Assessment of measures for reducing impacts of particulate matter - partly based on results of the German PAREST Project (PAREST = PArticle REduction STrategies)

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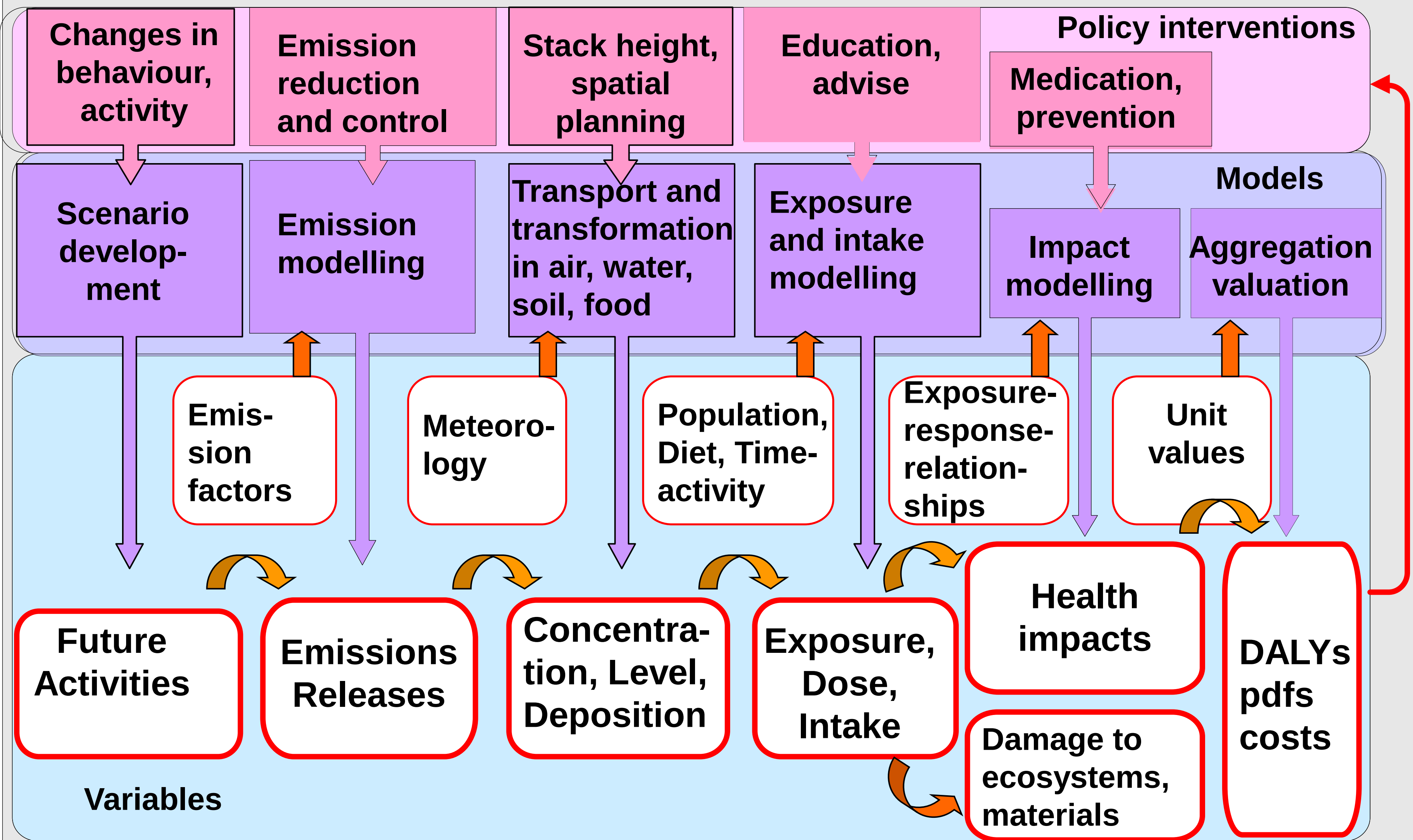
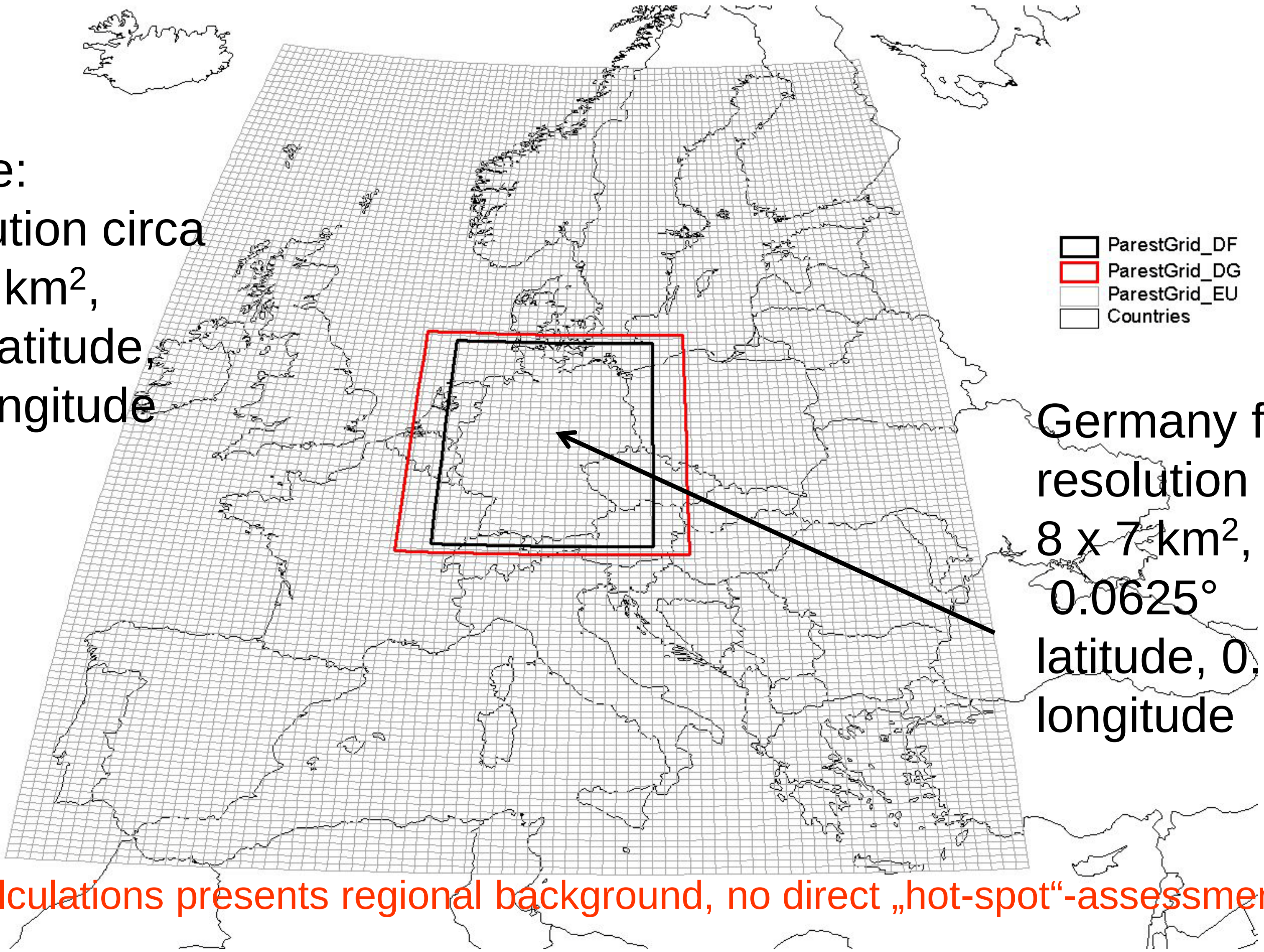
The Impact Pathway Approach



PAREST = PArticle REduction STrategies

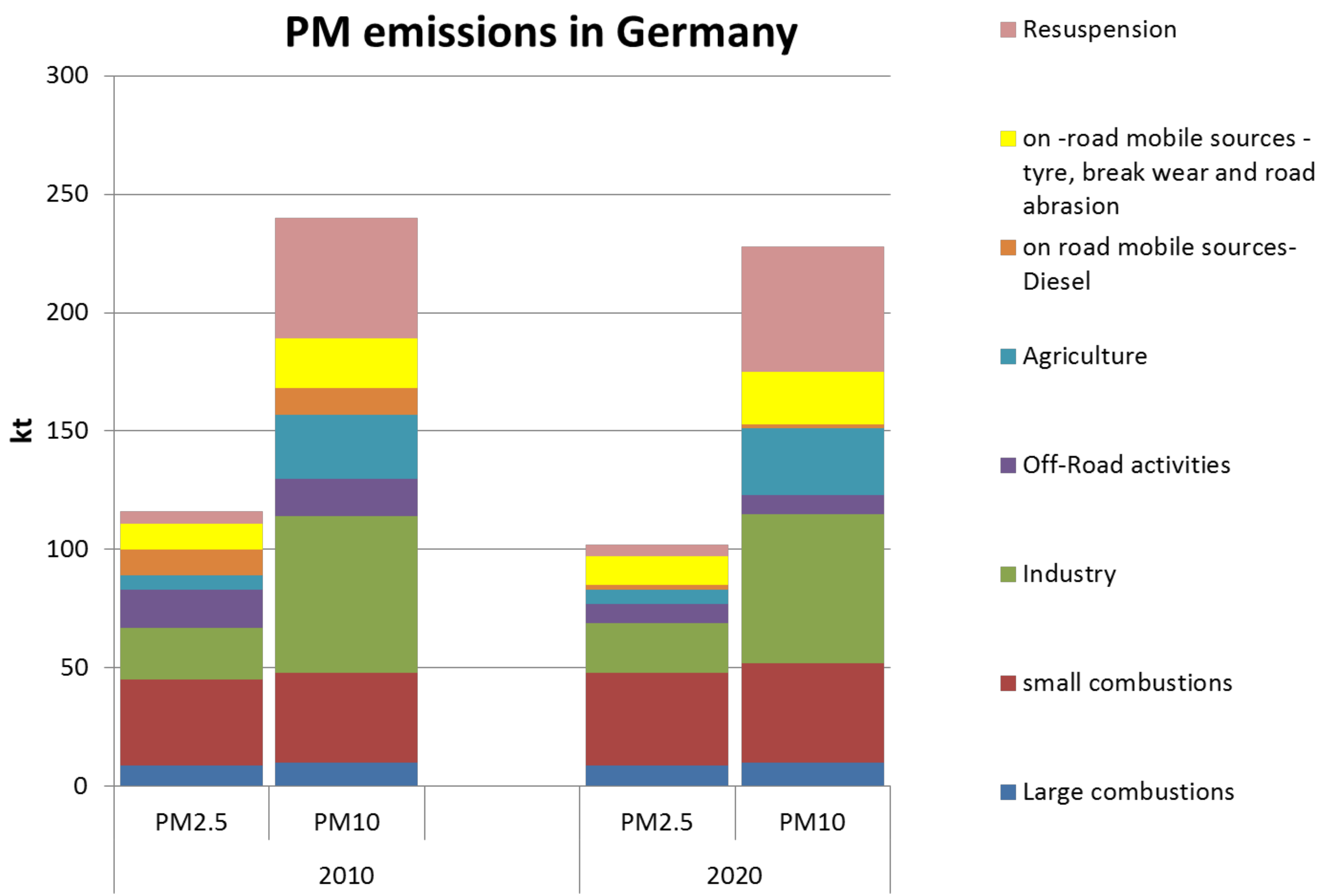
- Supported by UBA
- Partners: TNO (coordinator), Freie Universität Berlin, Universität Stuttgart, IZT Berlin, IfT Leipzig, VTI Braunschweig, IVU Freiburg
- Atmospheric model used: REM-CALGRID (RCG),
- European emissions according to NEC6-CP scenario: includes energy and climate package;
- Not included: IED; EcoDesignDir.; revised NEC
- New emission scenario for Germany

Europe:
Resolution circa 32x28 km^2, 0.25° latitude, 0.5° longitude

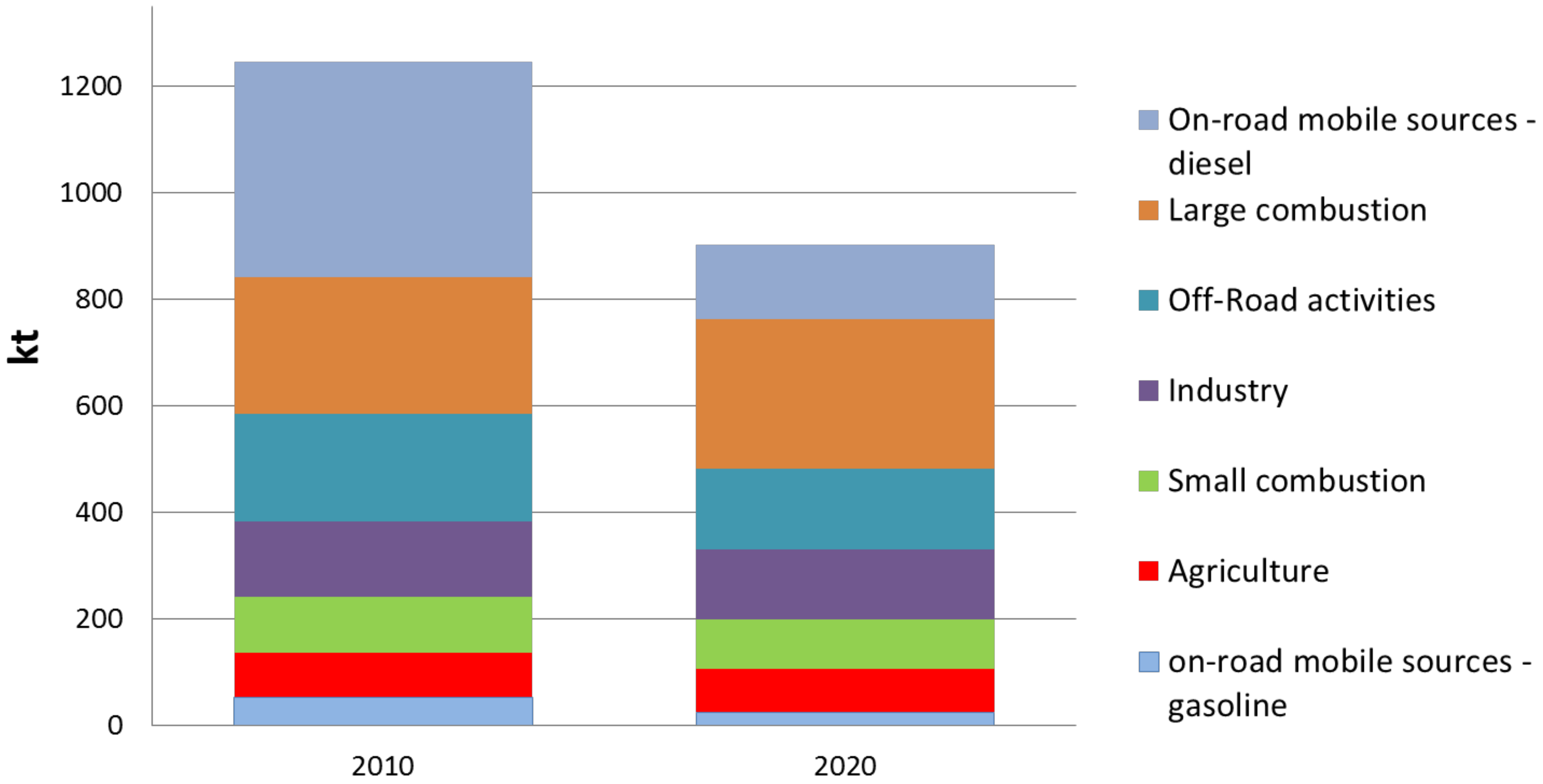


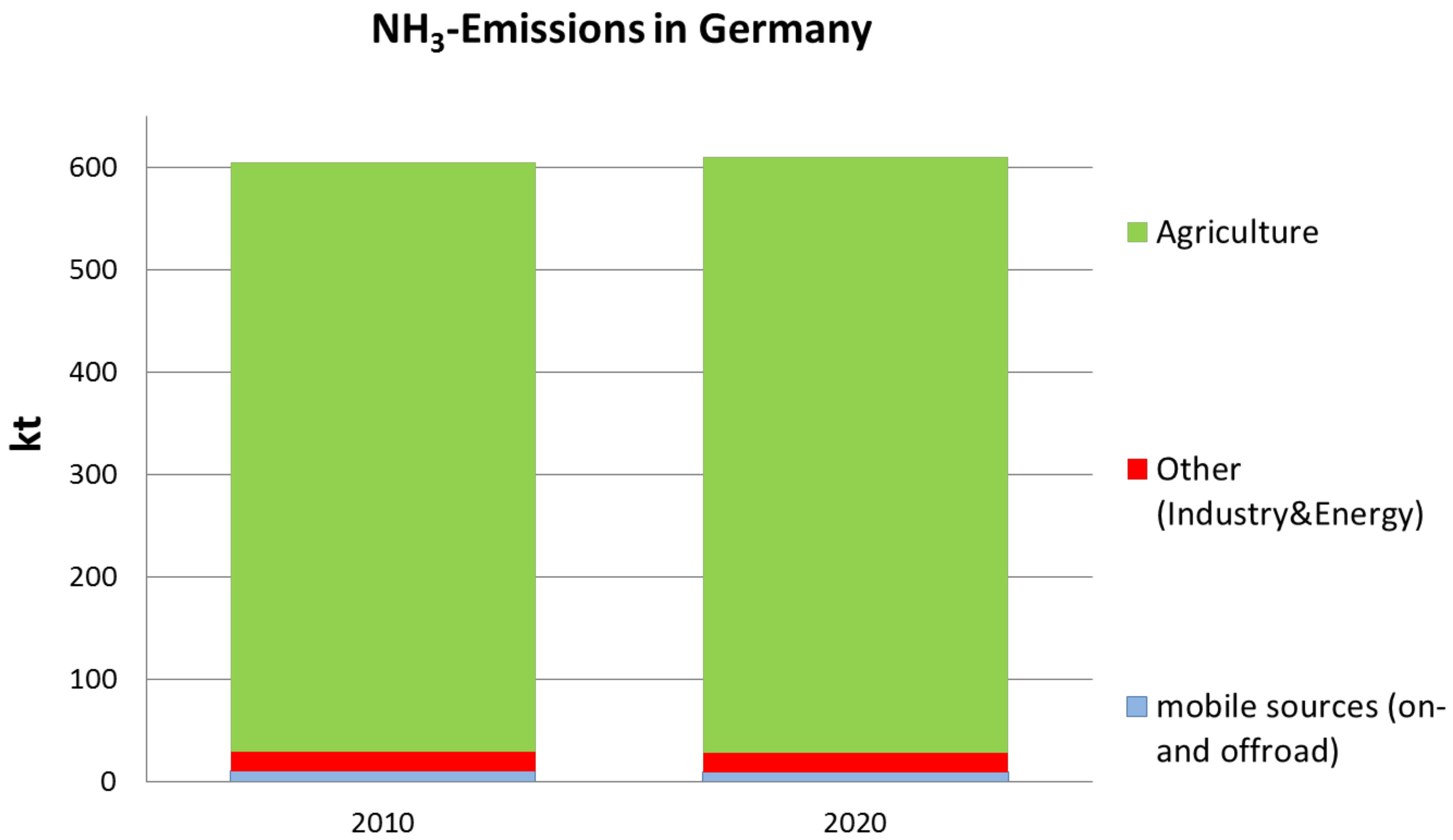
Germany fine: resolution circa 8 x 7 km^2, 0.0625° latitude, 0.125° longitude

Calculations presents regional background, no direct „hot-spot"-assessment !

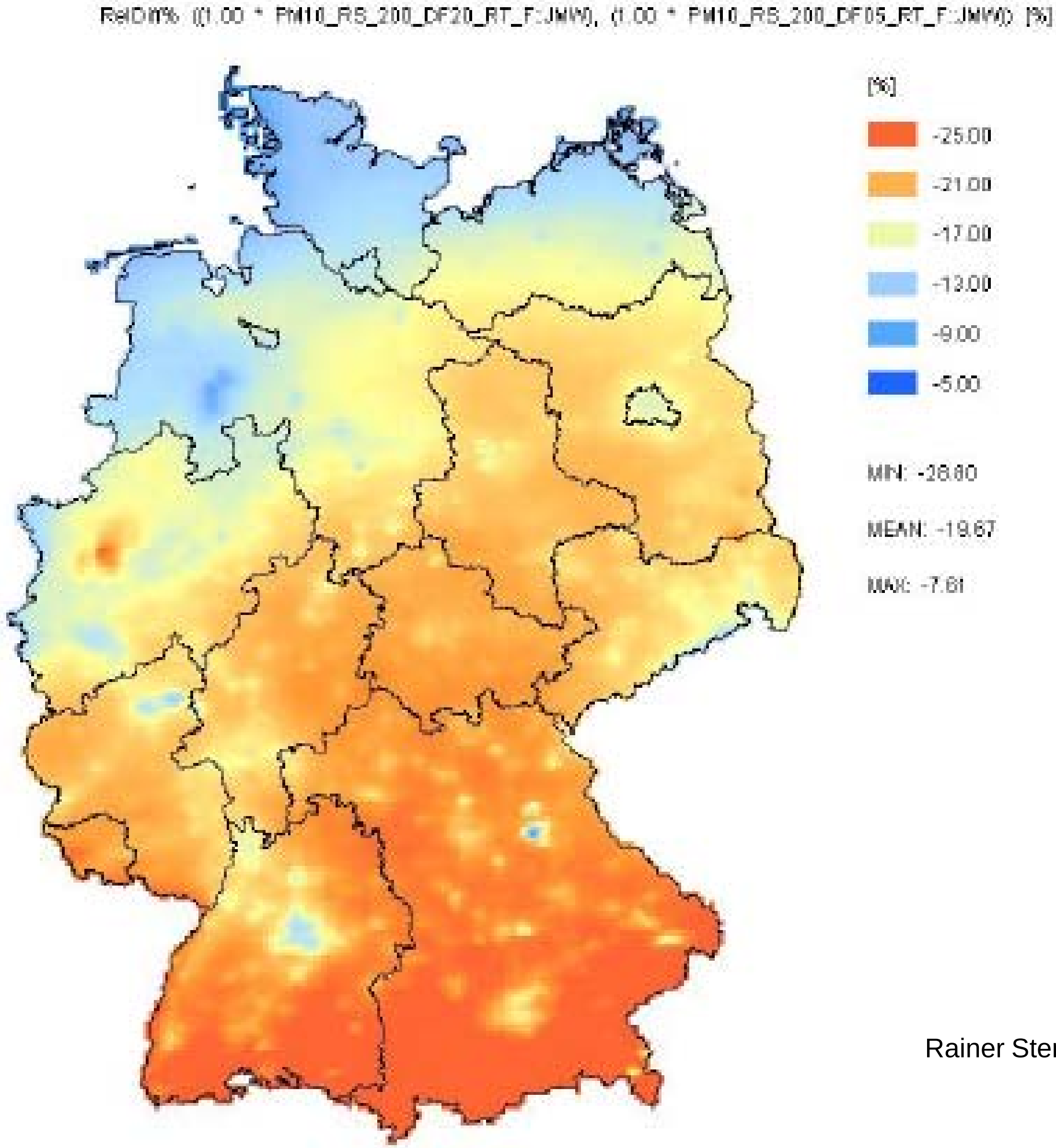

PM emissions in Germany
kt
300
250
200
150
100
50
0
PM2.5
PM10
PM2.5
PM10
2010
2020
Resuspension
on -road mobile sources - tyre, break wear and road abrasion
on road mobile sources- Diesel
Agriculture
Off-Road activities
Industry
small combustions
Large combustions

NO_x-Emissions in Germany



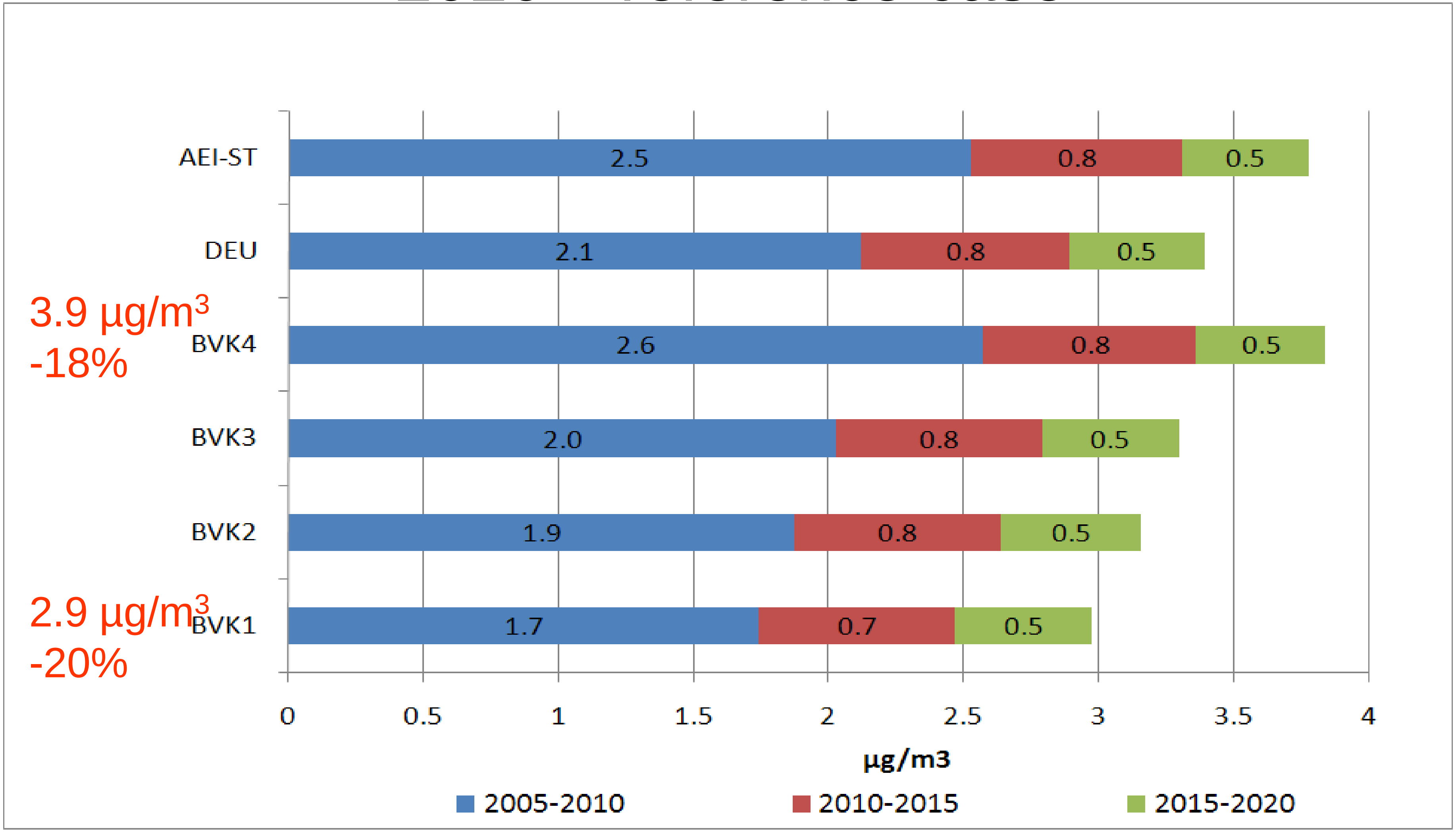

NH_3-Emissions in Germany
kt
0
100
200
300
400
500
600
2010
2020
Agriculture
Other (Industry&Energy)
mobile sources (on- and offroad)

Relative Change of PM10 Concentrations2005-2020



Rainer Stern et al., PAREST-Projekt

Reduction of PM10-Concentrations from 2005 to 2020 – reference case

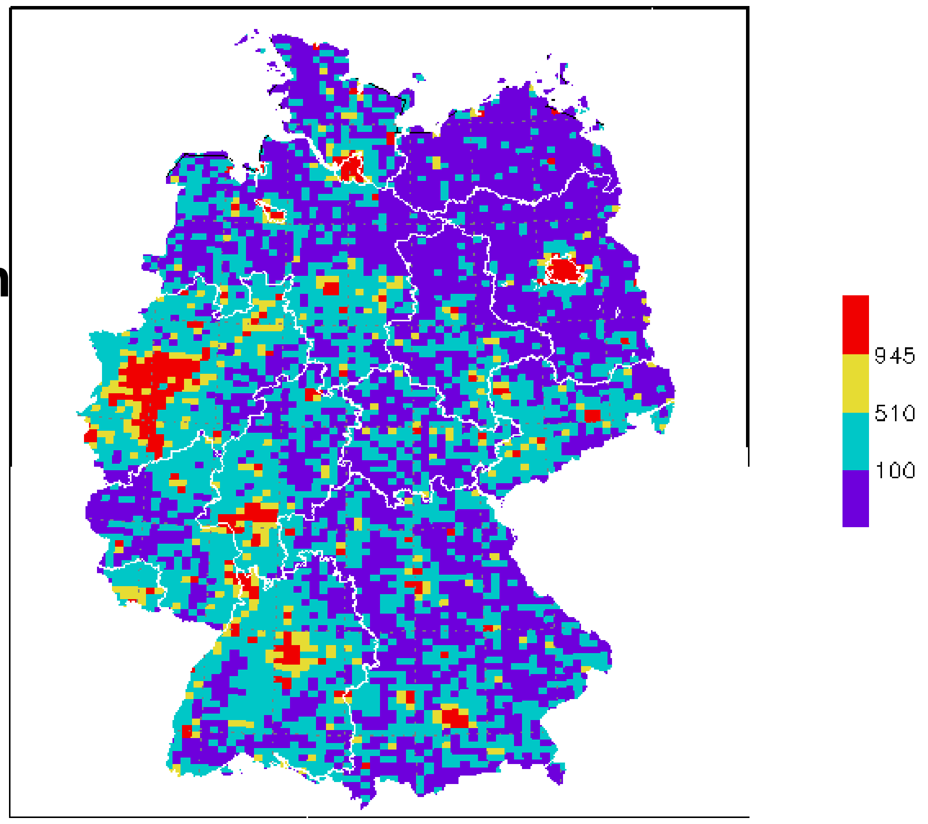


Quelle R.Stern et al, PAREST

Results are given for six area

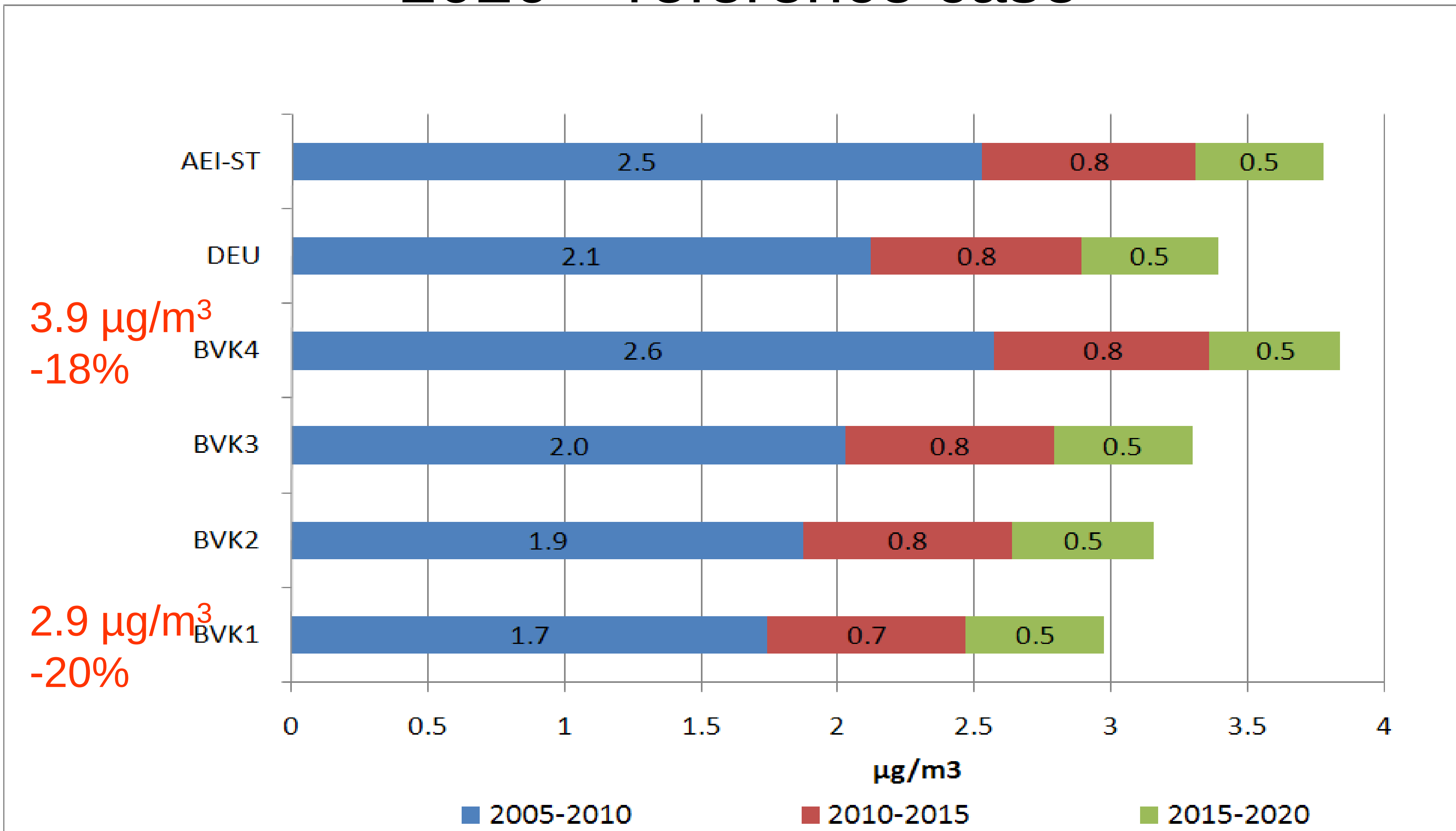
- **AEI-Stations, Average concentration at AEI-stations (Average Exposure Indicator für PM2.5)**
- **Germany: average concentration in Germany**
- **Class 4: Population density > 945 inhabitants/ km²**
- **Class 3: Population density 510 - 945 inhabitants/ km²**
- **Class 2: Population density 100 - 510 inhabitants/ km²**
- **Class 1: Population density < 100 inhabitants/ km²**

Bevoelkerungsdichte in 4 Klassen im Raster Nest 2



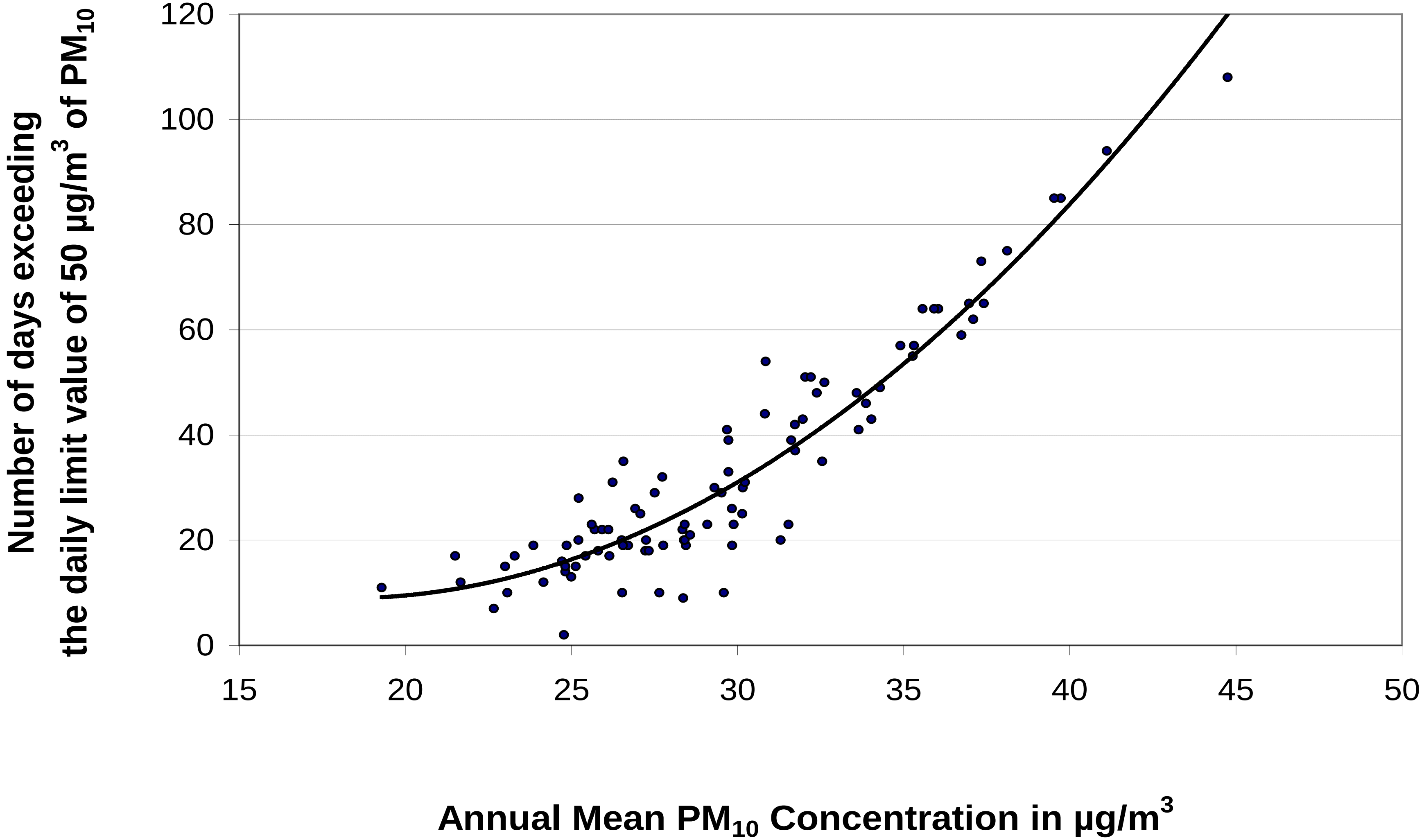
R.Stern, PAREST, 10. Juni 2010

Reduction of PM10-Concentrations from 2005 to 2020 – reference case

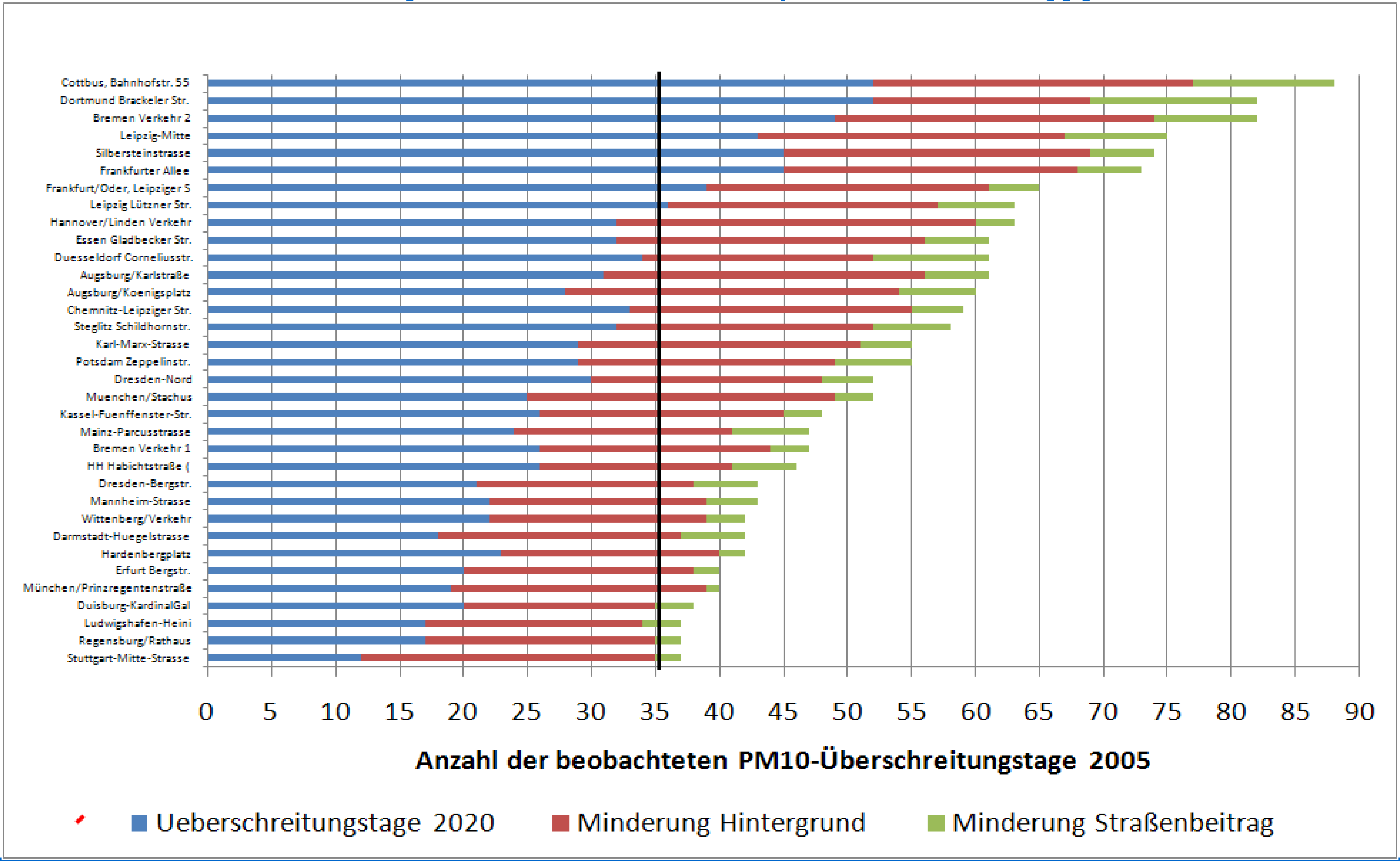


Quelle R.Stern et al, PAREST

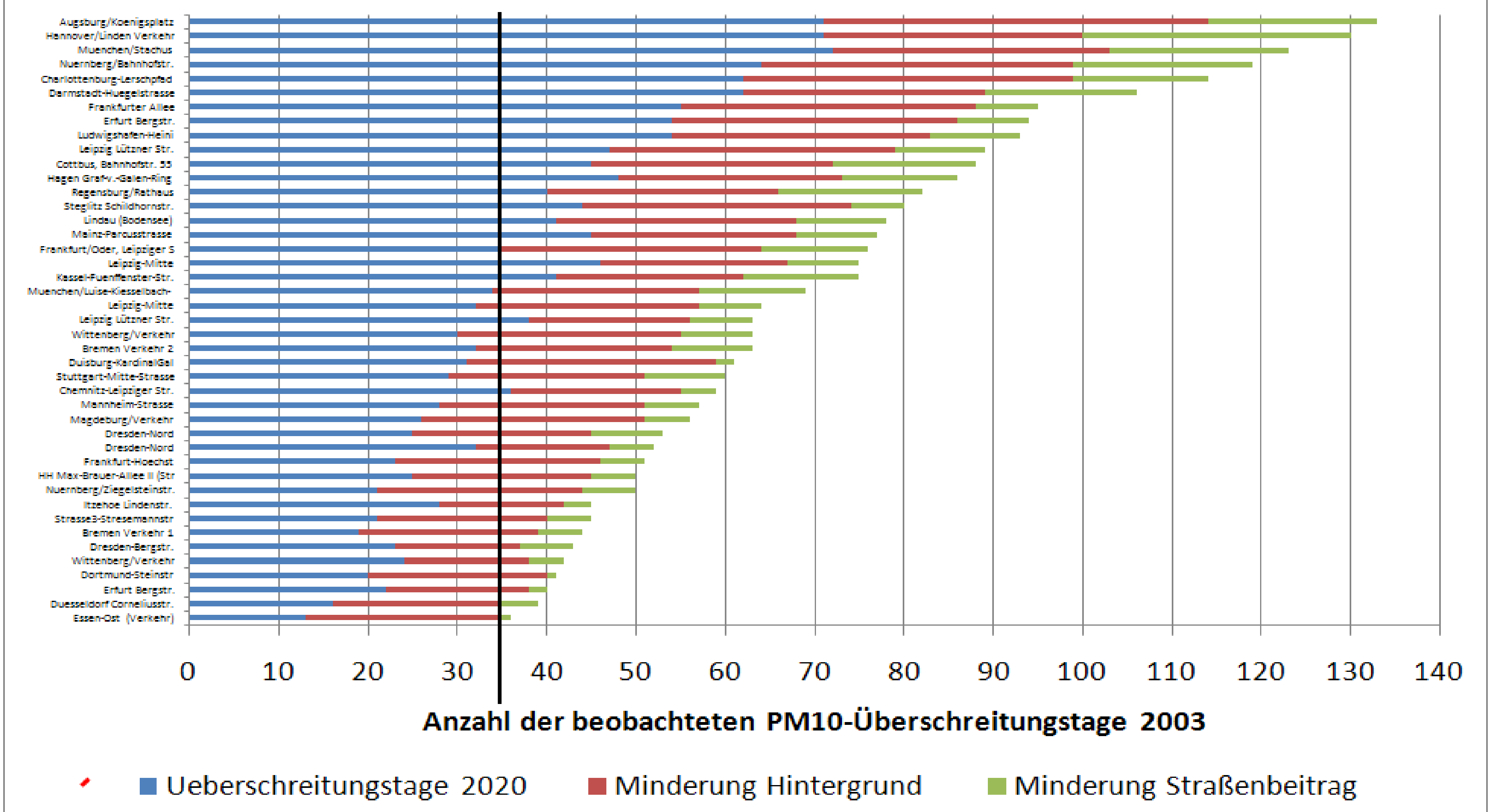
Relationship between the number of days exceeding the 50 μg/m³ threshold for PM10 and the yearly average PM10 concentration values



Days of exceedance of 50 µg/m³ for different stations in Germany 2005 and 2020, meteorology 2005



Days of exceedance of 50 µg/m³ for different stations in Germany 2003 and 2020.meteorology 2003



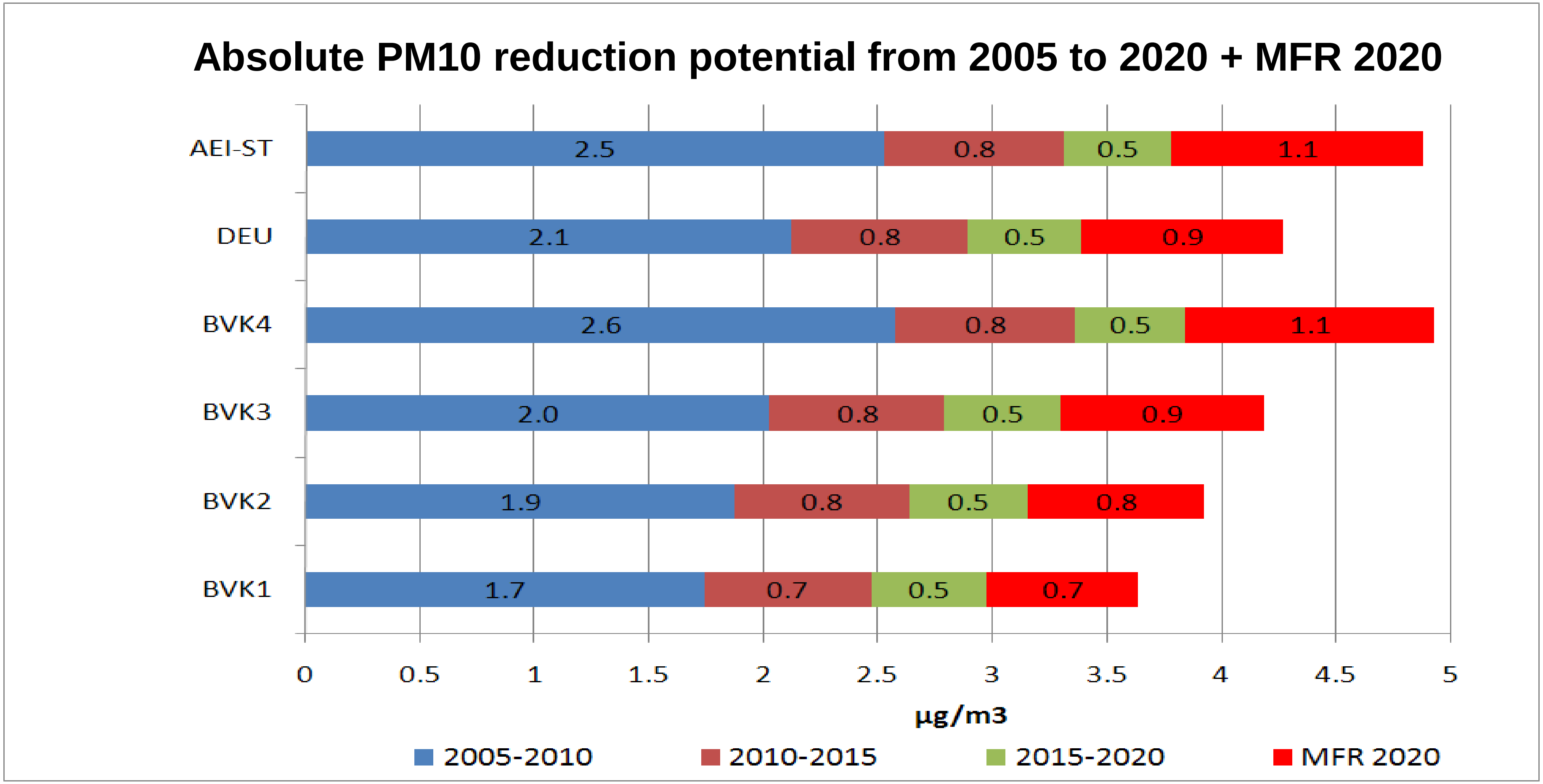
Emission reduction potential 2020 in kt – maximum feasible reduction (MFR)

Sector	Measure	NO_x	PM10	PM2.5	NH_3	SO_2	NMVOC
Reference emissions (2020)		904	228	101	609	455	1381
Max. reduction		126 14%	24 11%	16 11%	102 17%	110 24%	95 7%
Small combustion	3	12,3	9,9	9,2			
Large combustion	8	37,0	3,5	3,1		88,3	
Industry	10	30,1	4,8	2,1	1,1	21,6	
On-road	12	22,0	2,7	0,7	0,2	0,07	7,0
Off-road	10	24,2	0,5	0,5	0,2	0,4	15,4
Solvent use	6						72,7
Agriculture	13		2,9	0,4	100		

Measures – Industrial processes

Activity	Measure	Pollutant
Sinter	NO_x < 100 mg/Nm³ (SCR)	NO_x
Cement, Rolled steel	NO_x < 200 mg/Nm³ (SCR)	NO_x
Glass	NO_x < 500 mg/Nm³ (SCR)	NO_x
Sinter	SO_2 < 100 mg/Nm³ (wet desulfurisation)	SO_2
Sulphuric acid production	secondary abatement measures for SO_2 (activated carbon filter, wet scubber, other absorption techniques (only for double contact process!))	SO_2
Sinter, Cement, Glass	PM < 10 mg/Nm³ (fabric filter , improved electric precipitator)	PM10, PM2.5

Reduction of PM10-Concentrations 2005 -2020 maximum feasible reduction scenario (further ca 5% reduction of 2005 concentrations)



From here on:

Use of the ExternE methodology and the integrated assessment model ECOSENSE.

- **Includes: estimation of health impacts (health endpoints including YOLL and DALYs)**
- **Estimation of crop yield losses and material damage (e.g. soiling)**
- **Estimation of damage to ecosystems due to acidification, eutrophication (in pdfs)**
- **Monetising all effects using contingent valuation (willingness to pay)**

However: impacts on climate due to GHG emission changes not included, although they should be taken into account!!

Air pollutants: Impact functions $PM_{2.5}$ INTARESE/HEIMTSA

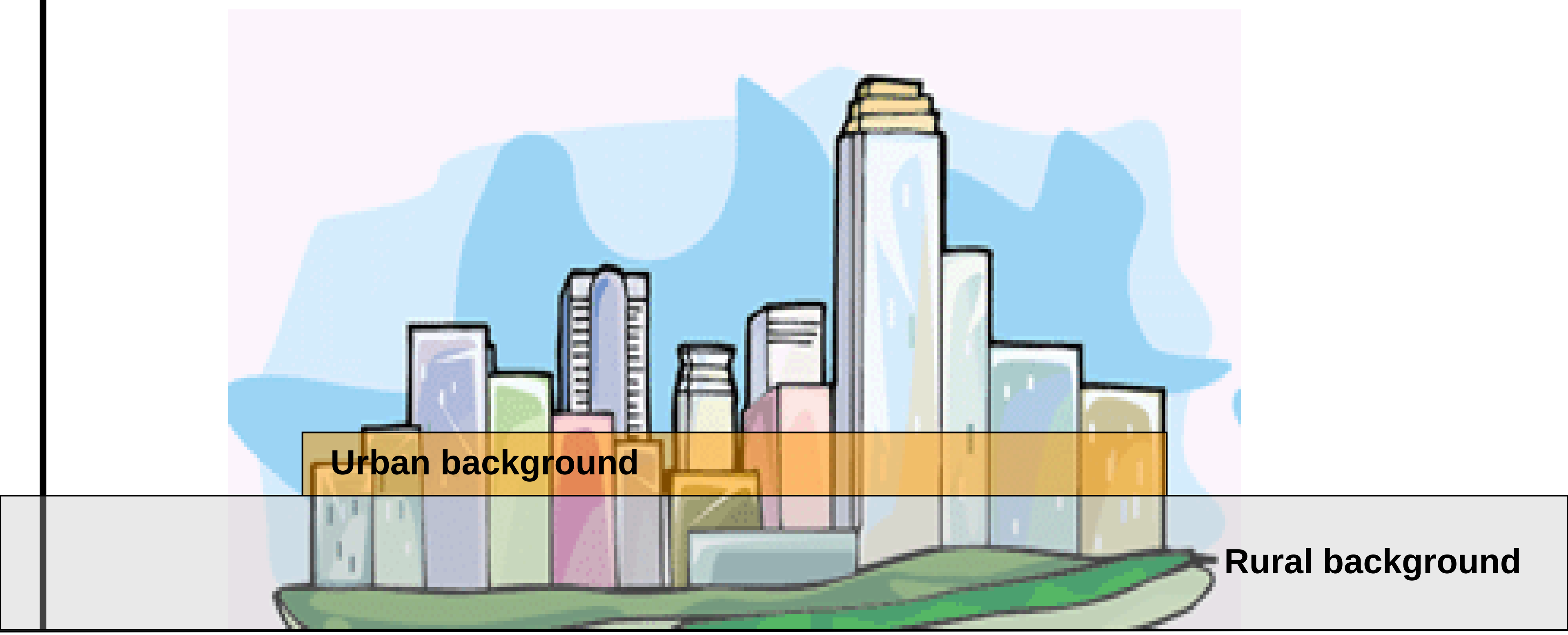
Health effect	Relative Risk	Age Group	Population	Impact Function
PM2.5				
Mortality (all cause)	6% (95% CI: 2%, 11%) change per 1 µg/m3 PM2.5	Adults 30 years and older	General Population	250.4 YOLLs
Work loss days (WLDs)	4.6% (95% CI: 3.9%, 5.3%) increase per 10 µg/m3 PM2.5	15-64 Years	General Population	20,700 (95% CI: 17,600, 23,800) additional work lost days per 10 µg/m3 increase in PM2.5 per 100,000 people aged 15-64 in the general population per year
Minor Restricted Activity Days (MRADs)	7.4% (95% CI: 6.0%, 8.8%) change per 10 µg/m3 PM2.5	18-64 Years	General Population	57,700 (95% CI: 46,800, 68,600) additional MRADs per 10 µg/m3 increase in PM2.5 per 100,000 adults aged 18-64 (general population) per year
Restricted activity days (RADs)	4.75% (95% CI: 4.17%, 5.33%) change per 10 µg/m3 PM2.5	18-64 Years	General Population	90,200 (95% CI: 79,200, 101,300) additional RADs per 10 µg/m3 increase in PM2.5 per 100,000 adults aged 18-64 (general population) per year

Air pollutants: Impact functions Ozone

Health effect	Relative Risk	Age Group	Population	Impact Function
Ozone				
Mortality (all cause)	0.3% (95% CI: 0.1%, 0.4%) change per 10 µg/m3 O3	All Ages	General Population	2.8 (95% CI: 0.92, 3.7) additional deaths (or life years lost) per 10 µg/m3 increase in O3 per 100,000 population (all ages), per year
Respiratory hospital admissions (adults aged 65+)	0.5% (95% CI: -0.2%, 1.2%) change per 10 µg/m3 O3 (8-hr daily average)	Adults aged 65 years and older	General Population	12.5 (95% CI: -5.0, 30.0) additional emergency respiratory hospital admissions per 10 µg/m3 increase in O3 per year per 100,000 people aged 65+, per year
Bronchodilator usage in children (general population)	21% (95% CI: 2.9%, 39%) change per 10 ug/m3 O3	5-14 Years	General Population	24,500 (95% CI: 3,400, 45,600) additional days of bronchodilator usage per 10 µg/m3 increase in O3 per 100,000 children aged 5-14 (general population), per year
Bronchodilator use in adults (aged 20 and older) with asthma	0.6% (95% CI: -0.2%, 1.4%) change per 10 ug/m3 O3	Adults aged 20 years and older	Adults with asthma (10.2% of adults in EU27 have asthma)	70,100 (95% CI: -23,400, 164,000) additional days of bronchodilator usage per 10 ug/m3 increase in O3 per 100,000 adults aged 20 and older with persistent asthma, per year

Pollutant Concentration in µg/m³

The typically higher pollutant levels in urban areas for most pollutants can be referred as urban increment, i.e., the difference between regional and urban background pollutant concentrations



Urban increment (PM2.5)

developed by Torras Ortiz (2010), USTUTT

$$C_{i\ urban} = \varpi_i + \phi_i \frac{E_{iUE}}{A_{UE} \cdot u_{avg}} + \gamma\, C_{i\ rural}$$

where

C_i urban = Urban increment of pollutant i.

E_{iUE} = Total emission of pollutant i within the urban entity in tons.

A_{UE} = Urban entity area in km^2.

u_{avg} = Urban entity average wind speed in m/s.

$C_{i\ rural}$ = Rural background concentration of pollutant i in $\mu g/m^3$

ω_i, φ_i, and γ_i = Multiple-regression parameters for pollutant i.

Torras Ortiz, S. (2010). "A hybrid dispersion modelling approach for quantifying and assessing air quality in Germany with focus on urban background and kerbside concentrations," submitted Doctoral Thesis, University of Stuttgart, Stuttgart.

Are all PM10/PM2.5 species equally important?

- **Weighting scheme 1 (WHO-recommendation):**

Same damage for all content of PM10/PM2.5.

- **Weighting scheme 2 (recommendation of ExternE and HEIMTSA):**

Primary $PM_{2.5}$ from combustion: *1,5

Nitrates: *0,5

Sulfates: *0,6

DALYs: Disability Adjusted Life Year

duration as fraction of year, DALY= weight*duration,

endpoint	weight	duration
Bronchodilator Usage Adults and Children	0.22	0.00274
Cardiac Hospital Admissions	0.71	0.038
Chronic Bronchitis	0.099	10
Infant Mortality	1	80
Lower Respiratory Symptoms Adults and Children	0.099	0,00274
Respiratory Hospital Admissions	0.64	0.038
Minor Restricted Acitvity Day	0.07	0.00274
Restricted Acitvity Day	0.099	0.00274
Work Loss Day	0.099	0.00274
Years Of Life Lost chronic. Mortality	1	1
Cough Days	0.07	0.00274
Lower Respiratory Symptoms Children Excl Cough	0.099	0.00274
Respiratory Hospital Admissions	0.64	0.038

Monetary values of health endpoints (EUR 2010)

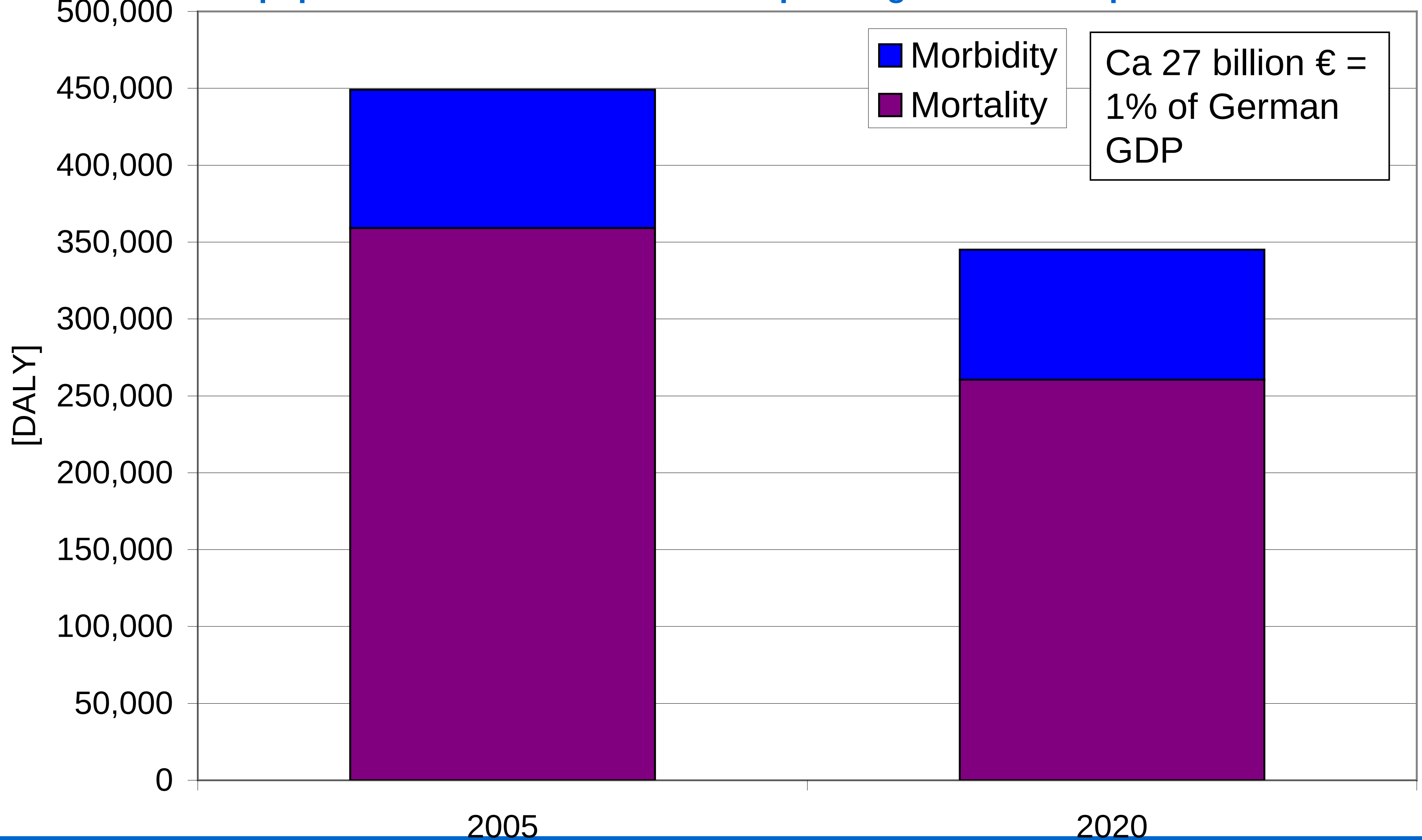
Health End-Point	Low	Central	High	per case
Increased mortality risk - VSLacute	1,121,433	1,121,433	5,607,164	Euro
Life expectancy reduction - Value of Life Years chronic	40,500	59,810	213,820	Euro
Sleep disturbance	400	1,045	1,320	Euro/year
Hypertension	740	800	930	Euro/year
Acute myocardial infarction	2,200	4,470	31,660	Euro
Lung cancer	69,080	719,212	4,187,879	Euro
Leukaemia	2,045,493	3,974,358	7,114,370	Euro
Neuro-development disorders	4,486	14,952	32,895	Euro
Skin cancer	10,953	13,906	26,765	Euro
Osteoporosis	2,990	5,682	8,074	Euro
Renal dysfunction	22,788	30,406	40,977	Euro
Anaemia	748	748	748	Euro

Air pollutants – monetary values (EUR 2010)

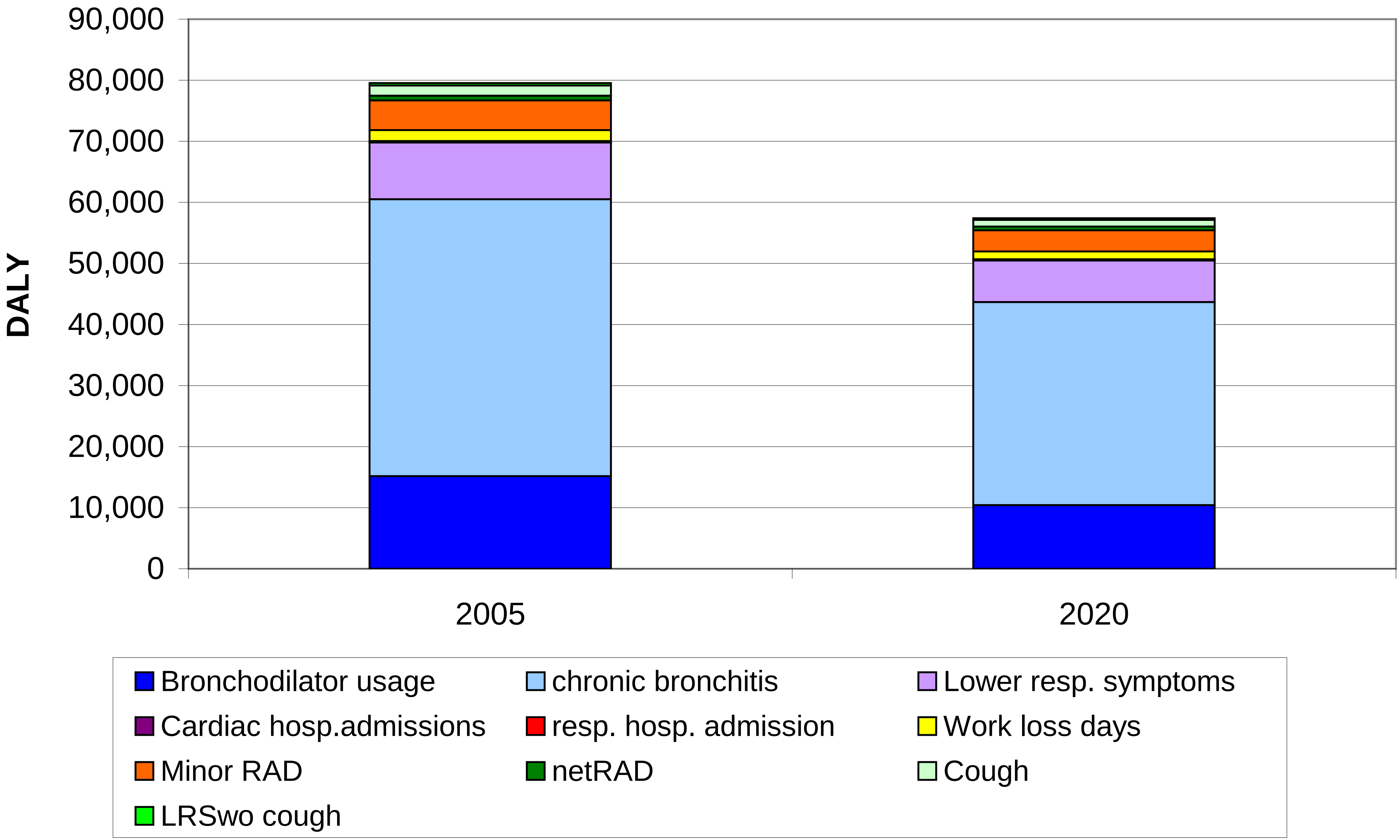
Health End-Point	Central	per case
Increased mortality risk (infants)	4,485,731	Euro
New cases of chronic bronchitis	66,000	Euro
Increased mortality risk - Value Of Life Years	89,715	Euro
Respiratory hospital admissions	2,990	Euro
Cardiac hospital admissions	2,990	Euro
Work loss days (WLD)	441	Euro
Restricted activity days (RADs)	194	Euro
Minor restricted activity days (MRAD)	57	Euro
Lower respiratory symptoms	57	Euro
LRS excluding cough	57	Euro
Cough days	57	Euro
Medication use / bronchodilator use	80	Euro

Health Impacts in Europe Caused by Anthropogenic Emissions in Germany (-23%)

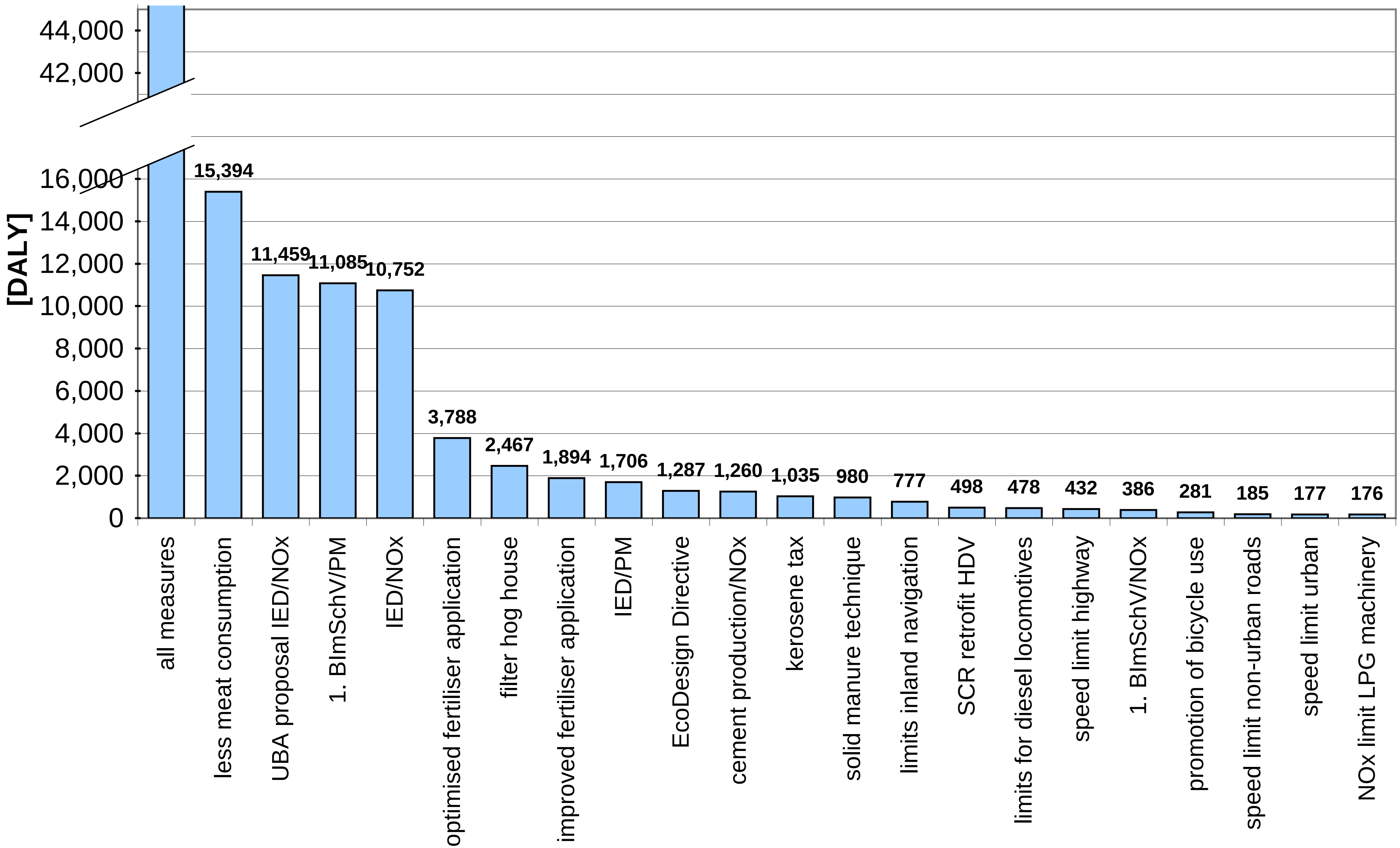
For German population ca. 1.5 DALYs/a corresponding to 3 months per lifetime



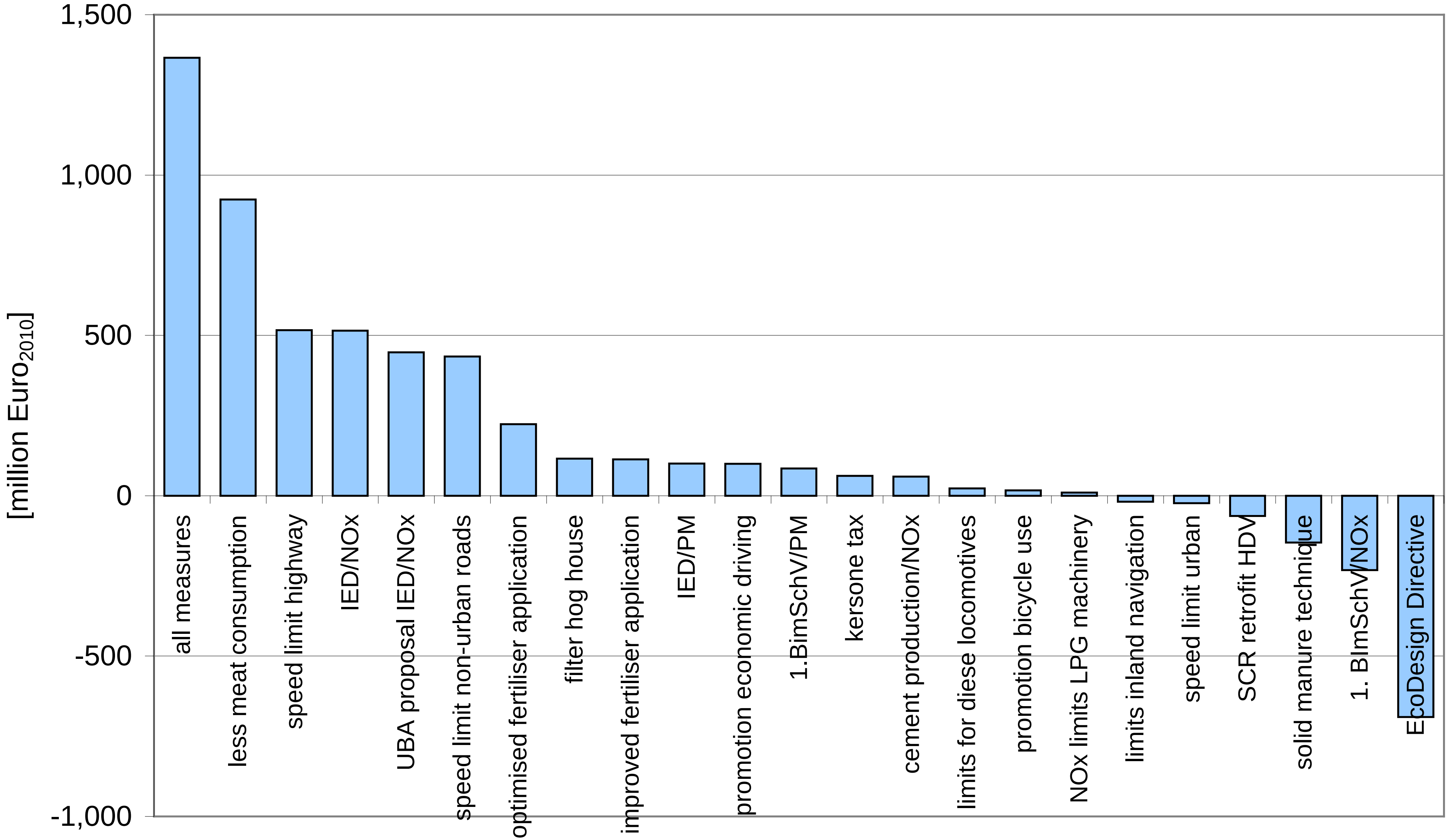
Morbidity effects in Europe caused by emissions in Germany



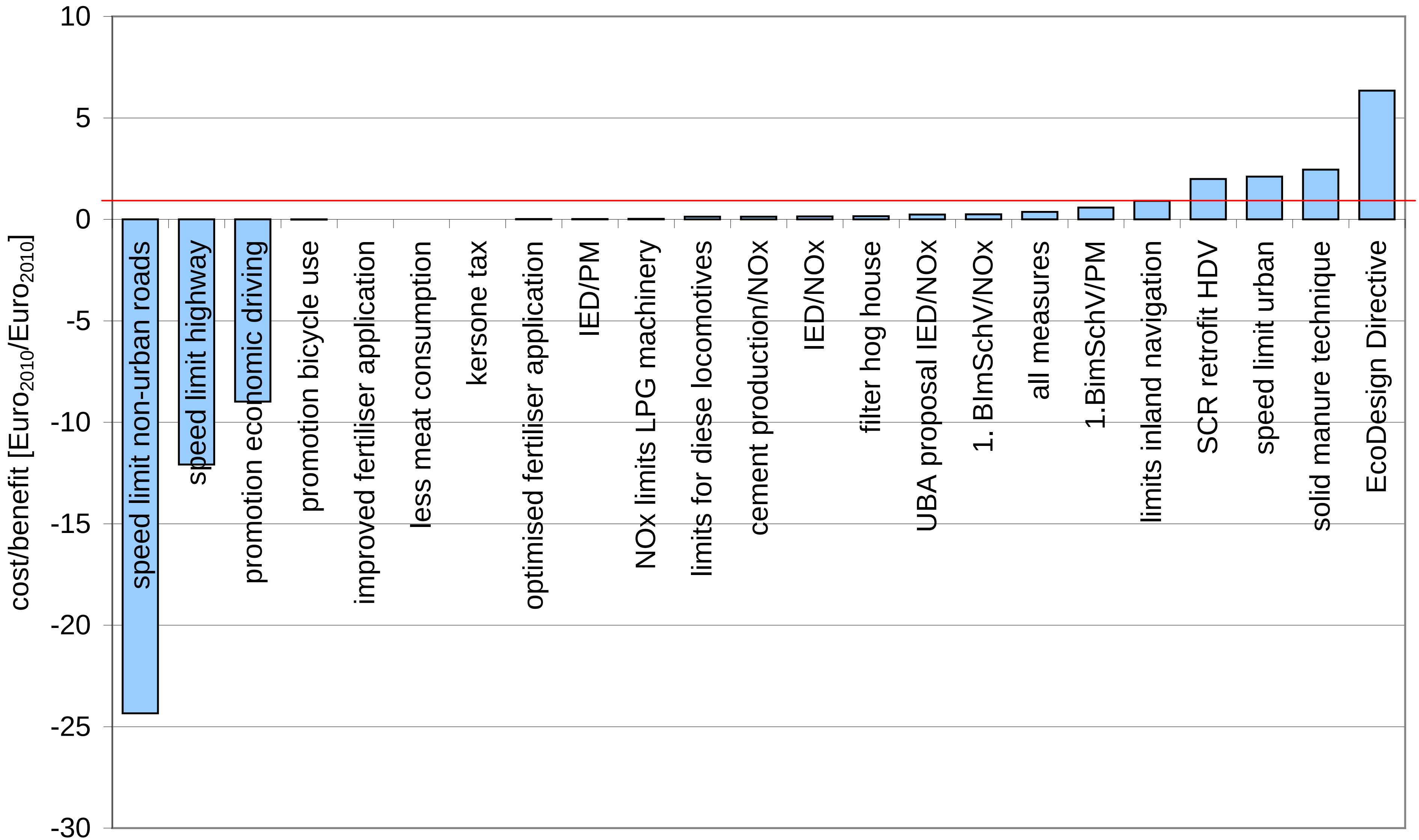
Reduction potentials



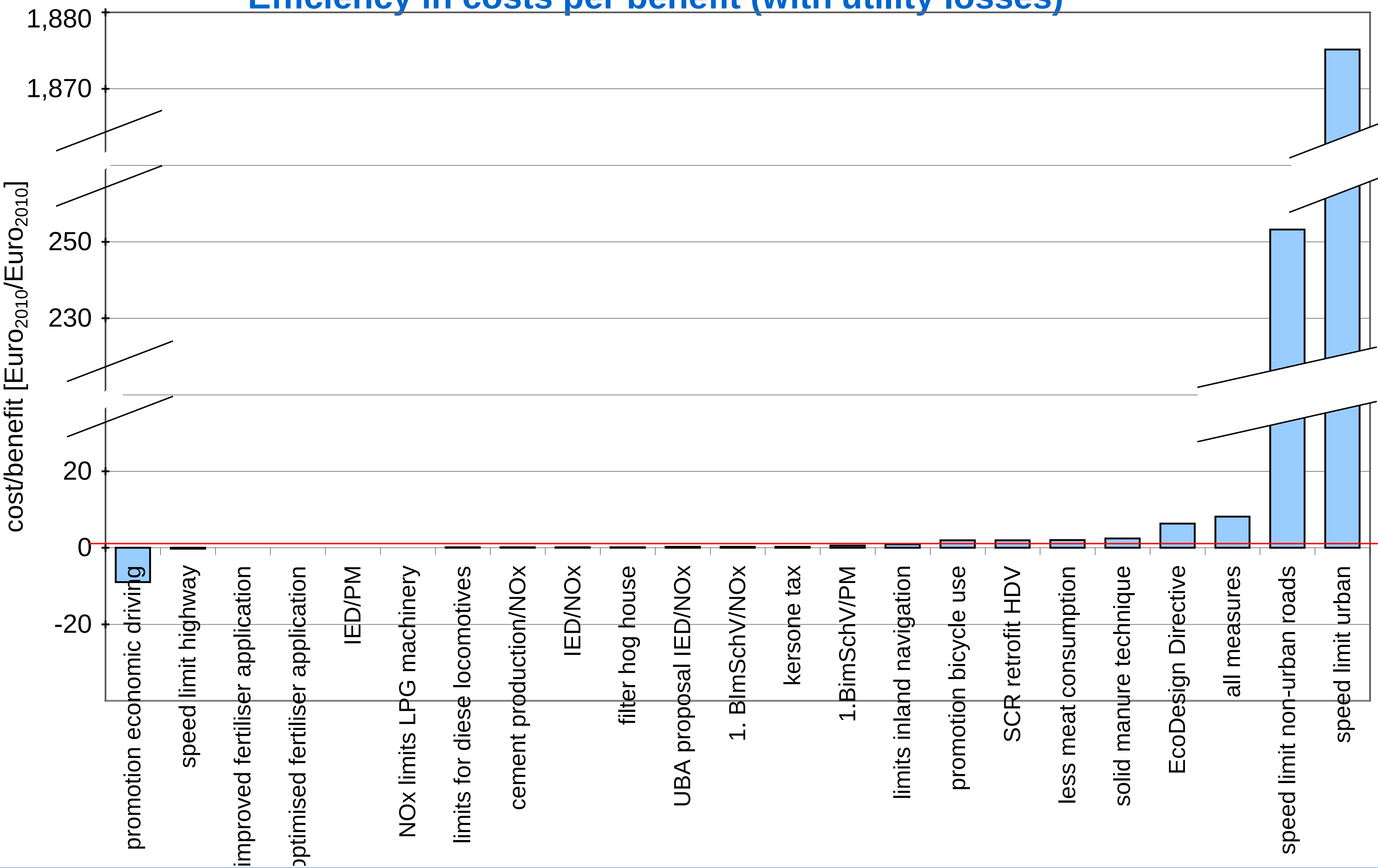
Benefits – costs (without utility losses)



Efficiency in costs per benefit (no utility losses)



Efficiency in costs per benefit (with utility losses)



Conclusions

- **Methodologies for supporting decisions about environmental pollution control with cost-benefit-analyses are available and are able to deliver useful results.**
- **Further reductions of PM and PM precursor emissions are necessary to meet thresholds and reduce impacts, especially health impacts.**
- **The assessment of policies and measures crucially depend on assumptions about the toxicity of PM ingredients or other measures like number.**
- **Effective and efficient additional measures for Germany would be:**

➢ **Promotion of economic driving (small effect), speed limit on motorways (small)**

➢ **Improved application and amount of fertilizer and manure (large), filter in hog houses (large),**

➢ **Less animal protein consumption on voluntary basis (very large)**

➢ **Offroad: diesel locomotives (small) , gasoline/LPG mobile machinery (small), kerosine tax (medium), inland navigation (small)**

➢ **Emission reduction industrial processes (cement, glas, sinter) (large)**

➢ **Further PM reduction large coal combustion (10 mg/m³) (medium)**

www.integrated-assessment.eu ; www.externe.info