CAFE Scenario Analysis Report Nr. 3

First Results from the RAINS Multi-Pollutant/Multi-Effect Optimization including Fine Particulate Matter

Background paper for the meeting of the
CAFE Working Group on Target Setting and Policy Advice,
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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).

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.

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. To this end, optimization analyses addressed health impacts attributable to the exposure of fine particulate matter (PM2.5) and of ozone, as well as ecosystems impacts from acidification and eutrophication. For each of these environmental end points, this initial study explored the cost-optimal set of emission control measures for three ambition levels

Section 2 of this report introduces the mathematical formulation of the optimization problem. Section 3 describes the input data used for the optimization analysis. Section 4 discusses assumptions, limitations and caveats, while targets for the optimization are elaborated in Section 5. Optimization results are presented in Section 6, and conclusions are drawn in Section 7.

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 new RAINS optimization module to the CAFE Working Group on Target Setting and Policy Advice at an early stage of development. 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 and ozone, the new representation of critical load data in the optimization module could not be extensively tested against the original database, and the approach for modeling urban air quality as developed within the City-Delta project could not yet be incorporated in this analysis. Thus, all quantitative results presented in this report have to be considered as provisional.

2 Formulation of the optimization problem

For particulate matter, the RAINS optimization takes into account the contributions to PM exposure originating from primary anthropogenic sources of particles and from secondary inorganic aerosols, but does not consider contributions from natural sources nor from secondary organic aerosols. It searches for the least-cost balance of reductions of primary PM emissions as well as the precursor emissions of secondary inorganic aerosols, i.e., SO_2, NO_x and NH_3 that meet environmental constraints expressed as ambient concentrations of PM2.5 for each 50*50 km^2 cell of the EMEP grid system. At the same time, cost-effective emission reductions have been explored that meet targets for ground-level ozone, acidification and eutrophication. While the initial analysis presented in this note addresses these problems individually, eventually the optimization routine will be used to identify the distribution of emission reduction measures that meet all these targets simultaneously.

The mathematical formulation of the optimization problem is provided in Annex 1.

The resulting (linear) optimization problem was implemented in GAMS modelling language and the solver contained in the GAMS package was used for the optimization. The solution time of a typical optimization problem for PM takes approximately one hour at a UNIX workstation. An alternative implementation that will validate the results of the optimization is under development, but could not be completed in time.

3 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.

- The 2004 database on critical loads and critical levels provided by the Coordination Centre for Effects at RIVM, as approved by the UN/ECE Working Group on Effects in its Session in August 2004.

- National population projections of the UN (median projection)

4 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.

4.1 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 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.

- **City-Delta results not yet included.** The initial optimization is implemented for grid-average air quality indicators, but does not consider systematic differences between air quality in cities and rural areas. The City-Delta project has developed an methodology that allows including urban air quality in these Europe-wide calculations, but due to the short time this has not yet been implemented in the RAINS optimization routine used for this report.

- **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.
- For **health impacts from ozone**, RAINS restricts itself to the quantification of premature mortality (see (http://www.euro.who.int/eprise/main/WHO/Progs/AIQ/Activities/20031204_1), but does not consider the important morbidity effects of ozone. For mortality, RAINS uses the SOMO35 index as the health-relevant ozone exposure metric (Amann *et al*. (2004c) - http://www.iiasa.ac.at/rains/review/review-full.pdf. This assumption ignores documented health effects on days with mean ozone concentrations below 35 ppb. However, before the implementation of the City-Delta results the present initial implementation of the RAINS optimization routine does not distinguish ozone concentrations in urban areas, but estimates health impacts from ozone based on grid-average concentrations.
- As suggested by the Working Group on Target Setting at its November Session, the initial optimization analysis does **not consider** the scope for further emission reductions of mobile sources offered by the introduction of **EURO-V and EURO-VI standards**. This has to be seen as a first step in an iterative analysis, reflecting the fact that such standards for mobile sources could in practice only be introduced Europe-wide. Such Europe-wide control measures, which could only be taken – or dismissed – for all countries together, but not for individual Member States, are not yet implemented in the RAINS optimization. To derive conclusions about the cost-effectiveness of such Europe-wide measures, a second set of optimization analyses would be conducted assuming the implementation of such Europe-wide measures, once agreement on a reduced set of environmental targets has been reached by the Working Group. The differences in costs between these two sets of optimization runs would then allow drawing conclusions about the cost-effectiveness of such policy options. However, when discussing the appropriate set of environmental ambitions, the potential from such Europe-wide measures needs to be taken into account.

4.2 Caveats

As discussed in the introduction, this report presents first outcomes of the new 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.

- Similar caveats also apply to the new approach for approximating the cumulative excess deposition over the critical loads for acidification and eutrophication. While the methodology has been published in peer reviewed literature (Hettelingh and Posch, 2004), its performance in conjunction with the most recent set of dispersion calculations produced by the new EMEP Eulerian model needs to be confirmed.

- Insufficient time did not allow implementation of the City-Delta methodology into the RAINS optimization. Thus, the results presented in this paper are biased because they relate to grid-average concentrations and ignore systematic differences in urban areas. For PM, this implies an under-prediction of health impacts, since urban PM levels are systematically higher than grid-average concentrations. In an optimization context this also leads to too little emphasis on primary emissions of PM, especially those from low-level sources such as traffic. With a full implementation of PM in urban areas the RAINS optimization would thus most likely put more pressure on such sources, and less on the precursors of secondary inorganic aerosols. For ozone, however, urban levels are systematically lower than grid-average concentrations, so that the present formulation of RAINS over-estimates population exposure. In addition, it ignores the diminishing impact of further NO_x reductions for ozone in urban areas, and might underestimate the need for VOC controls. While the City-Delta methodology that addresses these issues in a consistent way is ready for implementation into RAINS, more time is needed to actually modify the RAINS code and databases.

- 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.

5 Approach for initial target setting

In the RAINS optimization, emission reductions are driven by the environmental targets specified for the various environmental endpoints. Thus, the choice of the environmental endpoint and of the absolute and relative improvements imposed on the selected criteria has critical influence not only on the absolute levels of resulting emission reductions, but also on the distribution of abatement burdens across countries and sectors.

An environmental policy might aim at achieving no-effect levels throughout the territory. As shown with the analysis of the maximum technically feasible emission reduction scenarios, such targets are difficult and expensive to achieve in Europe for the environmental endpoints considered, at least up to 2020 with the presently anticipated levels of economic activities. This is caused (a) by the limited efficiency of present emission control technology, where the residual emissions result at least in the densely populated areas in Europe in a violation of the no-effect levels, and (b) by new scientific insights into health impacts from PM and ozone, which do not support the identification of no-effect levels for these problems.

Thus, in the past (e.g., in the analysis for the emission ceilings directive) environmental policy established interim targets as concrete milestones on the way towards the ultimate environmental target.

One traditional approach (applied, e.g., in the air quality directives) focuses on environmental improvements at the most polluted sites by imposing absolute limits (or caps) on air quality (or effect indicators) that need to be achieved throughout the entire territory of the EU.

Applied to the air quality management problems at hand, it turns out that substantial spatial variations in the environmental indicators exist over Europe, even if the values of these indicators for individual grid cells are aggregated to the country level. As shown in the top panels of Figure 5.2 to Figure 5.5, the country-average indicators for the 25 Member States show extremely large variations, both for the base year 2000 and the most ambitious MTFR level that could be achieved through full application of presently available emission control technology. Obviously, a practical (interim) policy target must be realistically achievable in all Member States, i.e., it must be within the range that could be achieved even by the country where least improvements are possible. In practice, with the present RAINS data set the PM indicator for Belgium could not be reduced below 11 $\mu g/m^3$ even with full application of all available control measures throughout the EU-25. If adopted as an interim target, while it would force maximum measures in Belgium, such a level would not require any improvements for all other countries (except the Netherlands), because they would achieve this level already in the baseline (current legislation case) without any additional measures. Similar situations occur for the other problems: for ozone, a target that is computed to be barely achievable in Italy and Malta would not impose any improvements for all other 23 EU Member States. For acidification, all other countries are already in their baseline case below the maximum achievable indicator of the Netherlands, and for eutrophication Germany and the Netherlands stand out. Thus, such uniform targets expressed in absolute terms of air quality or environmental impact indicators would result in extremely inequitable distributions of environmental improvements and abatement burdens.

In addition, economic analysis has shown that, especially for pollution problems where no clear no-effect levels could be identified, larger benefits could be accrued from wide-spread improvements at less polluted places compared to approaches that solely focus on a few hot spots, which benefit only a limited number of people or ecosystems.

As an alternative, earlier analyses for the emission ceilings directive and for the Gothenburg Protocol of the UN/ECE Convention on Long-range Transboundary Air Pollution applied the “gap closure” concept, which calls for uniform *relative* improvements of the environmental indicators as an interim target. With these concept, more equitable distributions of economic burdens and environmental benefits could be achieved, which made these accords politically acceptable.

For the NEC directive, the model analysis with RAINS applied an effect-based approach to specify environmental targets, from which the resulting emission ceilings were then derived with the optimization. In particular, the “gap closure” concept specified the environmental targets in relation to the gap between the present environmental situation (at that time the status of 1990) and the ultimate environmental policy target of achieving no-effects levels (quantified through critical loads or at that time AOT40/60 for ozone) – see also Figure 5.1.

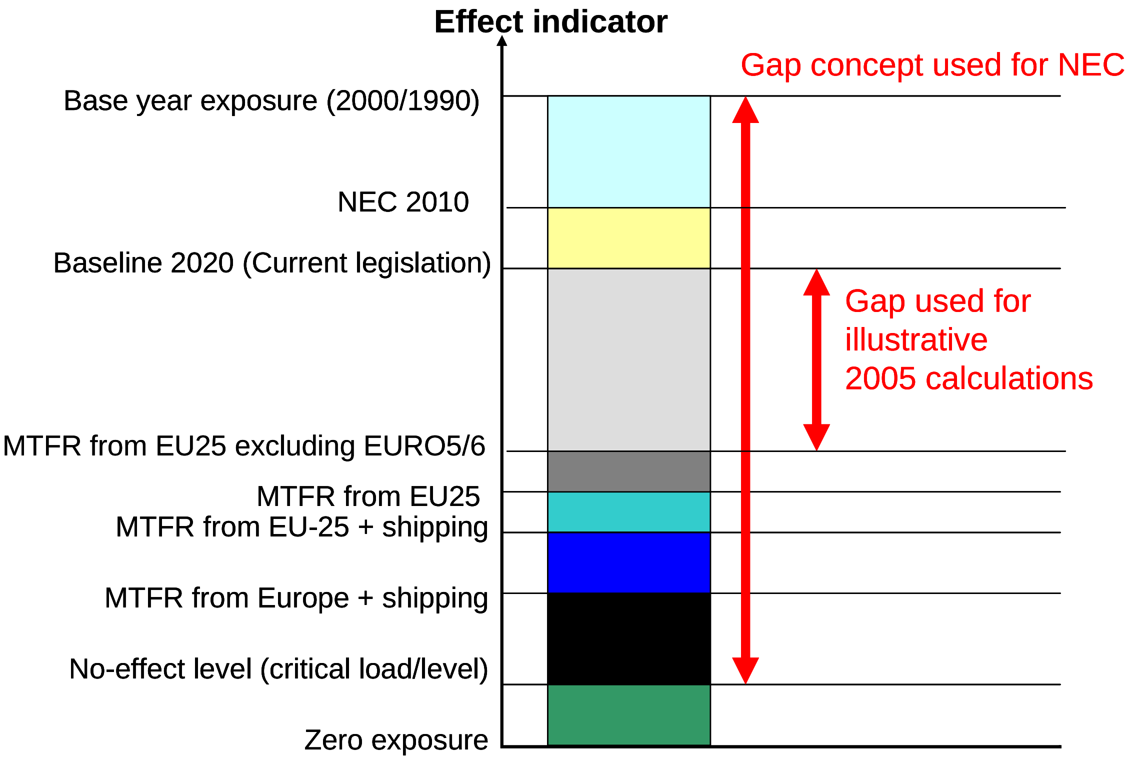


Figure 5.1: Concept of gap closure applied for this first set of exploratory RAINS calculations

With the constellation resulting from the current data set with revised emission ranges, atmospheric dispersion characteristics, the particular meteorological year chosen for this initial analysis and revised information on no-effect levels, there is in some cases very little space for improving environmental impacts (see Figure 5.2 to Figure 5.5, bottom left panels). For instance, influences from non-European emissions, the non-linearities in ozone chemistry and the range of feasible emission reductions will allow Cyprus to reduce its accumulated SOMO35 indicator in the maximum feasible reduction case by not more than 31 percent compared to the level of the year 2000, while the baseline projection is calculated to lead to a 22 percent improvement (Figure 5.3). Consequently, if, in order to establish a notion of “equity” in terms of environmental improvements, a uniform gap closure percentage target were used for all Member States, this could not exceed 31 percent to remain feasible in Cyprus. Even then this will require all European sources that contribute to ozone in Cyprus to reduce their emissions to the maximum feasible extent. At the same time, 23 other Member States would achieve this 31 percent gap closure in their own SOMO35 indicator already with the baseline projection, so that such a target would only put pressure on ozone in two Member States. Similar situations occur for acidification and eutrophication. Also for PM, if the gap closure were to be achieved in each grid cell, this situation would apply, especially for grid cells where PM emissions from EU-25 sources make only a minor contribution to ambient levels, such as in grid cells shared with non-EU countries.

Adopting the situation resulting from the emission ceilings directive in 2010 as a starting point for the gap closure instead of the base year 2000 does not significantly alleviate the target setting problem (see Figure 5.2 to Figure 5.5, bottom right panels).

Since the choice of an appropriate, equitable and efficient target is a genuine task of the Working Group on Target Setting and Policy Advice, the authors of this report refrain from proposing alternative concepts for target setting, but acknowledge the need for a dialogue with the Working Group.

In order to start the discussion with a first set of optimized scenarios, the authors have developed a series of optimization runs that explore the role of different environmental objectives within the feasible range of emission reductions in each Member State. Rather than effect-driven, these scenarios explore gap closures mapped to the feasible range of emission reductions, as illustrated in Figure 5.1.

Along these lines, the scenarios explore the cost-optimal balance of emission reductions over the various pollutants and countries that reduce the gap specified in terms of environmental impacts 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 excluding in this round of calculations the potential offered by Euro5/6 standards and excluding the scope for emission reductions from marine ships and from non-EU countries.

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.

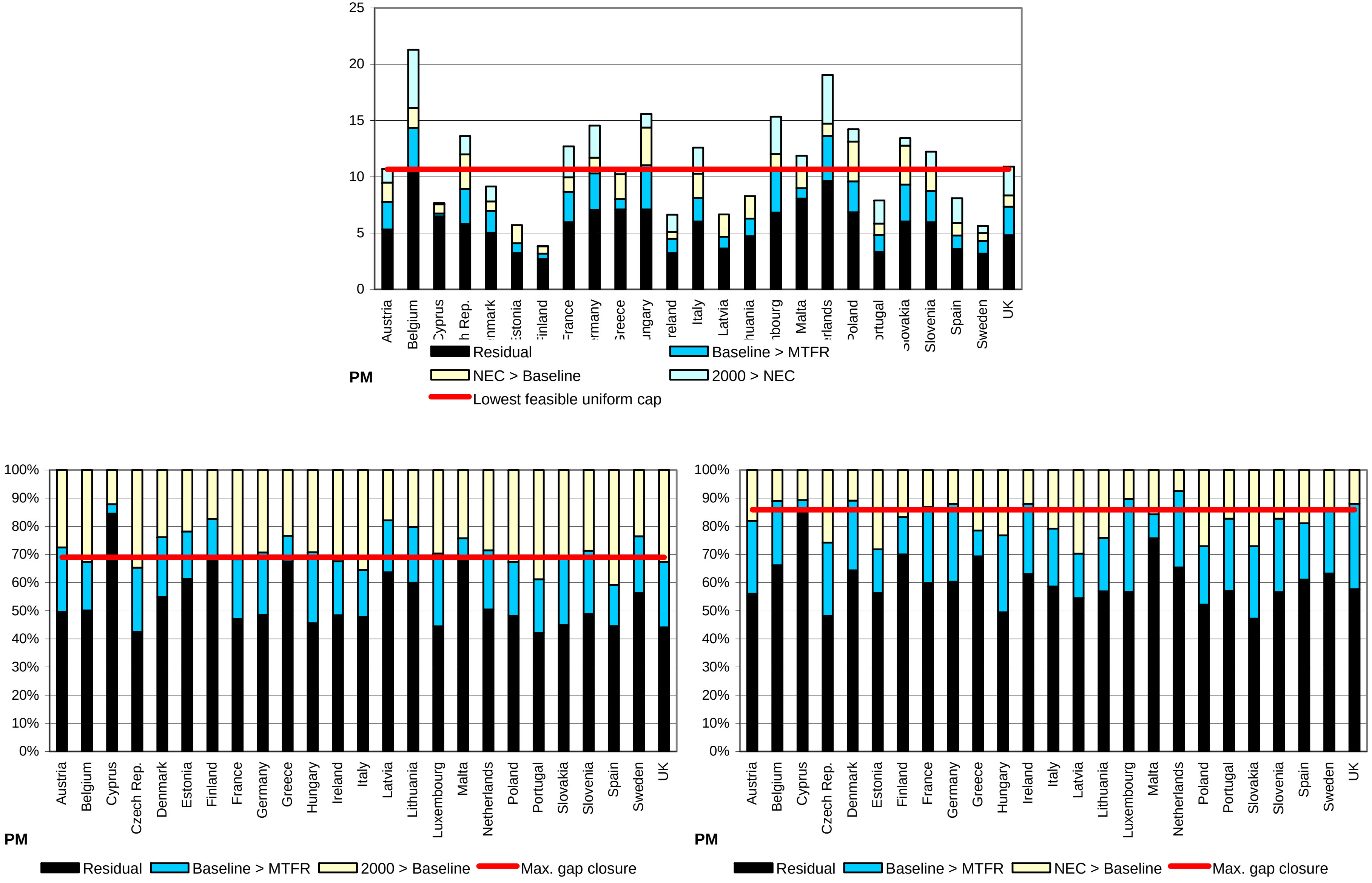


Figure 5.2: Scope for improvement of the PM indicator used for the optimization (Country-average PM2.5 concentrations [μg/m^3] absolute values, relative to 2000 and relative to NEC]])

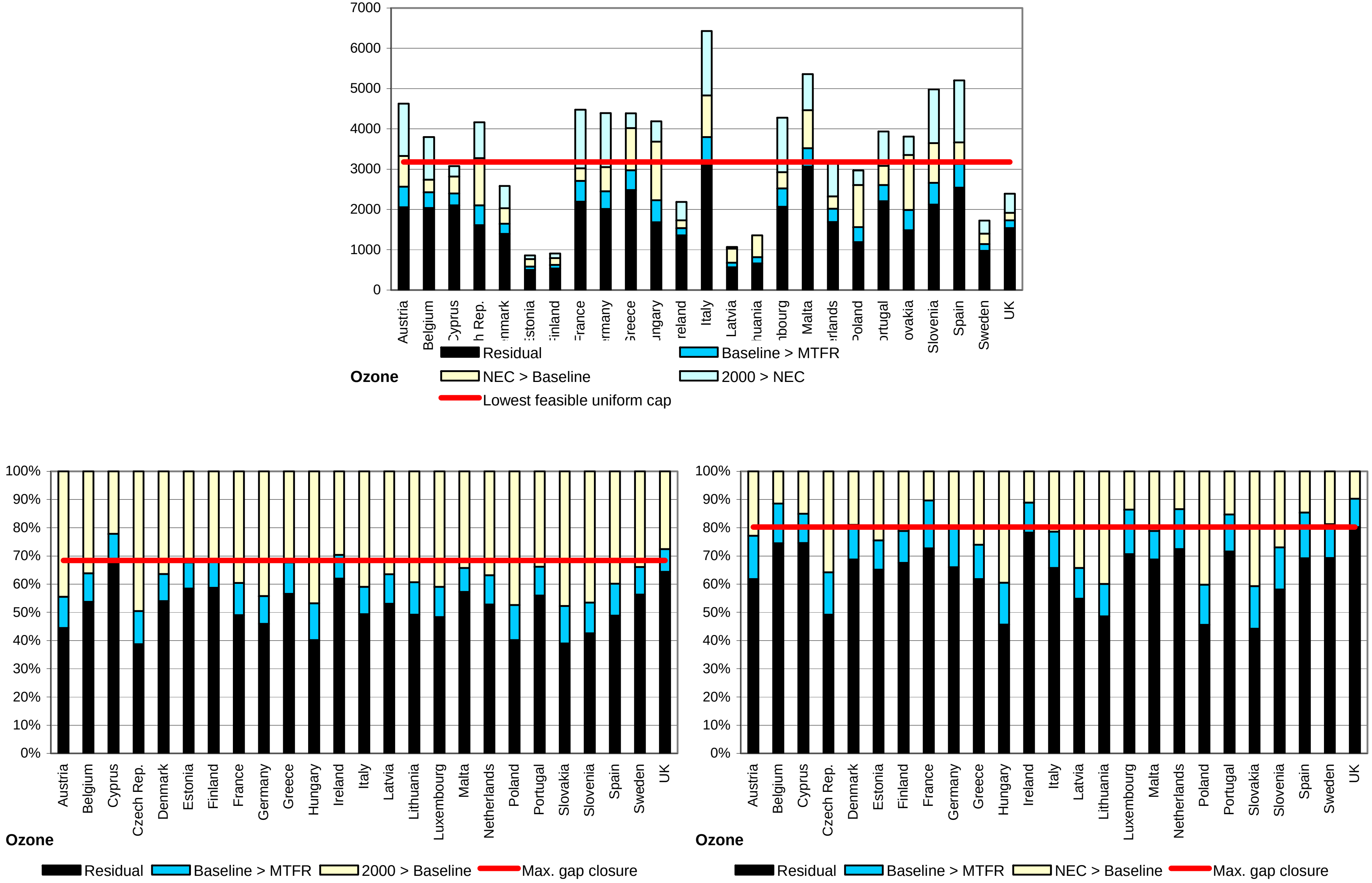


Figure 5.3: Scope for improvement of the ozone indicator used for the optimization (Country-average SOMO35 [ppd.days, absolute values, relative to 2000 and relative to NEC])

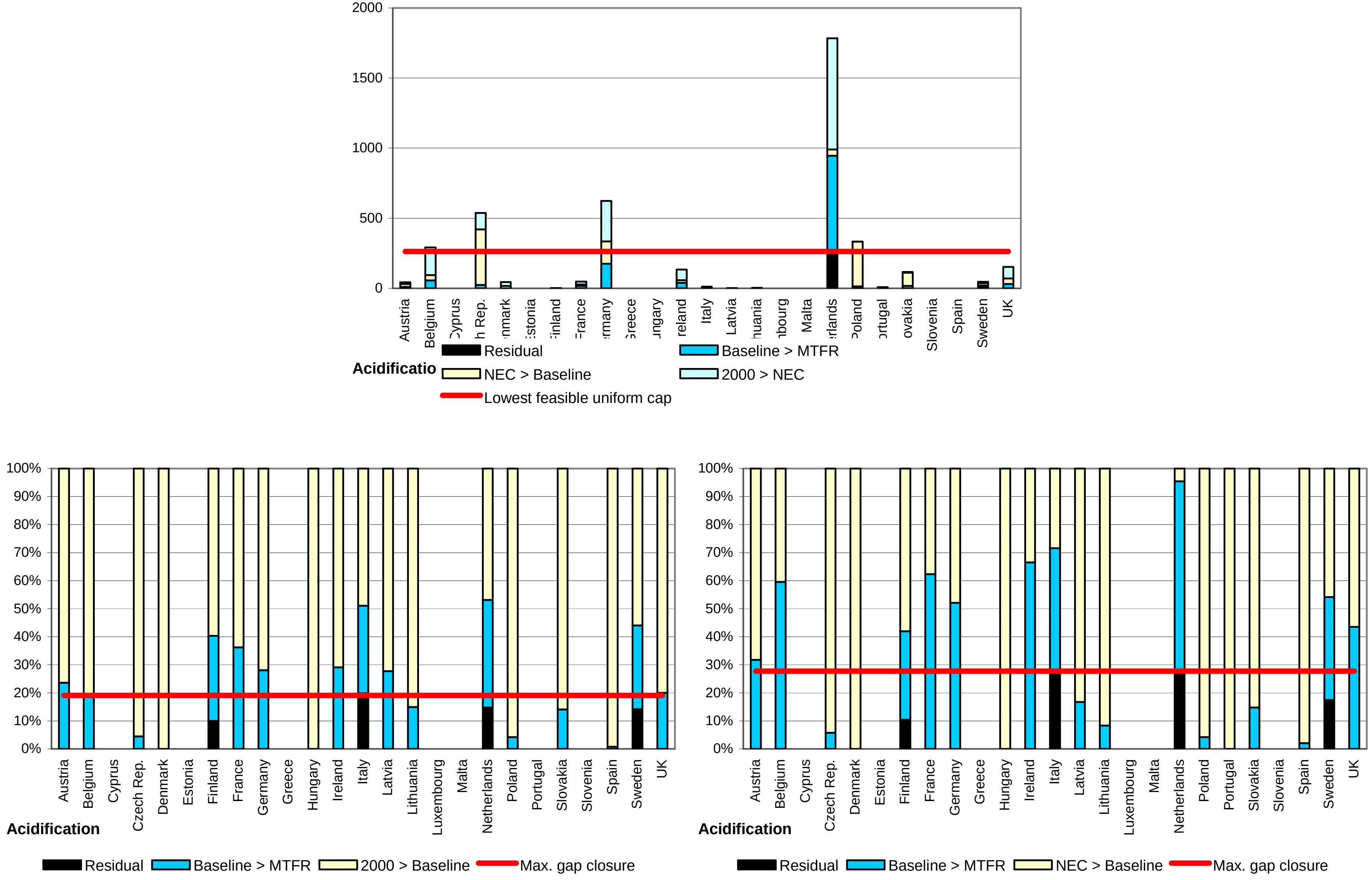


Figure 5.4: Scope for improvement of the acidification indicator used for the optimization (Country-average accumulated excess deposition [eq/hectares, absolute values, relative to 2000 and relative to NEC])

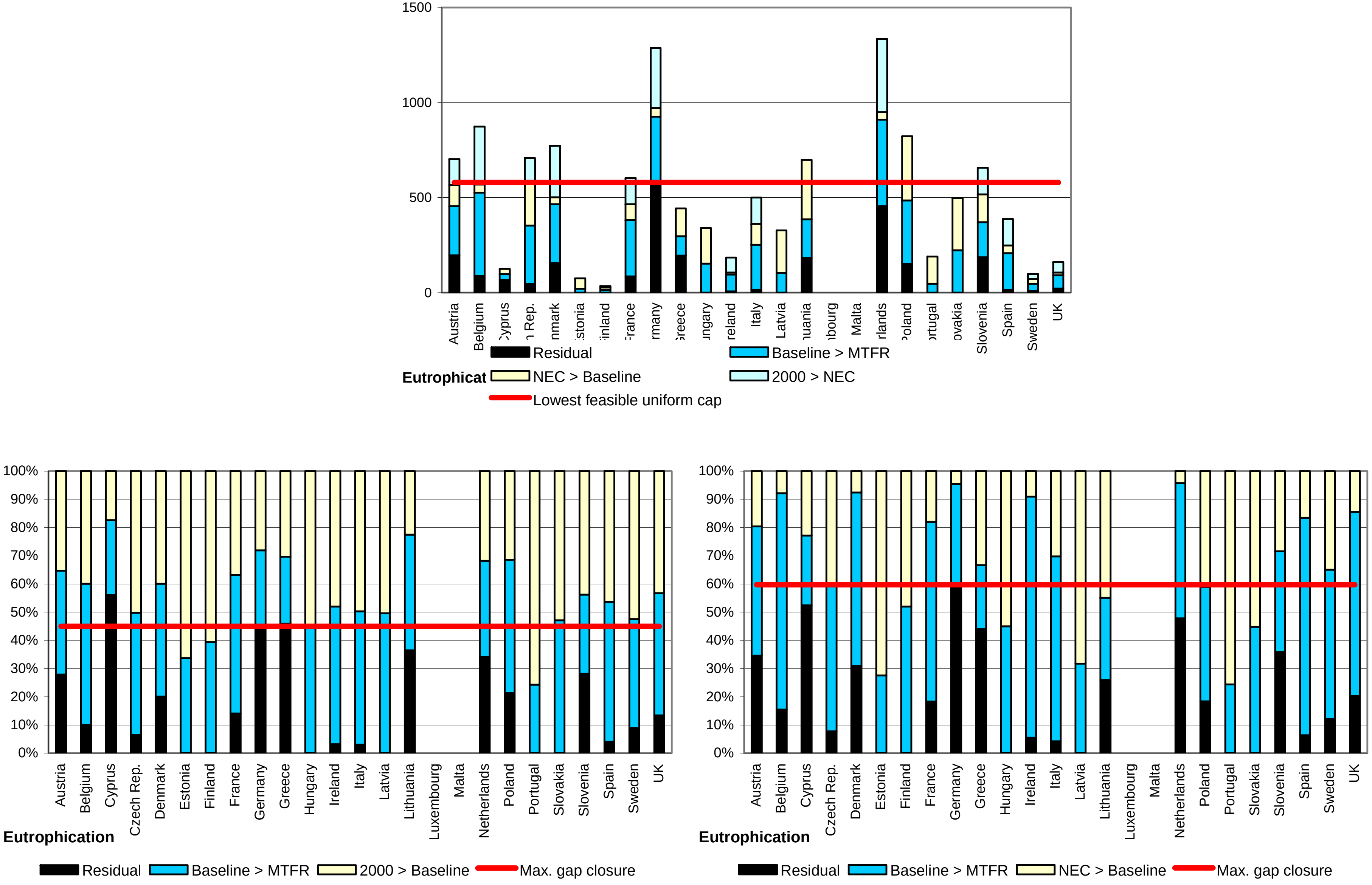


Figure 5.5: Scope for improvement of the eutrophication indicator used for the optimization (Country-average accumulated excess deposition [eq/hectares, absolute values, relative to 2000 and relative to NEC])

While acknowledging the limitations of such a modified approach, the exploratory analysis calculated based on this definition of the “gap” three reduction cases for the following three ambition levels:

- 25 percent (low ambition),
- 50 percent (medium ambition), and
- 75 percent (high ambition).

These three reduction levels have been explored for losses in life expectancy from PM (Scenarios A1), for the cases of premature deaths attributable to ozone (Scenarios A2), for accumulated excess deposition over the critical loads for acidification (Scenarios A3) and for accumulated excess deposition for eutrophication (Scenarios A4).

The following metrics are used as impact indicators, for which the gap closure is applied:

- For **health impacts attributable to PM2.5**, RAINS uses the loss in life expectancy as calculated by RAINS for each grid cell as the impact indicator for which the environmental gap closure target is specified. Formally, this is equivalent to a gap closure calculated for the annual mean concentrations of PM2.5, for each grid cell. As discussed above, grid-average values have been used for this exploratory series of calculations, but inclusion of City-Delta results will allow differentiating between urban and rural situations.

- For **health impacts attributable to ozone**, RAINS calculates the number of premature deaths attributable to ozone (SOMO35) on a grid basis and sums them up to a country balance. The gap closure is then applied to the country-balance only, i.e., it is not requested for each individual grid cell as long as the overall improvement within a given country is achieved. Formally, this is equivalent to a gap closure calculated on the basis of population-weighted SOMO35 grid data.

- For **acidification**, RAINS applies the gap closure concept to the total deposition of acidifying compounds in excess of the critical loads for acidification, accumulated over all ecosystem types (forests, semi-natural, water) and ecosystems area in a country. While this accumulated excess deposition cannot be interpreted to be proportional to ecological damage in a strict sense, it provides a continuous scale for quantifying excess deposition. For this exploratory set of computations, RAINS uses a linear representation of the accumulated excess deposition function as described in Hettelingh *et al.*, 2004. The implications of an optimized emission reduction scenario can then be displayed for each grid cell in terms of ecosystems area with acid deposition above/below critical loads.

- For **eutrophication**, RAINS applied the same “accumulated excess deposition” concept as for acidification. The gap closure is requested on a country basis, i.e., there is flexibility to compensate improvements at “hard to attain” targets at individual receptor sites by additional gains in other areas within the same country.

6 Results

The following graphs display the resulting emission reductions (relative to the emissions of the year 2000) and emission control costs in the year 2020 expressed in terms of per-capita (in €/person/year) and as a share of the GDP in 2020.

The 100% line indicates the emission level in the year 2000. The grey range indicates the scope for emission reductions considered in the RAINS optimization between the baseline projection for 2020 (top end) and the maximum technically feasible reductions (bottom end).

No measures are assumed for non-EU countries and for international shipping, i.e., their emissions are kept at the baseline level. These exploratory calculations are based on 1997 meteorology.

These model runs do not consider the potential from EURO V/VI for mobile sources, they assume mobile emissions kept at baseline with current legislation and only optimize stationary sources.

6.1 Cost-optimal emission cuts for reducing health impacts from PM (A1)

For health impacts attributable to PM2.5, RAINS uses the loss in life expectancy as calculated by RAINS for each grid cell as the impact indicator for which the environmental gap closure target is specified. Formally, this is equivalent to a gap closure calculated for the annual mean concentrations of PM2.5, for each grid cell. As discussed above, grid-average values have been used for this exploratory series of calculations, but inclusion of City-Delta results will allow differentiating between urban and rural situations.

Table 6.1: SO_2 emissions for the optimized scenarios targeted at the reduction of exposure to PM (in kt)

	2000	**NEC 2010**	**Baseline 2020**	**25% gap closure A1/1**	**50% gap closure A1/2**	**75% gap closure A1/3**	**MTFR 2020 excl. Euro5/6**
Austria	38	39	26	26	23	22	22
Belgium	187	99	83	70	59	52	50
Cyprus	46	39	8	7	6	4	3
Czech Rep.	250	265	53	46	33	33	26
Denmark	28	55	13	12	12	9	9
Estonia	91	100	10	6	6	4	3
Finland	77	110	62	57	55	47	46
France	654	375	345	263	218	161	148
Germany	643	520	332	298	286	262	220
Greece	481	523	110	99	82	61	40
Hungary	487	500	88	53	24	20	19
Ireland	132	42	19	14	13	10	10
Italy	747	475	281	195	135	119	113
Latvia	16	101	8	6	3	3	2
Lithuania	43	145	22	17	9	6	5
Luxembourg	4	4	2	2	1	1	1
Malta	26	9	2	2	2	2	1
Netherlands	84	50	64	53	53	43	42
Poland	1515	1397	554	485	302	201	167
Portugal	230	160	81	69	53	42	34
Slovakia	124	110	33	32	22	16	13
Slovenia	97	27	16	7	6	5	5
Spain	1489	746	335	283	204	175	155
Sweden	58	67	50	48	47	43	39
UK	1186	585	209	186	157	129	115
EU-25	8735	6543	2806	2336	1811	1470	1288

Table 6.2: NO_x emissions for the optimized scenarios targeted at the reduction of exposure to PM (in kt)

	2000	**NEC 2010**	**Baseline 2020**	**25% gap closure A1/1**	**50% gap closure A1/2**	**75% gap closure A1/3**	**MTFR 2020 excl. Euro5/6**
Austria	192	103	127	127	123	107	105
Belgium	333	176	190	177	160	153	133
Cyprus	26	23	18	18	18	16	12
Czech Rep.	318	286	113	108	102	79	68
Denmark	1645	1051	808	808	785	736	679
Estonia	207	127	105	104	99	93	81
Finland	37	60	15	15	15	14	9
France	1335	847	681	681	676	614	501
Germany	212	170	117	117	117	105	76
Greece	1447	810	819	789	753	718	609
Hungary	1753	1167	817	811	732	675	568
Ireland	322	344	209	209	209	205	149
Italy	188	198	83	83	70	65	50
Latvia	129	65	63	61	57	55	47
Lithuania	1389	990	663	630	587	508	500
Luxembourg	49	110	27	27	27	27	18
Malta	33	11	18	18	17	16	14
Netherlands	35	61	15	15	15	15	11
Poland	9	8	4	4	4	4	2
Portugal	399	260	240	239	238	211	204
Slovakia	843	879	364	364	350	325	233
Slovenia	263	250	156	156	156	154	120
Spain	251	148	150	150	150	148	105
Sweden	58	45	24	22	21	18	18
UK	106	130	60	60	60	59	40
EU-25	11581	8319	5886	5793	5541	5120	4352

Table 6.3: VOC emissions for the optimized scenarios targeted at the reduction of exposure to PM (in kt)

	2000	**NEC 2010**	**Baseline 2020**	**25% gap closure A1/1**	**50% gap closure A1/2**	**75% gap closure A1/3**	**MTFR 2020 excl. Euro5/6**
Austria	190	159	139	139	139	139	100
Belgium	242	139	147	147	147	147	117
Cyprus	13	14	6	6	6	6	5
Czech Rep.	242	220	120	120	120	120	82
Denmark	128	85	58	58	58	58	43
Estonia	34	49	17	17	17	17	12
Finland	171	130	97	97	97	97	68
France	1542	1050	923	923	923	923	704
Germany	1528	995	774	774	774	774	660
Greece	280	261	144	144	144	144	86
Hungary	169	137	91	91	91	91	60
Ireland	88	55	46	46	46	46	31
Italy	1738	1159	734	734	734	734	607
Latvia	52	136	28	28	28	28	16
Lithuania	75	92	44	44	44	44	25
Luxembourg	13	9	8	8	8	8	7
Malta	5	12	2	2	2	2	2
Netherlands	265	185	203	203	203	203	153
Poland	582	800	321	321	321	321	238
Portugal	260	180	163	163	163	163	125
Slovakia	88	140	65	65	65	65	34
Slovenia	54	40	20	20	20	20	13
Spain	1121	662	700	700	700	700	535
Sweden	305	241	179	179	179	179	140
UK	1474	1200	878	878	878	878	685
EU-25	10661	8150	5907	5907	5907	5907	4548

Table 6.4: NH_3 emissions for the optimized scenarios targeted at the reduction of exposure to PM (in kt)

	2000	**NEC 2010**	**Baseline 2020**	**25% gap closure A1/1**	**50% gap closure A1/2**	**75% gap closure A1/3**	**MTFR 2020 excl. Euro5/6**
Austria	54	66	54	50	45	37	28
Belgium	81	74	76	70	64	57	47
Cyprus	6	9	6	6	5	4	3
Czech Rep.	74	80	65	62	54	46	38
Denmark	91	69	78	70	60	50	41
Estonia	10	29	12	8	8	7	5
Finland	35	31	32	31	31	25	23
France	728	780	702	629	545	441	390
Germany	638	550	603	556	518	477	435
Greece	55	73	52	51	48	41	34
Hungary	78	90	85	72	55	53	41
Ireland	127	116	121	113	108	100	94
Italy	432	419	399	375	330	293	261
Latvia	12	44	16	15	12	10	8
Lithuania	50	84	57	57	53	48	40
Luxembourg	7	7	6	6	5	4	4
Malta	1	3	1	1	1	1	1
Netherlands	157	128	139	125	113	108	101
Poland	309	468	333	278	248	219	169
Portugal	68	90	67	63	63	52	42
Slovakia	32	39	32	32	32	23	17
Slovenia	18	20	20	18	17	14	10
Spain	394	353	369	339	302	253	199
Sweden	53	57	48	46	41	36	31
UK	315	297	310	274	252	220	204
EU-25	3824	3976	3683	3347	3010	2619	2266

Table 6.5: Primary emissions of PM2.5 for the optimized scenarios targeted at the reduction of exposure to PM (in kt)

	2000	**NEC 2010**	**Baseline 2020**	**25% gap closure A1/1**	**50% gap closure A1/2**	**75% gap closure A1/3**	**MTFR 2020 excl. Euro5/6**
Austria	37		27	24	23	21	19
Belgium	43		24	22	19	18	17
Cyprus	2		2	2	2	2	2
Czech Rep.	66		18	14	13	13	12
Denmark	22		13	11	11	11	9
Estonia	22		6	4	4	3	2
Finland	36		27	24	18	17	13
France	290		166	149	132	118	96
Germany	171		111	103	94	93	88
Greece	49		41	34	31	27	22
Hungary	60		22	11	11	9	8
Ireland	14		9	8	7	7	6
Italy	209		100	88	80	77	70
Latvia	7		4	3	3	2	2
Lithuania	17		12	9	8	5	4
Luxembourg	3		2	2	2	2	2
Malta	1		0	0	0	0	0
Netherlands	36		26	25	24	24	21
Poland	215		102	86	82	61	49
Portugal	46		37	32	27	24	19
Slovakia	18		14	8	7	6	6
Slovenia	15		6	4	4	3	3
Spain	169		91	76	68	66	60
Sweden	67		40	34	28	23	18
UK	129		67	63	60	57	53
EU-25	37		27	24	23	21	19

Table 6.6: Emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of exposure to PM (million €/year)

	Baseline 2020 (total costs)	**25% gap closure A1/1**	**50% gap closure A1/2**	**75% gap closure A1/3**	**MTFR 2020 excl. Euro5/6**
Austria	1392	9	61	278	1378
Belgium	1985	22	101	272	953
Cyprus	129	1	4	14	80
Czech Rep.	1287	12	52	137	619
Denmark	1152	22	67	187	842
Estonia	182	4	5	28	157
Finland	1071	18	56	204	1075
France	7732	131	502	1482	7769
Germany	14054	60	275	759	4143
Greece	1923	3	14	80	984
Hungary	1002	13	51	86	573
Ireland	1017	12	58	160	696
Italy	7347	92	361	1212	3353
Latvia	213	1	6	19	131
Lithuania	375	2	24	72	428
Luxembourg	300	0	3	11	40
Malta	41	0	0	0	20
Netherlands	3857	19	51	251	1009
Poland	3858	49	196	532	3816
Portugal	1597	22	62	143	1411
Slovakia	701	1	8	40	337
Slovenia	250	6	12	52	186
Spain	5666	52	212	600	4323
Sweden	1621	35	93	333	1564
UK	18032	30	170	575	3233
EU-25	76784	617	2442	7529	39123

Table 6.7: Per-capita emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of exposure to PM (€/person/year)

	Baseline 2020	**25% gap closure A1/1**	**50% gap closure A1/2**	**75% gap closure A1/3**	**MTFR 2020 excl. Euro5/6**
Austria	180	1	8	36	178
Belgium	194	2	10	27	93
Cyprus	146	2	4	16	91
Czech Rep.	130	1	5	14	63
Denmark	215	4	12	35	157
Estonia	161	3	4	25	139
Finland	207	4	11	39	208
France	124	2	8	24	124
Germany	176	1	3	10	52
Greece	186	0	1	8	95
Hungary	111	1	6	10	63
Ireland	221	3	13	35	152
Italy	136	2	7	23	62
Latvia	99	1	3	9	61
Lithuania	108	1	7	21	123
Luxembourg	550	0	6	20	73
Malta	98	0	1	1	47
Netherlands	234	1	3	15	61
Poland	102	1	5	14	101
Portugal	161	2	6	14	142
Slovakia	130	0	2	7	63
Slovenia	132	3	6	27	99
Spain	148	1	6	16	113
Sweden	189	4	11	39	182
UK	296	0	3	9	53
EU-25	172	1	5	17	88

Table 6.8: Emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of exposure to PM, expressed as percentage of GDP in 2020 (% of GDP) using Market Exchange Rates (MER)

	Baseline 2020	**25% gap closure A1/1**	**50% gap closure A1/2**	**75% gap closure A1/3**	**MTFR 2020 excl. Euro5/6**
Austria	0.45%	0.00%	0.02%	0.09%	0.45%
Belgium	0.54%	0.01%	0.03%	0.07%	0.26%
Cyprus	0.67%	0.01%	0.02%	0.07%	0.42%
Czech Rep.	1.11%	0.01%	0.05%	0.12%	0.53%
Denmark	0.44%	0.01%	0.03%	0.07%	0.33%
Estonia	1.51%	0.03%	0.04%	0.23%	1.31%
Finland	0.54%	0.01%	0.03%	0.10%	0.54%
France	0.35%	0.01%	0.02%	0.07%	0.35%
Germany	0.46%	0.00%	0.01%	0.02%	0.14%
Greece	0.77%	0.00%	0.01%	0.03%	0.39%
Hungary	0.94%	0.01%	0.05%	0.08%	0.54%
Ireland	0.50%	0.01%	0.03%	0.08%	0.34%
Italy	0.40%	0.00%	0.02%	0.07%	0.18%
Latvia	1.19%	0.01%	0.03%	0.11%	0.73%
Lithuania	1.29%	0.01%	0.08%	0.25%	1.48%
Luxembourg	0.71%	0.00%	0.01%	0.03%	0.10%
Malta	0.45%	0.00%	0.00%	0.01%	0.22%
Netherlands	0.61%	0.00%	0.01%	0.04%	0.16%
Poland	0.90%	0.01%	0.05%	0.12%	0.89%
Portugal	0.72%	0.01%	0.03%	0.06%	0.64%
Slovakia	1.49%	0.00%	0.02%	0.09%	0.72%
Slovenia	0.69%	0.02%	0.03%	0.14%	0.52%
Spain	0.52%	0.00%	0.02%	0.06%	0.40%
Sweden	0.42%	0.01%	0.02%	0.09%	0.41%
UK	0.71%	0.00%	0.01%	0.02%	0.13%
EU-25	0.53%	0.00%	0.02%	0.05%	0.27%

Table 6.9: Emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of exposure to PM, expressed as percentage of GDP in 2020 (% of GDP) using Purchasing Power Standards (PPS)

	Baseline 2020	**25% gap closure A1/1**	**50% gap closure A1/2**	**75% gap closure A1/3**	**MTFR 2020 excl. Euro5/6**
Austria	0.45%	0.00%	0.02%	0.09%	0.45%
Belgium	0.54%	0.01%	0.03%	0.07%	0.26%
Cyprus	0.56%	0.01%	0.02%	0.06%	0.35%
Czech Rep.	0.53%	0.00%	0.02%	0.06%	0.25%
Denmark	0.44%	0.01%	0.03%	0.07%	0.33%
Estonia	0.73%	0.02%	0.02%	0.11%	0.63%
Finland	0.54%	0.01%	0.03%	0.10%	0.54%
France	0.35%	0.01%	0.02%	0.07%	0.35%
Germany	0.46%	0.00%	0.01%	0.02%	0.14%
Greece	0.77%	0.00%	0.01%	0.03%	0.39%
Hungary	0.46%	0.01%	0.02%	0.04%	0.26%
Ireland	0.50%	0.01%	0.03%	0.08%	0.34%
Italy	0.40%	0.00%	0.02%	0.07%	0.18%
Latvia	0.58%	0.00%	0.02%	0.05%	0.35%
Lithuania	0.58%	0.00%	0.04%	0.11%	0.66%
Luxembourg	0.71%	0.00%	0.01%	0.03%	0.10%
Malta	0.41%	0.00%	0.00%	0.00%	0.20%
Netherlands	0.61%	0.00%	0.01%	0.04%	0.16%
Poland	0.51%	0.01%	0.03%	0.07%	0.50%
Portugal	0.72%	0.01%	0.03%	0.06%	0.64%
Slovakia	0.59%	0.00%	0.01%	0.03%	0.28%
Slovenia	0.46%	0.01%	0.02%	0.10%	0.35%
Spain	0.52%	0.00%	0.02%	0.06%	0.40%
Sweden	0.42%	0.01%	0.02%	0.09%	0.41%
UK	0.71%	0.00%	0.01%	0.02%	0.13%
EU-25	0.51%	0.00%	0.02%	0.05%	0.26%

Table 6.10: Emission control costs in 2020 of the Baseline projection (million €/year)

	SO_2	**NO_x**	**NH_3**	**VOC**	**PM2.5**	**Mobile sources**	**Total**
Austria	316	30	23	48	205	769	1391
Belgium	463	43	178	80	116	1102	1982
Cyprus	63	1	0	1	5	58	129
Czech Rep.	275	46	39	32	184	712	1287
Denmark	144	12	381	15	61	539	1151
Estonia	36	5	0	2	15	123	182
Finland	320	25	33	12	236	444	1071
France	1920	58	135	545	853	4220	7732
Germany	2142	1130	747	385	1248	8231	13884
Greece	459	49	0	24	217	1174	1923
Hungary	155	20	46	20	52	710	1002
Ireland	179	21	0	24	43	749	1017
Italy	1611	188	187	286	316	4757	7345
Latvia	33	1	0	6	9	166	213
Lithuania	59	6	0	6	10	294	375
Luxembourg	58	2	0	2	3	235	300
Malta	17	1	0	0	2	21	41
Netherlands	360	285	1143	55	70	1947	3860
Poland	895	199	0	64	545	2155	3858
Portugal	305	32	0	25	71	1164	1597
Slovakia	143	27	0	13	72	446	701
Slovenia	57	5	5	6	3	175	250
Spain	1364	83	0	156	261	3801	5666
Sweden	436	18	46	50	299	769	1618
UK	11810	65	188	229	306	5434	18032
EU-25	23619	2352	3150	2087	5202	40198	76608

Table 6.11: Emission control costs in 2020 of the 25 percent gap closure scenario A1/1 (million €/year), on top of the costs of the baseline scenario

	SO_2	**NO_x**	**NH_3**	**VOC**	**PM2.5**	**Total**
Austria	0	0	5	0	4	9
Belgium	6	4	11	0	1	22
Cyprus	1	0	1	0	0	1
Czech Rep.	4	1	3	0	3	12
Denmark	1	0	14	0	7	22
Estonia	2	0	2	0	1	4
Finland	4	0	2	0	12	18
France	43	10	63	0	16	131
Germany	19	0	40	0	1	60
Greece	2	0	0	0	1	3
Hungary	9	0	2	0	2	13
Ireland	3	1	7	0	1	12
Italy	47	14	26	0	5	92
Latvia	0	0	1	0	0	1
Lithuania	1	0	0	0	1	2
Luxembourg	0	0	0	0	0	0
Malta	0	0	0	0	0	0
Netherlands	6	0	12	0	0	19
Poland	28	0	14	0	7	49
Portugal	4	0	7	0	11	22
Slovakia	0	0	0	0	1	1
Slovenia	4	1	1	0	0	6
Spain	18	0	29	0	5	52
Sweden	3	0	7	0	24	35
UK	10	1	18	0	1	30
EU-25	216	34	265	0	102	617

Table 6.12: Emission control costs in 2020 of the 50 percent gap closure scenario A1/2 (million €/year), on top of the costs of the baseline scenario

	SO_2	**NO_x**	**NH_3**	**VOC**	**PM2.5**	**Total**
Austria	5	5	31	0	20	61
Belgium	21	21	47	0	12	101
Cyprus	1	0	2	0	1	4
Czech Rep.	23	5	20	0	4	52
Denmark	1	3	54	0	9	67
Estonia	2	0	2	0	1	5
Finland	7	0	3	0	46	56
France	94	28	272	0	109	502
Germany	35	11	206	0	22	275
Greece	9	0	2	0	3	14
Hungary	25	5	19	0	2	51
Ireland	5	4	41	0	7	58
Italy	123	101	92	0	44	361
Latvia	2	0	3	0	1	6
Lithuania	6	0	11	0	7	24
Luxembourg	1	0	2	0	0	3
Malta	0	0	0	0	0	0
Netherlands	6	2	41	0	1	51
Poland	134	4	44	0	15	196
Portugal	12	0	7	0	43	62
Slovakia	6	0	0	0	2	8
Slovenia	5	3	3	0	1	12
Spain	70	1	98	0	42	212
Sweden	9	0	26	0	58	93
UK	27	45	92	0	6	170
EU-25	634	238	1115	0	455	2442

Table 6.13: Emission control costs in 2020 of the 75 percent gap closure scenario A1/3 (million €/year), on top of the costs of the baseline scenario

	SO_2	**NO_x**	**NH_3**	**VOC**	**PM2.5**	**Total**
Austria	13	89	116	0	59	278
Belgium	55	44	154	0	20	272
Cyprus	4	1	8	0	1	14
Czech Rep.	27	42	61	0	8	137
Denmark	12	7	156	0	12	187
Estonia	9	0	8	0	11	28
Finland	40	4	45	0	115	204
France	294	85	867	0	236	1482
Germany	104	126	500	0	29	759
Greece	32	1	18	0	29	80
Hungary	30	15	31	0	10	86
Ireland	18	12	124	0	7	160
Italy	198	705	229	0	81	1212
Latvia	4	0	10	0	5	19
Lithuania	10	0	41	0	21	72
Luxembourg	3	2	6	0	0	11
Malta	0	0	0	0	0	0
Netherlands	33	119	92	0	7	251
Poland	263	22	116	0	131	532
Portugal	25	0	50	0	68	143
Slovakia	19	1	17	0	5	40
Slovenia	10	24	11	0	7	52
Spain	121	29	389	0	61	600
Sweden	36	1	87	0	209	333
UK	74	199	281	0	21	575
EU-25	1432	1527	3418	0	1152	7529

Table 6.14: Emission control costs in 2020 of the maximum technically feasible reduction scenario (million €/year), on top of the costs of the baseline scenario excluding Euro 5/6 measures

	SO_2	**NO_x**	**NH_3**	**VOC**	**PM2.5**	**Total**
Austria	13	117	449	59	741	1378
Belgium	68	221	448	25	191	953
Cyprus	20	10	39	2	10	80
Czech Rep.	113	138	218	33	118	619
Denmark	15	69	465	28	265	842
Estonia	14	14	34	6	89	157
Finland	64	129	145	44	694	1075
France	475	1067	2575	365	3287	7769
Germany	564	647	1392	214	1326	4143
Greece	144	146	217	46	431	984
Hungary	43	122	237	22	148	573
Ireland	26	76	434	23	138	696
Italy	274	837	1037	167	1038	3353
Latvia	8	14	46	13	51	131
Lithuania	16	35	157	28	191	428
Luxembourg	5	14	14	1	6	40
Malta	7	3	7	1	3	20
Netherlands	43	218	344	37	367	1009
Poland	562	421	1087	156	1590	3816
Portugal	74	107	514	55	662	1411
Slovakia	52	72	126	34	52	337
Slovenia	12	26	69	10	70	186
Spain	270	510	2502	194	847	4323
Sweden	85	170	226	62	1021	1564
UK	158	1164	802	554	555	3233
EU-25	3124	6348	13584	2177	13890	39123

Table 6.15: Loss in statistical life expectancy attributable to the exposure to PM2.5 from anthropogenic emissions of primary PM and secondary inorganic aerosols (in months).

	Baseline 2020	**25% gap closure A1/1**	**50% gap closure A1/2**	**75% gap closure A1/3**	**MTFR 2020 excl. Euro5/6**
Austria	4.9	4.5	4.1	3.7	3.3
Belgium	8.9	8.3	7.7	7.1	6.6
Cyprus	*)	*)	*)	*)	*)
Czech Rep.	5.7	5.2	4.7	4.2	3.7
Denmark	4.5	4.2	3.9	3.6	3.2
Estonia	2.8	2.6	2.5	2.3	2.2
Finland	2.0	1.9	1.8	1.7	1.7
France	5.4	4.9	4.5	4.1	3.7
Germany	6.5	5.9	5.4	4.9	4.4
Greece	4.9	4.8	4.6	4.5	4.4
Hungary	7.4	6.5	5.7	5.4	4.8
Ireland	2.9	2.6	2.4	2.2	2.0
Italy	5.0	4.6	4.2	3.9	3.7
Latvia	3.3	3.1	2.9	2.7	2.5
Lithuania	4.4	4.1	3.8	3.6	3.3
Luxembourg	6.8	6.1	5.5	4.9	4.3
Malta	5.7	5.6	5.4	5.3	5.2
Netherlands	8.6	7.9	7.3	6.7	6.1
Poland	6.4	5.9	5.4	5.0	4.6
Portugal	3.0	2.8	2.5	2.3	2.1
Slovakia	6.3	5.6	5.1	4.6	4.1
Slovenia	5.6	5.2	4.7	4.3	3.8
Spain	2.9	2.7	2.5	2.4	2.2
Sweden	2.6	2.4	2.2	2.1	1.9
UK	4.6	4.2	3.8	3.4	3.0
EU-25	5.3	4.9	4.5	4.1	3.8

*) will be supplied later

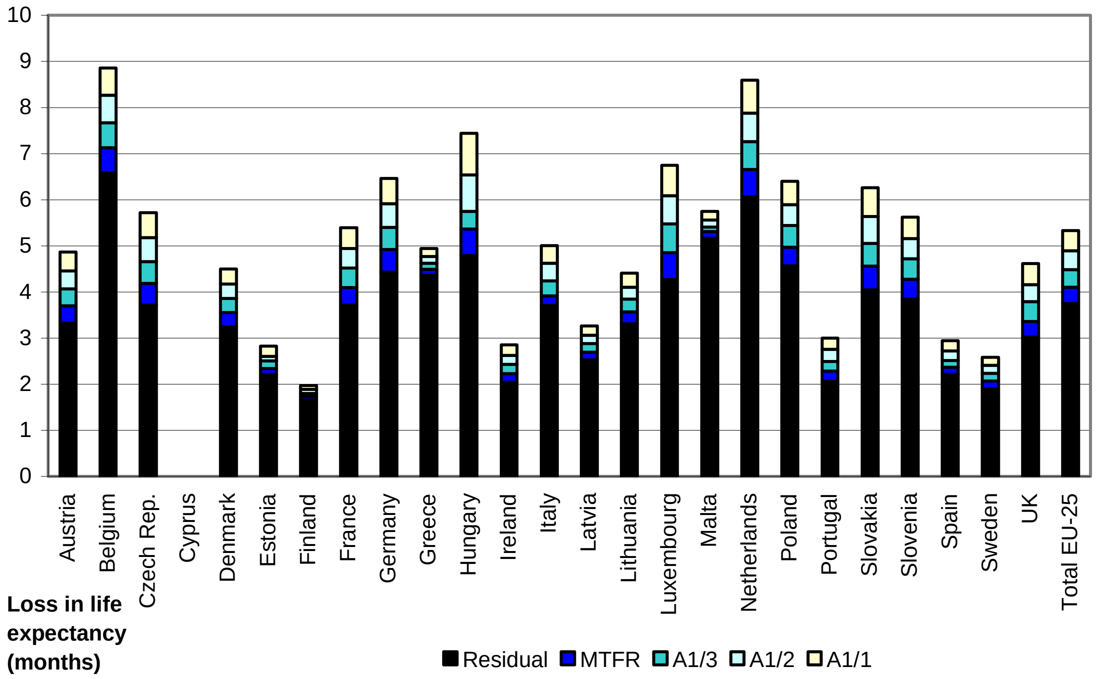


Figure 6.1: Loss in statistical life expectancy attributable to the exposure to PM2.5 originating from identified anthropogenic emissions (in months)

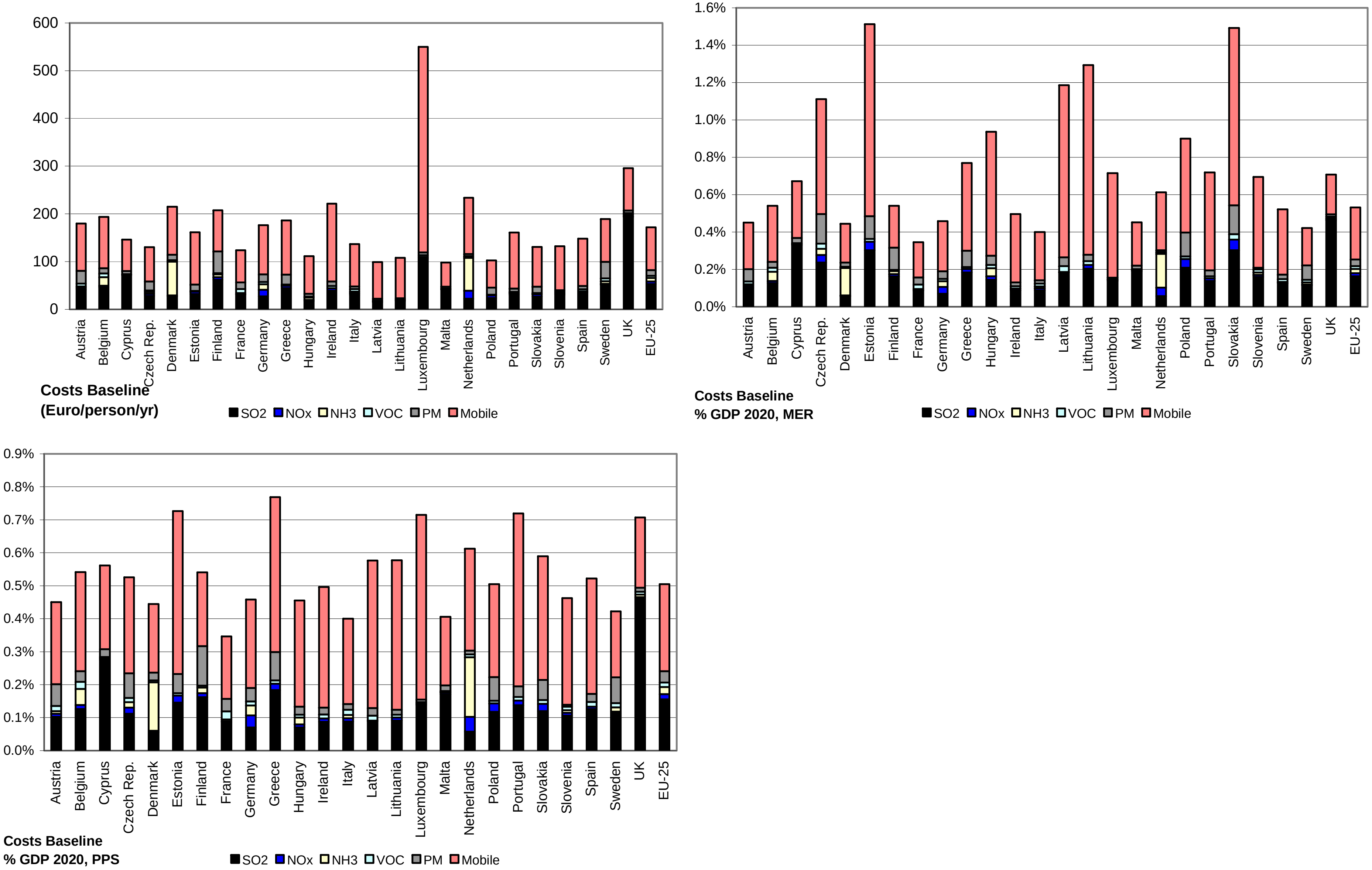
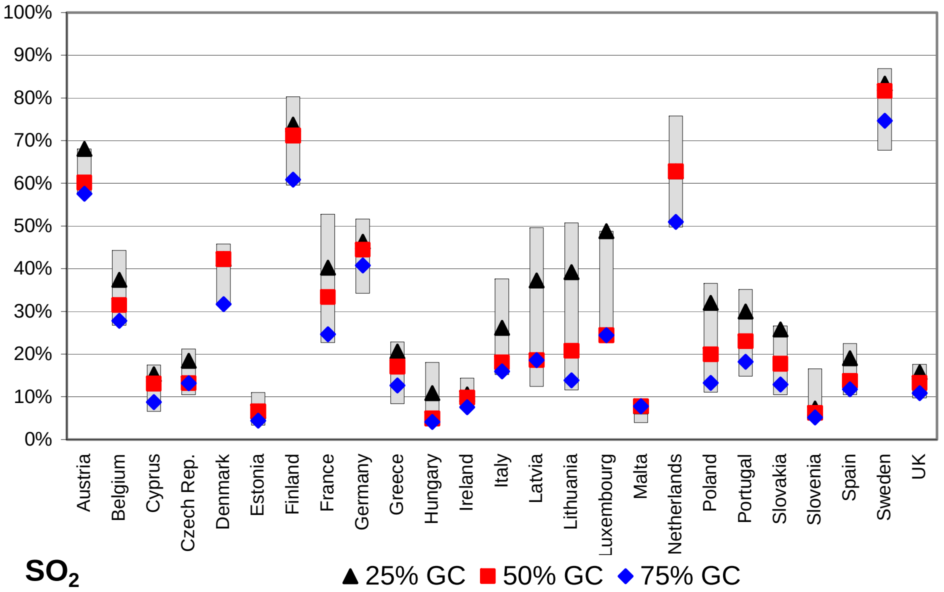


Figure 6.2: Emission control costs of the baseline projection in 2020, expressed as per-capita costs and as fractions of the GDP in 2020 using MER and PPS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60%
50%
40%
30%
20%
10%
0%
Austria
Belgium
Cyprus
Czech Rep.
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Latvia
Lithuania
Luxembourg
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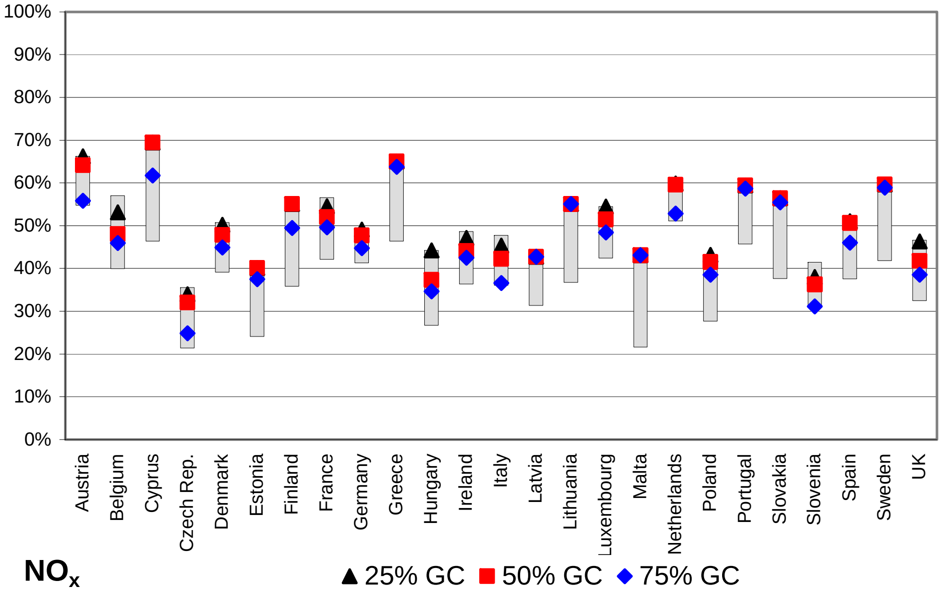
▲ 25% GC ■ 50% GC ◆ 75% GC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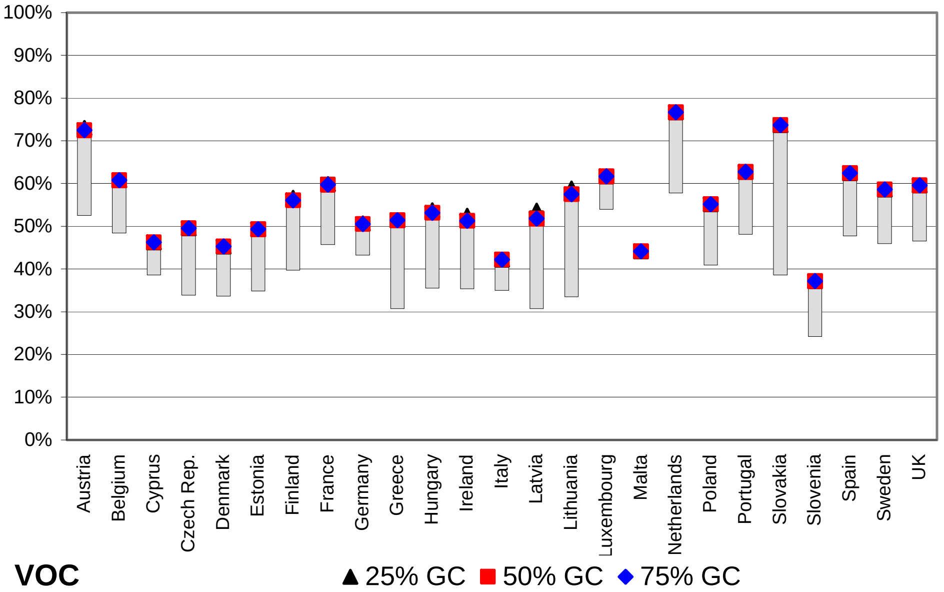
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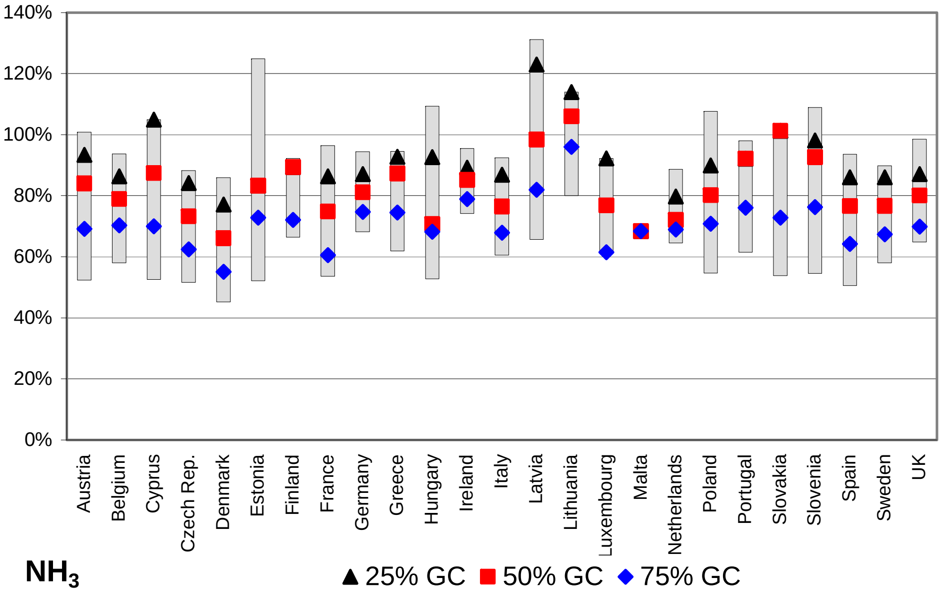
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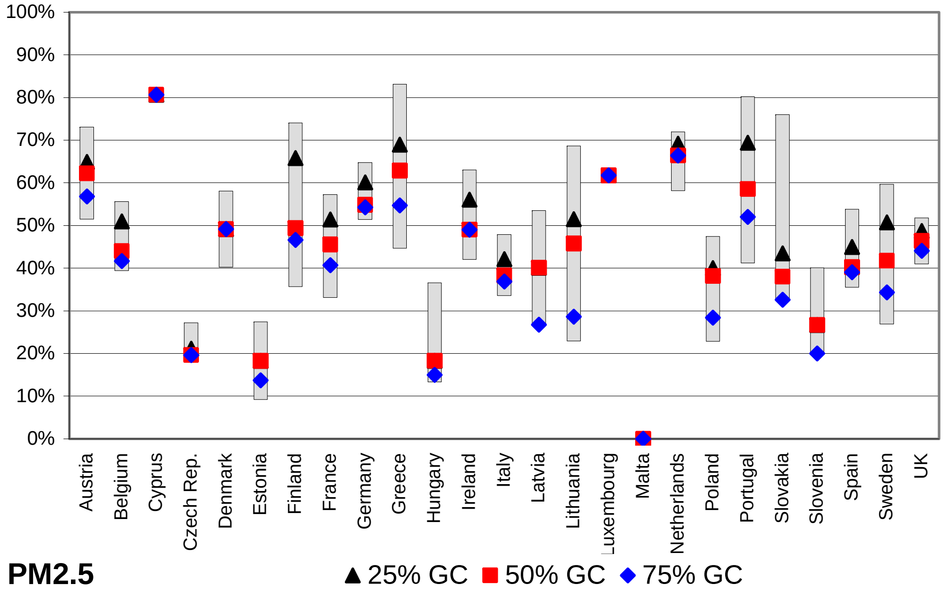


Figure 6.3: Cost-minimal emission reductions for reducing health impacts from fine particulate matter. The 100 percent line refers to the emission level in the year 2000. The grey range indicates the scope for emission reductions considered in the RAINS optimization between the baseline projection for 2020 (top end) and the maximum technically feasible reductions (bottom end). Results for Cyprus, Luxembourg and Malta are below the numerical accuracy of the present RAINS optimization code.

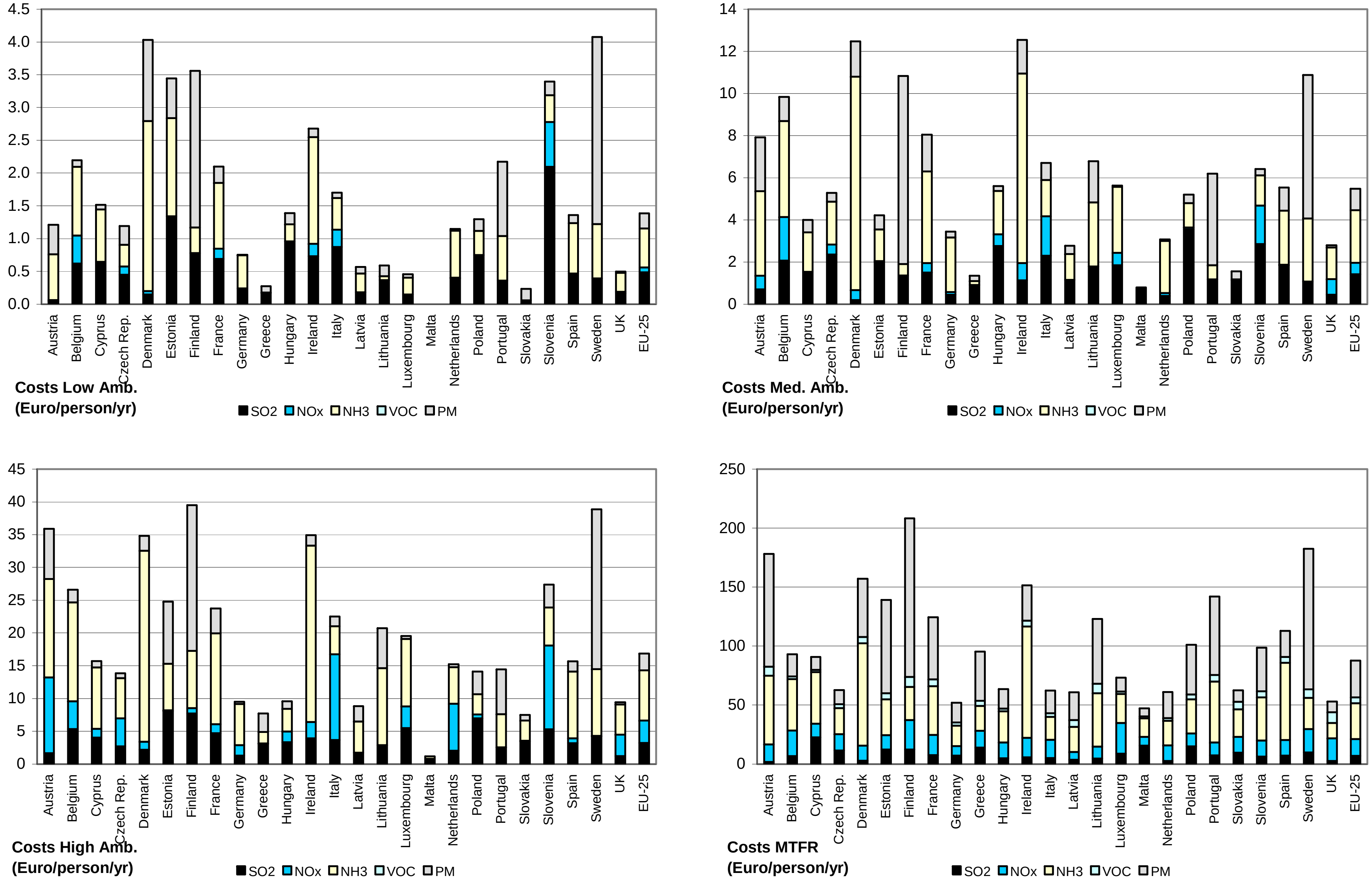


Figure 6.4: Per-capita emission control costs of the optimized scenarios for reducing health impacts from PM (€/person/year)

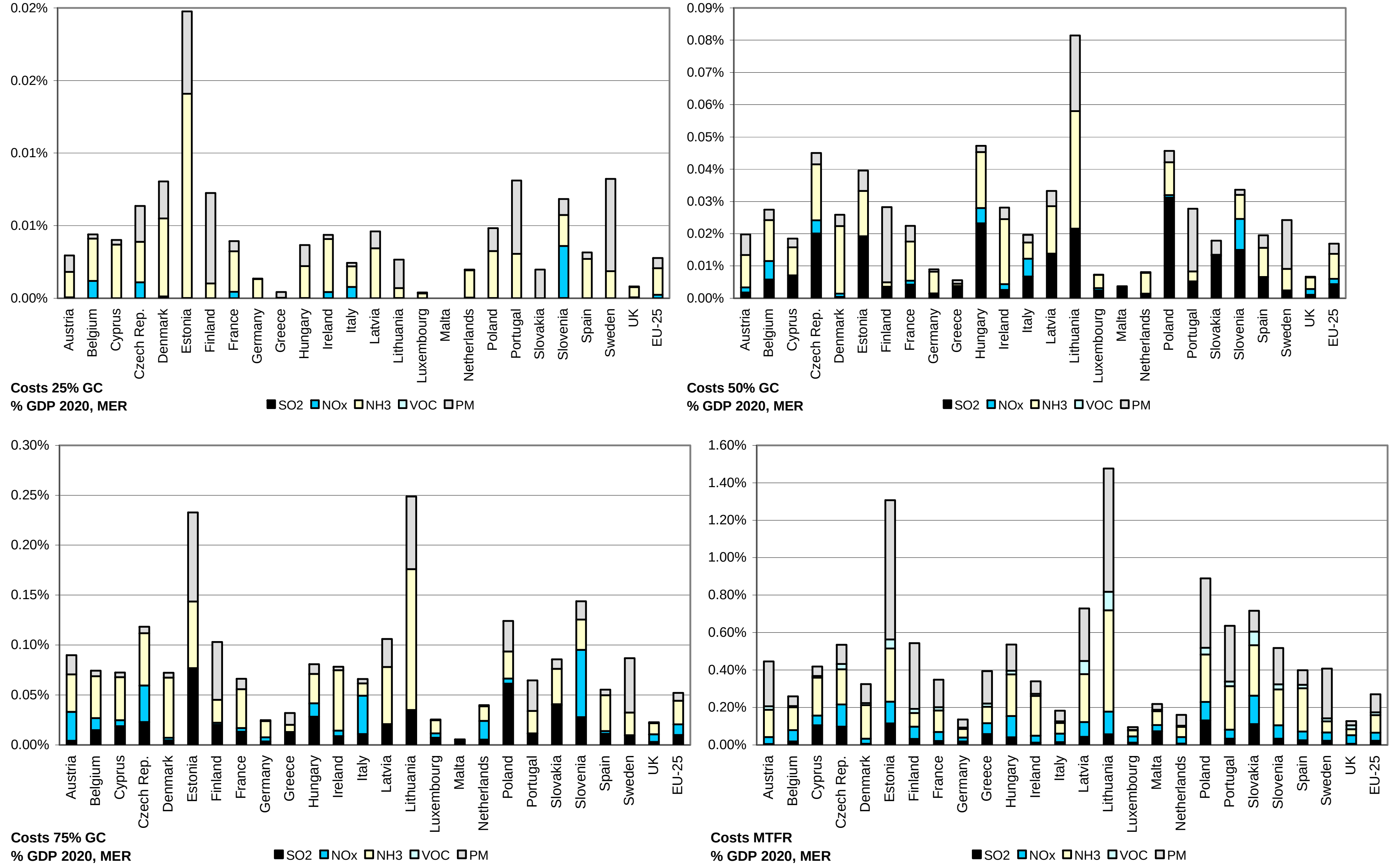


Figure 6.5: Emission control costs in 2020 expressed as percentage of GDP using Market Exchange Rates (MER) for 2020

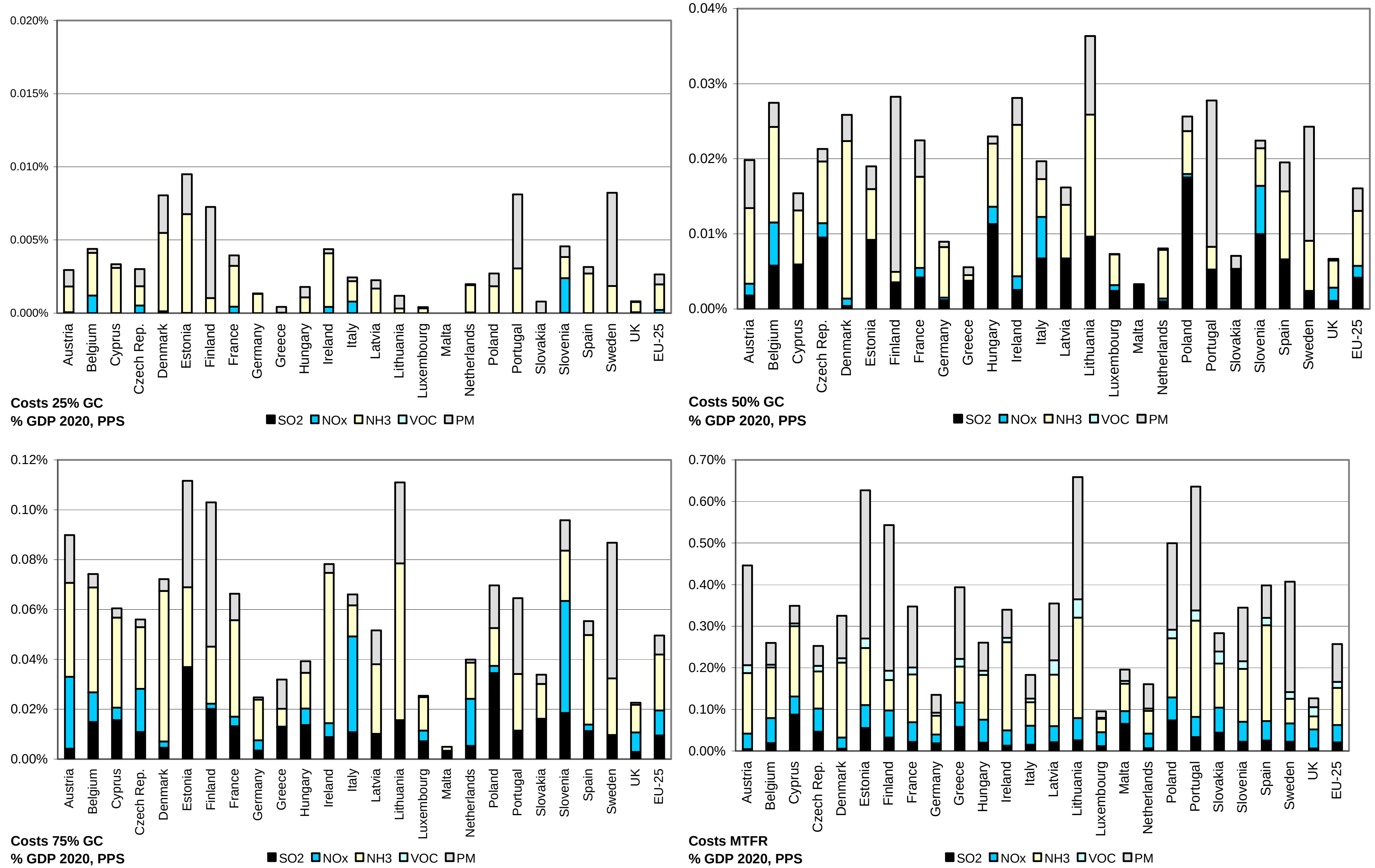


Figure 6.6: Emission control costs in 2020 expressed as percentage of GDP using Purchasing Power Standards (PPS) for 2020

6.2 Cost-optimal emission cuts for reducing health impacts from ozone (A2)

For health impacts attributable to ozone RAINS calculates the number of premature deaths attributable to ozone (SOMO35) on a grid basis and sums them up to a country balance. The gap closure is then applied to the country-balance only, i.e., it is not requested for each individual grid cell as long as the overall improvement within a given country is achieved. Formally, this is equivalent to a gap closure calculated on the basis of population-weighted SOMO35 grid data.

Table 6.16: NO_x emissions for the optimized scenarios targeted at the reduction of health impacts from ozone (in kt)

	2000	**NEC 2010**	**Baseline 2020**	**25% gap closure A2/1**	**50% gap closure A2/2**	**75% gap closure A2/3**	**MTFR 2020 excl. Euro5/6**
Austria	192	103	127	122	117	111	105
Belgium	333	176	190	187	163	157	133
Cyprus	26	23	18	17	15	13	12
Czech Rep.	318	286	113	99	83	75	68
Denmark	207	127	105	97	88	84	81
Estonia	37	60	15	13	11	9	9
Finland	212	170	117	106	97	86	76
France	1447	810	819	753	708	642	609
Germany	1645	1051	808	786	752	720	679
Greece	322	344	209	196	179	162	149
Hungary	188	198	83	70	68	59	50
Ireland	129	65	63	62	56	53	47
Italy	1389	990	663	623	583	542	500
Latvia	35	61	15	14	12	12	11
Lithuania	49	110	27	25	22	20	18
Luxembourg	33	11	18	17	16	15	14
Malta	9	8	4	3	3	2	2
Netherlands	399	260	240	240	239	236	204
Poland	843	879	364	331	298	262	233
Portugal	263	250	156	147	140	128	120
Slovakia	106	130	60	57	49	44	40
Slovenia	58	45	24	22	21	19	18
Spain	1335	847	681	633	575	544	501
Sweden	251	148	150	137	126	112	105
UK	1753	1167	817	763	701	640	568
EU-25	11581	8319	5888	5520	5122	4748	4354

Table 6.17: VOC emissions for the optimized scenarios targeted at the reduction of health impacts of ozone (in kt)

	2000	**NEC 2010**	**Baseline 2020**	**25% gap closure A2/1**	**50% gap closure A2/2**	**75% gap closure A2/3**	**MTFR 2020 excl. Euro5/6**
Austria	190	159	139	135	128	115	100
Belgium	242	139	147	133	122	117	117
Cyprus	13	14	6	6	6	6	5
Czech Rep.	242	220	120	107	101	89	82
Denmark	128	85	58	55	53	44	43
Estonia	34	49	17	16	15	15	12
Finland	171	130	97	96	93	91	68
France	1542	1050	923	885	853	740	704
Germany	1528	995	774	721	704	683	660
Greece	280	261	144	116	115	113	86
Hungary	169	137	91	75	75	69	60
Ireland	88	55	46	41	34	31	31
Italy	1738	1159	734	711	665	642	607
Latvia	52	136	28	26	25	22	16
Lithuania	75	92	44	40	40	37	25
Luxembourg	13	9	8	8	7	7	7
Malta	5	12	2	2	2	2	2
Netherlands	265	185	203	171	158	157	153
Poland	582	800	321	318	310	298	238
Portugal	260	180	163	157	151	137	125
Slovakia	88	140	65	60	59	56	34
Slovenia	54	40	20	20	19	19	13
Spain	1121	662	700	675	637	618	535
Sweden	305	241	179	178	174	172	140
UK	1474	1200	878	840	792	749	685
EU-25	10661	8150	5908	5588	5339	5030	4546

Table 6.18: Emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of health impacts of ozone (million €/year)

	Baseline 2020 (total costs)	**25% gap closure A2/1**	**50% gap closure A2/2**	**75% gap closure A2/3**	**MTFR 2020 excl. Euro5/6**
Austria	1392	8	28	81	1378
Belgium	1985	1	21	51	953
Cyprus	129	1	2	5	80
Czech Rep.	1287	8	34	69	619
Denmark	1152	4	20	54	842
Estonia	182	1	4	12	157
Finland	1071	4	18	64	1075
France	7732	30	131	662	7769
Germany	14054	17	88	253	4143
Greece	1923	4	15	46	984
Hungary	1002	6	10	43	573
Ireland	1017	1	16	40	696
Italy	7347	23	135	417	3353
Latvia	213	1	2	6	131
Lithuania	375	1	4	14	428
Luxembourg	300	0	2	8	40
Malta	41	1	1	2	20
Netherlands	3857	2	10	20	1009
Poland	3858	17	63	173	3816
Portugal	1597	3	9	62	1411
Slovakia	701	2	12	32	337
Slovenia	250	1	4	13	186
Spain	5666	20	76	179	4323
Sweden	1621	9	32	99	1564
UK	18032	21	172	652	3233
EU-25	76784	184	909	3057	39123

Table 6.19: Per-capita emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of health impacts from ozone (€/person/year)

	Baseline 2020	**25% gap closure A2/1**	**50% gap closure A2/2**	**75% gap closure A2/3**	**MTFR 2020 excl. Euro5/6**
Austria	180	1	4	11	178
Belgium	194	0	2	5	93
Cyprus	146	1	2	6	91
Czech Rep.	130	1	3	7	63
Denmark	215	1	4	10	157
Estonia	161	0	3	11	139
Finland	207	1	4	12	208
France	124	0	2	11	124
Germany	176	0	1	3	52
Greece	186	0	1	4	95
Hungary	111	1	1	5	63
Ireland	221	0	3	9	152
Italy	136	0	3	8	62
Latvia	99	0	1	3	61
Lithuania	108	0	1	4	123
Luxembourg	550	1	4	15	73
Malta	98	1	3	5	47
Netherlands	234	0	1	1	61
Poland	102	0	2	5	101
Portugal	161	0	1	6	142
Slovakia	130	0	2	6	63
Slovenia	132	1	2	7	99
Spain	148	1	2	5	113
Sweden	189	1	4	12	182
UK	296	0	3	11	53
EU-25	172	0	2	7	88

Table 6.20: Emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of health impacts from ozone, expressed as percentage of GDP in 2020 (% of GDP) using Market Exchange Rates (MER)

	Baseline 2020	**25% gap closure A2/1**	**50% gap closure A2/2**	**75% gap closure A2/3**	**MTFR 2020 excl. Euro5/6**
Austria	0.45%	0.00%	0.01%	0.03%	0.45%
Belgium	0.54%	0.00%	0.01%	0.01%	0.26%
Cyprus	0.67%	0.00%	0.01%	0.03%	0.42%
Czech Rep.	1.11%	0.01%	0.03%	0.06%	0.53%
Denmark	0.44%	0.00%	0.01%	0.02%	0.33%
Estonia	1.51%	0.00%	0.03%	0.10%	1.31%
Finland	0.54%	0.00%	0.01%	0.03%	0.54%
France	0.35%	0.00%	0.01%	0.03%	0.35%
Germany	0.46%	0.00%	0.00%	0.01%	0.14%
Greece	0.77%	0.00%	0.01%	0.02%	0.39%
Hungary	0.94%	0.01%	0.01%	0.04%	0.54%
Ireland	0.50%	0.00%	0.01%	0.02%	0.34%
Italy	0.40%	0.00%	0.01%	0.02%	0.18%
Latvia	1.19%	0.00%	0.01%	0.03%	0.73%
Lithuania	1.29%	0.00%	0.01%	0.05%	1.48%
Luxembourg	0.71%	0.00%	0.00%	0.02%	0.10%
Malta	0.45%	0.01%	0.01%	0.02%	0.22%
Netherlands	0.61%	0.00%	0.00%	0.00%	0.16%
Poland	0.90%	0.00%	0.01%	0.04%	0.89%
Portugal	0.72%	0.00%	0.00%	0.03%	0.64%
Slovakia	1.49%	0.00%	0.03%	0.07%	0.72%
Slovenia	0.69%	0.00%	0.01%	0.04%	0.52%
Spain	0.52%	0.00%	0.01%	0.02%	0.40%
Sweden	0.42%	0.00%	0.01%	0.03%	0.41%
UK	0.71%	0.00%	0.01%	0.03%	0.13%
EU-25	0.53%	0.00%	0.01%	0.02%	0.27%

Table 6.21: Emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of exposure to PM, expressed as percentage of GDP in 2020 (% of GDP) using Purchasing Power Standards (PPS)

	Baseline 2020	**25% gap closure A1/1**	**50% gap closure A1/2**	**75% gap closure A1/3**	**MTFR 2020 excl. Euro5/6**
Austria	0.45%	0.00%	0.01%	0.03%	0.45%
Belgium	0.54%	0.00%	0.01%	0.01%	0.26%
Cyprus	0.56%	0.00%	0.01%	0.02%	0.35%
Czech Rep.	0.53%	0.00%	0.01%	0.03%	0.25%
Denmark	0.44%	0.00%	0.01%	0.02%	0.33%
Estonia	0.73%	0.00%	0.02%	0.05%	0.63%
Finland	0.54%	0.00%	0.01%	0.03%	0.54%
France	0.35%	0.00%	0.01%	0.03%	0.35%
Germany	0.46%	0.00%	0.00%	0.01%	0.14%
Greece	0.77%	0.00%	0.01%	0.02%	0.39%
Hungary	0.46%	0.00%	0.00%	0.02%	0.26%
Ireland	0.50%	0.00%	0.01%	0.02%	0.34%
Italy	0.40%	0.00%	0.01%	0.02%	0.18%
Latvia	0.58%	0.00%	0.01%	0.02%	0.35%
Lithuania	0.58%	0.00%	0.01%	0.02%	0.66%
Luxembourg	0.71%	0.00%	0.00%	0.02%	0.10%
Malta	0.41%	0.01%	0.01%	0.02%	0.20%
Netherlands	0.61%	0.00%	0.00%	0.00%	0.16%
Poland	0.51%	0.00%	0.01%	0.02%	0.50%
Portugal	0.72%	0.00%	0.00%	0.03%	0.64%
Slovakia	0.59%	0.00%	0.01%	0.03%	0.28%
Slovenia	0.46%	0.00%	0.01%	0.02%	0.35%
Spain	0.52%	0.00%	0.01%	0.02%	0.40%
Sweden	0.42%	0.00%	0.01%	0.03%	0.41%
UK	0.71%	0.00%	0.01%	0.03%	0.13%
EU-25	0.51%	0.00%	0.01%	0.02%	0.26%

Table 6.22: Emission control costs in 2020 of the 25 percent gap closure scenario A2/1 (million €/year), on top of the costs of the baseline scenario

	SO_2	**NO_x**	**NH_3**	**VOC**	**PM2.5**	**Total**
Austria	0.0	8.0	0.0	0.2	0.0	8.2
Belgium	0.0	0.8	0.0	0.4	0.0	1.2
Cyprus	0.0	0.6	0.0	0.0	0.0	0.6
Czech Rep.	0.0	7.8	0.0	0.2	0.0	8.0
Denmark	0.0	3.4	0.0	0.3	0.0	3.7
Estonia	0.0	0.5	0.0	0.0	0.0	0.5
Finland	0.0	3.5	0.0	0.0	0.0	3.5
France	0.0	27.8	0.0	2.5	0.0	30.3
Germany	0.0	9.9	0.0	6.6	0.0	16.6
Greece	0.0	4.1	0.0	0.4	0.0	4.5
Hungary	0.0	5.1	0.0	0.6	0.0	5.7
Ireland	0.0	0.4	0.0	0.7	0.0	1.0
Italy	0.0	21.4	0.0	2.0	0.0	23.3
Latvia	0.0	0.6	0.0	0.1	0.0	0.6
Lithuania	0.0	0.8	0.0	0.1	0.0	1.0
Luxembourg	0.0	0.4	0.0	0.0	0.0	0.4
Malta	0.0	0.6	0.0	0.0	0.0	0.6
Netherlands	0.0	0.0	0.0	1.7	0.0	1.7
Poland	0.0	16.7	0.0	0.3	0.0	16.9
Portugal	0.0	2.7	0.0	0.2	0.0	2.9
Slovakia	0.0	1.7	0.0	0.2	0.0	2.0
Slovenia	0.0	1.4	0.0	0.1	0.0	1.5
Spain	0.0	19.2	0.0	0.5	0.0	19.7
Sweden	0.0	8.7	0.0	0.1	0.0	8.8
UK	0.0	20.0	0.0	1.2	0.0	21.3
EU-25	0.0	165.9	0.0	18.4	0.0	184.3

Table 6.23: Emission control costs in 2020 of the 50 percent gap closure scenario A2/2 (million €/year), on top of the costs of the baseline scenario

	SO_2	NO_x	NH_3	VOC	PM2.5	Total
Austria	0.0	24.5	0.0	3.4	0.0	27.9
Belgium	0.0	13.7	0.0	7.5	0.0	21.2
Cyprus	0.0	2.1	0.0	0.0	0.0	2.1
Czech Rep.	0.0	32.3	0.0	2.1	0.0	34.5
Denmark	0.0	18.0	0.0	1.6	0.0	19.6
Estonia	0.0	3.8	0.0	0.1	0.0	3.9
Finland	0.0	18.0	0.0	0.3	0.0	18.3
France	0.0	115.9	0.0	14.9	0.0	130.8
Germany	0.0	72.7	0.0	14.9	0.0	87.7
Greece	0.0	14.5	0.0	0.5	0.0	15.0
Hungary	0.0	8.9	0.0	0.6	0.0	9.6
Ireland	0.0	5.6	0.0	10.1	0.0	15.7
Italy	0.0	113.4	0.0	21.9	0.0	135.3
Latvia	0.0	2.3	0.0	0.1	0.0	2.4
Lithuania	0.0	4.1	0.0	0.1	0.0	4.2
Luxembourg	0.0	1.8	0.0	0.2	0.0	2.0
Malta	0.0	1.3	0.0	0.0	0.0	1.3
Netherlands	0.0	0.5	0.0	9.7	0.0	10.2
Poland	0.0	61.1	0.0	2.0	0.0	63.1
Portugal	0.0	6.4	0.0	2.8	0.0	9.1
Slovakia	0.0	12.2	0.0	0.3	0.0	12.4
Slovenia	0.0	3.5	0.0	0.4	0.0	3.9
Spain	0.0	69.6	0.0	6.1	0.0	75.7
Sweden	0.0	30.4	0.0	1.3	0.0	31.8
UK	0.0	123.6	0.0	48.3	0.0	171.9
EU-25	0.0	760.1	0.0	149.4	0.0	909.5

Table 6.24: Emission control costs in 2020 of the 75 percent gap closure scenario A2/3 (million €/year), on top of the costs of the baseline scenario

	SO_2	**NO_x**	**NH_3**	**VOC**	**PM2.5**	**Total**
Austria	0.0	66.9	0.0	14.4	0.0	81.4
Belgium	0.0	31.5	0.0	20.0	0.0	51.5
Cyprus	0.0	5.1	0.0	0.0	0.0	5.1
Czech Rep.	0.0	60.1	0.0	9.0	0.0	69.2
Denmark	0.0	38.7	0.0	15.0	0.0	53.8
Estonia	0.0	11.5	0.0	0.3	0.0	11.9
Finland	0.0	62.0	0.0	1.7	0.0	63.7
France	0.0	484.1	0.0	178.3	0.0	662.4
Germany	0.0	213.3	0.0	39.6	0.0	252.9
Greece	0.0	44.7	0.0	0.8	0.0	45.6
Hungary	0.0	40.0	0.0	3.1	0.0	43.0
Ireland	0.0	18.3	0.0	21.7	0.0	39.9
Italy	0.0	370.1	0.0	47.2	0.0	417.2
Latvia	0.0	4.4	0.0	1.4	0.0	5.8
Lithuania	0.0	13.2	0.0	1.3	0.0	14.5
Luxembourg	0.0	7.7	0.0	0.4	0.0	8.1
Malta	0.0	2.1	0.0	0.1	0.0	2.1
Netherlands	0.0	5.2	0.0	14.3	0.0	19.5
Poland	0.0	165.9	0.0	7.3	0.0	173.2
Portugal	0.0	37.4	0.0	24.2	0.0	61.6
Slovakia	0.0	30.1	0.0	1.4	0.0	31.5
Slovenia	0.0	12.9	0.0	0.5	0.0	13.5
Spain	0.0	167.6	0.0	11.1	0.0	178.7
Sweden	0.0	95.8	0.0	3.2	0.0	99.0
UK	0.0	430.6	0.0	221.0	0.0	651.6
EU-25	0.0	2419.3	0.0	637.3	0.0	3056.6

Table 6.25: Number of premature deaths attributable to the exposure to ozone – provisional results

	Baseline 2020	**25% gap closure A2/1**	**50% gap closure A2/2**	**75% gap closure A2/3**	**MTFR 2020 excl. Euro5/6**
Austria	327	310	294	278	261
Belgium	416	396	380	363	350
Cyprus	24	23	22	22	21
Czech Rep.	396	372	346	325	303
Denmark	162	156	149	143	137
Estonia	98	93	88	84	79
Finland	52	50	48	46	45
France	2301	2184	2082	1957	1865
Germany	3571	3412	3253	3094	2935
Greece	479	459	440	420	400
Hungary	524	488	460	428	395
Ireland	80	77	75	73	70
Italy	3492	3350	3207	3065	2922
Latvia	50	47	45	43	41
Lithuania	46	44	42	40	38
Luxembourg	28	27	25	24	23
Malta	18	17	17	16	16
Netherlands	455	433	414	397	380
Poland	996	937	878	819	760
Portugal	443	426	409	392	374
Slovakia	167	156	145	135	124
Slovenia	80	76	72	68	64
Spain	319	308	296	286	275
Sweden	176	169	163	156	150
UK	1853	1800	1749	1698	1646
EU-25	16552	15810	15100	14369	13675

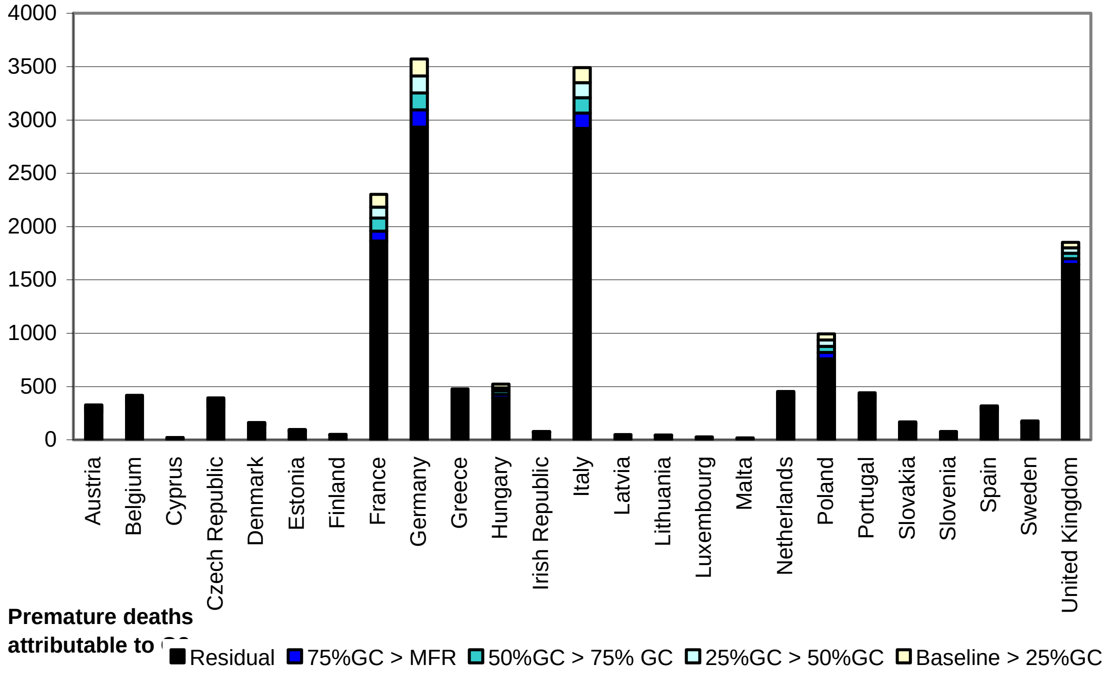
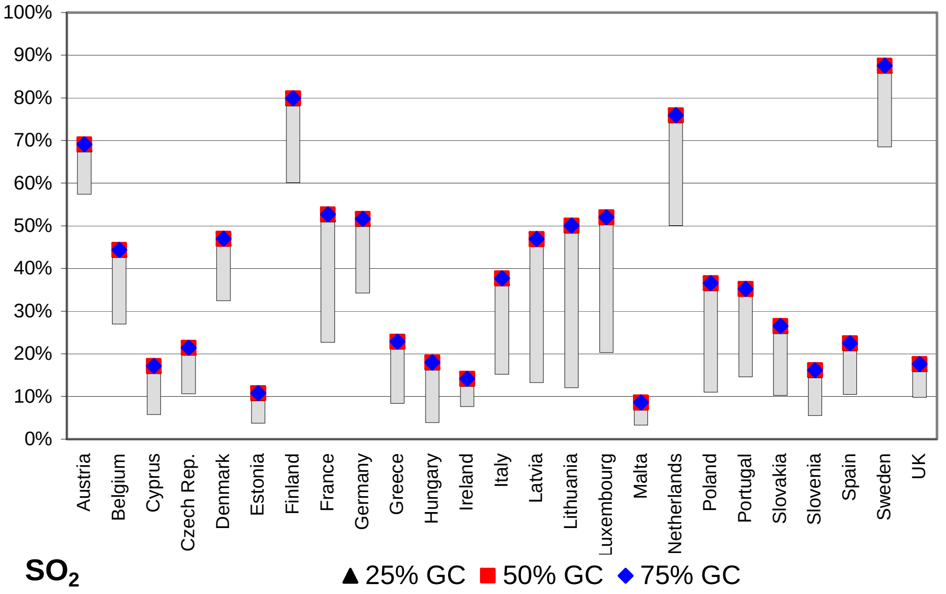
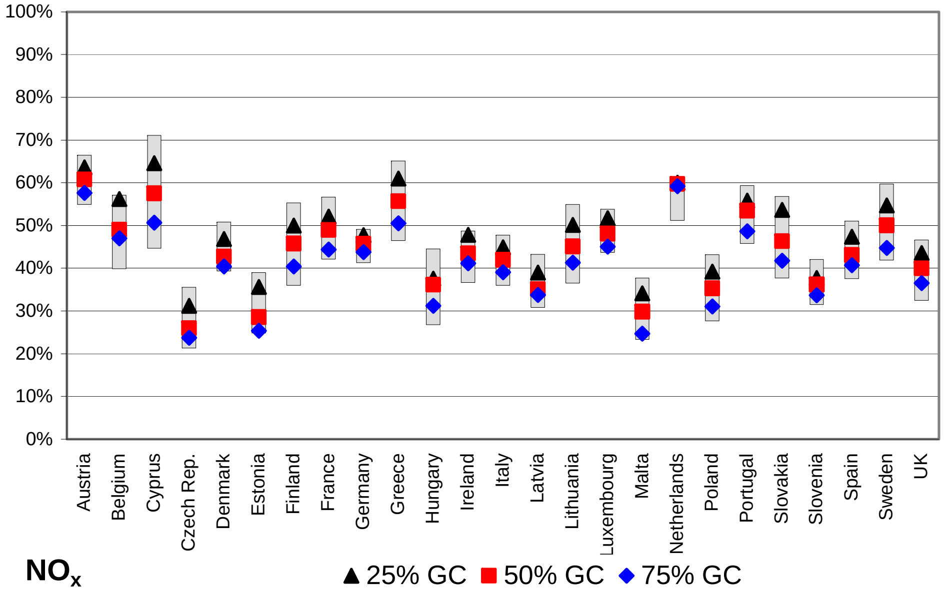


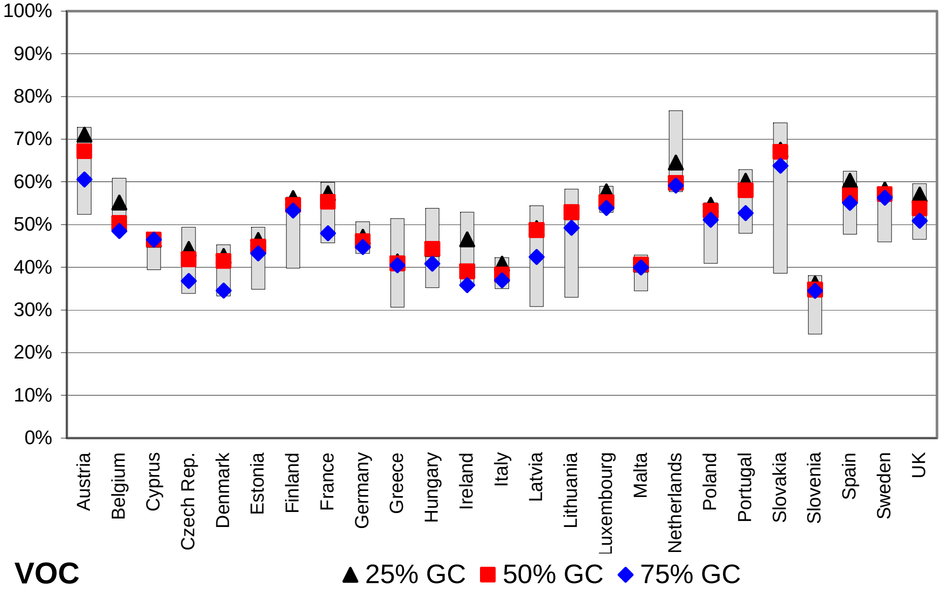
Figure 6.7: Cases of premature death attributable to ozone in 2020 – provisional results



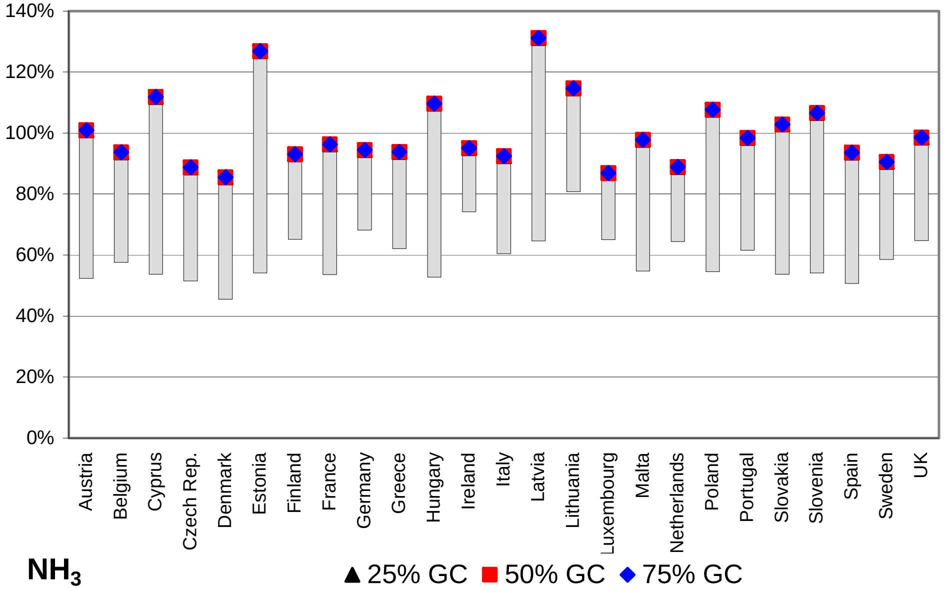
SO_2



NO_x



VOC



NH_3

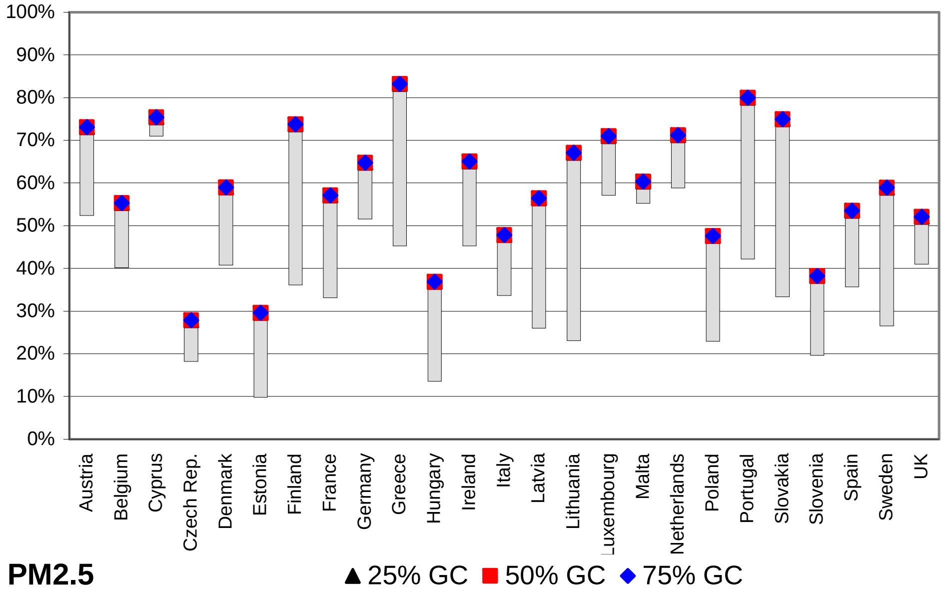


Figure 6.8: Cost-minimal emission reductions for reducing health impacts from ozone. The 100 percent line refers to the emission level in the year 2000. The grey range indicates the scope for emission reductions considered in the RAINS optimization between the baseline projection for 2020 (top end) and the maximum technically feasible reductions (bottom end). Results for Cyprus, Luxembourg and Malta are below the numerical accuracy of the present RAINS optimization code.

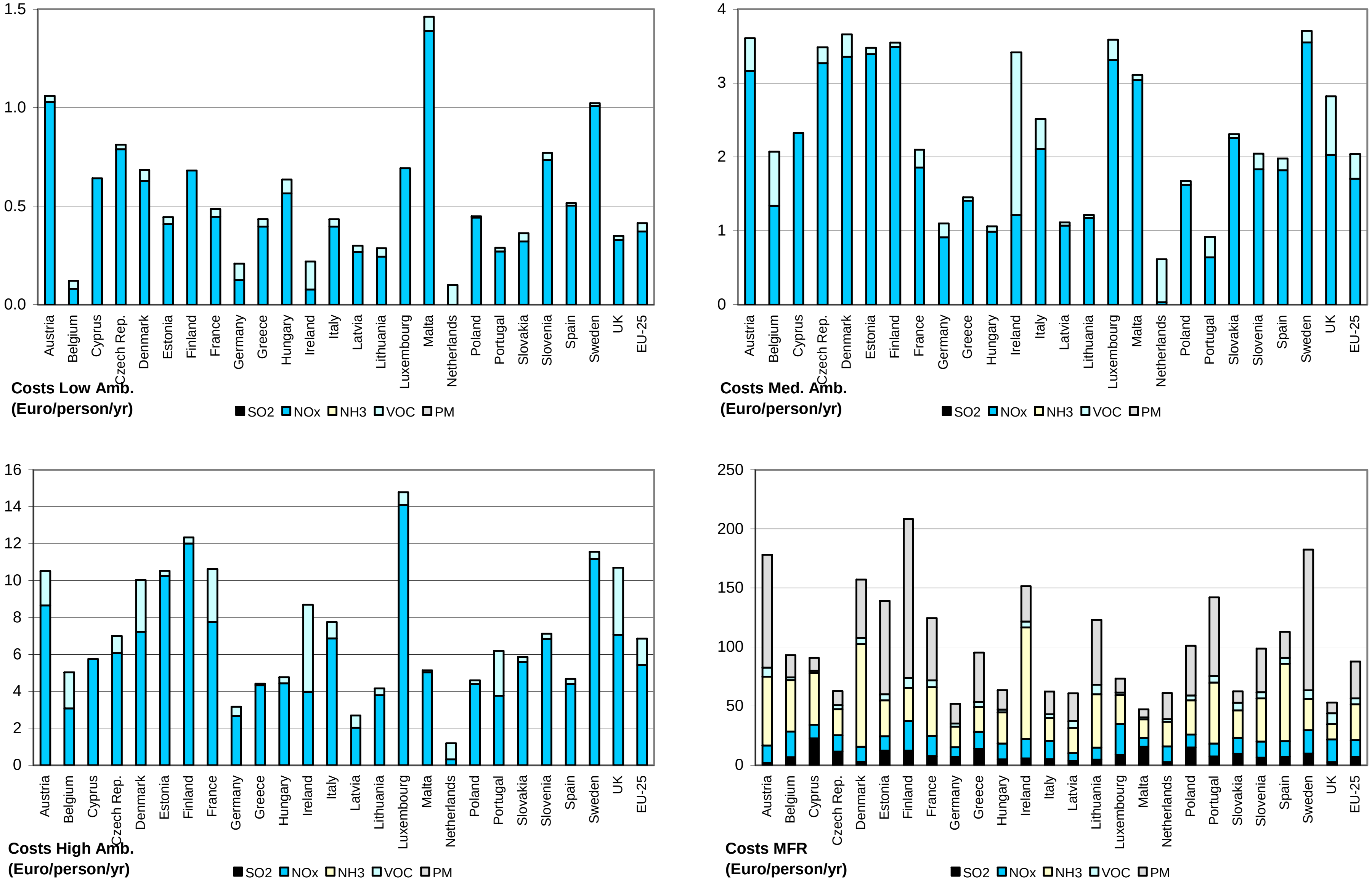


Figure 6.9: Per-capita emission control costs of the optimized scenarios for reducing health impacts from ozone (€/person/year)

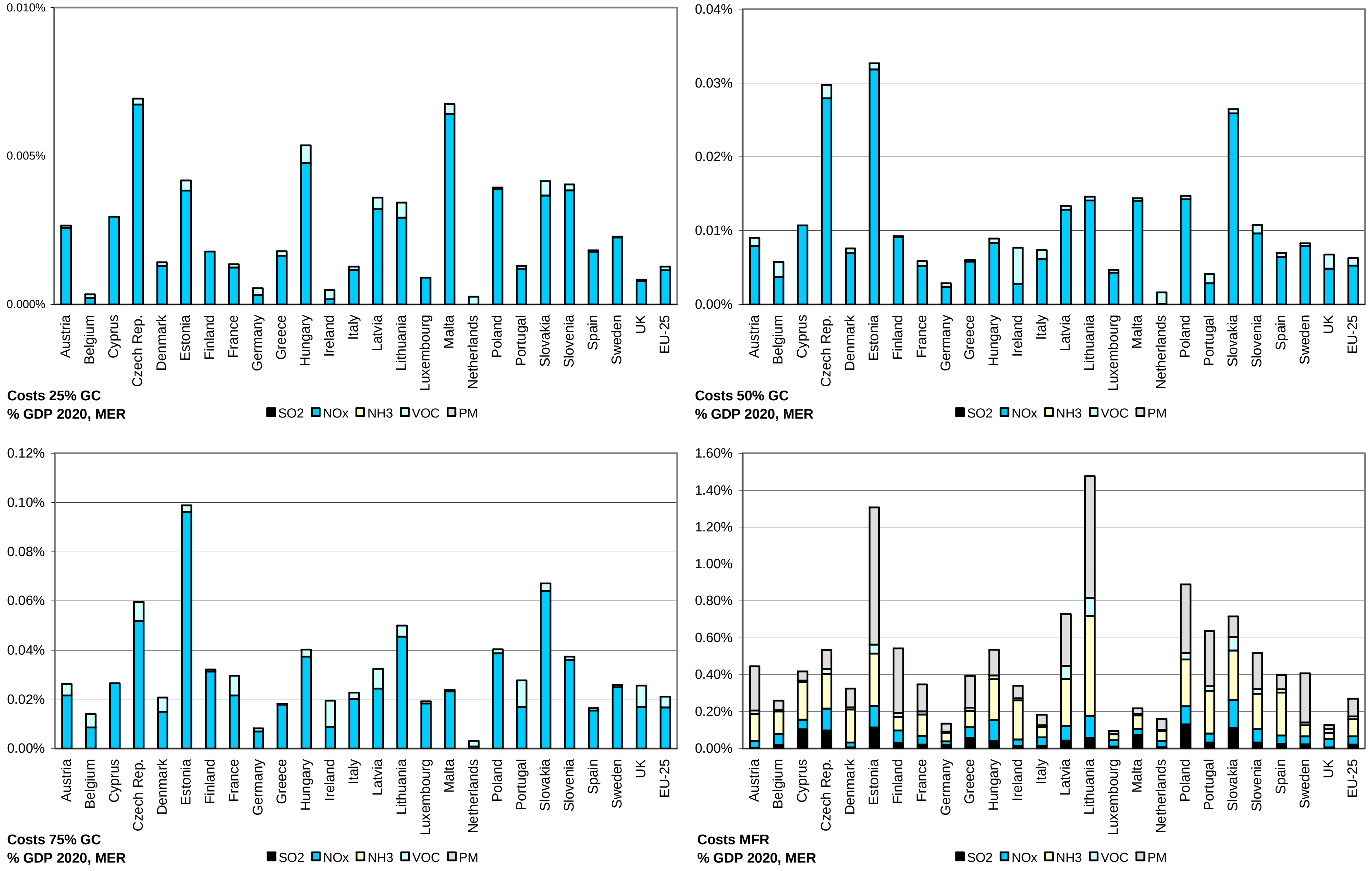


Figure 6.10: Emission control costs in 2020 expressed as percentage of GDP using Market Exchange Rates (MER) for 2020

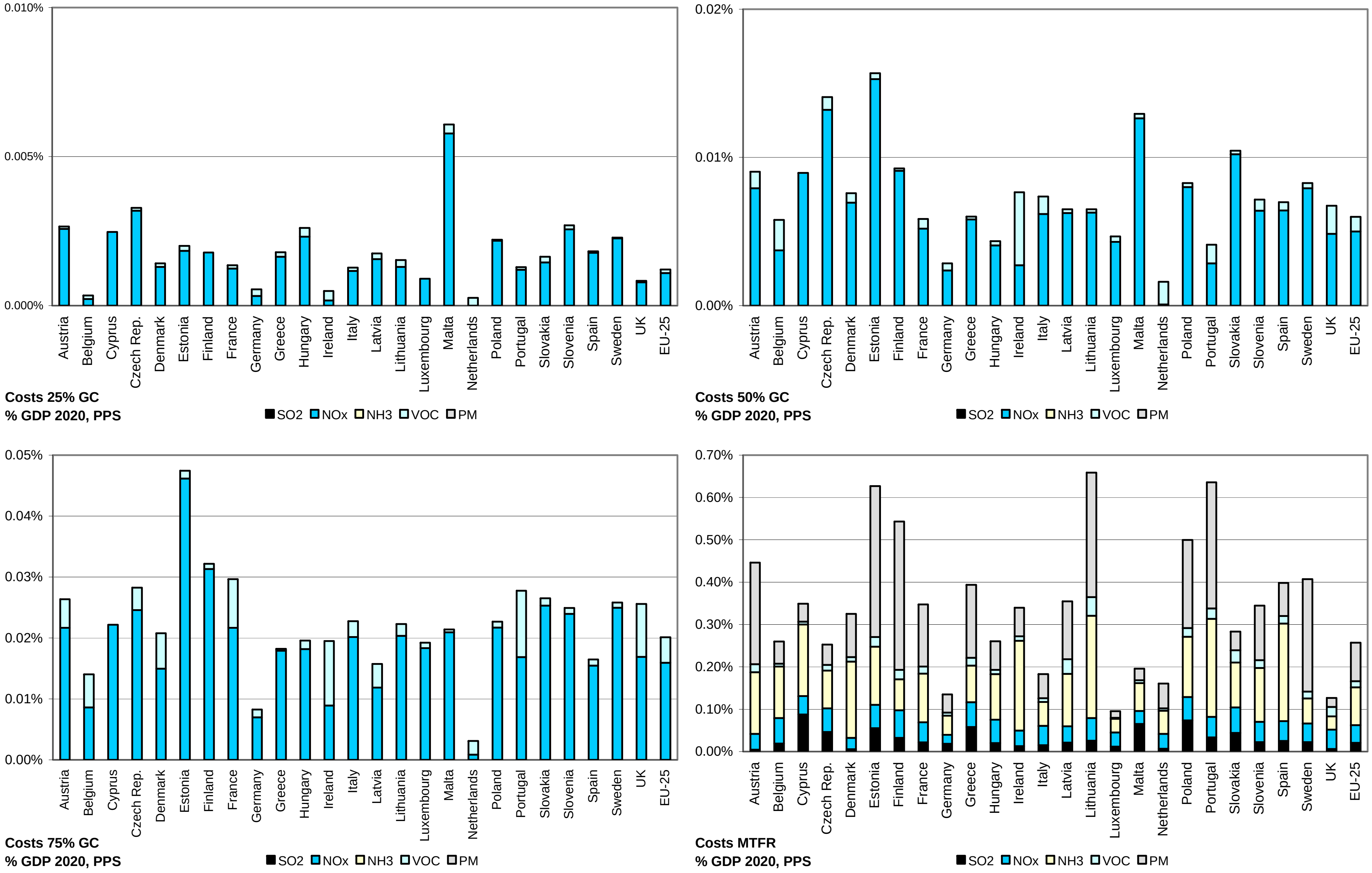


Figure 6.11: Emission control costs in 2020 expressed as percentage of GDP using Purchasing Power Standards (PPS) for 2020

6.3 Cost-optimal emission cuts for reducing acidification (A3)

For acidification RAINS applies the gap closure concept to the total deposition of acidifying compounds in excess of the critical loads for acidification, accumulated over all ecosystem types (forests, semi-natural, water) and ecosystems area in a country. While this accumulated excess deposition cannot be interpreted to be proportional to ecological damage in a strict sense, it provides a continuous scale for quantifying excess deposition. For this exploratory set of computations, RAINS uses a linear representation of the accumulated excess deposition function as described in Hettelingh *et al*., 2004. The implications of an optimized emission reduction scenario can then be displayed for each grid cell in terms of ecosystems area with acid deposition above/below critical loads.

Table 6.26: SO$_2$ emissions for the optimized scenarios targeted at the reduction of acidification (in kt)

	2000	**NEC 2010**	**Baseline 2020**	**25% gap closure A3/1**	**50% gap closure A3/2**	**75% gap closure A3/3**	**MTFR 2020 excl. Euro5/6**
Austria	38	39	26	23	23	26	22
Belgium	187	99	83	68	59	54	50
Cyprus	46	39	8	8	8	8	3
Czech Rep.	250	265	53	49	44	33	26
Denmark	28	55	13	12	11	9	9
Estonia	91	100	10	6	5	4	3
Finland	77	110	62	56	52	47	46
France	654	375	345	240	191	188	148
Germany	643	520	332	298	267	256	220
Greece	481	523	110	110	110	107	40
Hungary	487	500	88	43	53	24	19
Ireland	132	42	19	14	12	10	10
Italy	747	475	281	183	172	121	113
Latvia	16	101	8	6	3	3	2
Lithuania	43	145	22	9	9	6	5
Luxembourg	4	4	2	2	1	1	1
Malta	26	9	2	2	2	2	1
Netherlands	84	50	64	53	53	43	42
Poland	1515	1397	554	539	302	201	167
Portugal	230	160	81	81	81	73	34
Slovakia	124	110	33	22	29	21	13
Slovenia	97	27	16	15	10	7	5
Spain	1489	746	335	330	293	227	155
Sweden	58	67	50	48	46	39	39
UK	1186	585	209	196	135	129	115
EU-25	8735	6543	2805	2417	1971	1641	1290

Table 6.27: NO_x emissions for the optimized scenarios targeted at the reduction of acidification (in kt)

	2000	**NEC 2010**	**Baseline 2020**	**25% gap closure A3/1**	**50% gap closure A3/2**	**75% gap closure A3/3**	**MTFR 2020 excl. Euro5/6**
Austria	192	103	127	127	127	127	105
Belgium	333	176	190	179	166	160	133
Cyprus	26	23	18	18	18	18	12
Czech Rep.	318	286	113	108	104	98	68
Denmark	207	127	105	95	92	84	81
Estonia	37	60	15	14	11	10	9
Finland	212	170	117	105	103	88	76
France	1447	810	819	787	737	731	609
Germany	1645	1051	808	802	771	761	679
Greece	322	344	209	209	209	209	149
Hungary	188	198	83	81	81	70	50
Ireland	129	65	63	63	57	55	47
Italy	1389	990	663	663	658	613	500
Latvia	35	61	15	14	13	12	11
Lithuania	49	110	27	25	24	22	18
Luxembourg	33	11	18	18	16	16	14
Malta	9	8	4	4	4	4	2
Netherlands	399	260	240	239	239	236	204
Poland	843	879	364	353	342	291	233
Portugal	263	250	156	155	154	153	120
Slovakia	106	130	60	59	59	57	40
Slovenia	58	45	24	24	23	22	18
Spain	1335	847	681	681	667	621	501
Sweden	251	148	150	132	129	107	105
UK	1753	1167	817	802	737	717	568
EU-25	11581	8319	5888	5756	5543	5283	4354

Table 6.28: NH_3 emissions for the optimized scenarios targeted at the reduction of acidification (in kt)

	2000	**NEC 2010**	**Baseline 2020**	**25% gap closure A3/1**	**50% gap closure A3/2**	**75% gap closure A3/3**	**MTFR 2020 excl. Euro5/6**
Austria	54	66	54	46	43	51	28
Belgium	81	74	76	75	70	66	47
Cyprus	6	9	6	6	6	6	3
Czech Rep.	74	80	65	62	58	58	38
Denmark	91	69	78	75	65	50	41
Estonia	10	29	12	8	8	7	5
Finland	35	31	32	31	27	25	23
France	728	780	702	632	547	520	390
Germany	638	550	603	556	515	494	435
Greece	55	73	52	51	51	51	34
Hungary	78	90	85	72	72	64	41
Ireland	127	116	121	113	107	97	94
Italy	432	419	399	392	330	284	261
Latvia	12	44	16	13	12	10	8
Lithuania	50	84	57	56	57	53	40
Luxembourg	7	7	6	6	5	5	4
Malta	1	3	1	1	1	1	1
Netherlands	157	128	139	132	117	106	101
Poland	309	468	333	278	276	221	169
Portugal	68	90	67	67	67	67	42
Slovakia	32	39	32	28	31	30	17
Slovenia	18	20	20	20	18	18	10
Spain	394	353	369	369	369	363	199
Sweden	53	57	48	41	36	32	31
UK	315	297	310	274	260	248	204
EU-25	3824	3976	3685	3406	3150	2927	2266

Table 6.29: Emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of acidification (million €/year)

	Baseline 2020 (total costs)	**25% gap closure A3/1**	**50% gap closure A3/2**	**75% gap closure A3/3**	**MTFR 2020 excl. Euro5/6**
Austria	1392	30	51	5	1378
Belgium	1985	11	43	96	953
Cyprus	129	0	0	0	80
Czech Rep.	1287	6	20	44	619
Denmark	1152	9	40	201	842
Estonia	182	3	9	23	157
Finland	1071	11	47	139	1075
France	7732	129	446	592	7769
Germany	14054	62	322	513	4143
Greece	1923	0	0	0	984
Hungary	1002	16	12	38	573
Ireland	1017	10	67	229	696
Italy	7347	56	157	515	3353
Latvia	213	2	6	15	131
Lithuania	375	8	8	26	428
Luxembourg	300	0	2	5	40
Malta	41	0	0	0	20
Netherlands	3857	10	33	153	1009
Poland	3858	22	157	438	3816
Portugal	1597	0	0	2	1411
Slovakia	701	10	3	10	337
Slovenia	250	0	4	6	186
Spain	5666	1	17	78	4323
Sweden	1621	45	116	406	1564
UK	18032	26	151	263	3233
EU-25	76784	469	1711	3794	39123

Table 6.30: Per-capita emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of acidification (€/person/year)

	Baseline 2020	**25% gap closure A3/1**	**50% gap closure A3/2**	**75% gap closure A3/3**	**MTFR 2020 excl. Euro5/6**
Austria	180	4	7	1	178
Belgium	194	1	4	9	93
Cyprus	146	0	0	0	91
Czech Rep.	130	1	2	4	63
Denmark	215	2	7	37	157
Estonia	161	3	8	21	139
Finland	207	2	9	27	208
France	124	2	7	9	124
Germany	176	1	4	6	52
Greece	186	0	0	0	95
Hungary	111	2	1	4	63
Ireland	221	2	15	50	152
Italy	136	1	3	10	62
Latvia	99	1	3	7	61
Lithuania	108	2	2	7	123
Luxembourg	550	0	4	9	73
Malta	98	0	0	1	47
Netherlands	234	1	2	9	61
Poland	102	1	4	12	101
Portugal	161	0	0	0	142
Slovakia	130	2	0	2	63
Slovenia	132	0	2	3	99
Spain	148	0	0	2	113
Sweden	189	5	14	47	182
UK	296	0	2	4	53
EU-25	172	1	4	9	88

Table 6.31: Emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of acidification, expressed as percentage of GDP in 2020 (% of GDP) using Market Exchange Rates (MER)

	Baseline 2020	**25% gap closure A3/1**	**50% gap closure A3/2**	**75% gap closure A3/3**	**MTFR 2020 excl. Euro5/6**
Austria	0.45%	0.01%	0.02%	0.00%	0.45%
Belgium	0.54%	0.00%	0.01%	0.03%	0.26%
Cyprus	0.67%	0.00%	0.00%	0.00%	0.42%
Czech Rep.	1.11%	0.01%	0.02%	0.04%	0.53%
Denmark	0.44%	0.00%	0.02%	0.08%	0.33%
Estonia	1.51%	0.03%	0.08%	0.19%	1.31%
Finland	0.54%	0.01%	0.02%	0.07%	0.54%
France	0.35%	0.01%	0.02%	0.03%	0.35%
Germany	0.46%	0.00%	0.01%	0.02%	0.14%
Greece	0.77%	0.00%	0.00%	0.00%	0.39%
Hungary	0.94%	0.02%	0.01%	0.04%	0.54%
Ireland	0.50%	0.00%	0.03%	0.11%	0.34%
Italy	0.40%	0.00%	0.01%	0.03%	0.18%
Latvia	1.19%	0.01%	0.03%	0.08%	0.73%
Lithuania	1.29%	0.03%	0.03%	0.09%	1.48%
Luxembourg	0.71%	0.00%	0.01%	0.01%	0.10%
Malta	0.45%	0.00%	0.00%	0.00%	0.22%
Netherlands	0.61%	0.00%	0.01%	0.02%	0.16%
Poland	0.90%	0.01%	0.04%	0.10%	0.89%
Portugal	0.72%	0.00%	0.00%	0.00%	0.64%
Slovakia	1.49%	0.02%	0.01%	0.02%	0.72%
Slovenia	0.69%	0.00%	0.01%	0.02%	0.52%
Spain	0.52%	0.00%	0.00%	0.01%	0.40%
Sweden	0.42%	0.01%	0.03%	0.11%	0.41%
UK	0.71%	0.00%	0.01%	0.01%	0.13%
EU-25	0.53%	0.00%	0.01%	0.03%	0.27%

Table 6.32: Emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of acidification, expressed as percentage of GDP in 2020 (% of GDP) using Purchasing Power Standards (PPS)

	Baseline 2020	**25% gap closure A3/1**	**50% gap closure A3/2**	**75% gap closure A3/3**	**MTFR 2020 excl. Euro5/6**
Austria	0.45%	0.01%	0.02%	0.00%	0.45%
Belgium	0.54%	0.00%	0.01%	0.03%	0.26%
Cyprus	0.56%	0.00%	0.00%	0.00%	0.35%
Czech Rep.	0.53%	0.00%	0.01%	0.02%	0.25%
Denmark	0.44%	0.00%	0.02%	0.08%	0.33%
Estonia	0.73%	0.01%	0.04%	0.09%	0.63%
Finland	0.54%	0.01%	0.02%	0.07%	0.54%
France	0.35%	0.01%	0.02%	0.03%	0.35%
Germany	0.46%	0.00%	0.01%	0.02%	0.14%
Greece	0.77%	0.00%	0.00%	0.00%	0.39%
Hungary	0.46%	0.01%	0.01%	0.02%	0.26%
Ireland	0.50%	0.00%	0.03%	0.11%	0.34%
Italy	0.40%	0.00%	0.01%	0.03%	0.18%
Latvia	0.58%	0.01%	0.02%	0.04%	0.35%
Lithuania	0.58%	0.01%	0.01%	0.04%	0.66%
Luxembourg	0.71%	0.00%	0.01%	0.01%	0.10%
Malta	0.41%	0.00%	0.00%	0.00%	0.20%
Netherlands	0.61%	0.00%	0.01%	0.02%	0.16%
Poland	0.51%	0.00%	0.02%	0.06%	0.50%
Portugal	0.72%	0.00%	0.00%	0.00%	0.64%
Slovakia	0.59%	0.01%	0.00%	0.01%	0.28%
Slovenia	0.46%	0.00%	0.01%	0.01%	0.35%
Spain	0.52%	0.00%	0.00%	0.01%	0.40%
Sweden	0.42%	0.01%	0.03%	0.11%	0.41%
UK	0.71%	0.00%	0.01%	0.01%	0.13%
EU-25	0.51%	0.00%	0.01%	0.02%	0.26%

Table 6.33: Emission control costs in 2020 of the 25 percent gap closure scenario A3/1 (million €/year), on top of the costs of the baseline scenario

	SO_2	NO_x	NH_3	VOC	PM2.5	Total
Austria	5.5	0.0	24.4	0.0	0.0	29.9
Belgium	7.1	3.4	0.7	0.0	0.0	11.2
Cyprus	0.0	0.0	0.0	0.0	0.0	0.0
Czech Rep.	2.1	1.3	3.1	0.0	0.0	6.4
Denmark	0.8	4.7	3.3	0.0	0.0	8.8
Estonia	1.5	0.3	1.7	0.0	0.0	3.5
Finland	4.9	4.2	2.0	0.0	0.0	11.1
France	61.8	10.3	56.5	0.0	0.0	128.6
Germany	19.1	2.3	40.3	0.0	0.0	61.7
Greece	0.0	0.0	0.0	0.0	0.0	0.0
Hungary	13.0	0.7	2.4	0.0	0.0	16.1
Ireland	2.5	0.1	7.3	0.0	0.0	9.8
Italy	54.9	0.0	1.6	0.0	0.0	56.4
Latvia	0.3	0.3	1.5	0.0	0.0	2.2
Lithuania	6.3	0.6	1.1	0.0	0.0	8.0
Luxembourg	0.1	0.0	0.0	0.0	0.0	0.1
Malta	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	6.4	0.2	3.8	0.0	0.0	10.4
Poland	5.8	2.7	13.9	0.0	0.0	22.5
Portugal	0.0	0.0	0.0	0.0	0.0	0.0
Slovakia	6.2	0.3	3.5	0.0	0.0	9.9
Slovenia	0.1	0.0	0.0	0.0	0.0	0.1
Spain	1.0	0.0	0.0	0.0	0.0	1.0
Sweden	3.5	12.8	29.0	0.0	0.0	45.3
UK	3.9	4.3	17.8	0.0	0.0	26.0
EU-25	206.7	48.6	213.8	0.0	0.0	469.1

Table 6.34: Emission control costs in 2020 of the 50 percent gap closure scenario A3/2 (million €/year), on top of the costs of the baseline scenario

	SO_2	**NO_x**	**NH_3**	**VOC**	**PM2.5**	**Total**
Austria	5.5	0.5	44.7	0.0	0.0	50.8
Belgium	21.1	10.7	10.7	0.0	0.0	42.6
Cyprus	0.0	0.0	0.0	0.0	0.0	0.0
Czech Rep.	6.4	3.3	10.4	0.0	0.0	20.0
Denmark	3.7	7.5	29.0	0.0	0.0	40.2
Estonia	2.6	3.2	3.7	0.0	0.0	9.5
Finland	15.8	5.1	25.8	0.0	0.0	46.8
France	141.6	44.3	260.5	0.0	0.0	446.4
Germany	75.3	26.4	219.9	0.0	0.0	321.7
Greece	0.0	0.0	0.0	0.0	0.0	0.0
Hungary	8.6	0.7	2.4	0.0	0.0	11.7
Ireland	8.3	3.8	55.2	0.0	0.0	67.3
Italy	63.9	1.1	92.4	0.0	0.0	157.4
Latvia	2.5	1.1	2.3	0.0	0.0	5.8
Lithuania	6.3	1.2	0.2	0.0	0.0	7.6
Luxembourg	1.0	0.8	0.5	0.0	0.0	2.3
Malta	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	6.4	0.5	25.7	0.0	0.0	32.6
Poland	133.8	7.3	15.9	0.0	0.0	157.0
Portugal	0.0	0.1	0.0	0.0	0.0	0.1
Slovakia	1.6	0.3	0.6	0.0	0.0	2.5
Slovenia	2.5	0.3	0.9	0.0	0.0	3.7
Spain	12.9	4.3	0.0	0.0	0.0	17.1
Sweden	16.6	17.6	82.1	0.0	0.0	116.3
UK	56.1	39.5	55.8	0.0	0.0	151.3
EU-25	592.7	179.6	938.5	0.0	0.0	1710.8

Table 6.35: Emission control costs in 2020 of the 75 percent gap closure scenario A3/3 (million €/year), on top of the costs of the baseline scenario

	SO_2	**NO_x**	**NH_3**	**VOC**	**PM2.5**	**Total**
Austria	0.3	0.2	4.2	0.0	0.0	4.7
Belgium	43.5	21.1	31.4	0.0	0.0	96.0
Cyprus	0.0	0.0	0.0	0.0	0.0	0.0
Czech Rep.	23.3	10.1	10.4	0.0	0.0	43.7
Denmark	14.2	38.7	147.6	0.0	0.0	200.5
Estonia	9.4	4.7	9.2	0.0	0.0	23.3
Finland	39.8	52.2	47.1	0.0	0.0	139.1
France	147.8	55.0	389.3	0.0	0.0	592.2
Germany	135.2	44.9	332.7	0.0	0.0	512.8
Greece	0.2	0.0	0.1	0.0	0.0	0.3
Hungary	24.8	5.1	8.4	0.0	0.0	38.3
Ireland	18.0	10.2	200.4	0.0	0.0	228.6
Italy	181.1	33.9	300.2	0.0	0.0	515.1
Latvia	3.8	2.7	8.1	0.0	0.0	14.5
Lithuania	10.1	4.8	10.6	0.0	0.0	25.5
Luxembourg	1.1	1.8	1.7	0.0	0.0	4.6
Malta	0.0	0.0	0.2	0.0	0.0	0.2
Netherlands	35.0	5.2	113.1	0.0	0.0	153.3
Poland	263.1	70.7	104.1	0.0	0.0	437.9
Portugal	1.4	0.5	0.0	0.0	0.0	1.9
Slovakia	6.7	1.7	1.2	0.0	0.0	9.7
Slovenia	4.0	0.9	0.9	0.0	0.0	5.8
Spain	49.3	24.8	3.5	0.0	0.0	77.6
Sweden	84.6	133.3	187.8	0.0	0.0	405.7
UK	73.6	76.1	113.2	0.0	0.0	262.9
EU-25	1170.3	598.7	2025.3	0.0	0.0	3794.3

Table 6.36: Average acid deposition in excess over the critical loads for acidification accumulated over all ecosystems for the acidification scenarios (eq/hectare/year) – provisional results

	Baseline 2020	**25% gap closure A3/1**	**50% gap closure A3/2**	**75% gap closure A3/3**	**MTFR 2020 excl. Euro5/6**
Austria	10	4	0	0	0
Belgium	56	17	0	0	0
Cyprus	0	0	0	0	0
Czech Rep.	24	0	0	0	0
Denmark	0	0	0	0	0
Estonia	0	0	0	0	0
Finland	1	1	1	0	0
France	17	10	3	0	0
Germany	175	106	37	0	0
Greece	0	0	0	0	0
Hungary	0	0	0	0	0
Ireland	39	28	17	7	0
Italy	6	5	4	3	2
Latvia	0	0	0	0	0
Lithuania	0	0	0	0	0
Luxembourg	0	0	0	0	0
Malta	0	0	0	0	0
Netherlands	946	776	588	434	263
Poland	14	0	0	0	0
Portugal	0	0	0	0	0
Slovakia	16	5	0	0	0
Slovenia	0	0	0	0	0
Spain	0	0	0	0	0
Sweden	20	17	13	10	7
UK	31	18	6	0	0

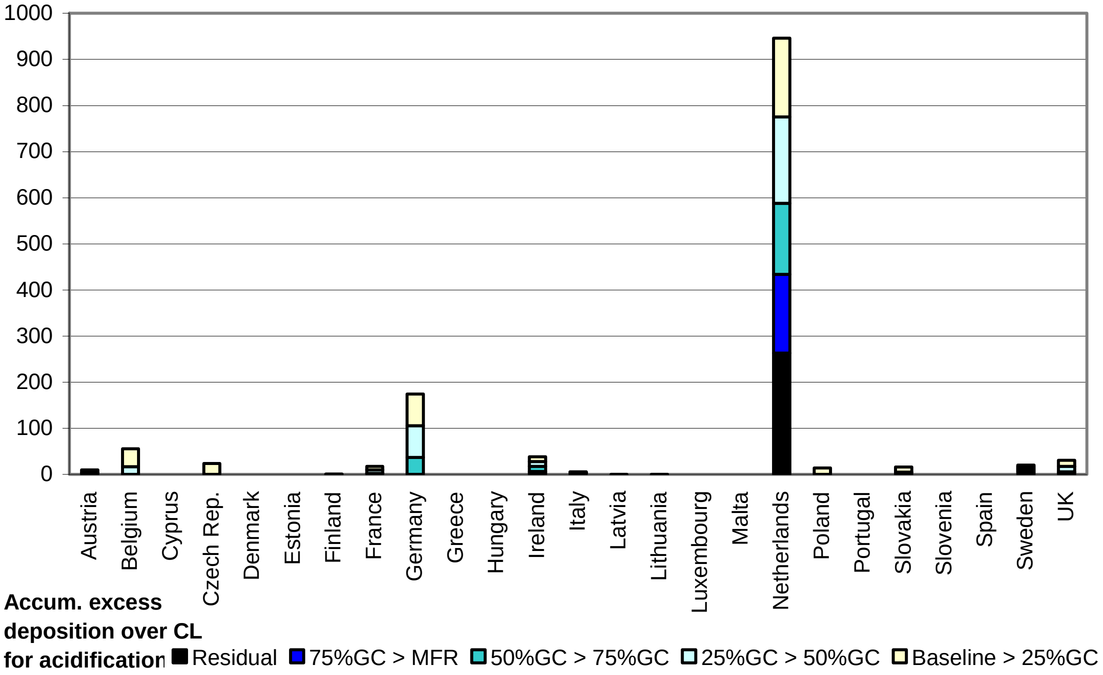
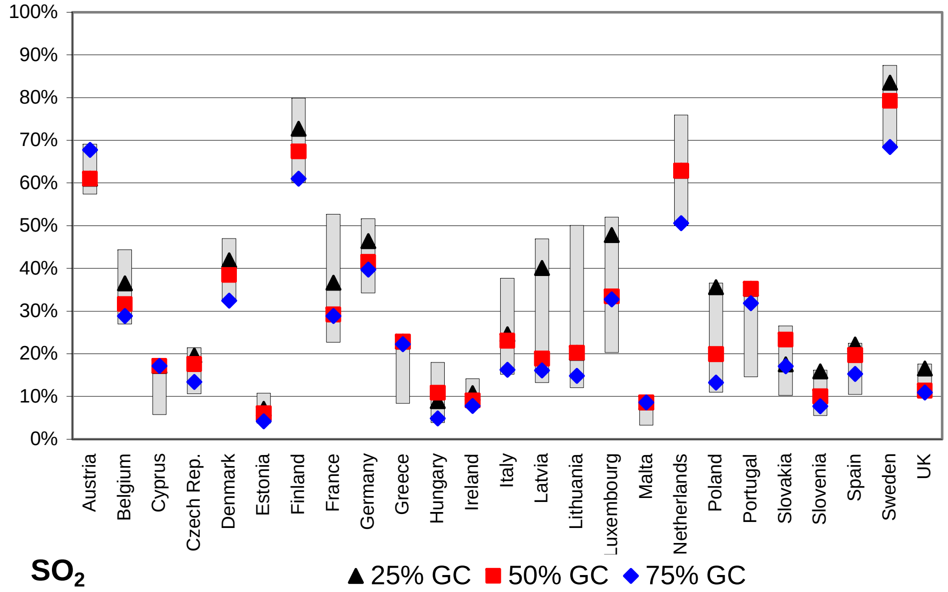


Figure 6.12: Average acid deposition in excess over the critical loads for acidification accumulated over all ecosystems for the acidification A3 scenarios (eq/ha/year) (provisional results)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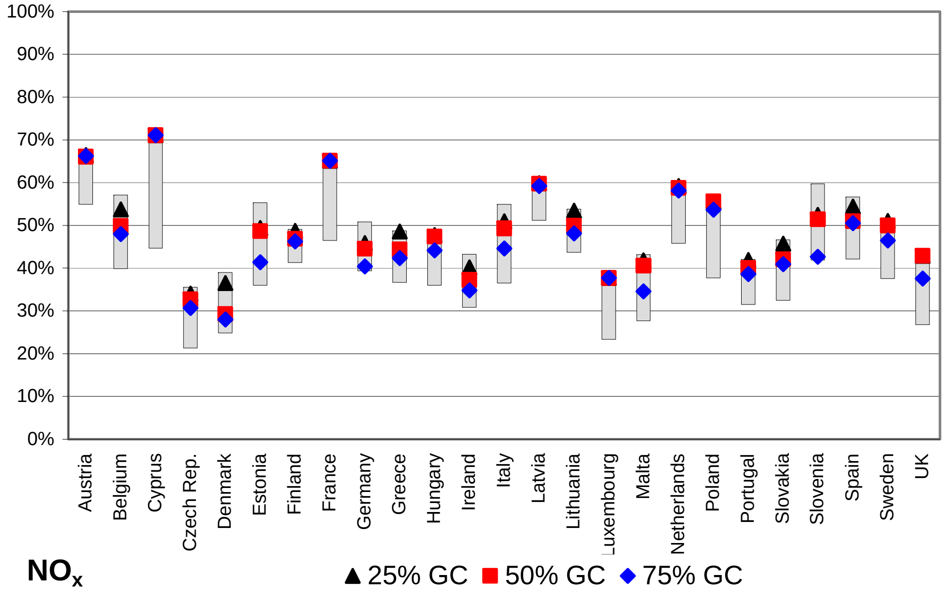
SO_2
▲ 25% GC ■ 50% GC ◆ 75% GC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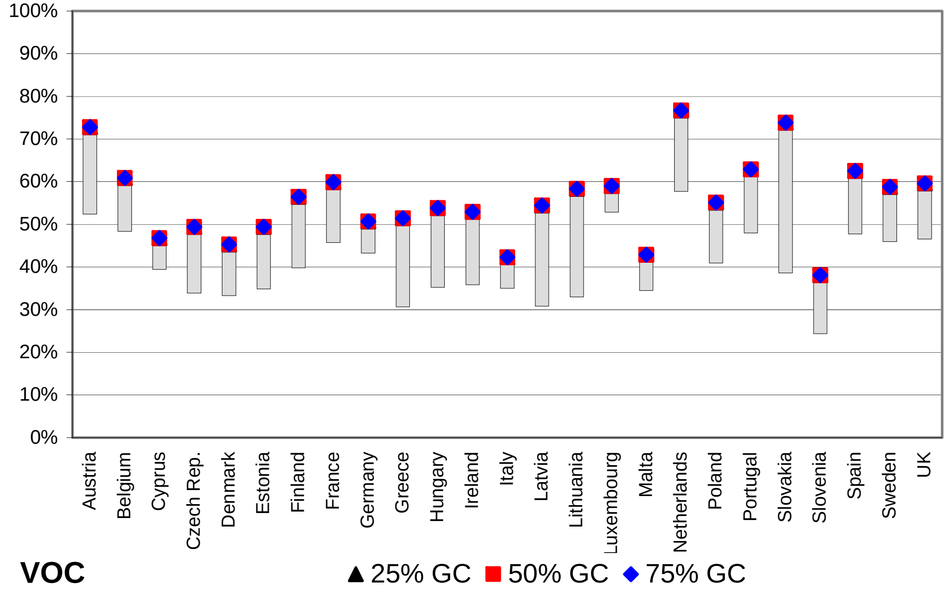
▲ 25% GC ■ 50% GC ◆ 75% GC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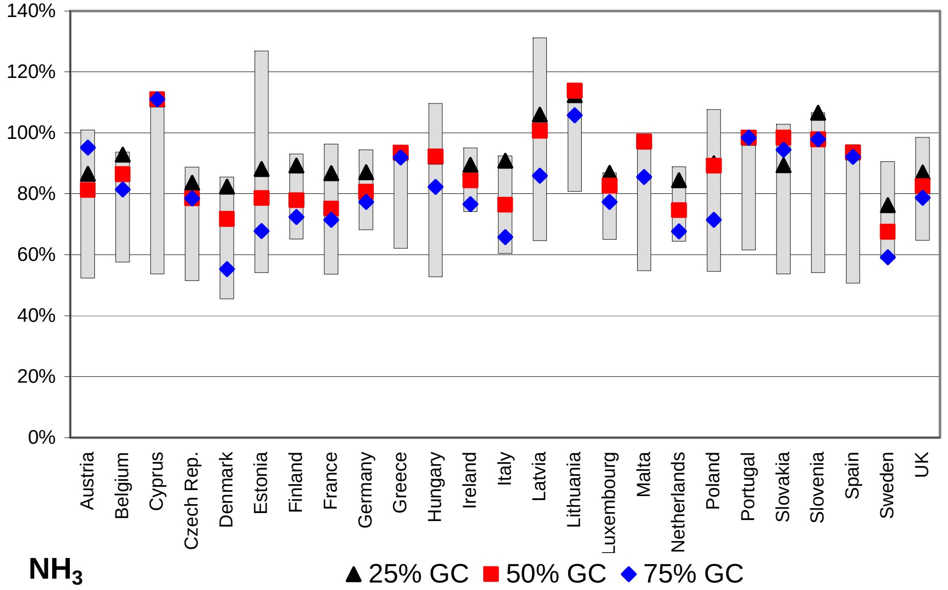
▲ 25% GC ■ 50% GC ◆ 75% GC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▲ 25% GC ■ 50% GC ◆ 75% GC

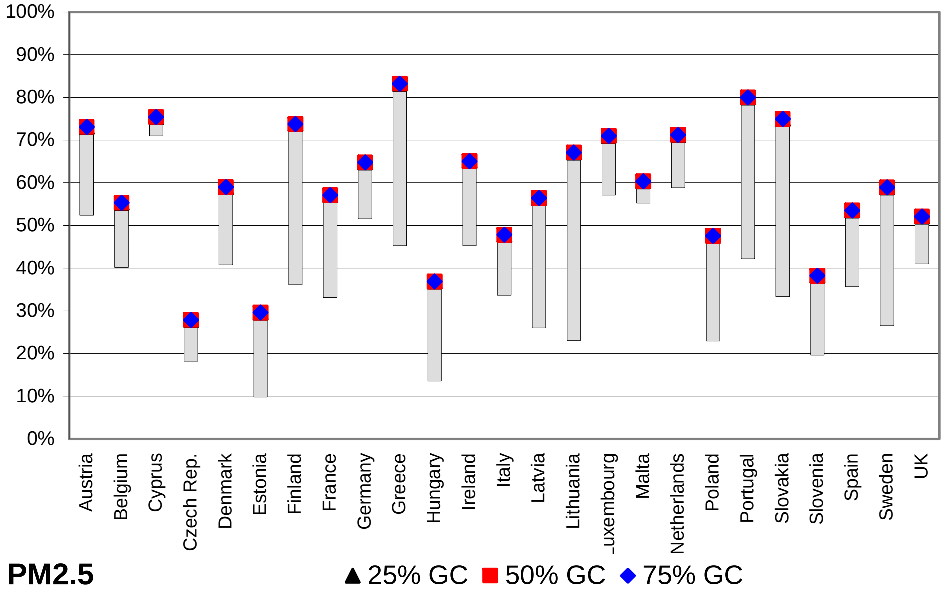
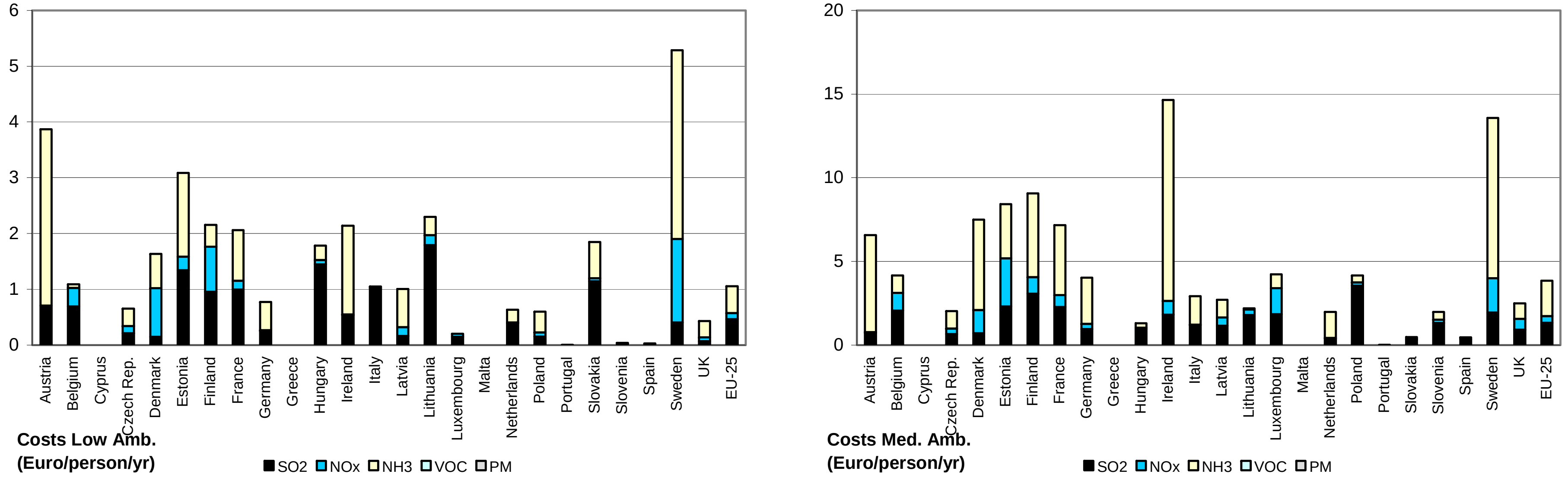
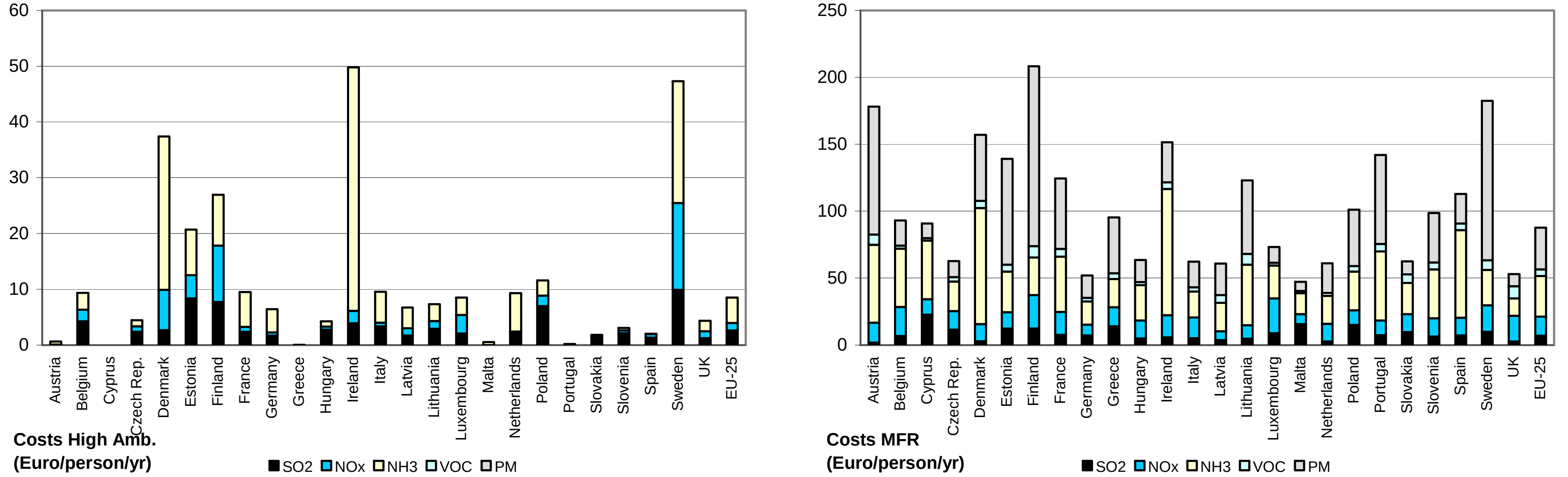


Figure 6.13: Cost-minimal emission cuts for reducing acidification. The 100 percent line refers to the emission level in the year 2000. The grey range indicates the scope for emission reductions considered in the RAINS optimization between the baseline projection for 2020 (top end) and the maximum technically feasible reductions (bottom end)..



Costs Low Amb. (Euro/person/yr)

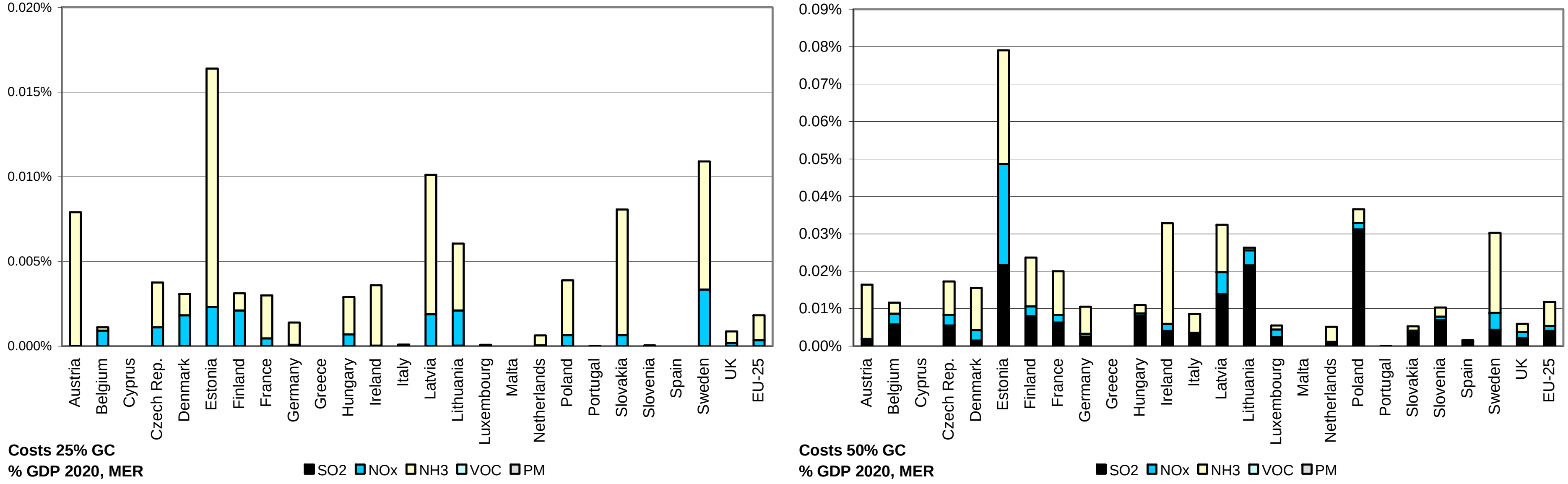
Costs Med. Amb. (Euro/person/yr)



Costs High Amb. (Euro/person/yr)

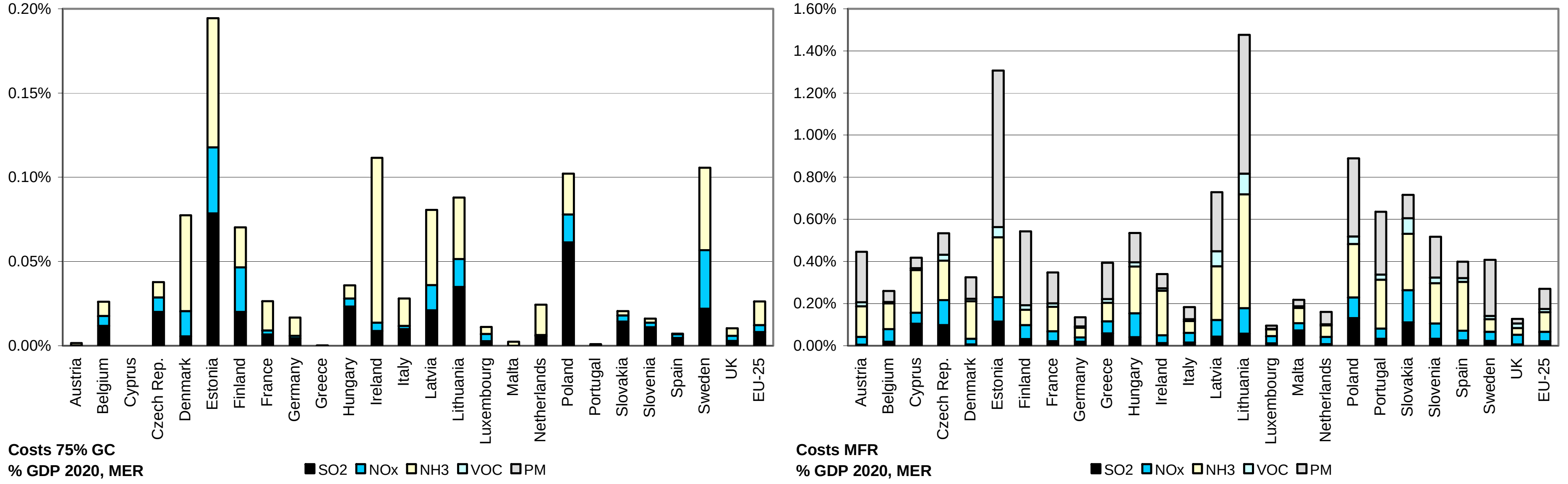
Costs MFR (Euro/person/yr)

Figure 6.14: Per-capita emission control costs of the optimized scenarios for reducing acidification (€/person/year)



Costs 25% GC
% GDP 2020, MER

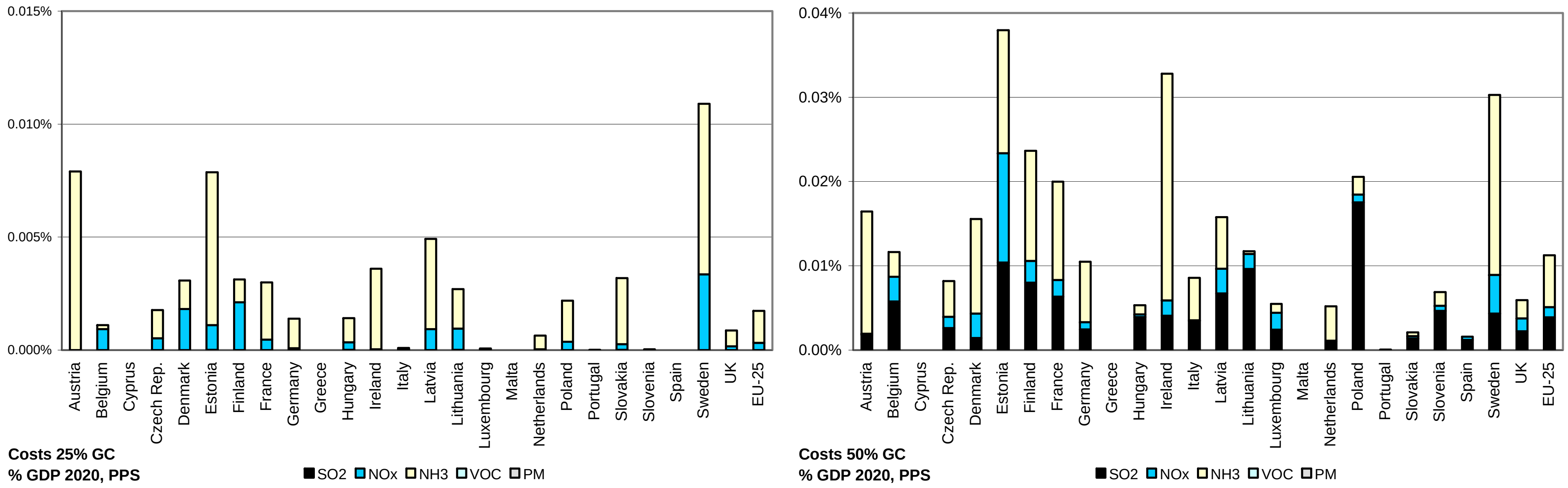
Costs 50% GC
% GDP 2020, MER



Costs 75% GC
% GDP 2020, MER

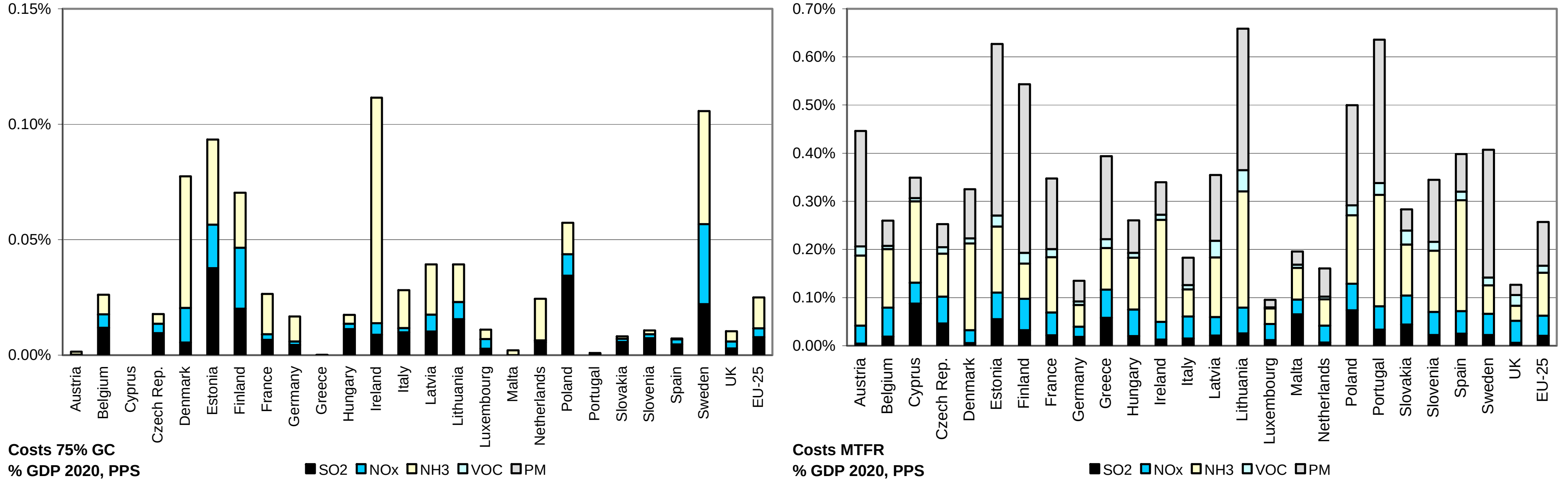
Costs MFR
% GDP 2020, MER

Figure 6.15: Emission control costs in 2020 expressed as percentage of GDP using Market Exchange Rates (MER) for 2020



Costs 25% GC
% GDP 2020, PPS

Costs 50% GC
% GDP 2020, PPS



Costs 75% GC
% GDP 2020, PPS

Costs MTFR
% GDP 2020, PPS

Figure 6.16: Emission control costs in 2020 expressed as percentage of GDP using Purchasing Power Standards (PPS) for 2020

6.4 Cost-optimal emission cuts for reducing eutrophication (A4)

For eutrophication, RAINS applies the same “accumulated excess deposition” concept as for acidification. The gap closure is requested on a country basis, i.e., there is flexibility to compensate improvements at “hard to attain” targets at individual receptor sites by additional gains in other areas within the same country.

Table 6.37: NO_x emissions for the optimized scenarios targeted at the reduction of eutrophication (in kt)

	2000	**NEC 2010**	**Baseline 2020**	**25% gap closure A4/1**	**50% gap closure A4/2**	**75% gap closure A4/3**	**MTFR 2020 excl. Euro5/6**
Austria	192	103	127	127	124	116	105
Belgium	333	176	190	168	163	153	133
Cyprus	26	23	18	16	15	12	12
Czech Rep.	318	286	113	104	99	80	68
Denmark	207	127	105	95	92	84	81
Estonia	37	60	15	14	11	11	9
Finland	212	170	117	104	102	88	76
France	1447	810	819	755	735	718	609
Germany	1645	1051	808	790	768	736	679
Greece	322	344	209	204	184	163	149
Hungary	188	198	83	80	70	66	50
Ireland	129	65	63	62	56	55	47
Italy	1389	990	663	658	630	601	500
Latvia	35	61	15	14	13	12	11
Lithuania	49	110	27	25	23	22	18
Luxembourg	33	11	18	17	16	16	14
Malta	9	8	4	4	4	4	2
Netherlands	399	260	240	239	239	236	204
Poland	843	879	364	350	336	283	233
Portugal	263	250	156	141	141	133	120
Slovakia	106	130	60	59	57	47	40
Slovenia	58	45	24	23	22	21	18
Spain	1335	847	681	649	575	539	501
Sweden	251	148	150	142	129	119	105
UK	1753	1167	817	802	732	675	568
EU-25	11581	8319	5888	5641	5336	4991	4354

Table 6.38: NH_3 emissions for the optimized scenarios targeted at the reduction of eutrophication (in kt)

	2000	**NEC 2010**	**Baseline 2020**	**25% gap closure A4/1**	**50% gap closure A4/2**	**75% gap closure A4/3**	**MTFR 2020 excl. Euro5/6**
Austria	54	66	54	47	39	33	28
Belgium	81	74	76	69	62	53	47
Cyprus	6	9	6	6	5	4	3
Czech Rep.	74	80	65	58	49	43	38
Denmark	91	69	78	68	59	49	41
Estonia	10	29	12	8	8	7	5
Finland	35	31	32	30	26	24	23
France	728	780	702	623	539	453	390
Germany	638	550	603	556	514	468	435
Greece	55	73	52	45	41	37	34
Hungary	78	90	85	72	55	55	41
Ireland	127	116	121	113	106	99	94
Italy	432	419	399	358	321	283	261
Latvia	12	44	16	13	11	9	8
Lithuania	50	84	57	53	48	44	40
Luxembourg	7	7	6	5	5	4	4
Malta	1	3	1	1	1	1	1
Netherlands	157	128	139	128	113	110	101
Poland	309	468	333	278	244	205	169
Portugal	68	90	67	62	64	53	42
Slovakia	32	39	32	28	24	19	17
Slovenia	18	20	20	15	14	12	10
Spain	394	353	369	324	284	240	199
Sweden	53	57	48	44	38	34	31
UK	315	297	310	278	251	223	204
EU-25	3824	3976	3685	3284	2921	2561	2266

Table 6.39: Emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of eutrophication (million €/year)

	Baseline 2020 (total costs)	**25% gap closure A4/1**	**50% gap closure A4/2**	**75% gap closure A4/3**	**MTFR 2020 excl. Euro5/6**
Austria	1392	21	80	200	1378
Belgium	1985	24	91	294	953
Cyprus	129	2	6	16	80
Czech Rep.	1287	13	46	130	619
Denmark	1152	25	72	204	842
Estonia	182	2	7	12	157
Finland	1071	9	38	123	1075
France	7732	99	349	869	7769
Germany	14054	47	257	747	4143
Greece	1923	8	29	104	984
Hungary	1002	3	24	32	573
Ireland	1017	9	67	150	696
Italy	7347	52	132	359	3353
Latvia	213	2	6	17	131
Lithuania	375	9	42	76	428
Luxembourg	300	1	6	8	40
Malta	41	0	0	0	20
Netherlands	3857	9	39	73	1009
Poland	3858	18	62	318	3816
Portugal	1597	16	11	64	1411
Slovakia	701	4	18	81	337
Slovenia	250	5	9	29	186
Spain	5666	58	269	743	4323
Sweden	1621	21	72	196	1564
UK	18032	19	141	459	3233
EU-25	76784	475	1871	5305	39123

Table 6.40: Per-capita emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of eutrophication (€/person/year)

	Baseline 2020	**25% gap closure A4/1**	**50% gap closure A4/2**	**75% gap closure A4/3**	**MTFR 2020 excl. Euro5/6**
Austria	180	3	10	26	178
Belgium	194	2	9	29	93
Cyprus	146	2	7	18	91
Czech Rep.	130	1	5	13	63
Denmark	215	5	14	38	157
Estonia	161	2	6	11	139
Finland	207	2	7	24	208
France	124	2	6	14	124
Germany	176	1	3	9	52
Greece	186	1	3	10	95
Hungary	111	0	3	4	63
Ireland	221	2	14	33	152
Italy	136	1	2	7	62
Latvia	99	1	3	8	61
Lithuania	108	3	12	22	123
Luxembourg	550	1	12	14	73
Malta	98	0	0	0	47
Netherlands	234	1	2	4	61
Poland	102	0	2	8	101
Portugal	161	2	1	6	142
Slovakia	130	1	3	15	63
Slovenia	132	3	5	15	99
Spain	148	2	7	19	113
Sweden	189	2	8	23	182
UK	296	0	2	8	53
EU-25	172	1	4	12	88

Table 6.41: Emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of eutrophication, expressed as percentage of GDP in 2020 (% of GDP) using Market Exchange Rates (MER)

	Baseline 2020	**25% gap closure A4/1**	**50% gap closure A4/2**	**75% gap closure A4/3**	**MTFR 2020 excl. Euro5/6**
Austria	0.45%	0.01%	0.03%	0.06%	0.45%
Belgium	0.54%	0.01%	0.02%	0.08%	0.26%
Cyprus	0.67%	0.01%	0.03%	0.08%	0.42%
Czech Rep.	1.11%	0.01%	0.04%	0.11%	0.53%
Denmark	0.44%	0.01%	0.03%	0.08%	0.33%
Estonia	1.51%	0.02%	0.06%	0.10%	1.31%
Finland	0.54%	0.00%	0.02%	0.06%	0.54%
France	0.35%	0.00%	0.02%	0.04%	0.35%
Germany	0.46%	0.00%	0.01%	0.02%	0.14%
Greece	0.77%	0.00%	0.01%	0.04%	0.39%
Hungary	0.94%	0.00%	0.02%	0.03%	0.54%
Ireland	0.50%	0.00%	0.03%	0.07%	0.34%
Italy	0.40%	0.00%	0.01%	0.02%	0.18%
Latvia	1.19%	0.01%	0.03%	0.09%	0.73%
Lithuania	1.29%	0.03%	0.14%	0.26%	1.48%
Luxembourg	0.71%	0.00%	0.02%	0.02%	0.10%
Malta	0.45%	0.00%	0.00%	0.00%	0.22%
Netherlands	0.61%	0.00%	0.01%	0.01%	0.16%
Poland	0.90%	0.00%	0.01%	0.07%	0.89%
Portugal	0.72%	0.01%	0.00%	0.03%	0.64%
Slovakia	1.49%	0.01%	0.04%	0.17%	0.72%
Slovenia	0.69%	0.01%	0.03%	0.08%	0.52%
Spain	0.52%	0.01%	0.02%	0.07%	0.40%
Sweden	0.42%	0.01%	0.02%	0.05%	0.41%
UK	0.71%	0.00%	0.01%	0.02%	0.13%
EU-25	0.53%	0.00%	0.01%	0.04%	0.27%

Table 6.42: Emission control costs for the baseline and the additional costs of the optimized scenarios targeted at the reduction of eutrophication, expressed as percentage of GDP in 2020 (% of GDP) using Purchasing Power Standards (PPS)

	Baseline 2020	**25% gap closure A4/1**	**50% gap closure A4/2**	**75% gap closure A4/3**	**MTFR 2020 excl. Euro5/6**
Austria	0.45%	0.01%	0.03%	0.06%	0.45%
Belgium	0.54%	0.01%	0.02%	0.08%	0.26%
Cyprus	0.56%	0.01%	0.03%	0.07%	0.35%
Czech Rep.	0.53%	0.01%	0.02%	0.05%	0.25%
Denmark	0.44%	0.01%	0.03%	0.08%	0.33%
Estonia	0.73%	0.01%	0.03%	0.05%	0.63%
Finland	0.54%	0.00%	0.02%	0.06%	0.54%
France	0.35%	0.00%	0.02%	0.04%	0.35%
Germany	0.46%	0.00%	0.01%	0.02%	0.14%
Greece	0.77%	0.00%	0.01%	0.04%	0.39%
Hungary	0.46%	0.00%	0.01%	0.01%	0.26%
Ireland	0.50%	0.00%	0.03%	0.07%	0.34%
Italy	0.40%	0.00%	0.01%	0.02%	0.18%
Latvia	0.58%	0.00%	0.02%	0.05%	0.35%
Lithuania	0.58%	0.01%	0.06%	0.12%	0.66%
Luxembourg	0.71%	0.00%	0.02%	0.02%	0.10%
Malta	0.41%	0.00%	0.00%	0.00%	0.20%
Netherlands	0.61%	0.00%	0.01%	0.01%	0.16%
Poland	0.51%	0.00%	0.01%	0.04%	0.50%
Portugal	0.72%	0.01%	0.00%	0.03%	0.64%
Slovakia	0.59%	0.00%	0.02%	0.07%	0.28%
Slovenia	0.46%	0.01%	0.02%	0.05%	0.35%
Spain	0.52%	0.01%	0.02%	0.07%	0.40%
Sweden	0.42%	0.01%	0.02%	0.05%	0.41%
UK	0.71%	0.00%	0.01%	0.02%	0.13%
EU-25	0.51%	0.00%	0.01%	0.03%	0.26%

Table 6.43: Emission control costs in 2020 of the 25 percent gap closure scenario A4/1 (million €/year), on top of the costs of the baseline scenario

	SO_2	**NO_x**	**NH_3**	**VOC**	**PM2.5**	**Total**
Austria	0.0	0.2	21.1	0.0	0.0	21.2
Belgium	0.0	9.3	14.2	0.0	0.0	23.5
Cyprus	0.0	0.8	0.8	0.0	0.0	1.6
Czech Rep.	0.0	2.9	9.7	0.0	0.0	12.6
Denmark	0.0	4.6	20.5	0.0	0.0	25.0
Estonia	0.0	0.3	1.7	0.0	0.0	2.0
Finland	0.0	4.6	4.8	0.0	0.0	9.4
France	0.0	26.4	72.6	0.0	0.0	99.1
Germany	0.0	7.1	40.3	0.0	0.0	47.4
Greece	0.0	1.3	6.6	0.0	0.0	7.8
Hungary	0.0	1.0	2.4	0.0	0.0	3.4
Ireland	0.0	0.5	8.3	0.0	0.0	8.9
Italy	0.0	1.1	50.5	0.0	0.0	51.6
Latvia	0.0	0.3	1.5	0.0	0.0	1.8
Lithuania	0.0	0.6	8.8	0.0	0.0	9.4
Luxembourg	0.0	0.3	0.5	0.0	0.0	0.8
Malta	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	0.0	0.2	8.7	0.0	0.0	8.9
Poland	0.0	3.6	13.9	0.0	0.0	17.5
Portugal	0.0	5.6	10.2	0.0	0.0	15.8
Slovakia	0.0	0.3	3.9	0.0	0.0	4.2
Slovenia	0.0	0.3	4.8	0.0	0.0	5.1
Spain	0.0	11.9	46.2	0.0	0.0	58.1
Sweden	0.0	5.1	15.7	0.0	0.0	20.8
UK	0.0	4.3	15.1	0.0	0.0	19.4
EU-25	0.0	92.7	382.4	0.0	0.0	475.1

Table 6.44: Emission control costs in 2020 of the 50 percent gap closure scenario A4/2 (million €/year), on top of the costs of the baseline scenario

	SO_2	**NO_x**	**NH_3**	**VOC**	**PM2.5**	**Total**
Austria	0.0	3.3	76.5	0.0	0.0	79.8
Belgium	0.0	13.7	77.8	0.0	0.0	91.5
Cyprus	0.0	2.1	3.6	0.0	0.0	5.8
Czech Rep.	0.0	7.8	38.3	0.0	0.0	46.1
Denmark	0.0	7.5	65.0	0.0	0.0	72.5
Estonia	0.0	3.2	3.7	0.0	0.0	6.9
Finland	0.0	7.2	31.2	0.0	0.0	38.4
France	0.0	48.4	300.2	0.0	0.0	348.6
Germany	0.0	30.6	226.1	0.0	0.0	256.7
Greece	0.0	10.7	18.0	0.0	0.0	28.6
Hungary	0.0	5.1	18.5	0.0	0.0	23.6
Ireland	0.0	5.2	61.3	0.0	0.0	66.5
Italy	0.0	14.3	117.5	0.0	0.0	131.8
Latvia	0.0	1.3	4.8	0.0	0.0	6.1
Lithuania	0.0	2.5	39.3	0.0	0.0	41.9
Luxembourg	0.0	1.7	4.8	0.0	0.0	6.5
Malta	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	0.0	0.5	38.3	0.0	0.0	38.8
Poland	0.0	11.2	50.5	0.0	0.0	61.7
Portugal	0.0	6.0	4.5	0.0	0.0	10.5
Slovakia	0.0	1.7	16.5	0.0	0.0	18.2
Slovenia	0.0	1.4	7.8	0.0	0.0	9.2
Spain	0.0	69.6	199.2	0.0	0.0	268.8
Sweden	0.0	17.6	54.0	0.0	0.0	71.5
UK	0.0	45.2	95.4	0.0	0.0	140.6
EU-25	0.0	317.7	1552.9	0.0	0.0	1870.6

Table 6.45: Emission control costs in 2020 of the 75 percent gap closure scenario A4/3 (million €/year), on top of the costs of the baseline scenario

	SO_2	**NO_x**	**NH_3**	**VOC**	**PM2.5**	**Total**
Austria	0.0	25.0	175.4	0.0	0.0	200.4
Belgium	0.0	43.7	250.1	0.0	0.0	293.7
Cyprus	0.0	7.0	9.2	0.0	0.0	16.2
Czech Rep.	0.0	40.4	89.3	0.0	0.0	129.7
Denmark	0.0	37.4	167.0	0.0	0.0	204.5
Estonia	0.0	4.0	8.1	0.0	0.0	12.1
Finland	0.0	51.9	70.7	0.0	0.0	122.6
France	0.0	85.0	784.2	0.0	0.0	869.2
Germany	0.0	125.9	621.2	0.0	0.0	747.1
Greece	0.0	42.1	61.9	0.0	0.0	104.0
Hungary	0.0	13.8	18.5	0.0	0.0	32.3
Ireland	0.0	9.4	140.2	0.0	0.0	149.5
Italy	0.0	55.7	303.3	0.0	0.0	359.0
Latvia	0.0	2.1	14.9	0.0	0.0	17.0
Lithuania	0.0	4.1	71.8	0.0	0.0	75.9
Luxembourg	0.0	2.3	5.6	0.0	0.0	7.9
Malta	0.0	0.0	0.1	0.0	0.0	0.1
Netherlands	0.0	5.2	67.6	0.0	0.0	72.8
Poland	0.0	88.8	228.8	0.0	0.0	317.6
Portugal	0.0	18.8	45.4	0.0	0.0	64.2
Slovakia	0.0	16.8	64.6	0.0	0.0	81.4
Slovenia	0.0	3.5	25.4	0.0	0.0	28.9
Spain	0.0	190.8	552.3	0.0	0.0	743.2
Sweden	0.0	58.7	137.4	0.0	0.0	196.2
UK	0.0	199.4	260.0	0.0	0.0	459.4
EU-25	0.0	1131.6	4173.3	0.0	0.0	5304.9

Table 6.46: Average nitrogen deposition in excess over the critical loads for eutrophication accumulated over all ecosystems for the eutrophication A4 scenarios (eq/hectare) – provisional results

	Baseline 2020	**25% gap closure A4/1**	**50% gap closure A4/2**	**75% gap closure A4/3**	**MTFR 2020 excl. Euro5/6**
Austria	455	390	325	261	196
Belgium	525	416	307	197	88
Cyprus	96	89	81	73	65
Czech Rep.	352	276	199	120	45
Denmark	464	387	310	232	155
Estonia	21	10	4	0	0
Finland	14	10	6	2	0
France	382	308	233	159	85
Germany	926	837	753	666	580
Greece	296	271	245	220	195
Hungary	153	86	7	0	0
Ireland	95	73	51	28	6
Italy	252	193	133	74	15
Latvia	104	71	45	15	0
Lithuania	385	334	283	232	181
Luxembourg	0	0	0	0	0
Malta	0	0	0	0	0
Netherlands	952	815	663	579	455
Poland	485	389	318	235	151
Portugal	46	8	0	0	0
Slovakia	223	159	95	31	0
Slovenia	366	276	217	143	69
Spain	208	160	112	64	16
Sweden	46	37	28	18	9
UK	91	74	56	39	21

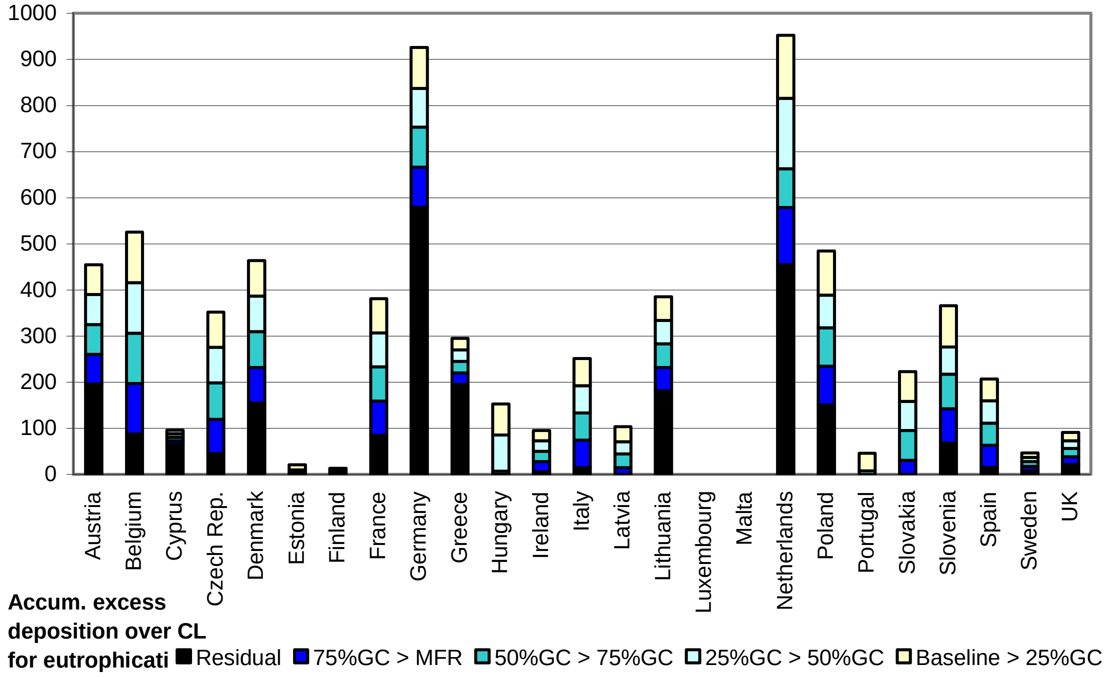
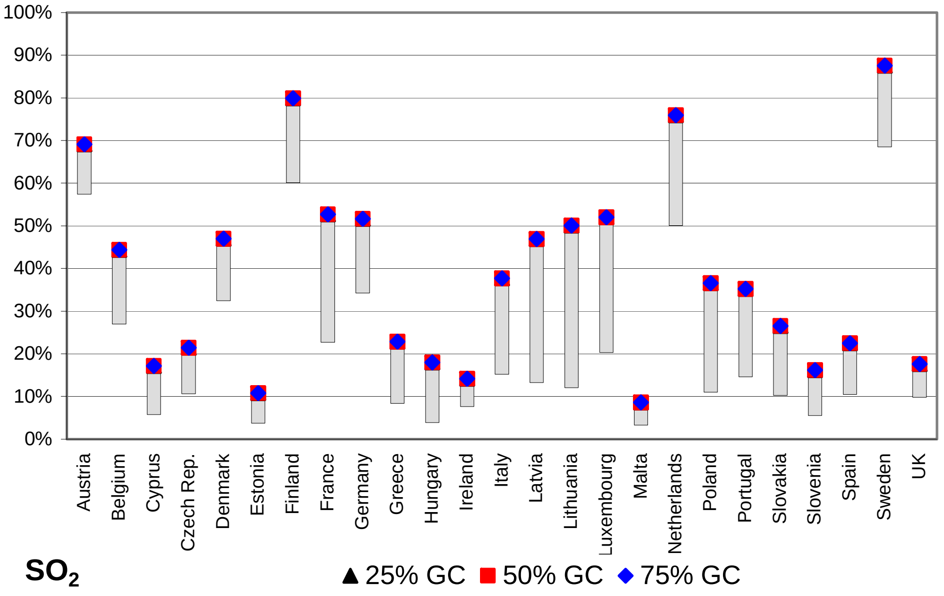


Figure 6.17: Nitrogen deposition in excess over the critical loads for eutrophication accumulated over all ecosystems for the eutrophication A4 scenarios (eq/ha/year) - provisional results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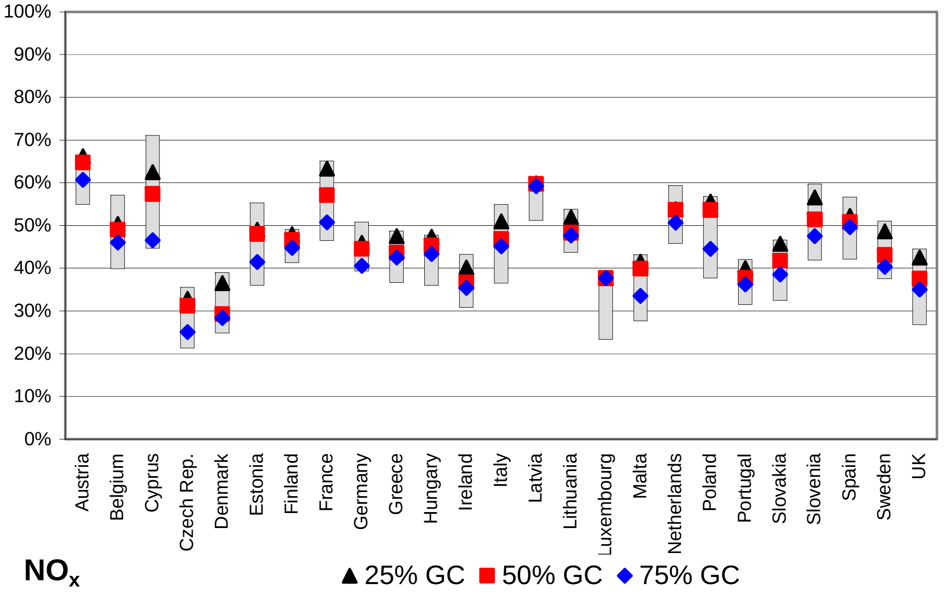
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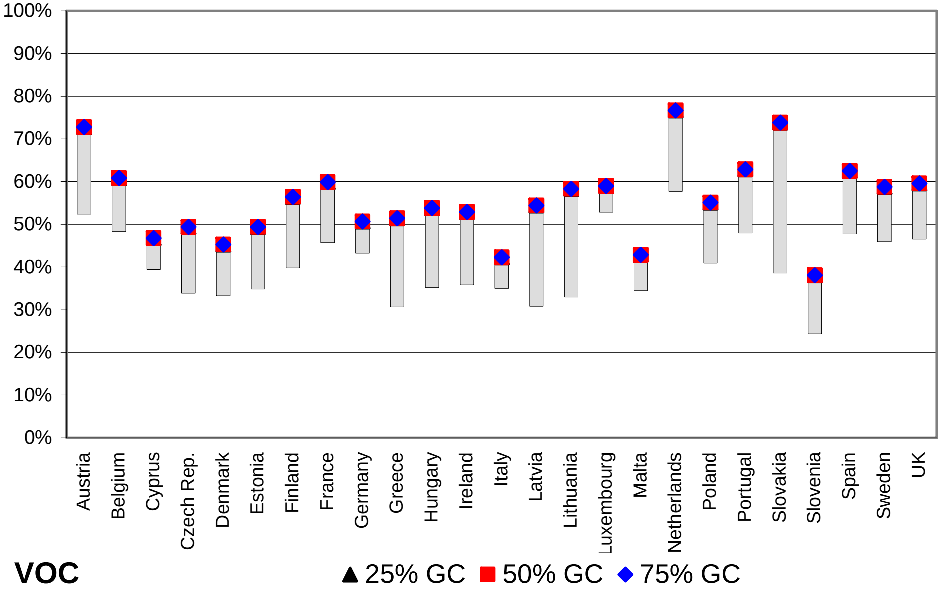
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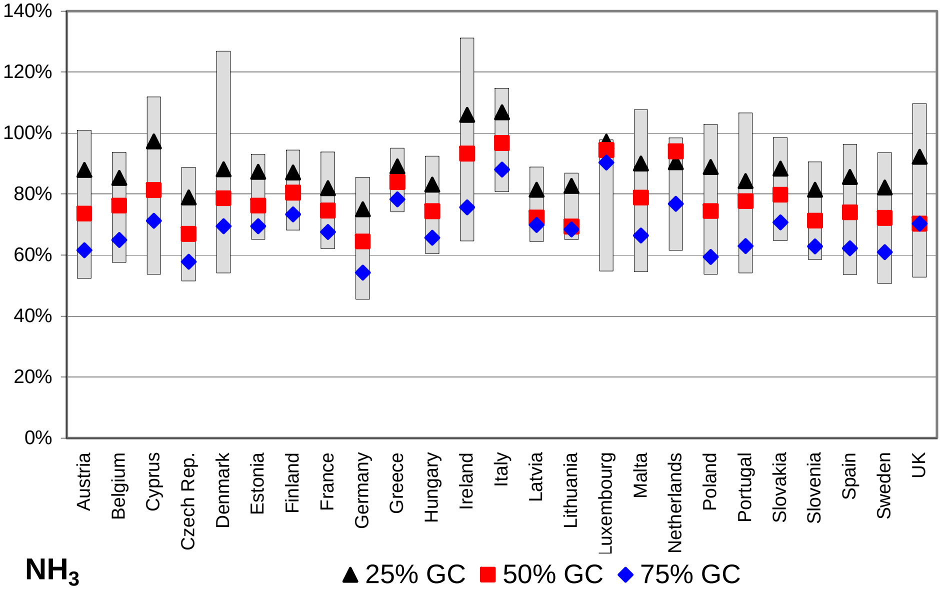
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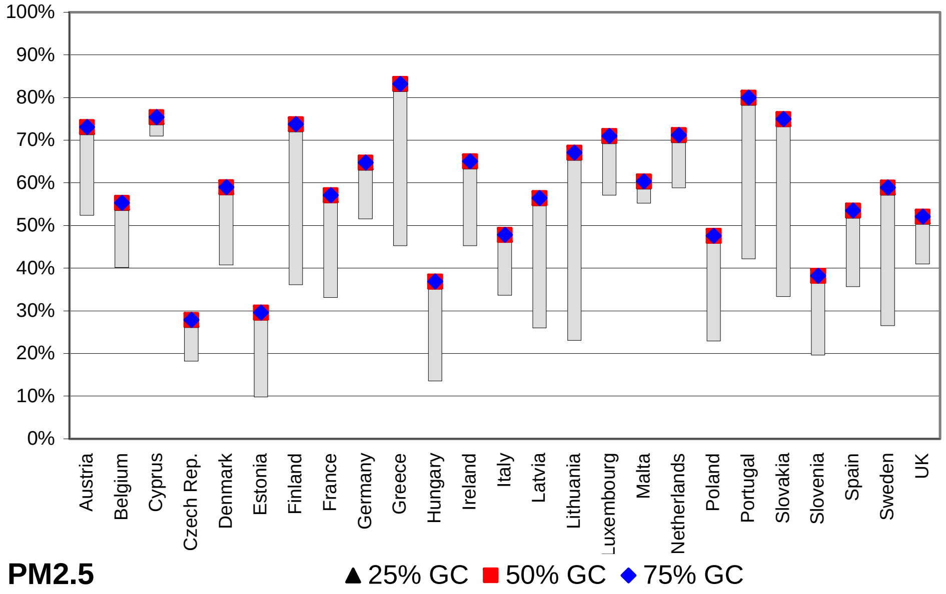

Figure 6.18: Cost-minimal emission cuts for reducing eutrophication. The 100 percent line refers to the emission level in the year 2000. The grey range indicates the scope for emission reductions considered in the RAINS optimization between the baseline projection for 2020 (top end) and the maximum technically feasible reductions (bottom end).

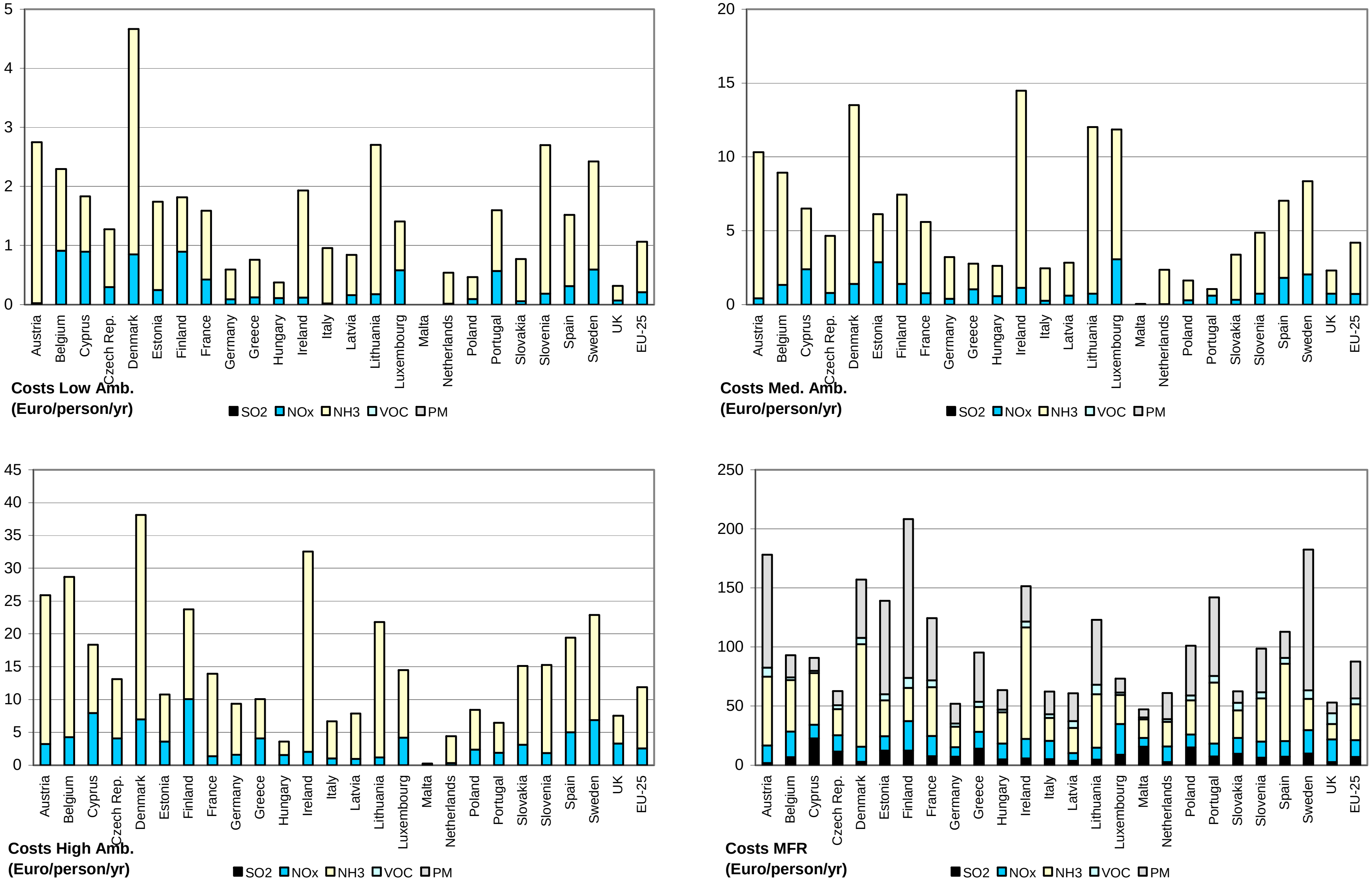

Figure 6.19: Per-capita emission control costs of the optimized scenarios for reducing eutrophication (€/person/year)

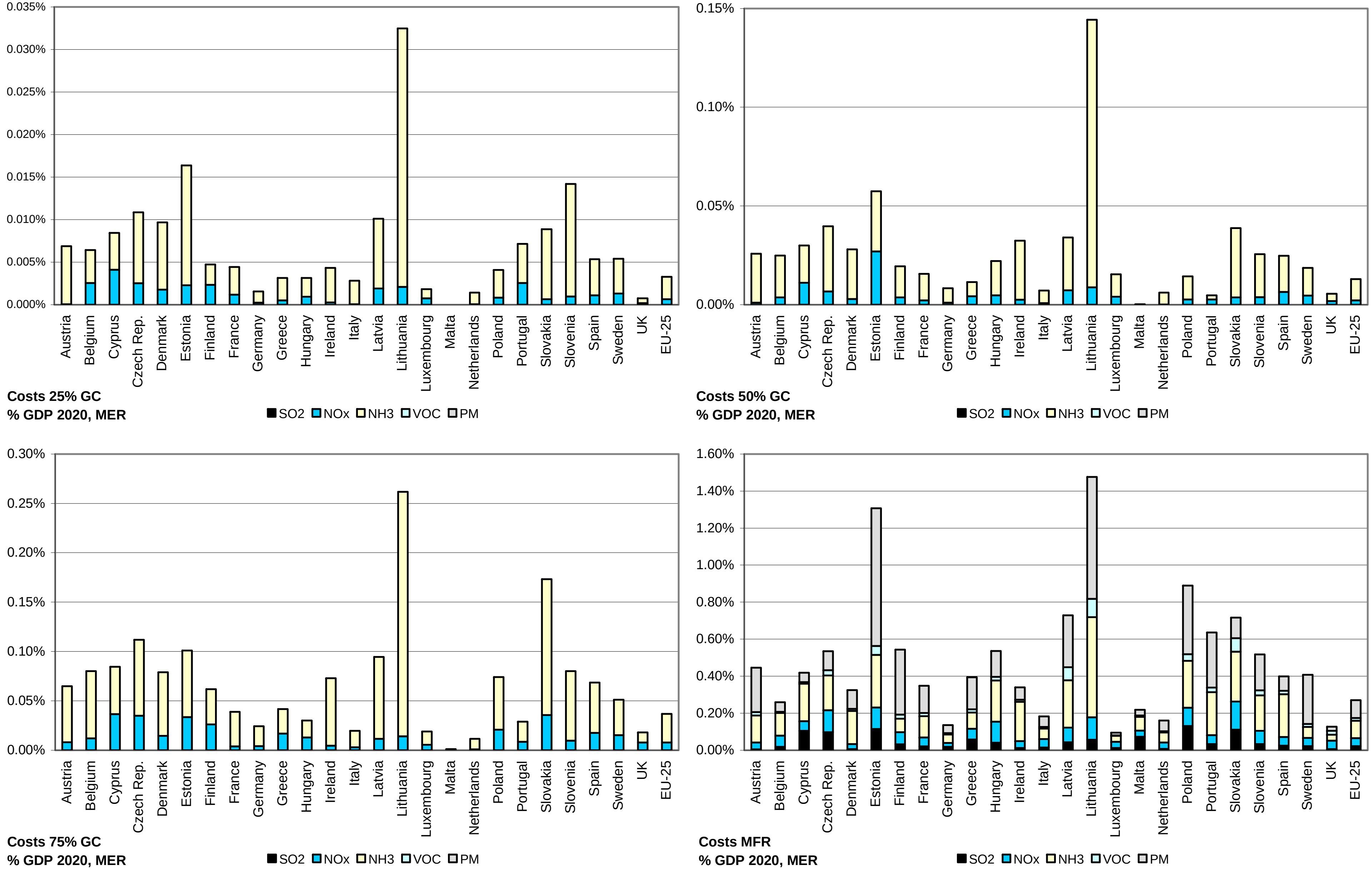

Figure 6.20: Emission control costs in 2020 expressed as percentage of GDP using Market Exchange Rates (MER) for 2020

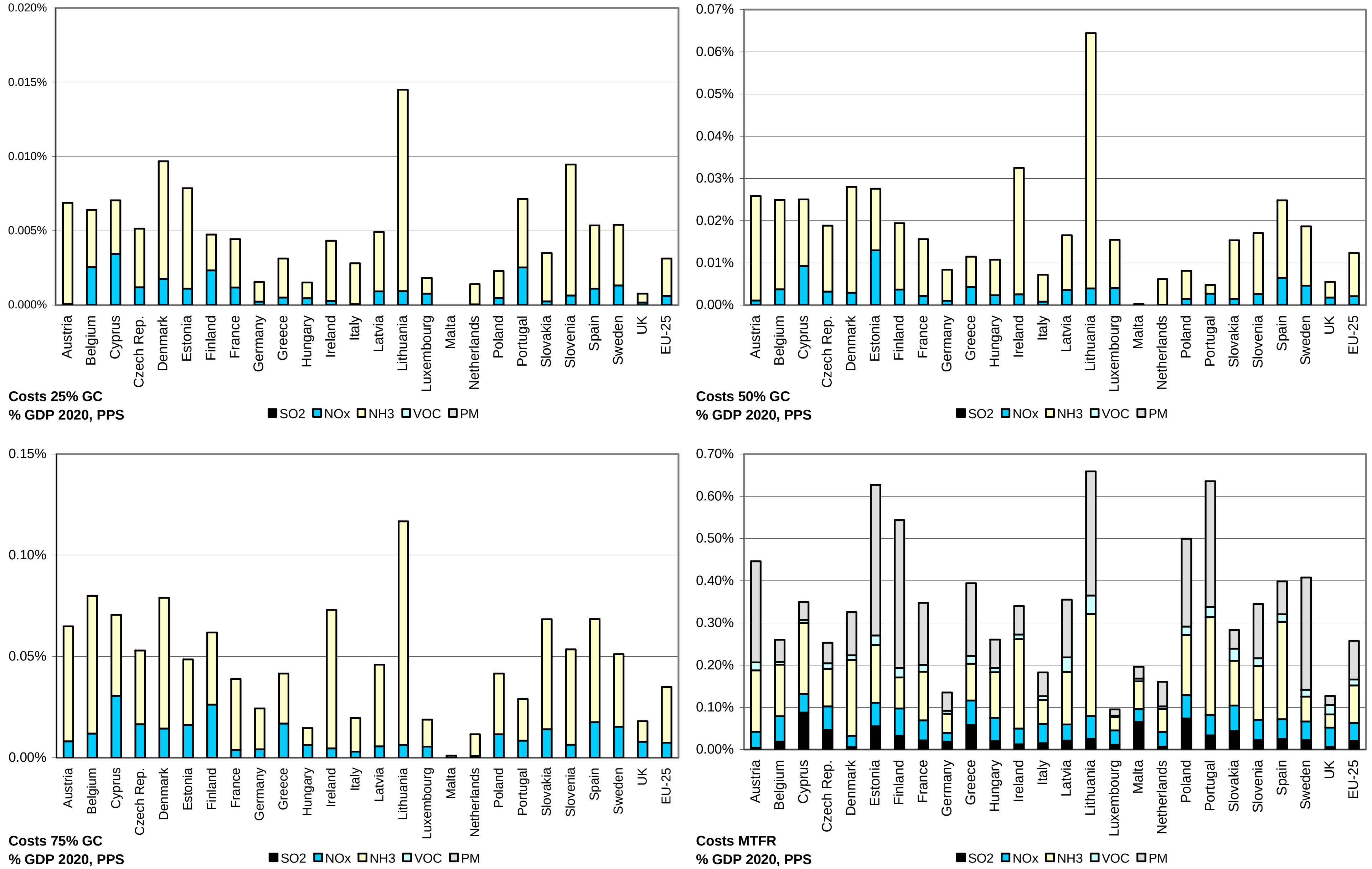

Figure 6.21: Emission control costs in 2020 expressed as percentage of GDP using Purchasing Power Standards (PPS) for 2020

7 Conclusions

A first set of optimization runs have been produced by the RAINS model that explore the scope for cost-effective emission reductions that achieve different environmental targets at least cost. While a number of caveats call for a cautious interpretation of the quantitative results, the illustrative calculations should aid the Working Group on Target Setting and Policy Advice in their deliberations on the choice of appropriate environmental interim targets towards the long-term policy objectives.

Most importantly, these results from the extended RAINS model provide for the first time a practical tool for balancing emission control measures aimed at the reduction of health impacts from fine particulate matter.

Refined analyses will be required to derive an appropriate set of environmental targets that balance the environmental achievements and the economic burdens across the Member States and the economic sectors in an acceptable way, while maximizing the cost effectiveness of the strategy.

While the set of optimized scenarios presented in this paper relate to the different environmental objectives separately, a next step will explore cost-effective emission reductions that simultaneously achieve all environmental targets at least cost. This joint optimization will identify synergies between the reductions of different pollutants and different environmental problems and thus establish an essential step towards attaining overall cost-effective emission control strategies.

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Annex 1: Mathematical formulation of the optimization problem