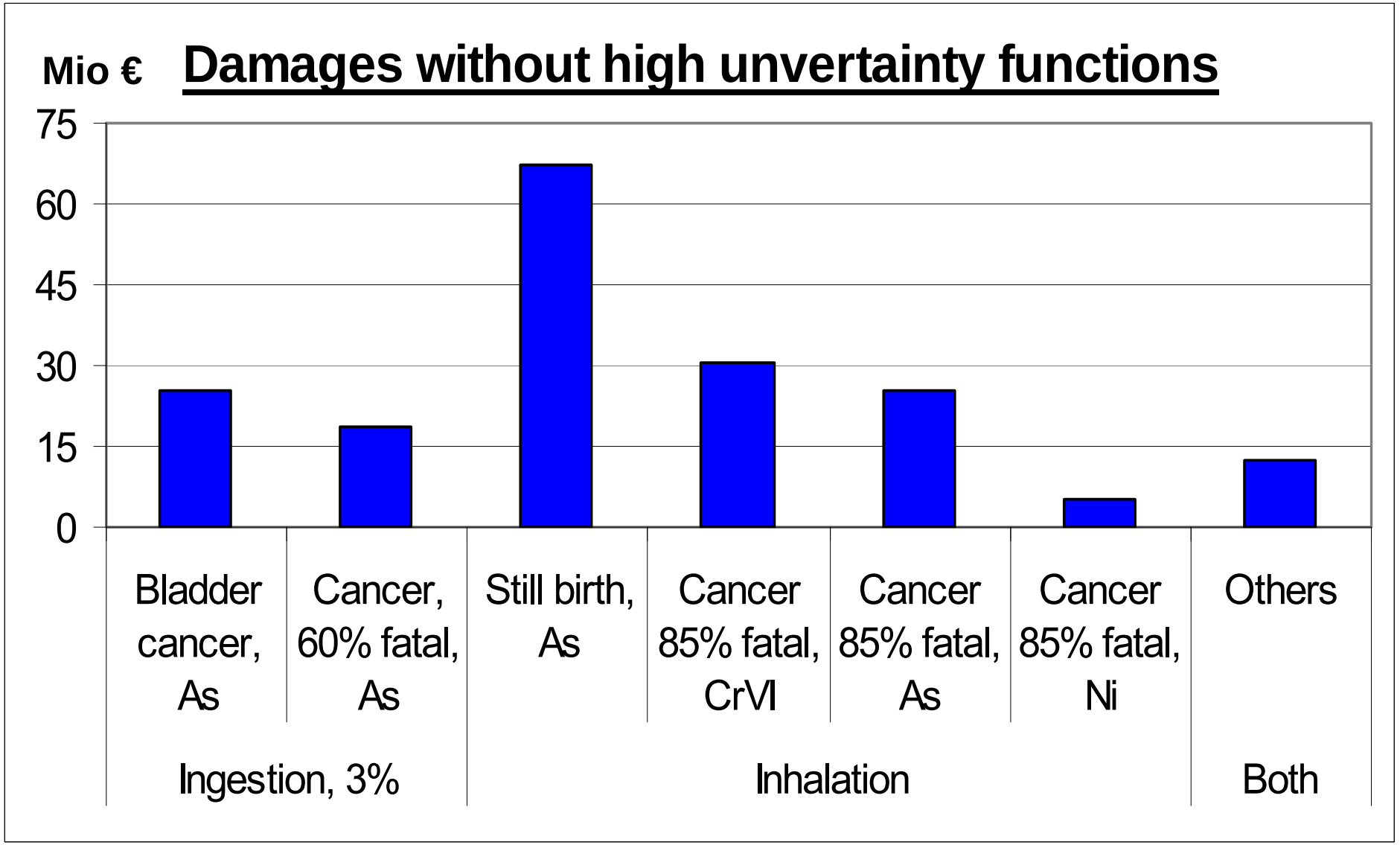
Health end-points with higher uncertainties

Pollutant	Exposure Pathway	Exposure [years]	Human Health End-point
As	Ingestion (Food/Water)	35	Cardiovascular mortality
As	Inhalation	35	Cardiovascular mortality
Cd	Ingestion (Food/Water)	35	Osteoporosis
Cd	Inhalation	35	Osteoporosis
Cd	Ingestion (Food/Water)	35	Renal dysfunction
Cd	Inhalation	35	Renal dysfunction
Hg	Ingestion (Food/Water)	35	CHS effects in adults (ataxia)
Hg	Inhalation	35	CHS effects in adults (ataxia)
Hg	Inhalation	35	Renal dysfunction (preclinical effects)
Pb	Ingestion (Food/Water)	1	Anaemia
Pb	Inhalation	1	Anaemia

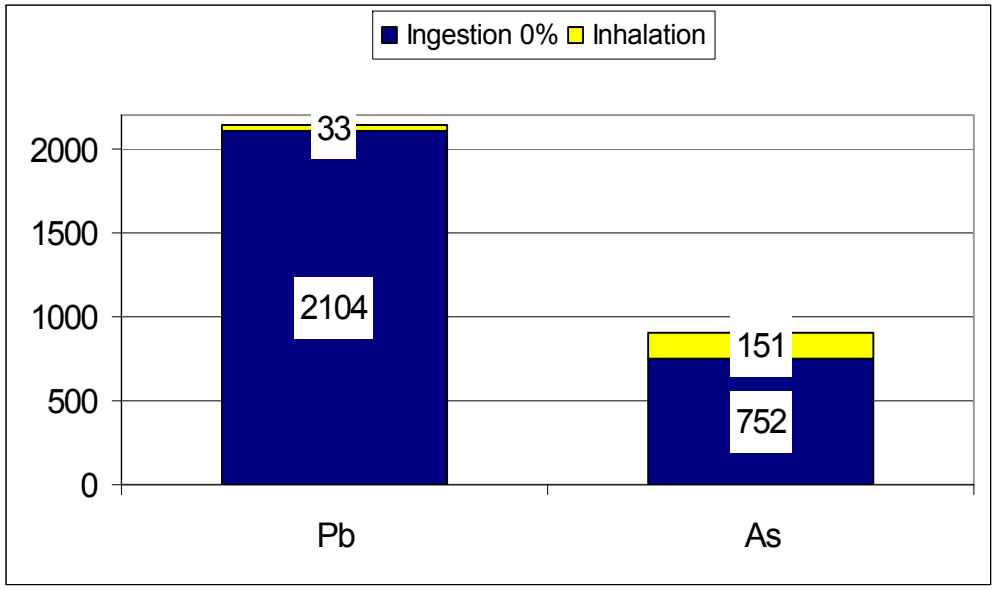
Highest overall impacts, all C-R-R; I-R-R, 3% discounting

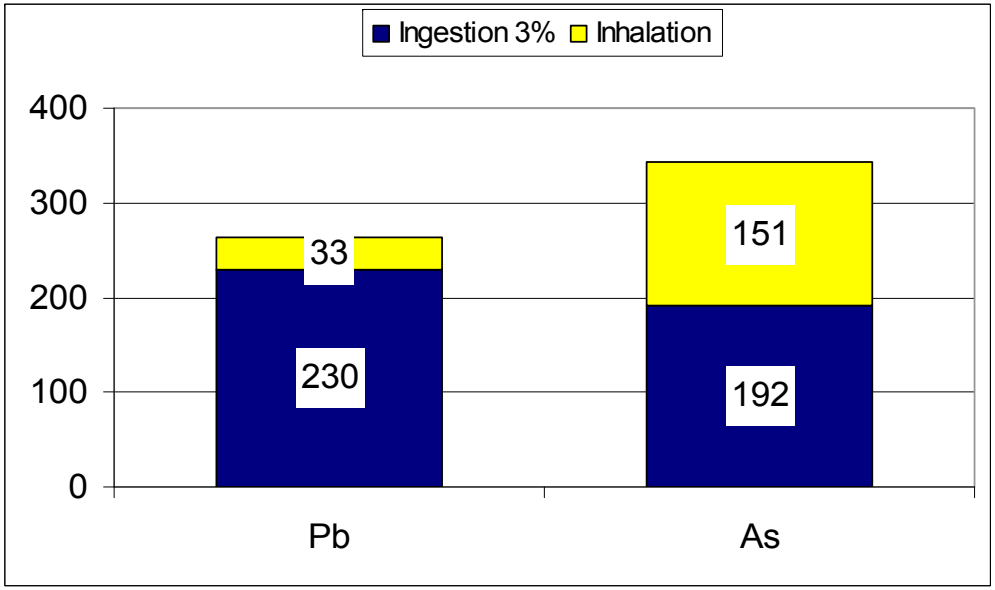


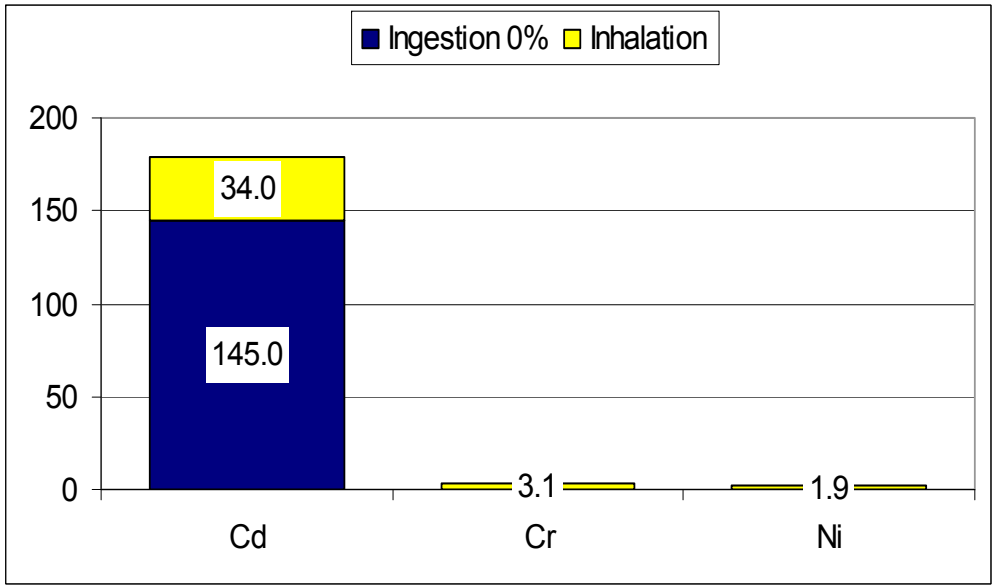
Damages 4

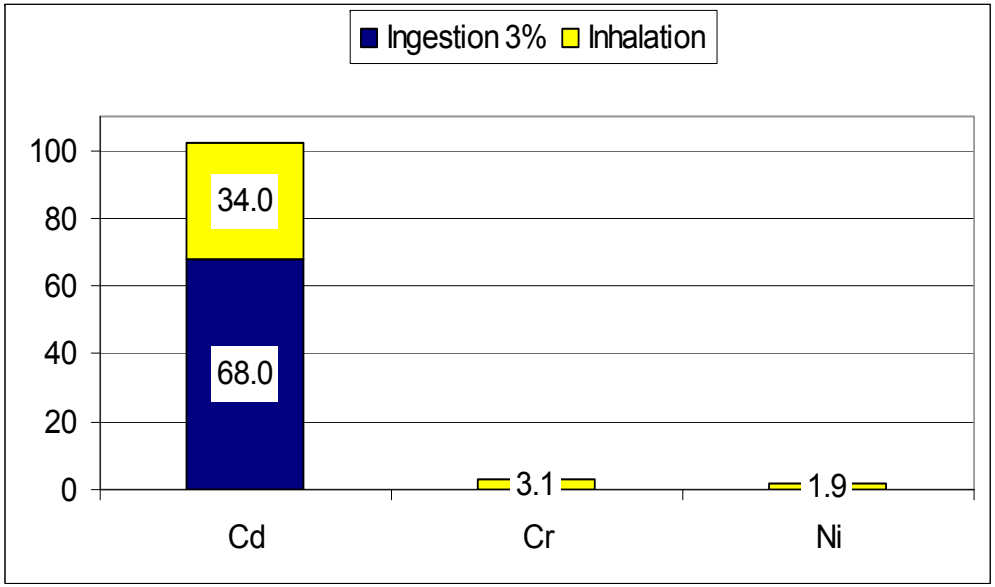

Mio €
Damages without high unvertainty functions
75
60
45
30
15
0
Bladder cancer, As
Cancer, 60% fatal, As
Still birth, As
Cancer 85% fatal, CrVI
Cancer 85% fatal, As
Cancer 85% fatal, Ni
Others
Ingestion, 3%
Inhalation
Both

Marginal External Costs [€ per $kg_{released}$], European average









Marginal External Costs [€ per $kg_{released}$]

Mercury: 8000 €/kg

€/kg	Cancer via food	Cancer via drinking water
PCBs	1 €/kg	0,006 €/kg
Dioxins/furanes	5 000 €/kg	40 €/kg

PM10 high stack Germany: 9€/kg

PM10, transport, agglomeration: 400 €/kg

Cost-benefit analysis

Sector	Measure	Hg red. efficiency	HM red. efficiency	Costs per SAI	PPM2.5	Inhalation	Ingestion	Efficiency
					Reduction of external costs/SAI			
Hard coal combus	dry ESP 1	24,0	95,0	3,9	31,0	0,5	0,3	28,0
Hard coal combus	dry ESP 2	72,0	100,0	7,1	32,6	0,6	0,6	26,0
Cement productio	FF medium efficient	5,0	96,0	1,6	200,7	1,8	0,7	201,6
Cement productio	FF (optimized)	98,0	99,9	3,1	209,0	1,8	1,8	209,5

Conclusions

- Tool to carry out integrated assessment for heavy metals developed and available, however high uncertainties at all steps.
- Hg, Pb and As cause higher overall impacts than Cd, Cr VI, Ni, dioxins/furans and PCBs.
- Marginal external costs per kg range from several € (Ni, CrVI), ca 200 € (Cd), 1000 € (As), 2000 € (Pb) to several 1000 € (Hg) (with zero discounting).
- With 3 % discounting values for As, Pb and Cd are 350 €, 250 € and 100 € resp
- Generally damage due to ingestion is much higher than damage due to inhalation; however it occurs farer in the future, thus issue of sustainability versus current welfare.
- Agricultural activities cause the highest (long term) human health damage for Pb and Cd and possess the highest reduction potential (e.g. sewage sludge incineration with efficient filters).
- Open issue: waste: old landfills.
- Reduction measures have a positive capital value, if they also have a positive effect on other damage categories (PM10 reduction, climate change).
- For coal combustion and industrial processes, an improvement of implementation and of efficiency of dust filters may be efficient – also PM 10 strategy. Mercury: further implementation of FGD. For household heating, switch from coal and oil to natural gas or renewables or to central heating (CHP) – also climate strategy. For lead, explore possibilities to further reduce lead in lead-free gasoline and use biofuels.
- The contribution of annual emissions to critical load exceedance is low. However critical loads would be frequently exceeded in the far future, if emissions continue for very long time spans.

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