CAFE Scenario Analysis Report Nr. 4

Target Setting Approaches for Cost-effective Reductions of Population Exposure to Fine Particulate Matter in Europe

Background paper for the meeting of the
CAFE Working Group on Target Setting and Policy Advice,
February 4, 2005

Extended Version for the CAFE Steering Group

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1 Introduction

1.1 Background

The Clean Air For Europe (CAFE) programme of the European Commission aims at a comprehensive assessment of the available measures for further improving European air quality beyond the achievements expected from the full implementation of all present air quality legislation. For this purpose, CAFE has compiled a set of baseline projections outlining the consequences of present legislation on the future development of emissions, of air quality and of health and environmental impacts up to the year 2020.

In its integrated assessment, CAFE will explore the cost-effectiveness of further measures, using the optimization approach of the RAINS model. This optimization will identify the cost-effective set of measures beyond current legislation that achieve exogenously determined environmental policy targets at least cost. For this purpose, the RAINS model will explore in an iterative way the costs and environmental impacts implied by gradually tightened environmental quality objectives, starting from the baseline (current legislation - CLE) case up to the maximum that can be achieved through full application of all presently available technical emission control measures (the maximum technically feasible reduction case - MTFR).

The results from the CAFE baseline assessment have been described in Amann *et al*. (2004a) (http://www.iiasa.ac.at/rains/CAFE_files/Cafe-Lot1_FINAL(Oct).pdf). The estimate of the maximum range for emission reductions that is offered from full application of presently available emission control technology is documented in Amann *et al.* (2004b) (http://www.iiasa.ac.at/rains/CAFE_files/baseline3v2.pdf). Detailed results on sectoral and country-specific emission and cost estimates can be extracted from the Internet version of the RAINS model (www.iiasa.ac.at/rains).

In its previous report, IIASA has explored cost-effective emission reductions for meeting environmental targets for human health (from PM and ozone) and for ecosystems.

1.2 Objective of this report

Against this background information, this paper informs the CAFE Working Group on Target Setting and Policy Advice about recent modeling results on cost-effective emission control strategies for reducing health impacts from PM.

The first version of the RAINS optimization model for particulate matter has been used to identify cost-minimal sets of emission control measures that lead to environmental improvements at least cost. For this report, optimization analyses addressed health impacts attributable to the exposure of fine particulate matter (PM2.5) and explores alternative ways of target setting. This report does not address the other environmental problems, nor the implications of PM reduction strategies on these other problems.

1.3 Disclaimer

To assist the Working Group in their deliberations on an appropriate approach for setting environmental targets for the Clean Air For Europe programme, this report presents first results of the RAINS optimization module to the CAFE Working Group on Target Setting and Policy Advice at an early stage of development, taking into account comments received from the Working Group at the last meeting. This report should offer the Working Group a possibility for providing feedbacks to the modeling team at a point in time when they could be taken on board when developing the final version. However, much of the work presented in this report is still in progress, and the standard quality control procedures of the RAINS team (e.g., double-checking all results with a second independent software package) could not be completed within the given time. Also there was insufficient time for a full validation of the newly developed functional relationships describing the atmospheric dispersion and formation of fine particulate matter. The City-Delta approach for addressing urban air quality in a Europe-wide assessment has been improved, but has not yet reached a fully satisfactory stage. Thus, all quantitative results presented in this report have to be considered as provisional.

2 Input data

The analysis presented in this report relies on:

- The CAFE baseline projections of anthropogenic activities for the year 2020 as described in the CAFE baseline report (http://www.iiasa.ac.at/rains/CAFE_files/Cafe-Lot1_FINAL(Oct).pdf), in particular the energy projections of the revised "with climate measures" projection of the PRIMES model. Cost data and resulting cost curves used for the optimization analysis are available from the RAINS Internet version (www.iiasa.ac.at/rains) – Version November 2004.

- Source-receptor relationships that reflect the response of air quality towards changes in the various precursor emissions as modelled by the recent version (October 2004) of the EMEP Eulerian dispersion model. This initial optimization analysis relies on calculations for the meteorological conditions of the year 1997, while final calculations need to consider the full range of inter-annual meteorological variability.

- National population projections of the UN (median projection)

2.1 Emission control measures for mobile sources

Since the recent report, the RAINS model has been extended to include additional emission control measures for mobile sources.

Unfortunately, it was impossible to obtain, in time for this report, agreed estimates of the emission reduction efficiencies and costs for achieving currently discussed Euro-V and Euro-VI standards. Given this situation and given the strong wish of the Working Group to see cost-effectiveness analysis, hypothetical assumptions have been made on emission reduction efficiencies of further emission control measures for road transport. This is without prejudice to the actual emission limit values which have yet to be proposed by the Commission and adopted by the Council and the European Parliament.

The provisional simulations presented in this report are based on the findings of a study on emission factors for road transport conducted by RICARDO (RICARDO, 2003: Support for updating the RAINS model concerning road transport. Final report November 2003 with updates from April 2004. RICARDO UK Ltd.).

For diesel light-duty vehicles (cars and light-duty trucks), the RICARDO study quotes emission factors for NO_x of about 0.06 g/km and for PM of 0.004 g/km, implying removal efficiencies for NO_x of about 85 percent compared with the "unabated" (late 1980's) case and about 98 percent for PM. RAINS applies these removal efficiencies to the country-specific "unabated" emission factors that reflect fleet compositions, driving patterns and other country-specific circumstances.

For heavy-duty vehicles the illustrative RAINS calculations refer to emission factors of 0.4 g/kWh for NO_x and of 0.01 g/kWh for PM, implying emission reduction efficiencies of about 95 percent for NO_x and 97 percent for PM compared with the "unabated" (late 1980's) case.

No assumptions have been made on changed emissions from gasoline vehicles, as well as on costs of the above listed emission reductions.

It is assumed that emission reductions for passenger cars and light duty vehicles come on the market in 2010, and those for heavy duty vehicles in 2014. The penetration would follow the natural replacement rate, and no premature scrapping of vehicles and no retrofit measures are considered.

If the emissions factors were to be introduced over the timescale envisaged, in 2020 European NO_x emissions would be 10 percent below the current legislation level. Primary emissions of PM2.5 would be 2.4 percent lower (Table 2.1).

Table 2.1: Impacts of further road measures on NO_x and PM2.5 emissions in the EU-25 calculated for 2020 (kilotons), based on the assumptions above.

	NO_x			PM2.5		
	CLE	with further measures	Difference	CLE	with further measures	Difference
Diesel heavy duty trucks	1079	724	-33%	12.1	10.3	-15%
Diesel cars and light duty vehicles	508	245	-52%	39.8	18.1	-55%
Total emissions	5888	5270	-10%	964.5	941.0	-2.4%

2.2 Costs of current legislation for the baseline scenario

Figure 2.1 to Figure 2.3 present corrected graphs showing costs of the emission control measures implied by current legislation in the year 2020 for the "with climate measures" CAFE baseline scenario.

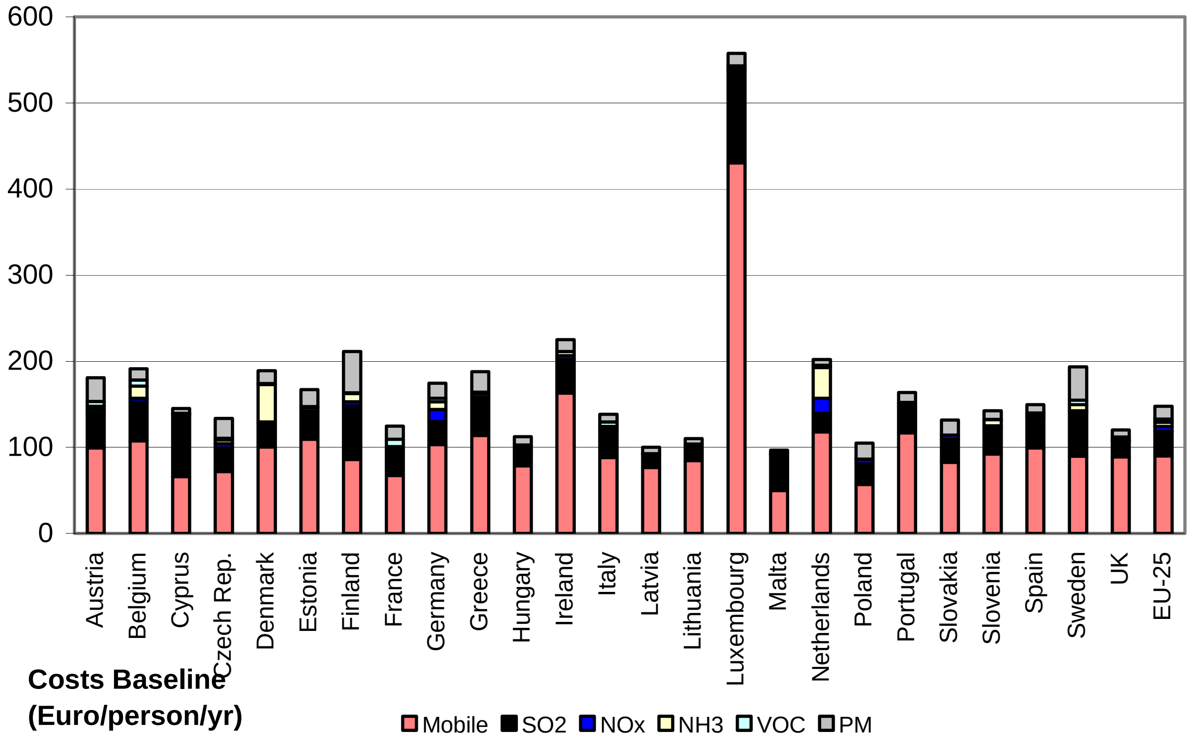


Figure 2.1: Costs of current legislation measures for the CAFE baseline scenario in 2020 on a per-capita basis (€/person/year)

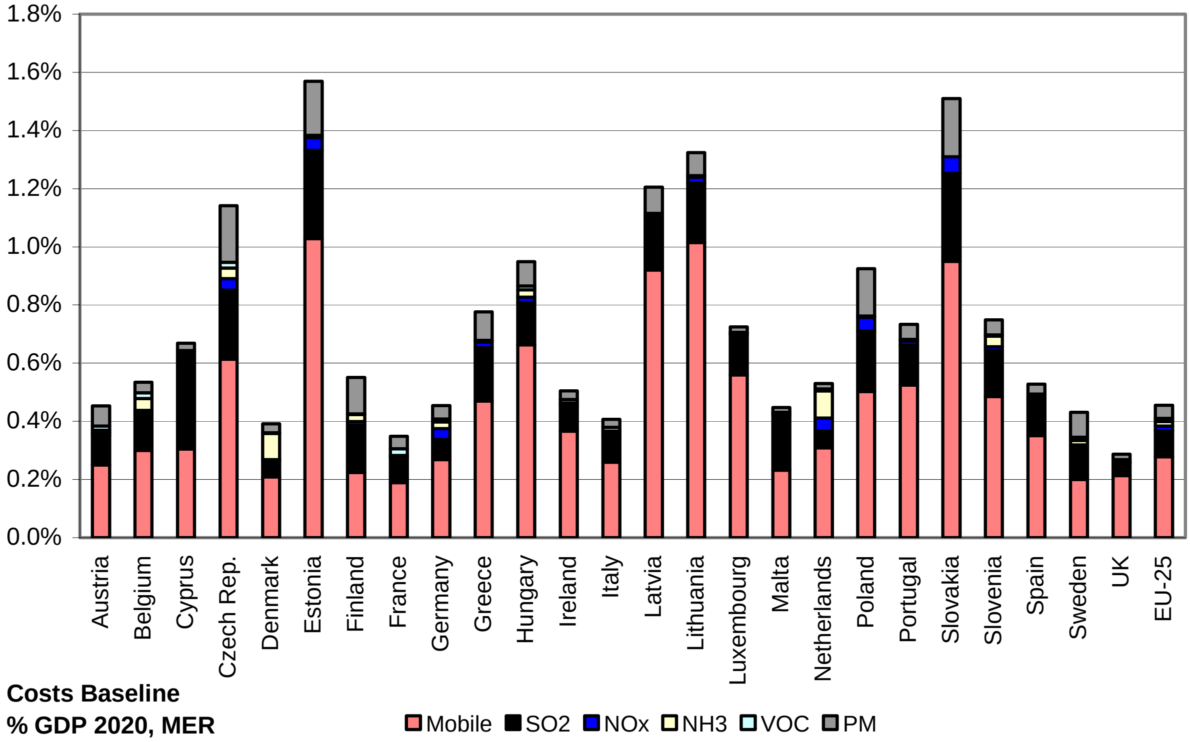


Figure 2.2: Costs of current legislation measures for the CAFE baseline scenario in 2020 related to GDP in Market Exchange Rates (MER)

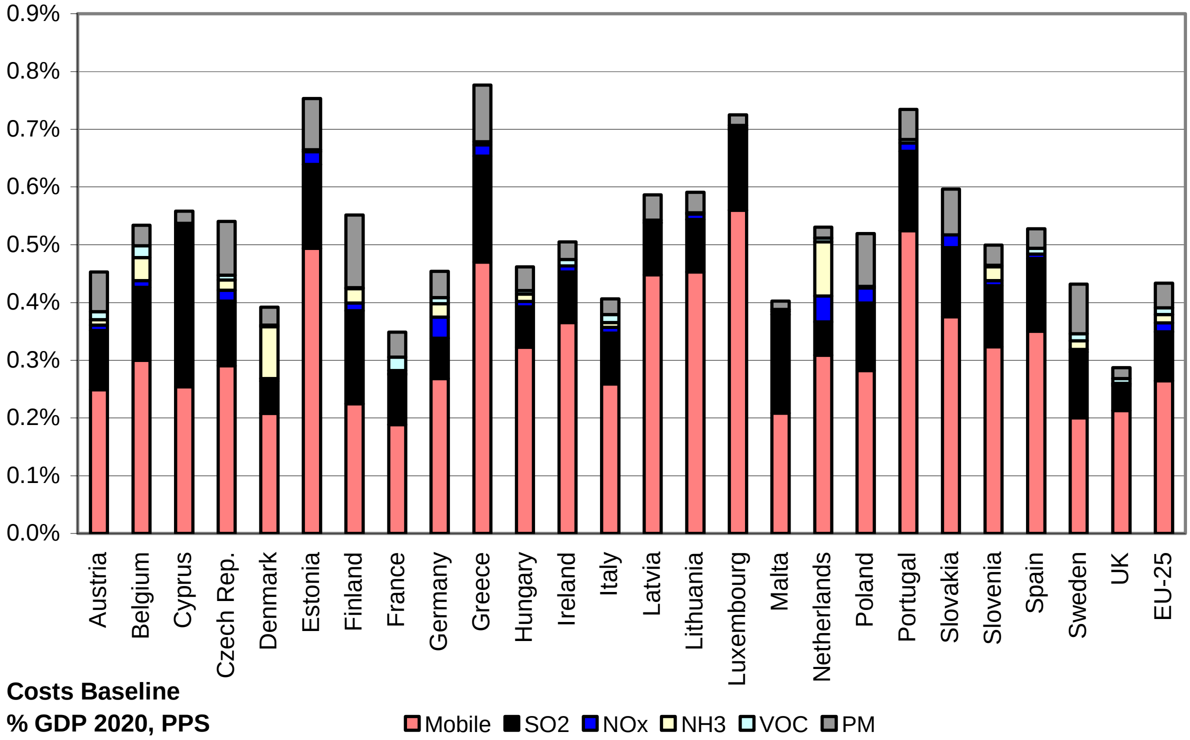


Figure 2.3: Costs of current legislation measures for the CAFE baseline scenario in 2020 related to GDP in Purchasing Power Standards (PPS)

3 Assumptions and caveats

The initial optimization results presented in this report reflect work in progress, with a number of assumptions taken, which have influence on the quantitative outcome. Thus it is essential to review the optimization results in the light of the assumptions taken.

3.1 Main assumptions

- **"With climate measures" CAFE baseline scenario.** The analysis presented in this paper is exclusively based on the "with climate measures" baseline projection developed by the PRIMES model (http://www.iiasa.ac.at/rains/CAFE_files/Cafe-Lot1_FINAL(Oct).pdf) (version August 2004), which provides one EU-wide consistent projection of future development. In several cases there are substantial disagreements with national experts, and alternative national projections might have significant implications on the optimization results. Further work will address the sensitivity of optimization results against differences in assumptions on important driving forces such as economic development and energy policy.

- **Maximum Technically Feasible Emission Reductions for stationary sources as presented to the Working Group at their last Session in November** (http://www.iiasa.ac.at/rains/CAFE_files/ baseline3v2.pdf)**.** Unavoidably, the choice of what is considered as technically feasible in 2020 is to some extent arbitrary. Voices were raised that suggested the assumptions made by RAINS to be very conservative (e.g., excluding certain retrofit options, e.g., of large point sources of marine vessels as well as assuming only the traditional replacement rate of small sources), while other stakeholders might claim certain assumptions to be too optimistic. Eventually, for developing solid policy advice, the target setting approach will need to prove robust with respect to uncertainties in the assumptions on what is technically feasible to implement.

- **Preliminary City-Delta results have been implemented in the optimisation, but are not in their final shape.** For the first time, City-Delta results have been incorporated into the RAINS optimization. The preliminary approach for quantifying the incremental pollution within urban areas originating from low-level sources as presented at the last meeting of the Working Group has been improved along various lines. However, a number of problems were detected with the newly introduced data sets on urban wind speeds and small-scale population densities, so that further work will be necessary to produce robust estimates. As explained earlier, the City-Delta approach with its focus on the health impact quantification addresses PM concentrations in urban background air, consistent with the recommendations of the joint WHO-UN/ECE Task Force on Health. Obviously, this approach does not address small-scale concentration differences within cities, e.g., in street canyons. Thus, the concentration results presented in this report cannot be readily related to potential air quality limit values, as they apply at all locations.

- **1997 meteorology.** All source-receptor relationships have been developed for the meteorology of 1997. As discussed in earlier meetings of the Working Group on Target Setting, the inter-annual meteorological variability is substantial and needs to be taken into account when producing final policy advice. Due to lack of time, it was not yet possible to incorporate additional meteorological years into the RAINS optimization.

- All **assumptions made for quantifying health impacts from PM** in the RAINS model (see Amann, 2004c). The RAINS methodology for calculating losses of life expectancy attributable to the exposure to fine particulate matter involves a number of assumptions, which have been discussed at and approved by the joint WHO-UN/ECE Task Force on Health (http://www.euro.who.int/eprise/main/WHO/Progs/AIQ/Activities/20031204_1). Important assumptions include
  - the association of mortality with the long-term exposure to PM2.5,
  - that effects occur only for people older than 30 years, i.e., that infant mortality is excluded,
  - that the coefficients for relative risk found in US studies (Pope et al., 2002) are applicable to Europe,
  - that the linear relative risk function is applicable to particles smaller than 2.5 μm originating from primary anthropogenic PM emissions and from secondary inorganic aerosols, but that PM2.5 from natural sources do not cause health effects. Also, due to the inability to accurately model the fate of secondary organic aerosols, their contribution to health impacts is ignored,
  - that potential differences of particles according to their chemical composition, size distribution and number counts of particles are ignored.
- While this analysis explores the cost-effectiveness of further road measures, only illustrative assumptions have been used for quantifying their emission reduction efficiencies. No assumptions have been made for the additional costs of these measures.

3.2 Caveats

As discussed in the introduction, this report presents first outcomes of a revised version of the RAINS optimization tool. Due to time limitations and in the interest of presenting a first qualitative picture of a cost-effectiveness analysis in time for the CAFE policy analysis, a number of issues could not be sufficiently resolved. Thus, all quantitative results presented in this report must be considered provisional due to a number of factors:

- There was limited time available to conduct the standard RAINS quality control procedures. In particular, under normal conditions all results of the RAINS model are cross-checked by different people with alternative independent software. Unfortunately, within the given time such validation was impossible to conduct, especially with respect to the optimization software, for which the alternative software could not be completed in time. However, since the present problem formulation is completely linear, chances are low that the standard GAMS software package would produce erroneous - or non-optimal - results.
- For all environmental problems considered, new functional relationships have been developed from the data set of EMEP model runs produced in October 2004. Due to limited time it was not yet possible to fully evaluate the performance of these new functional relationships with the scientific scrutiny that is usually applied for RAINS analyses. While the present formulation produces approximations that are considered acceptable by the model developers given the present scope of the RAINS analysis, further refinements might lead to more

accurate formulations. The full documentation of the source-receptor relationships has not yet been completed.

- While an essential part of any model analysis, lack of time did not permit performing any uncertainty analysis to establish the robustness of the model results. It will need to be discussed with the Working Group at what point in time available resources should be spent for a systematic uncertainty analysis instead on further refinements of the modelling tools.

4 Recent methodological advances

4.1 Source-receptor relationships for particulate matter

The RAINS optimization routine includes representations of atmospheric transport characteristics. For conducting the optimization task, these representations must be computationally efficient. Extensive analysis has demonstrated that, within the range of emissions that is of relevance for CAFE, acid deposition can be approximated through linear relationships. The response of ambient PM2.5 concentrations to changes in emissions, however, shows clear non-linearities. It has been concluded from an extended analysis of EMEP model calculations that linear formulations appear suitable also for the dispersion of the non-reactive primary PM emissions as well as the formation and transport of secondary sulphate aerosols. However, at an aggregated level there are clear non-linearities in the response of secondary nitrate aerosols towards changes in NO_x and NH_3 emissions, depending on the relative abundances of these pollutants.

For the RAINS model a formulation has been developed that decomposes the influence of the various precursor emissions into linear relationships. For primary PM and sulphates, such relationships can be directly extracted from a suitable data sample of EMEP model calculations. For nitrogen species, however, a distinction has been made between the chemistries in summer and winter, accounting for the different (ammonia or NO_x limited) chemical regimes during the winter (Equation 1).

$$
\begin{aligned}
PM2.5_j &= \sum_{i \in I} \pi_{ij}^A * p_i + \sum_{i \in I} \sigma_{ij}^A * s_i + \\
&+ 0.5 * \left(\sum_{i \in I} \alpha_{ij}^S * a_i + \sum_{i \in I} \nu_{ij}^S * n_i\right) + \\
&+ 0.5 * \min\left(\max\left(0, \sum_{i \in I} c1 * \alpha_{ij}^W * a_i - \sum_{i \in I} c1 * \frac{14}{32} * \sigma_{ij}^W * s_i + k1_j\right), \sum_{i \in I} c2 * \nu_{ij}^W * n_i + k2_j\right)
\end{aligned}
$$

Equation 1

with

$PM2.5_j$	Annual mean concentration of PM2.5 at receptor point *j*
I	Set of emission sources (countries)
J	Set of receptors (grid cells)
p_i	Primary emissions of PM2.5 in country *i*
s_i	SO_2 emissions in country *i*
n_i	NO_x emissions in country *i*
a_i	NH_3 emissions in country *i*
$\alpha^{S,W}_{ij}$, $\nu^{S,W}$,A_{ij}, $\sigma^{W,A}_{ij}$, π^{A}_{ij}	Linear transfer matrices for reduced and oxidized nitrogen, sulfur and primary PM2.5, winter, summer and annual

The performance of this formulation against results from the full EMEP model is shown in Figure 4.1.

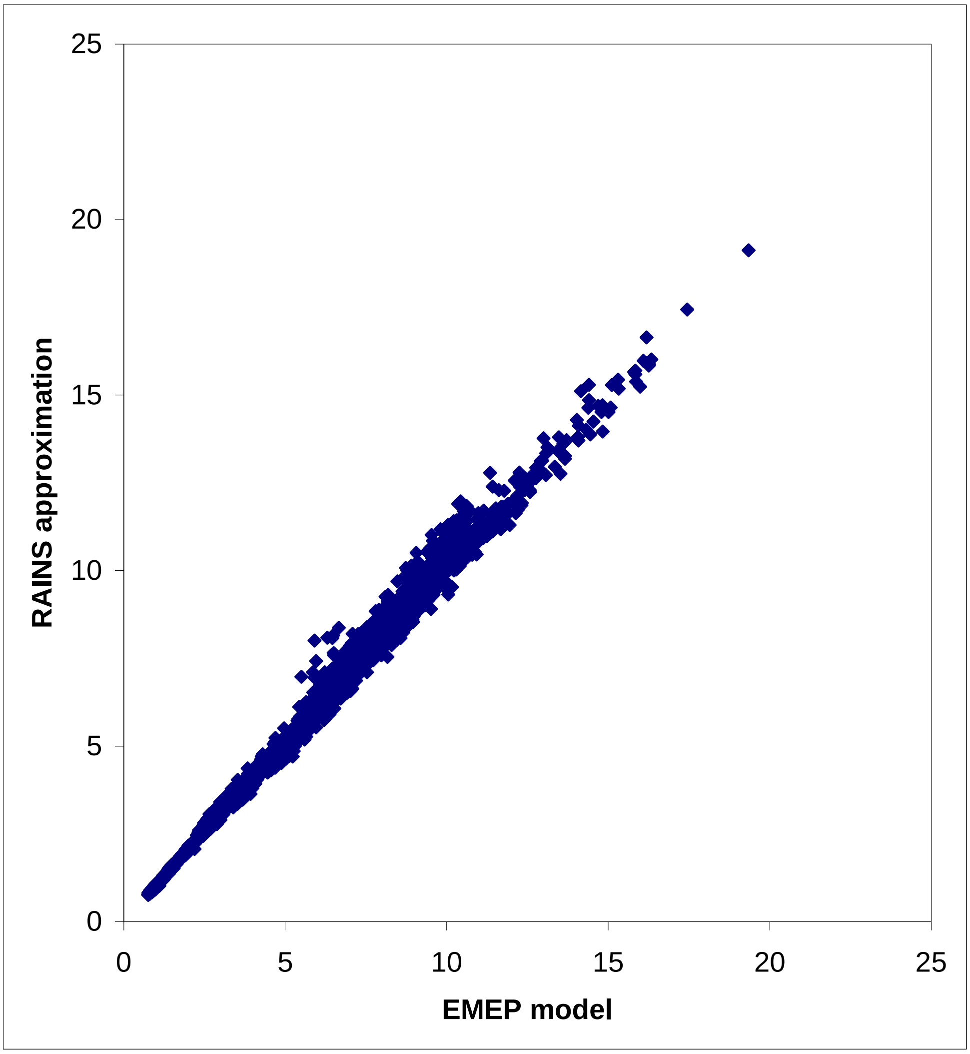


Figure 4.1: Comparison of the RAINS approximations of annual mean PM2.5 concentrations calculated with the results from the full EMEP model (μg/m^3)

4.2 City-Delta

Based on the City-Delta extended intercomparison exercise of 17 urban and regional atmospheric transport models (Cuvelier and Thunis, 2005), functional relationships have been derived to quantify the increments in PM2.5 concentrations that occur within cities compared to the surroundings.

These relationships relate the difference in the annual mean PM2.5 concentrations between in an urban area and average concentrations calculated over a 50*50 km grid cell surrounding the city with spatial differences in emission densities of low-level sources and city-specific wind speeds (Equation 2).

$$\Delta PM_{sub\text{-}grid} = (ED_{sub\text{-}grid} - ED_{EMEP}) * (k1 - k2*V_{wind})$$

Equation 2

with

$\Delta PM_{sub\text{-}grid}$ ..	Difference in PM concentration between sub-grid (urban/rural) area and EMEP grid average
ED_x …	Emission density for low sources (x=urban/rural/EMEP grid average)
V_{wind} …	Annual mean wind speed in EMEP grid cell
k1, k2 …	Parameters derived from the City-Delta ensemble model

Since there are no coherent urban emission inventories available at the European scale, the RAINS model – following the common practice in standard emission inventories – estimates urban emission densities based on population densities. With this, the Equation 2 turns into:

$$\begin{aligned} \Delta PM_{sub\text{-}grid} &= (ED_{sub\text{-}grid} - ED_{EMEP}) * (k1 - k2*V_{wind}) = \\ &= (ED_{EMEP} * (PD_{sub\text{-}grid} / PD_{EMEP}) - ED_{EMEP}) * (k1 - k2*V_{wind}) = \\ &= ED_{EMEP} * (PD_{sub\text{-}grid} / PD_{EMEP} - 1) * (k1 - k2*V_{wind}) \end{aligned}$$

Equation 3

With this equation RAINS estimates the urban increments that occur on the levels that are calculated by the EMEP model for the 50*50 km grid cells. RAINS relies on the gridded emission inventories compiled by EMEP, population density data derived from the LANDSCAN data set, and on wind speed data from the EMEP model and city-specific wind speeds from a WMO data set.

Provisional calculations have been implemented for approximately 150 large cities in the EU-25. There is a need for further improvement in all these data sets to improve the accuracy of the results. W

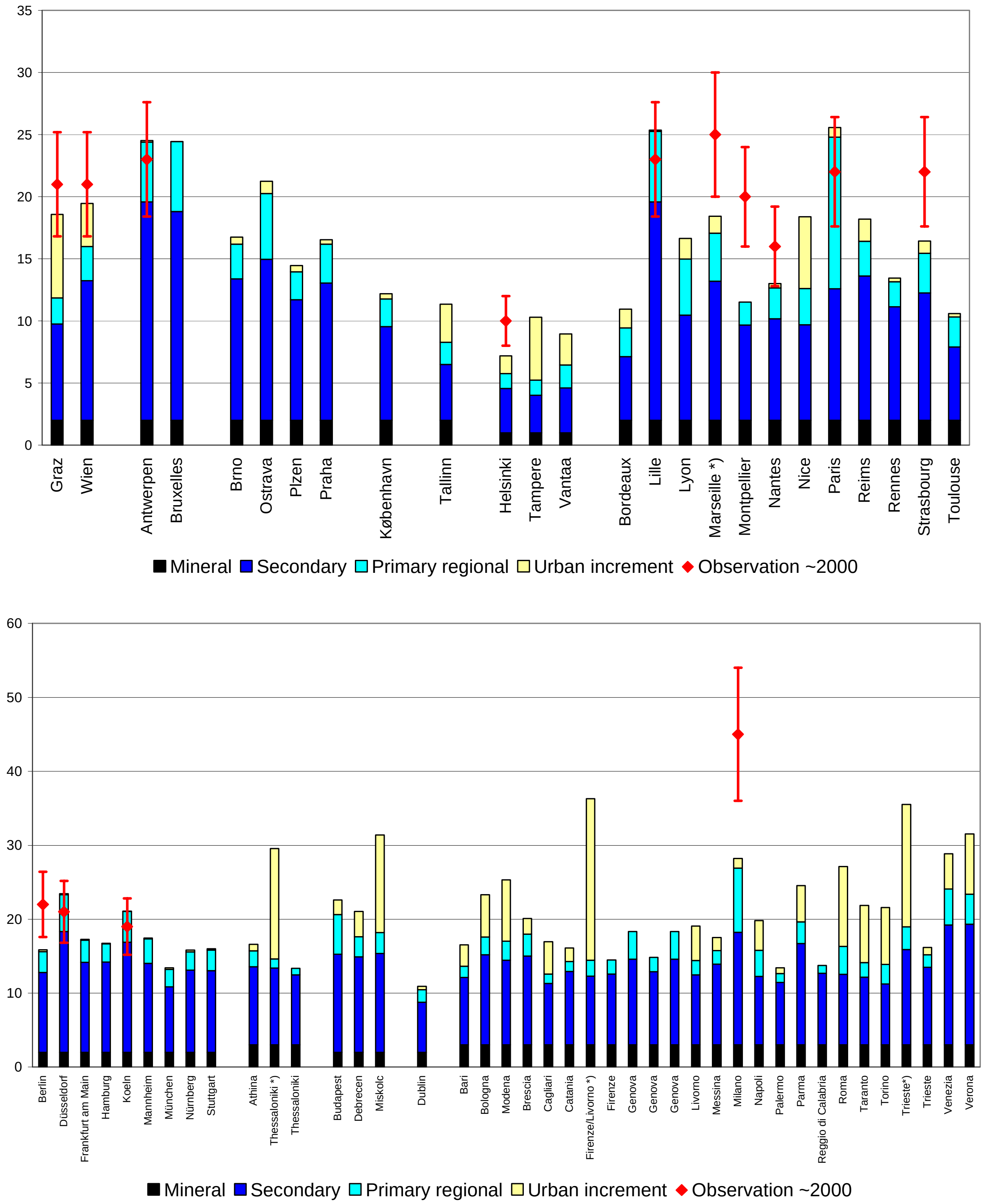
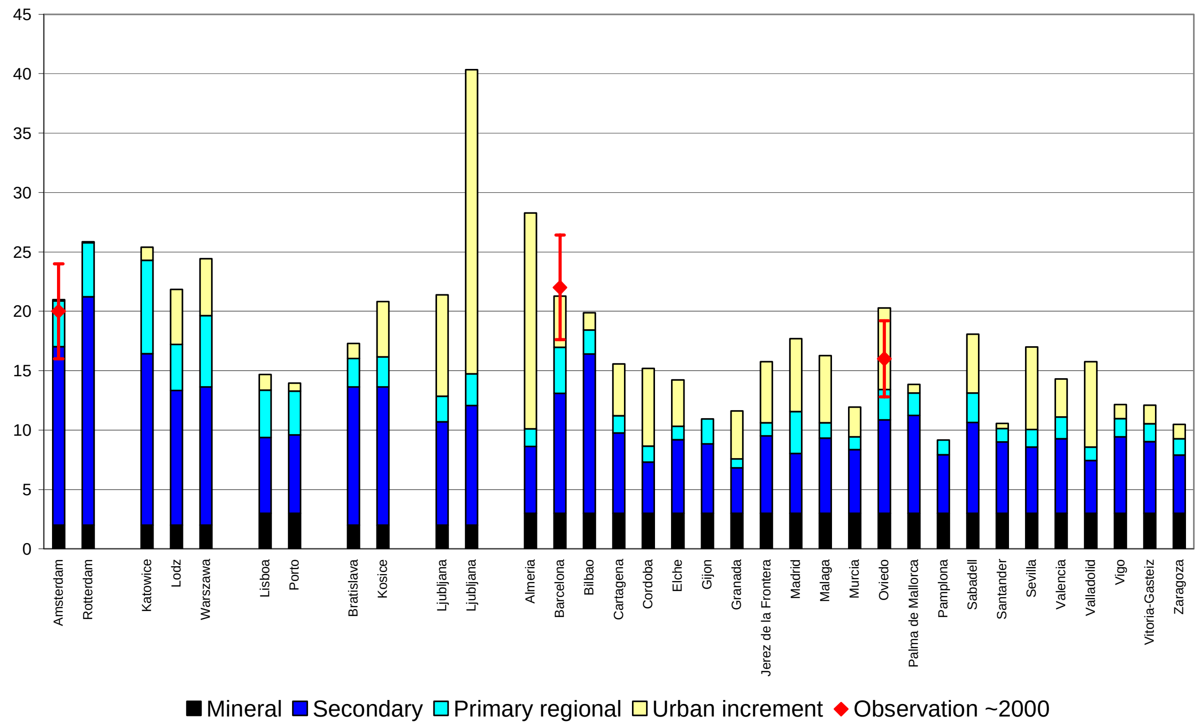


Figure 4.2: RAINS estimates of the contributions to PM2.5 annual mean concentrations in urban areas (in µg/m^3). The estimate of mineral contribution is based on literature data. Computations of regional primary and secondary articles are derived from the EMEP model, the urban increment is estimated with the City-Delta approach. For the available observations, the marked uncertainty range of ±20 percent indicates uncertainties related to the inter-annual meteorological variability, the location of the monitors, monitoring artifacts, sampling frequency, etc. These calculations do not include contributions from natural sources other than mineral and sea salt.



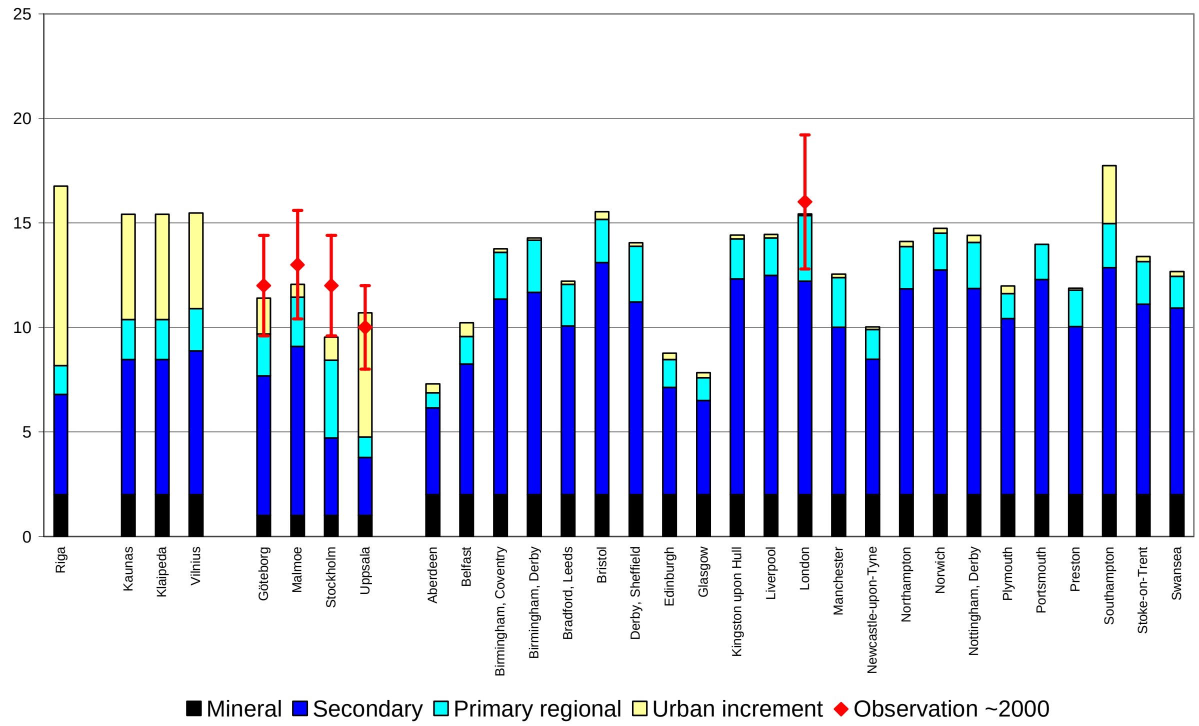


Figure 4.3: RAINS estimates of the contributions to PM2.5 annual mean concentrations in urban areas (in µg/m3). The estimate of mineral contribution is based on literature data. Computations of regional primary and secondary articles are derived from the EMEP model, the urban increment is estimated with the City-Delta approach. For the available observations, the marked uncertainty range of ±20 percent indicates uncertainties related to the inter-annual meteorological variability, the location of the monitors, monitoring artefacts, sampling frequency, etc. These calculations do not include contributions from natural sources other than mineral and sea salt.

5 Three approaches for target setting

It has been shown in earlier RAINS analyses that within the next few decades environmental ‘no-effect’ levels are not achievable with currently available emission control measures given the projected levels of anthropogenic activities, such as energy consumption and agricultural production. To design emission control strategies that lead to cost-effective environmental improvements on the way towards a full achievement of such no-effect levels, environmental interim targets might be a useful concept. The choice of an interim target will not only determine the cost-effectiveness of a next policy step, but has also critical impact on the distribution of costs and benefits across Member States.

The RAINS optimization identifies the least-cost combination of measures that achieve specified environmental objectives. Thus the RAINS optimization tool can provide valuable insight injto the cost-effectiveness of alternative target setting concepts and their implications on the distributions of costs and benefits.

Focusing on PM, this report explores the implications of three target setting principles:

- A “limit value” concept, which requests certain levels of PM2.5 concentrations to be achieved everywhere in the EU.
- A “gap closure” concept, which for equal *relative* improvements in (population-weighted) PM exposure or in terms of loss in life expectancy in each grid scales. A number of ambition levels have been defined using a common scale of what is achievable in terms of impacts through dedicated emission control measures between the “current legislation” of the baseline scenario and the maximum technically feasible emission reductions including further road measures.
- A “Europe-wide” target, exploring the optimal use of a given budget to reach maximum improvements in health impacts (or population-weighted PM exposure) irrespective of the location of the improvement.

6 Uniform targets on air quality

As a first approach, cost-effective emission reductions have been explored that bring PM2.5 concentrations in urban background air sheds everywhere in the EU-25 below a certain limit.

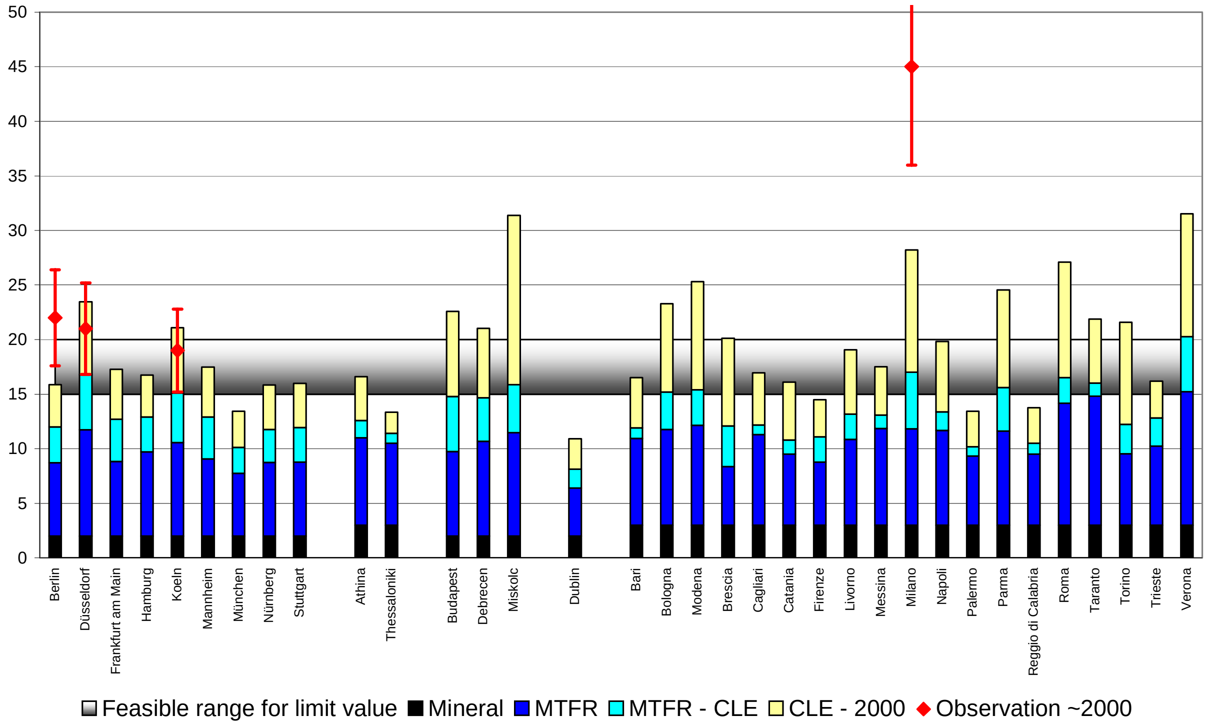
The RAINS model, with its inclusion of City-Delta, allows addressing concentrations at PM2.5 at urban background, but not at hot spots in street canyons or around industrial locations. Furthermore, the EMEP model, on which the RAINS model rests its calculations of PM dispersion, does not quantify contributions from natural sources, i.e., mineral dust, sea salt and biogenic material and of secondary organic aerosols.

While a quantification of the organic material from biogenic sources and of secondary organic aerosols is difficult, indications on the magnitude of the mineral fraction can be derived from chemical analyses of PM2.5 samples. A literature review, inter alia taking into account the information presented in the PM position paper of CAFE, quotes Spanish measurements with approximately 3 $\mu g/m^3$ mineral contributions, Scandinavian studies with roughly 1 $\mu g/m^3$, and measurements in Austria and the UK lying in between. Thus, in absence of more information, an assumption is made that the mineral contribution amounts in Mediterranean countries at 3 $\mu g/m^3$, in Scandinavia at 1 $\mu g/m^3$, and all other countries at 2 $\mu g/m^3$.

With these assumptions, for each of the urban areas that are presently considered in RAINS the level of PM2.5 in urban background has been estimated.

Figure 6.1 and Figure 6.2 illustrate for the urban areas that are presently considered in RAINS the PM2.5 concentrations in urban background air, for the year 2000, for 2020 resulting from current legislation, and the potential for further technical emission control measures including further road measures. In general, current legislation is expected to significantly reduce PM2.5 in urban areas, and there is scope for further reductions.

The provisional calculations shown in Figure 6.1 and Figure 6.2 erroneously allocate all PM emissions from marine ships to the ports, and thus deliver too high concentrations for port cities. Ignoring these port cities for a moment, a wide spread of PM2.5 concentrations is computed for the various cities.



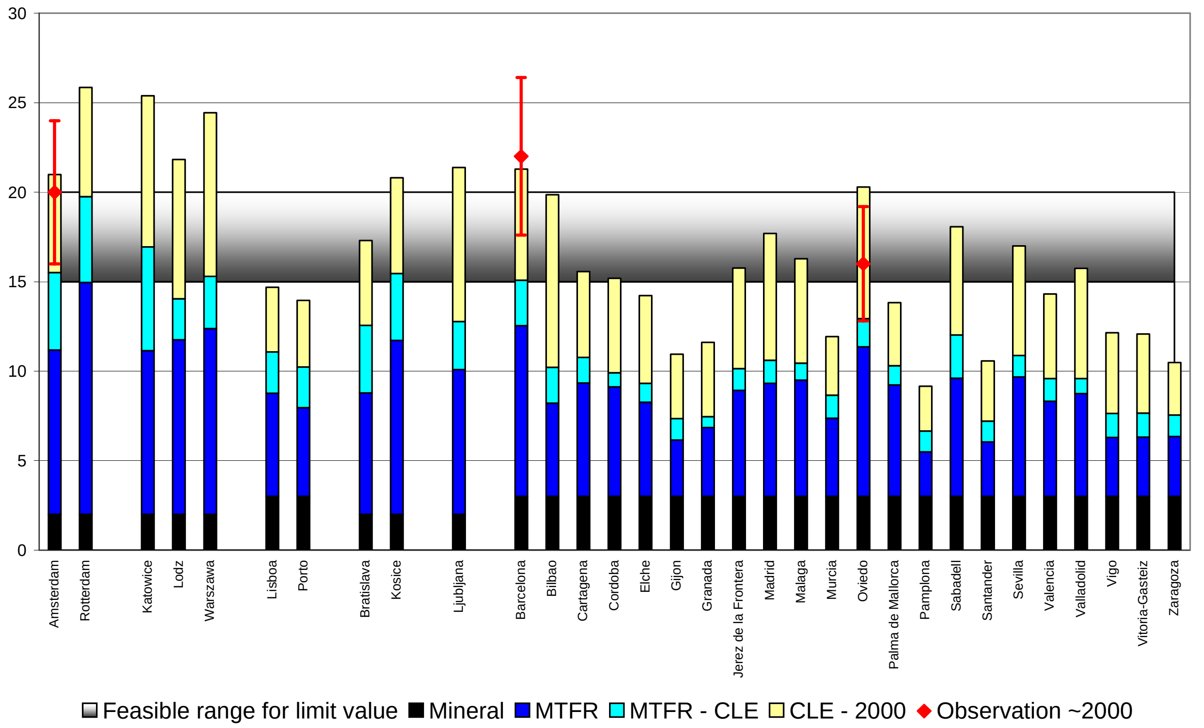


Figure 6.1: RAINS estimates of PM2.5 annual mean concentrations in urban areas (in µg/m^3). The black bars indicate mineral contribution from natural sources, and the dark blue bars the anthropogenic fraction that cannot be removed with present emission control technology (including further road measures). The light blue parts show the reduction potential in the year 2020, while the yellow part indicate the improvements expected to occur between 2000 and 2020 due to current legislation.

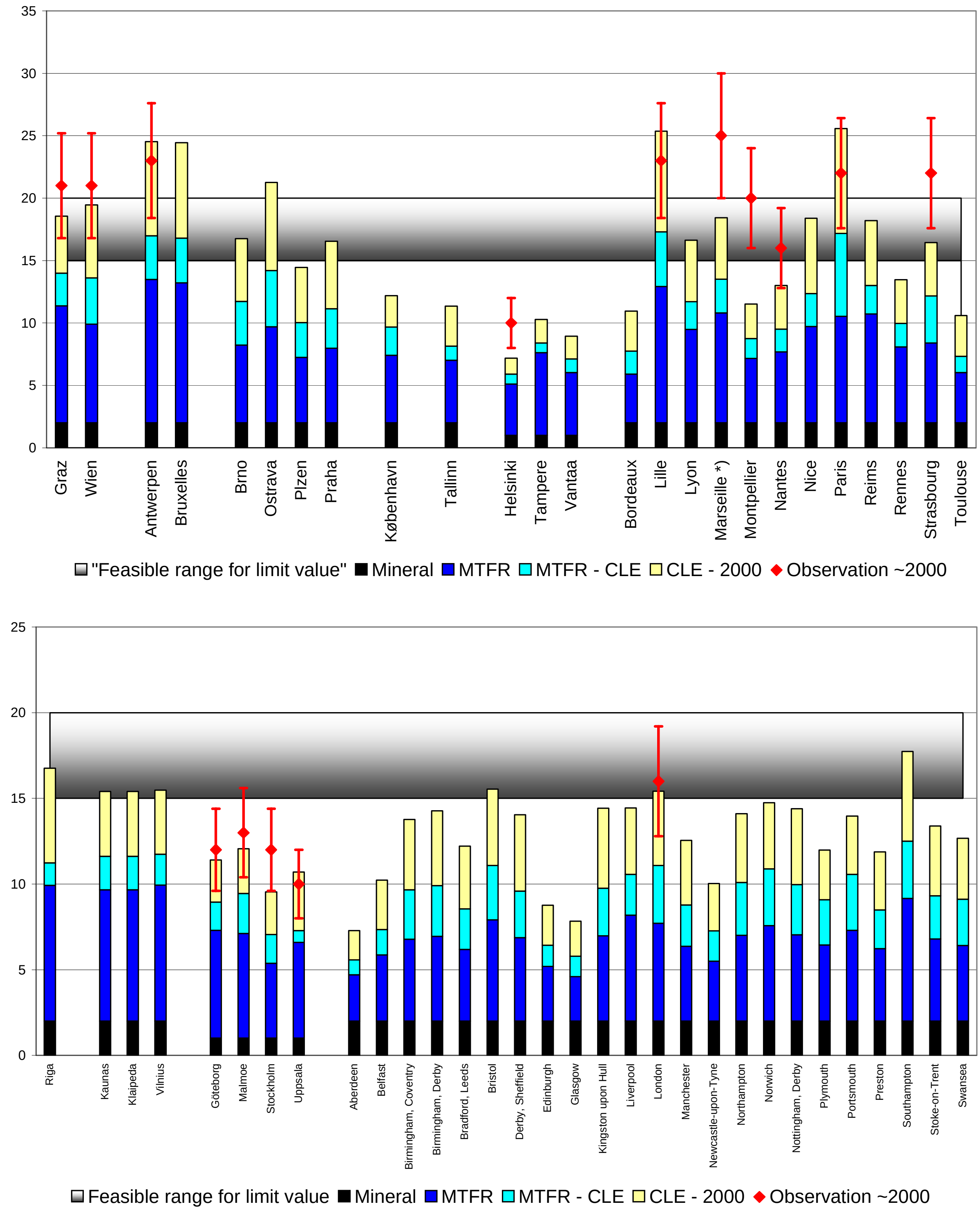


Figure 6.2: RAINS estimates of PM2.5 annual mean concentrations in urban areas (in µg/m^3). The black bars indicate mineral contribution from natural sources, and the dark blue bars the anthropogenic fraction that cannot be removed with present emission control technology (including further road measures). The light blue parts show the reduction potential in the year 2020, while the yellow part indicate the improvements expected to occur between 2000 and 2020 due to current legislation.

A first set of scenarios aims at reducing annual mean PM2.5 concentrations below a uniform limit value in all urban areas in the EU. As outlined above, the RAINS model does not include street canyon scale, and thus is not applicable for the present definition of the EU air quality limit value. The results presented here apply to urban background air.

Obviously, to be feasible a generally applicable limit value must be achievable everywhere. Thus, as illustrated in Figure 6.1 and Figure 6.2, with the present data set some cities (excluding the port cities) cannot reduce PM2.5 in 2020 much below 15 µg/m^3, even with full application of all available control measures at the European scale. On the other hand, there are very few spots where a level of 20 µg/m^3 is computed to remain exceeded.

Thus, a sequence of scenarios has been calculated to bring PM2.5 concentrations in urban background air below uniform levels of 15, 15.5, 16, 16.5, 17 and 19 µg/m^3. To compare with hypothetical air quality limit values, contributions from natural organic sources and from secondary organic aerosols must be added, and provisions need to be made to reflect street canyon situations. While an estimate of the biogenic fraction is difficult to derive, literature data suggest for the additional PM2.5 burden in street canyons compared to urban background air to reach typically up to 5 µg/m^3.

Table 6.1: Costs (million €/year, on top of the baseline current legislation scenario) and years of life lost of the limit value scenarios B1/A and B1/B

Limit value	With further road measures (B1/A)		Without further road measures (B1/B)	
	Costs [million €/yr]	Years of life lost [million years]	Costs [million €/yr]	Years of life lost [million years]
Baseline	0	138	0	140
19 µg/m^3	0	137	28	139
17 µg/m^3	819	127	1402	127
16.5 µg/m^3	1625	122	2492	121
16 µg/m^3	2851	117	4544	115
15.5 µg/m^3	5296	111	10645	108
15 µg/m^3	16658	107	infeasible	-

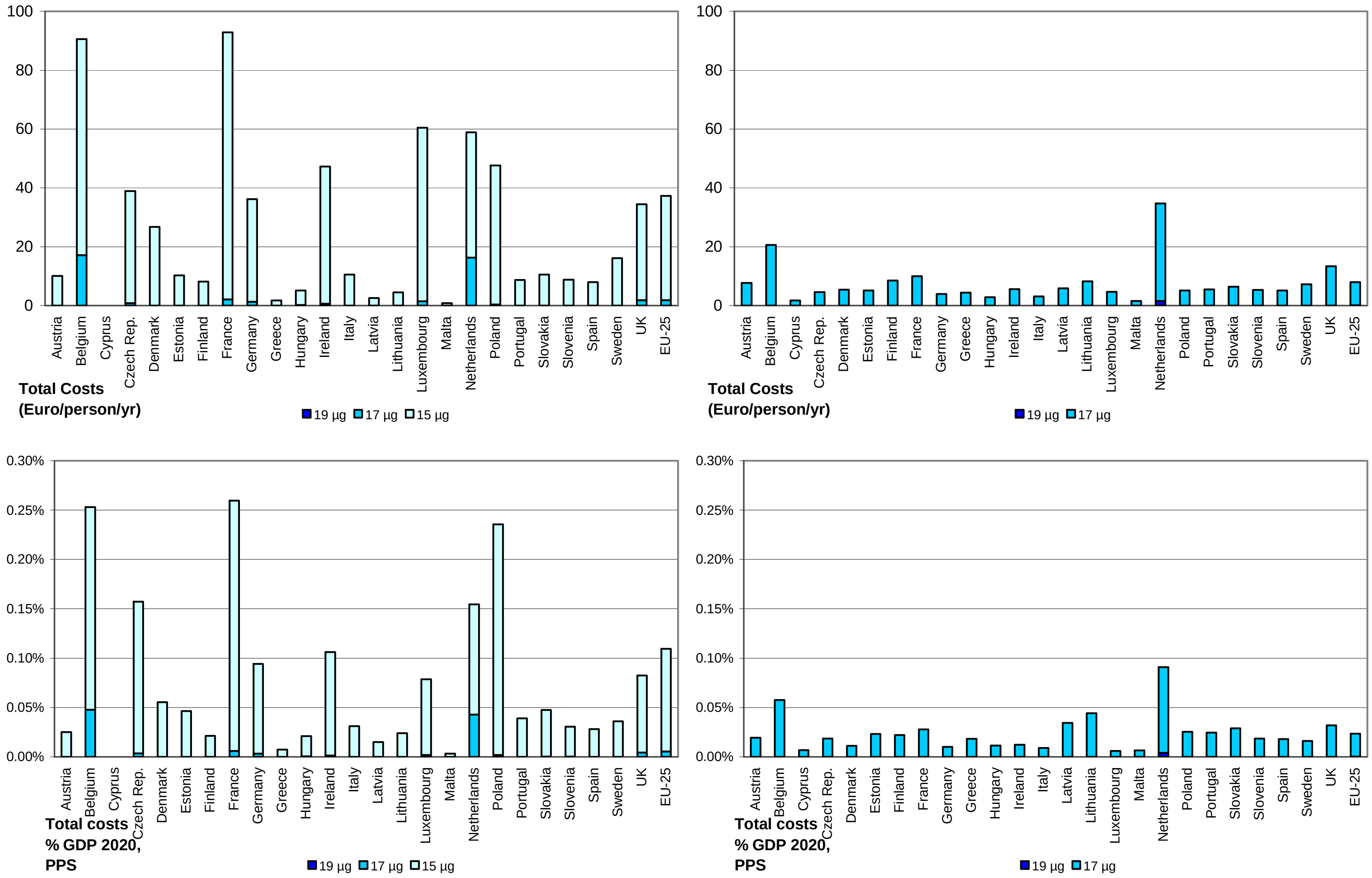


Figure 6.3: Emission control costs for bringing PM2.5 in urban background air everywhere below 19, 17 and 15 µg/m^3 on a per-capita basis (top row) and per GDP expressed in purchasing power standards (bottom row), for the scenarios with further road measures (left column) and without further road measures (right column)

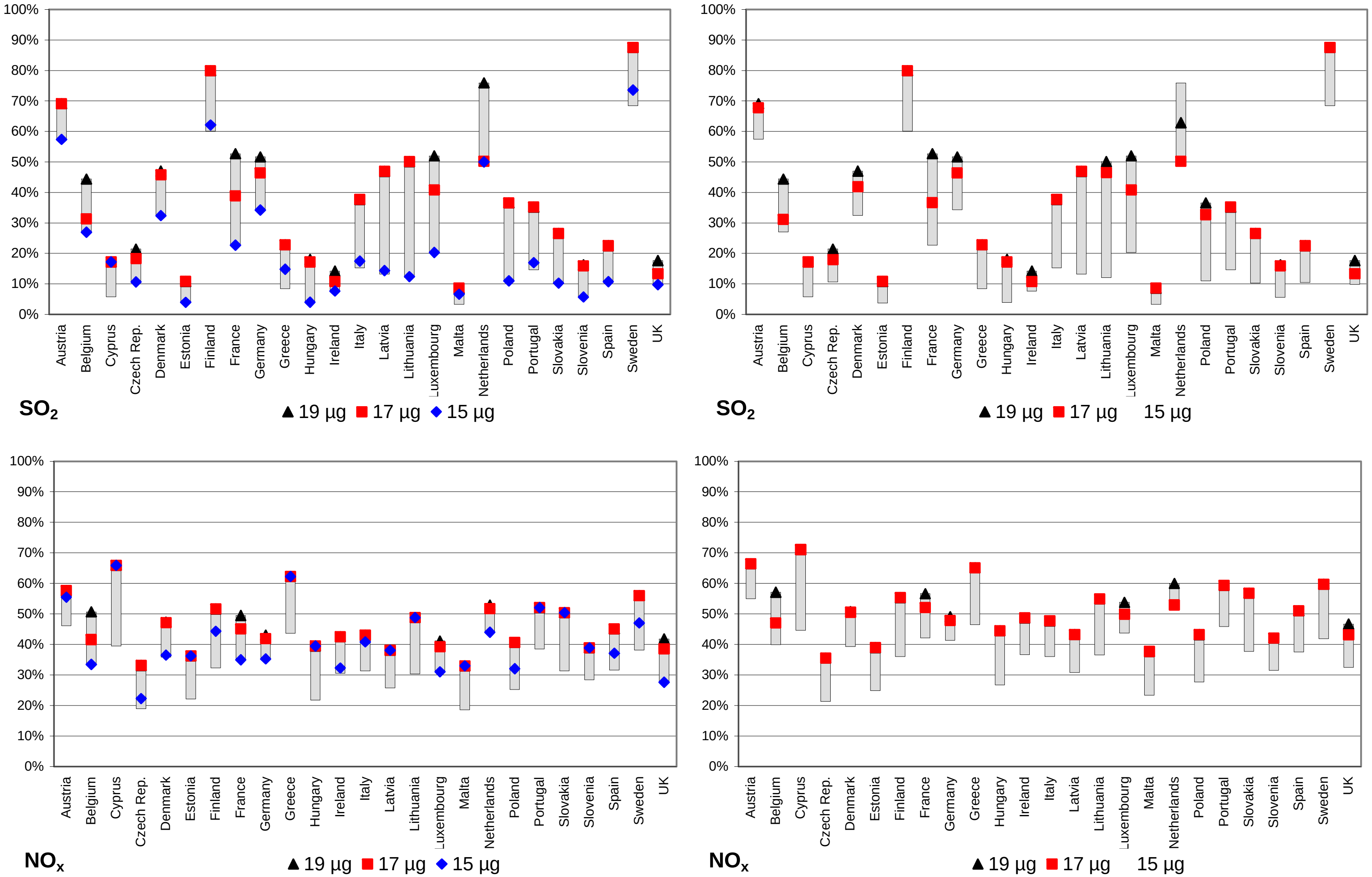
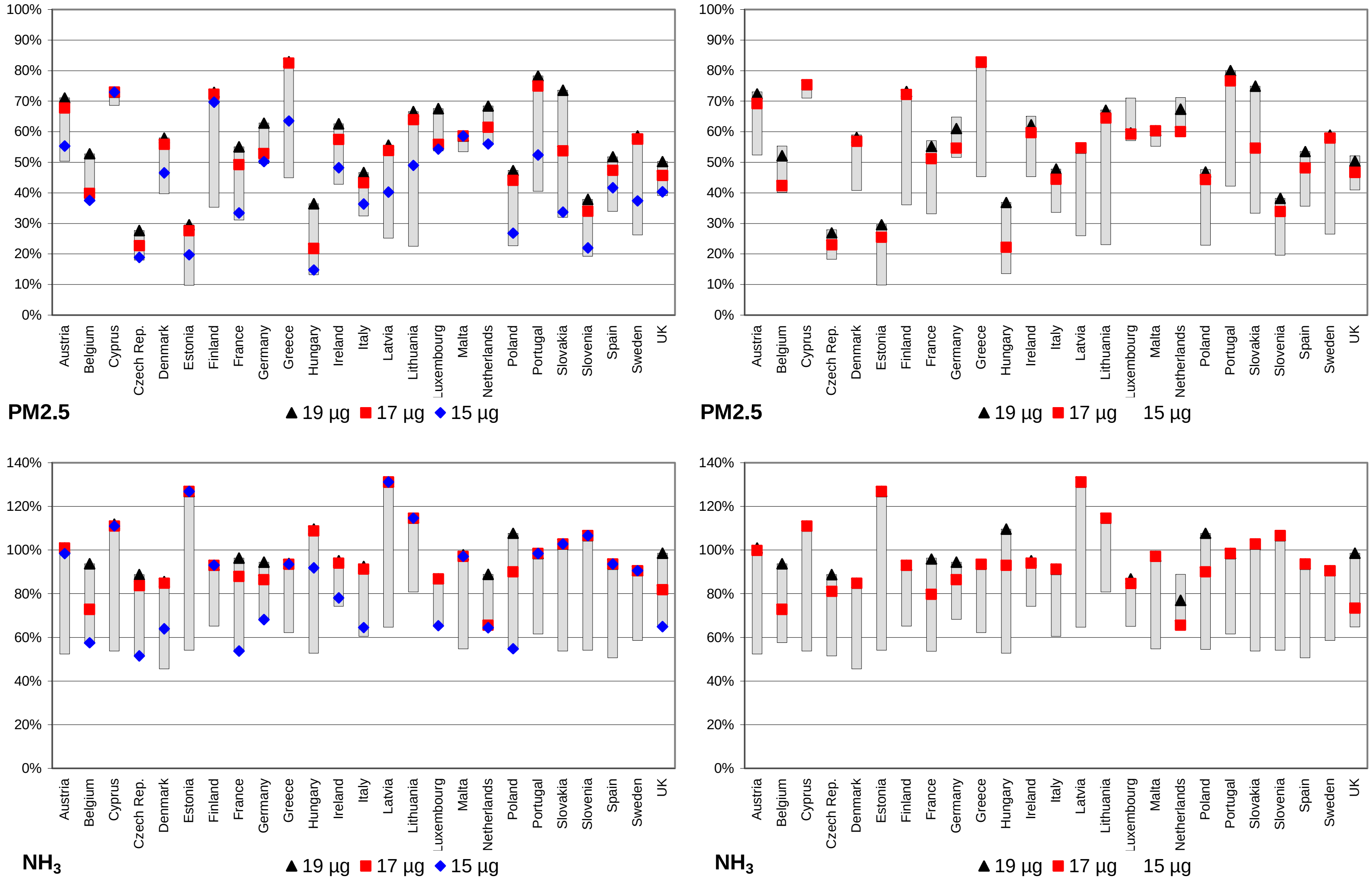


Figure 6.4: Cost-minimal emission reductions for bringing PM2.5 in urban background air everywhere below 19, 17 and 15 µg/m^3. The 100 percent line refers to the emission level in the year 2000. The grey range indicates the scope for emission reductions considered in the RAINS optimization. The left column refers to the scenarios with further road measures and the right column without further road measures



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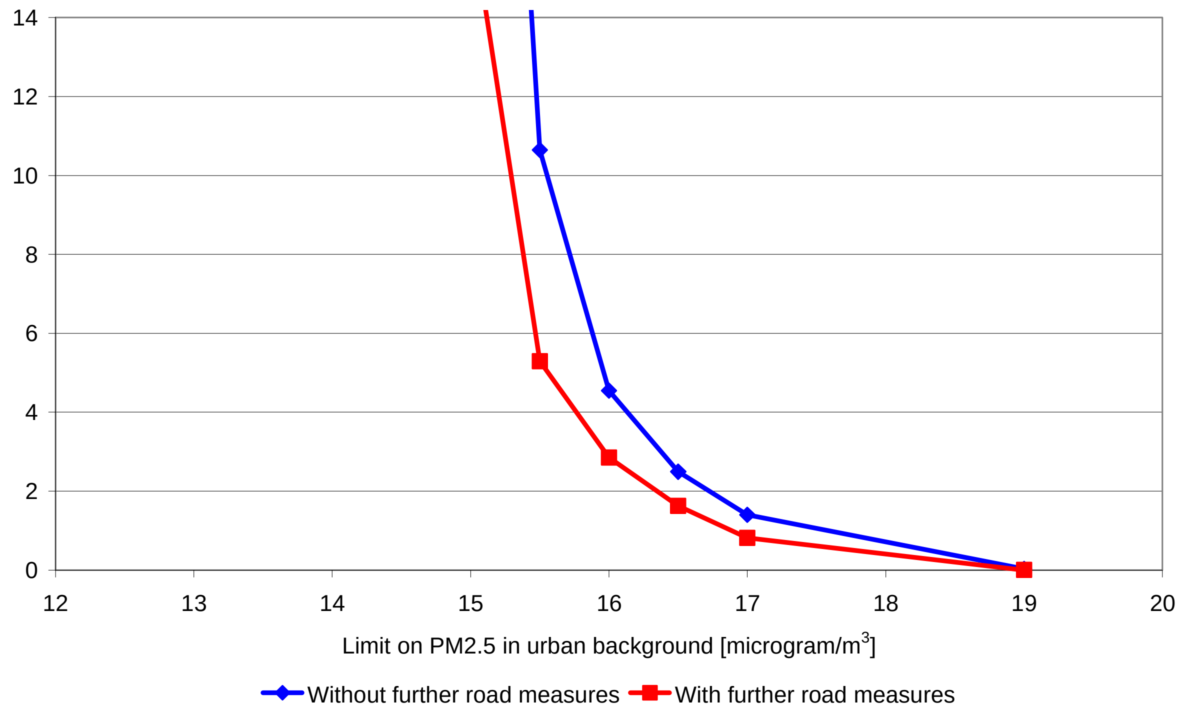


Figure 6.6: Costs for emission reductions at stationary sources of the limit value scenarios (billion €/year)

7 Uniform relative improvements (gap closure)

To reap health benefits that are not associated with peak exposure (e.g., those occurring below limit values) and to achieve a more equitable distribution of costs and benefits across Member States, the gap closure concept has been proposed and practically used, e.g., for the cost-effectiveness analyses of the NEC Directive.

As discussed in the previous report, the recent constellation of emission control potentials, atmospheric dispersion characteristics, contributions from non-EU sources and environmental sensitivity, a uniform relative improvement of the gap between current situation and the ultimate environmental objective of reaching the “no-effect” level is limited by little scope for improvements at a few locations with often untypical situations. Thus, the last report explored source-related “gap closure” concepts, dividing the scope for improvements between the projected “current legislation” case of the baseline scenario and the full application of all presently available control measures for stationary sources, however excluding further road measures (Figure 7.1).

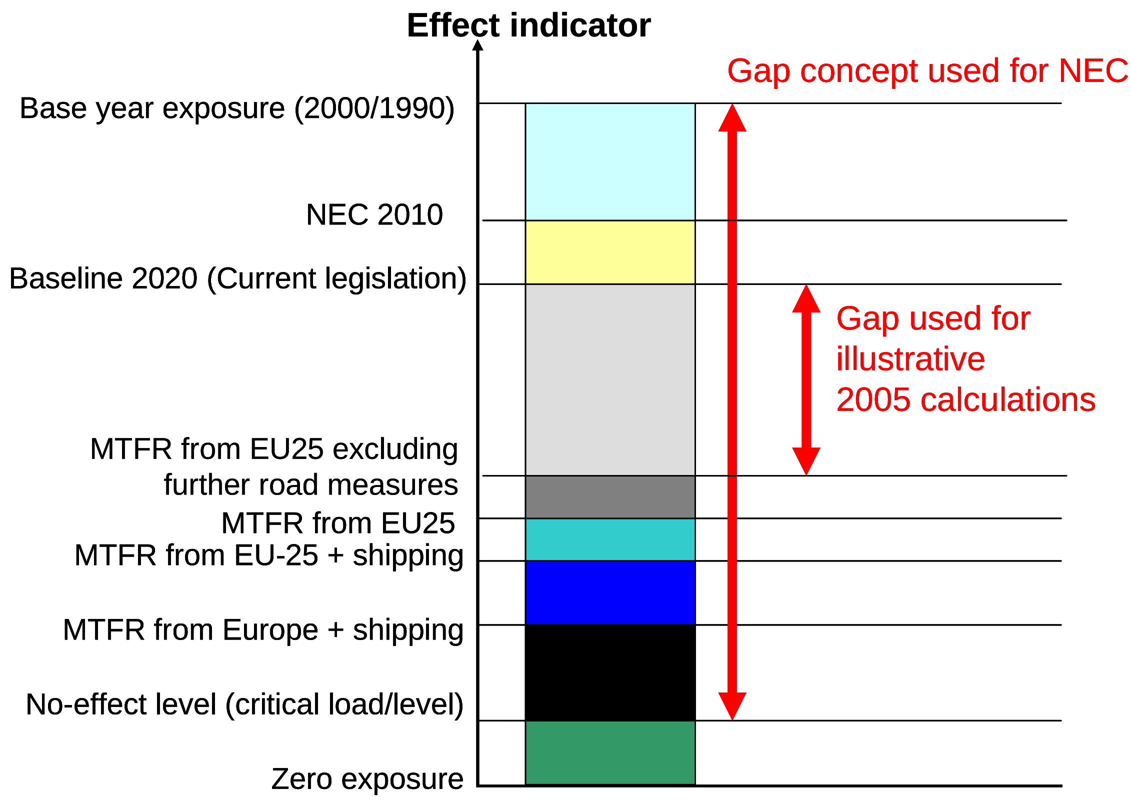


Figure 7.1: Concept of gap closure applied for the first set of exploratory RAINS calculations (Scenarios A)

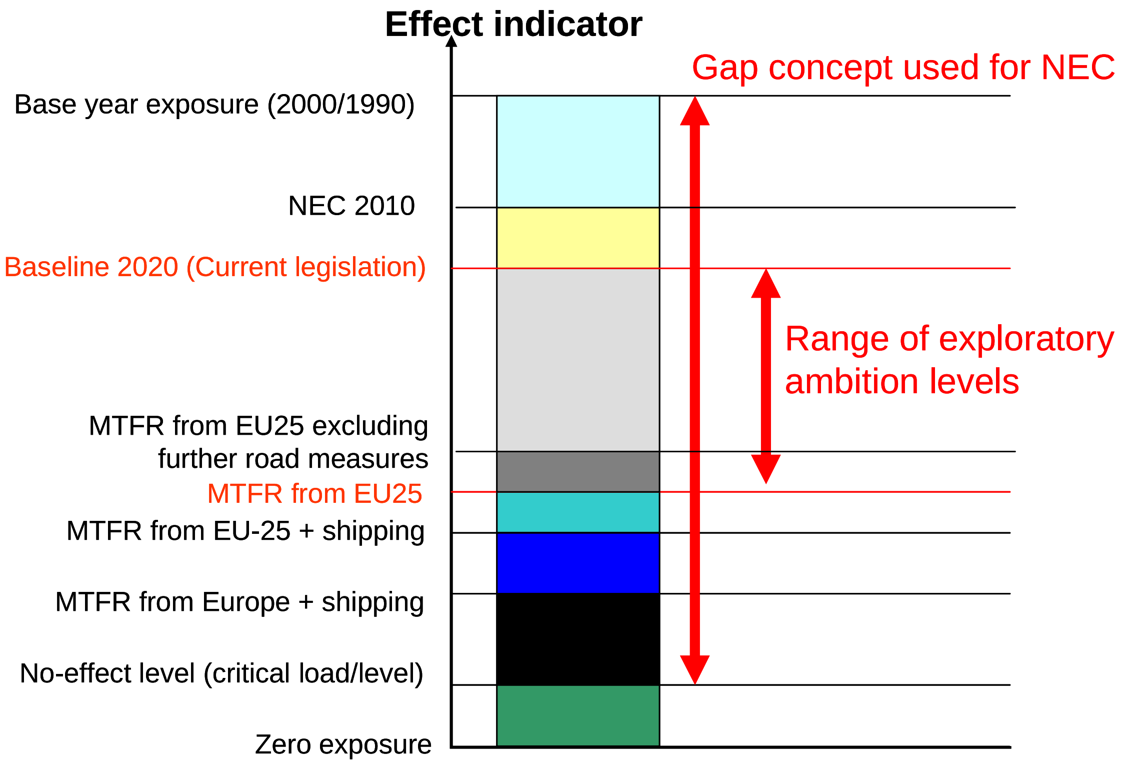


Figure 7.2: Concept of gap closure applied for the RAINS calculations presented in this report (Scenarios B)

This report follows this source-based definition of the gap, but includes the scope for measures at mobile sources (further road measures) in the analysis. Thus, a number of ambition levels dividing the range between

- the situation calculated for the baseline emissions in 2020, and the
- maximum technically feasible emission reductions that could be achieved within the EU-25 including the potential offered by further road measures and excluding the scope for emission reductions from marine ships and from non-EU countries

have been explored for in this analysis.

As stated in the recent report, it is understood that this provisional definition of a gap closure is entirely different from the “effect-based” gap closure concept that was used in the preparations for the NEC directive, since it does not establish any relationship with the environmental long-term target of the European Union. At the same time, both quantifications of the “baseline” emission levels for 2020 and the “maximum technically feasible reduction” (MTFR) case are loaded with serious uncertainties and potentially strategically motivated disagreements, which make this definition prone for political dispute.

The analysis carried out for this meeting of the Working groups addresses, inter alia, the scope for cost-effectiveness offered by stricter emission standards for mobile sources through introducing further road measures. It is clear that such standards need to be introduced as a Community-wide measure, and not for individual countries. To reflect this constraint, the RAINS optimization was carried out for given environmental targets twice:

- Case A assumes that further road measures will be introduced in all countries, and the optimization explores the scope for additional measures at stationary sources to meet the environmental objectives.
- Case B assumes that further road measures will not be introduced, and the environmental objectives need to be met with measures at stationary sources only.

With equal environmental objectives, a comparison of the emission control costs between these two cases will then allow drawing conclusions about the cost-effectiveness of further road measures.

The following scenarios have been calculated:

Ambition level (improvement of the "gap" between CLE and MTFR)	With further road measures	Without further road measures
25 %	Scenario B2/1A	Scenario B2/1B
40 %	Scenario B2/2A	Scenario B2/2B
50 %	Scenario B2/3A	Scenario B2/3B
60 %	Scenario B2/4A	Scenario B2/4B
70 %	Scenario B2/5A	Scenario B2/5B
75 %	Scenario B2/6A	Scenario B2/6B

Table 7.1: Costs (million €/year, on top of the baseline current legislation scenario) and years of life lost of the gap closure scenarios B2/A and B2/B

Ambition level (improvement of the "gap" between CLE and MTFR)	With further road measures (B2/A)		Without further road measures (B2/B)	
	Costs [million €/yr]	Years of life lost [million years]	Costs [million €/yr]	Years of life lost [million years]
Baseline	0	138	0	140
25 %	480	128	721	128
40 %	1240	122	1852	121
50 %	2051	118	3184	117
60 %	3289	114	5257	113
70 %	5078	110	10046	109
75 %	6502	108	infeasible	-

Since the costs of further road measures have not been provided for this analysis, no overall conclusions about the cost-effectiveness of further road measures for gap closure scenarios can be drawn at this stage.

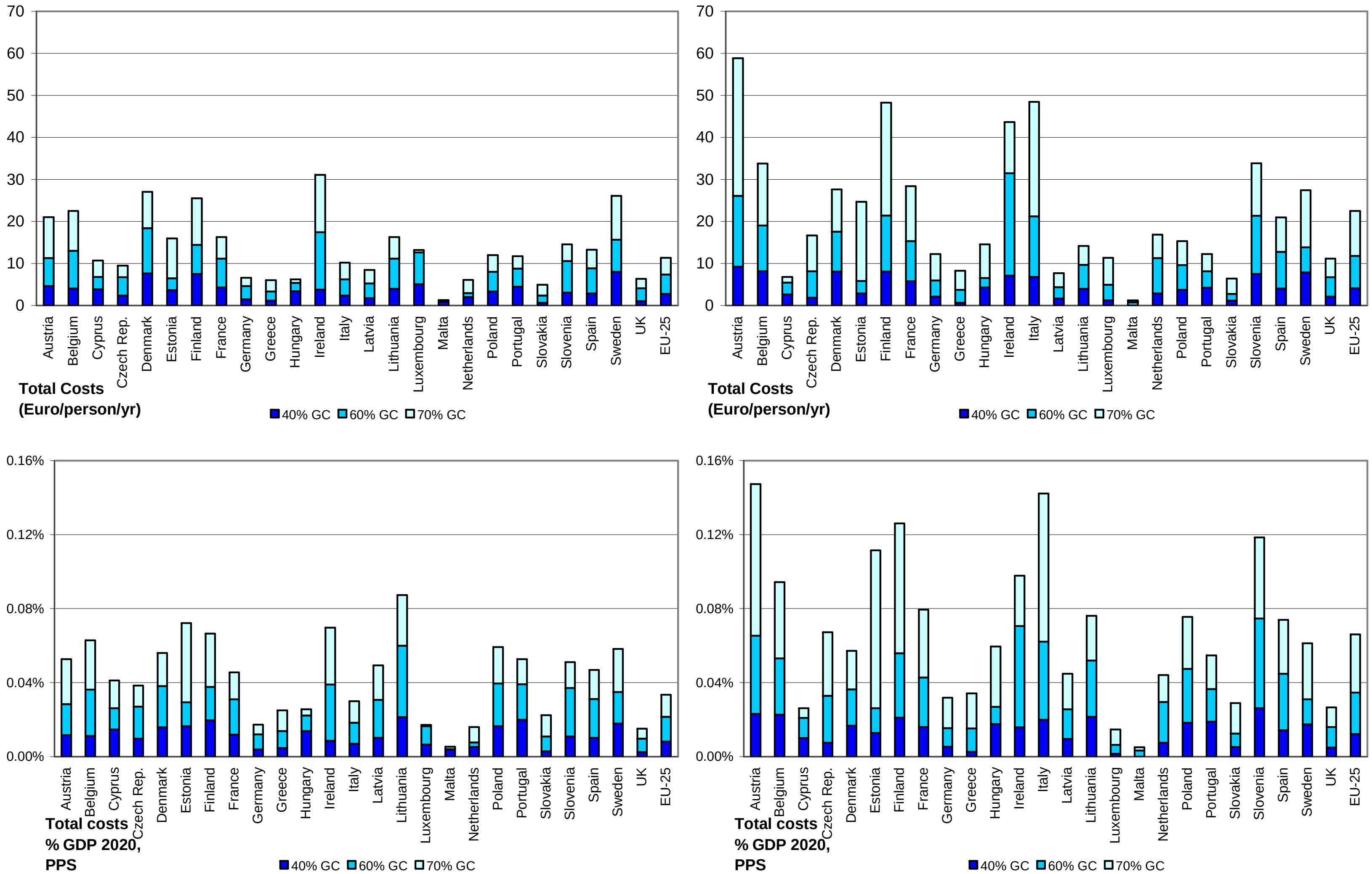


Figure 7.3: Emission control costs on a per-capita basis (top row) and per GDP expressed in purchasing power standards (bottom row), for the scenarios with further road measures (left column) and without further road measures (right column)

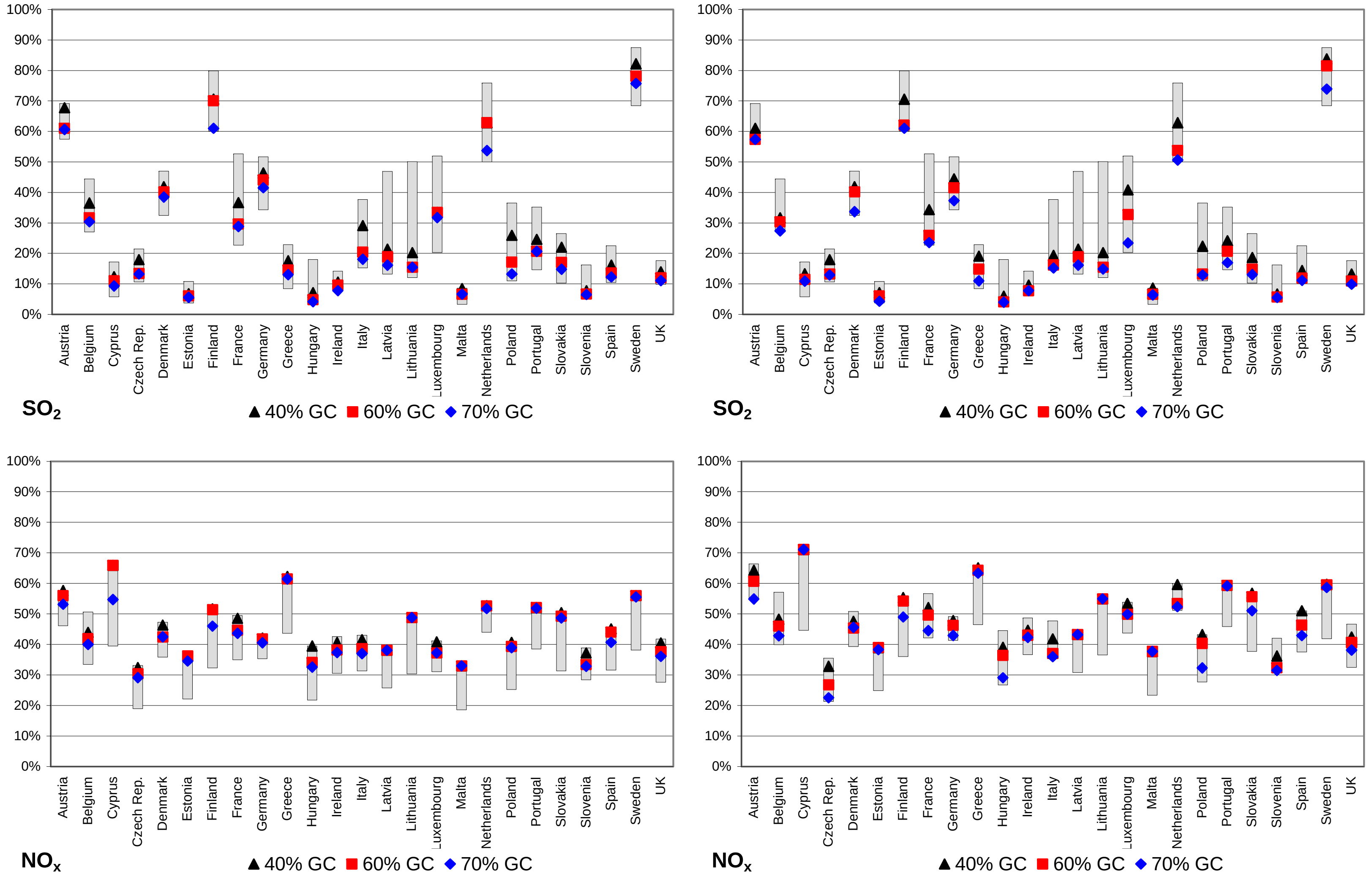
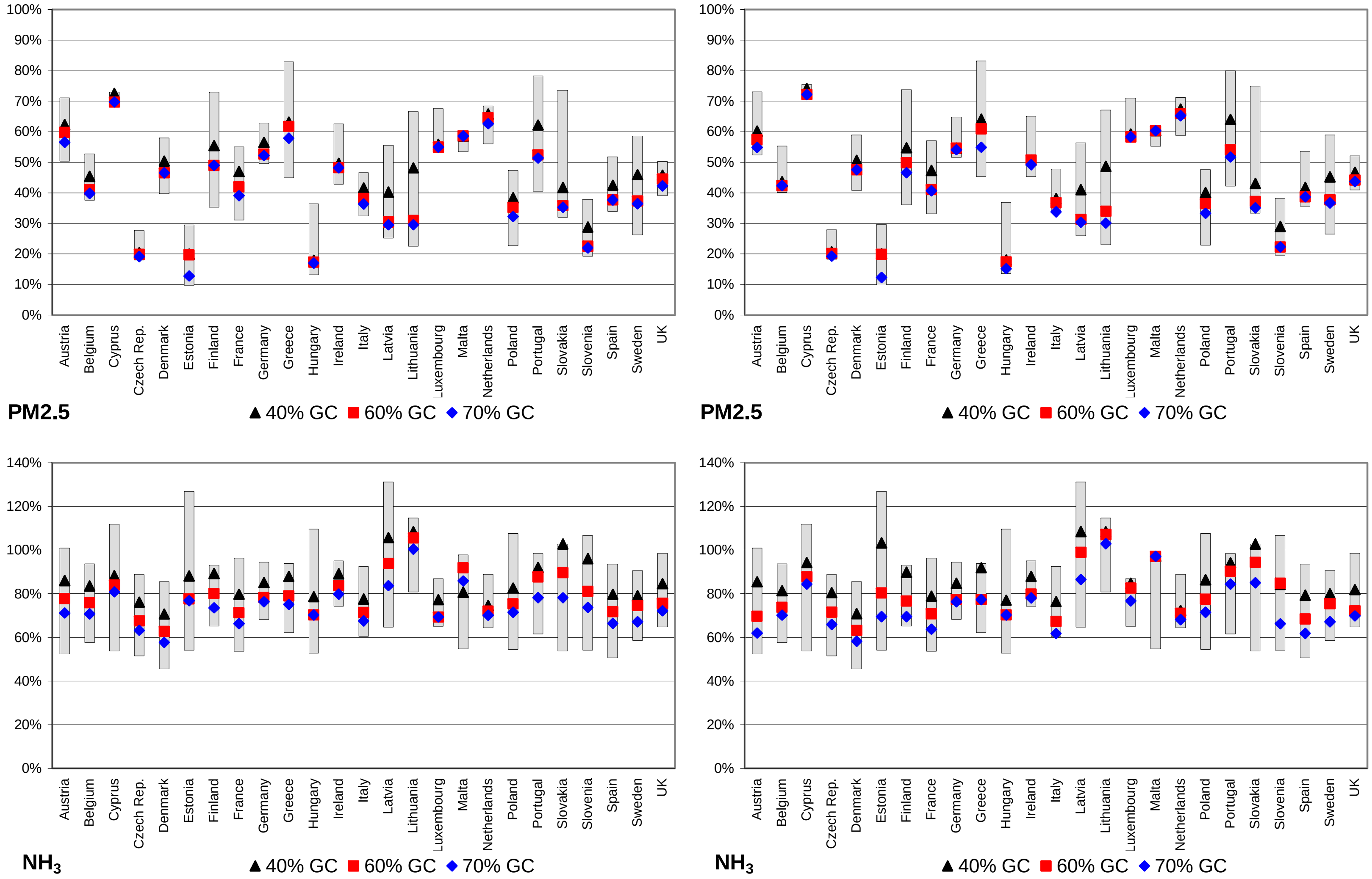


Figure 7.4: Cost-minimal emission reductions for reducing health impacts from fine particulate matter. The 100 percent line refers to the emission level in the year 2000. The grey range indicates the scope for emission reductions considered in the RAINS optimization. The left column refers to the scenarios with further road measures and the right column without further road measures



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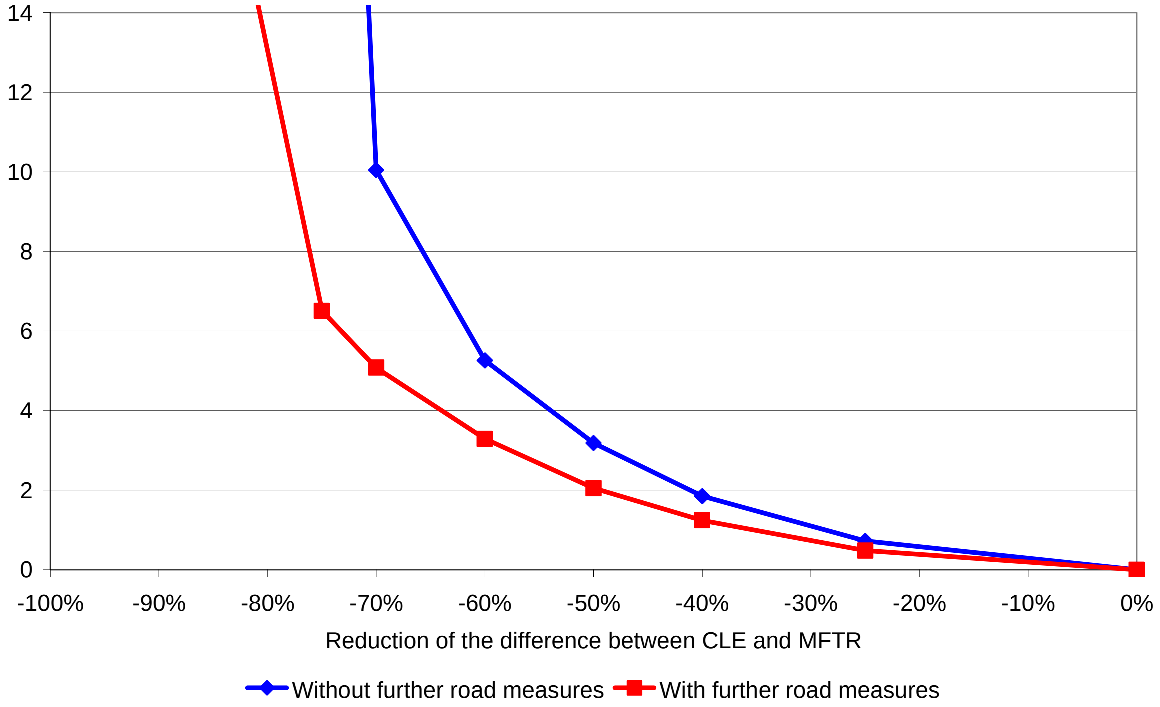

Figure 7.6: Costs for emission reductions at stationary sources of the gap closure scenarios (billion €/year)

8 A Europe-wide reduction target

As a third alternative, the environmental target could be established Europe-wide, for instance in terms of increased life expectancy or, if population-weighted, in terms of years of life lost (YOLL). The optimization would then identify those measures in the EU-25 that would achieve a given improvement of YOLL at least costs. The location where the health benefit occurs is thus not taken into account, and the optimization will allocate measures to those regions where benefits are largest over all of Europe. While this approach maximizes the use of resources, it might compromise on (perceived) equity aspects, because not all Member States do receive equitable environmental improvements.

An attempt has been made to explore with the RAINS optimization the features of such a target setting concept for reducing health impacts from PM.

This approach is based on the assumption of no threshold above which the PM2.5 concentration has a harmful effect on human health, but rather that any reduction in PM2.5 concentration will lead to health benefits. The actual benefit of a unit of reduced PM2.5 concentration, however, depends on the population density in the affected area. The more people live in an area, the more effective will be a reduction of PM concentration in the area.

The RAINS framework with its routine for life expectancy calculations and population databases has all information to implement such an approach. It can calculate YOLL for each individual grid cell with a 50*50 km resolution, and the results can be aggregated for the entire EU-25.

For the current legislation baseline case, accumulated life shortening is calculated at 140 million years. With maximum technically feasible emission reductions for stationary sources (excluding further road measures), this number would reduce to 98 million years, i.e., by approximately 30 percent.

A series of repeated optimization runs with stepwise reduced years of life lost YOLLs (starting with no additional costs on top of current legislation up to the costs of the maximum technically feasible reductions of 39 billion €/year has been conducted to explore the range between these two extreme cases. As to be expected, there is a potential for large reductions at low costs, while the maximum achievable improvement would be rather costly to reach (Figure 8.1).

Due to the lack of cost data for further road measures, the analysis carried out to date includes only emission controls from stationary sources. Because of the non-existence of a threshold for health effects of PM, the results presented below are independent from the absolute emission level, i.e., they are not influenced by the level of emissions from mobile sources. A final cost-effectiveness analysis, however, should treat the reduction potentials from stationary and mobile sources at an equal basis.

As indicated above, while this approach aims for the most effective use of resources, it compromises on equity issues. To explore this important aspect further, the distributions of costs and health benefits have been further examined.

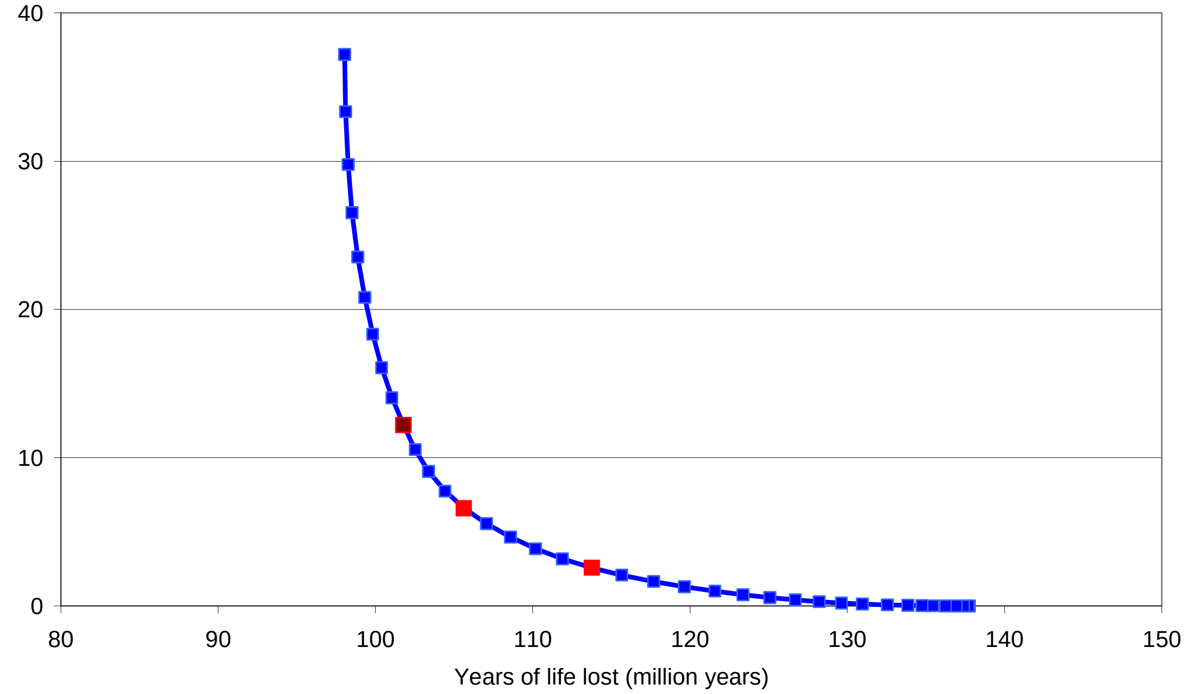

Figure 8.1: Years of life lost (YOLL, million years) attributable to the exposure to anthropogenic PM2.5 against annual emission control costs (in billion Euros per year). Preliminary estimates based on a simplified YOLL calculation. The red marks indicate the three illustrative cases B3/1 to B3/3 that are analyzed in more detail.

8.1 Optimized reductions for three ambition levels

Out from the large number of optimization runs, three cases for three levels of environmental ambition have been picked out and analyzed in more detail:

- B3/1A: 60 percent of the reduction in YOLL achievable through MTFR (24 million years), at costs of 2.6 billion €/yr, i.e., 7 percent of the MTFR costs.
- B3/2A: 80 percent of the reduction in YOLL achievable through MTFR (32 million years), at costs of 6.6 billion €/yr, i.e., 20 percent of the MTFR costs.
- B3/3A: 90 percent of the reduction in YOLL achievable through MTFR (36 million years), at costs of 12.2 billion €/yr, i.e., 33 percent of the MTFR costs.

Figure 8.2 presents the distribution of emission control costs across Member States for the optimized scenarios related to population and to GDP in Purchasing Power Standards, respectively. The reductions of the various pollutants are displayed in Figure 8.3.

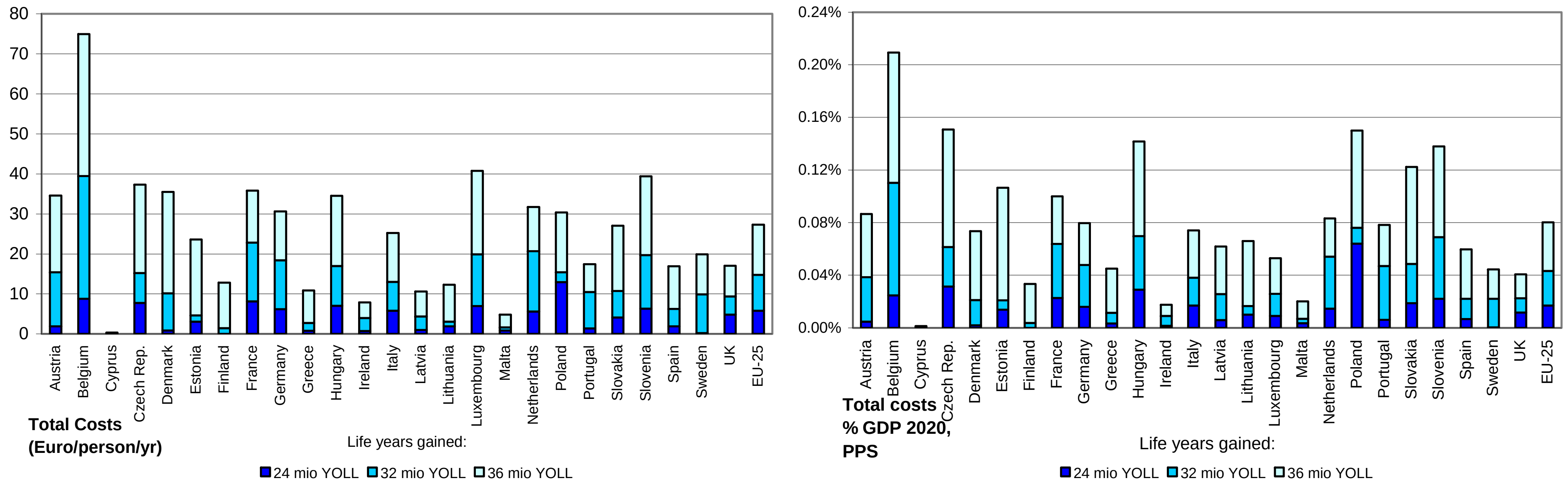

Figure 8.2: Emission control costs on a per-capita basis (left) and per GDP expressed in purchasing power standards (right)

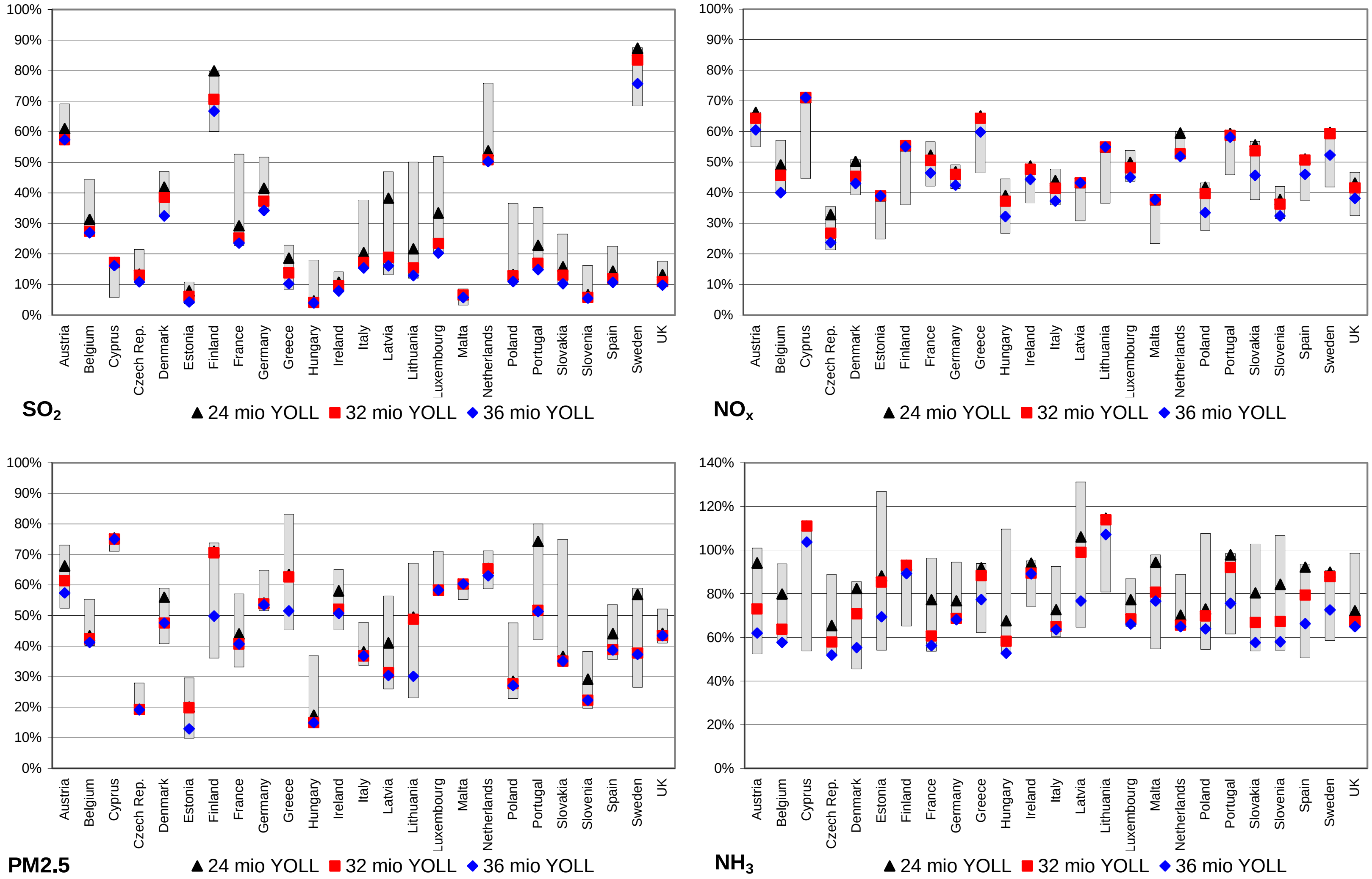

Figure 8.3: Cost-minimal emission reductions for reducing health impacts from fine particulate matter. The 100 percent line refers to the emission level in the year 2000. The grey range indicates the scope for emission reductions considered in the RAINS optimization.

Because there are significant variations in the costs for increasing life expectancy for Europe, and because the optimization approach selects emission controls that achieve the largest improvements in life expectancy at least cost, significant variations in life expectancy gains occur across the Member States (Figure 8.4). For instance, for the 24 million YOLL ambition scenario, life expectancy would improve in Hungary by approximately 1.2 months, while Finland would experience an improvement of less than 0.1 months.

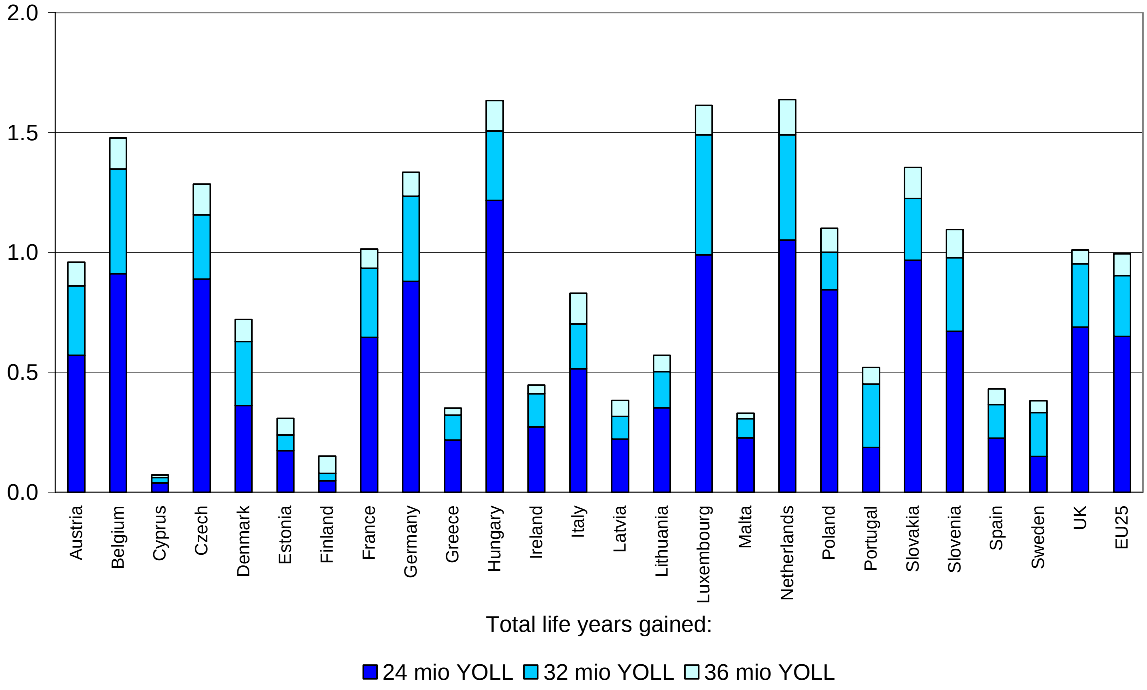

Figure 8.4: Gains in statistical life expectancy (in months) for the three optimized scenarios

As a consequence, there are also variations in the costs per gained month of life expectancy in Europe (Figure 8.5).

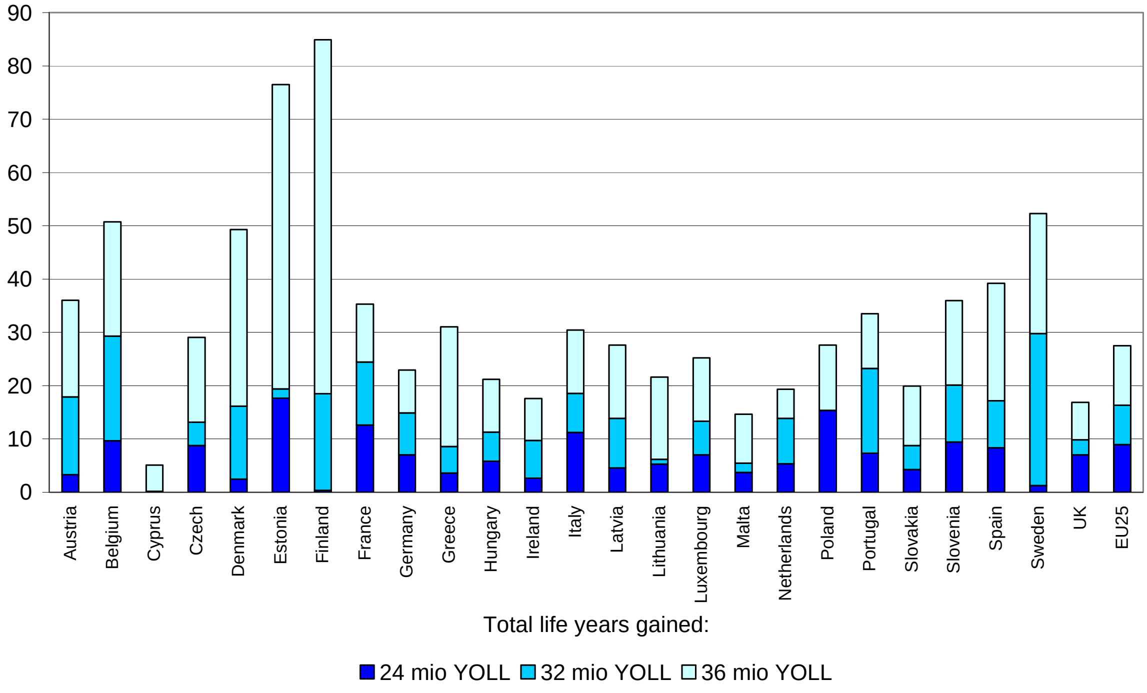

Figure 8.5: Costs for a gained month in statistical life expectancy (€/year) for the three optimized emission scenarios

9 Comparison of the three target setting approaches

The three target setting approaches can be compared against their costs and environmental achievements. Figure 9.1 plots the costs of the optimized scenarios presented in this paper against the years of life lost. If no further road measures are assumed, the overall cost-effectiveness of the limit value approach (black line) and the gap closure approach (red line) are similar, while the Europe-wide target (blue line) achieves distinctively better cost-effectiveness. For instance, the Europe-wide approach can reduce overall years of life lost (YOLL) to 108 million years at only 50-60 percent of the costs of the other approaches.

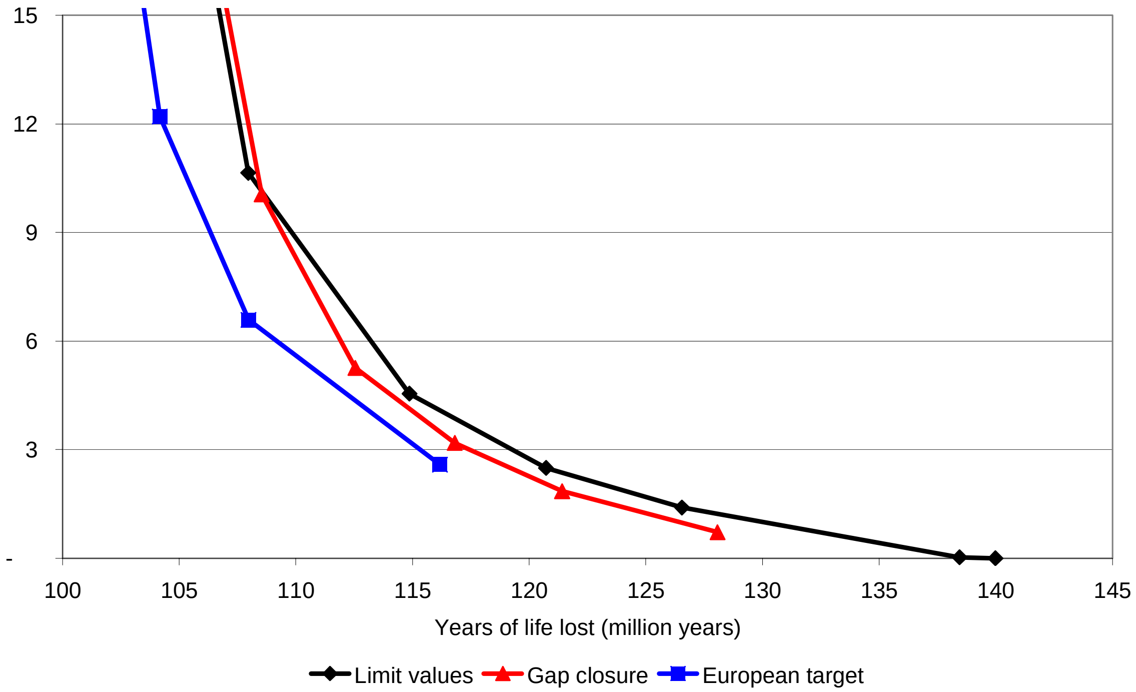

Figure 9.1: Emission control costs for stationary sources (in billion €/year) vs. Years of Life Lost (YOLL, million years) of the optimized scenarios for the three target setting approaches. This graph shows the scenarios without further road measures.

While the Europe-wide approach yields due to its design the best cost-effectiveness, the cost-effectiveness of a gap closure approach depends crucially on the definition of the gap and the constellation of environmental sensitivities, emission control potentials and costs over the Member States. This is illustrated in Figure 9.2, which displays the cost-effectiveness of the three target setting approaches with the assumption that further measures to reduce emission from road transport are taken. In this case, the gap closure approach shows a distinctively better cost-effectiveness than the limit value approach. It is likely that further refinements of the gap closure concept could lead to even more enhanced cost-effectiveness.

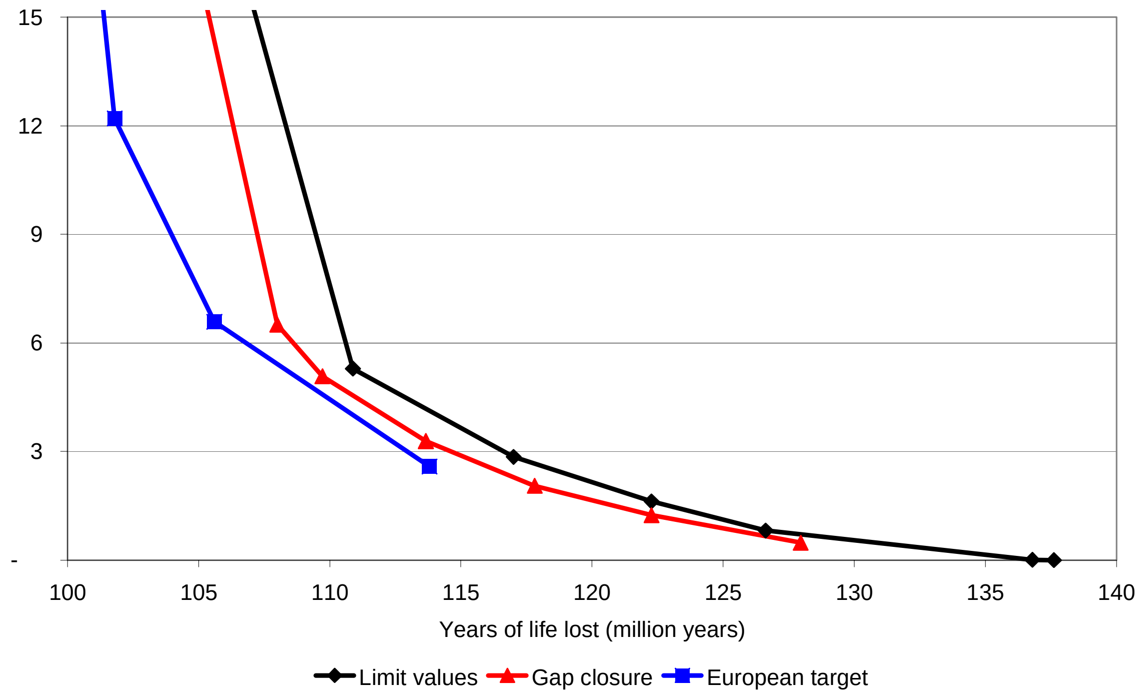

Figure 9.2: Emission control costs for stationary sources (in billion €/year) vs. years of life lost (YOLL, million years) of the optimized scenarios for the three target setting approaches. These scenarios assume implementation of further road measures.