CAFE Scenario Analysis Report Nr. 2

The "Current Legislation" and the "Maximum Technically Feasible Reduction" cases for the CAFE baseline emission projections

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

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 costs. 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 feasible reduction case - MFR).

To inform the CAFE Working Group on Target Setting and Policy Advice about the feasible range of targets for environmental improvements between CLE and MFR, this paper presents emissions, resulting air quality and environmental impacts for these two scenarios. The working group is invited to suggest a series of ambition levels of environmental impacts between CLE and MFR, for which the RAINS model will subsequently explore the cost-effective sets of emission control measures that would achieve these targets at least costs.

The paper describes the key results relevant the discussions in the CAFE Working Group on Target Setting and Policy Advice. A comprehensive documentation of the CAFE baseline scenario is provided in Amann *et al*. (2004). Detailed results on sectoral and country-specific emission estimates can be extracted from the Internet version of the RAINS model (www.iiasa.ac.at/rains).

Section 2 of this report describes the assumptions and results of the emission scenarios. Environmental impacts are presented in Section 3.

This draft paper provides emissions and site-specific impact estimates in form of European maps. Further work will produce summary statistics that present numerical results for all Member States of the European Union. Following the purpose of this paper to assist the Working Group on Target Setting in their deliberations of suitable targets for the RAINS optimization analysis, this provisional report does not address uncertainties in the presented results. The Working Group is invited to advice on the priorities for further work, i.e., of scenario analyses versus uncertainties assessment.

2 Emission scenarios

This paper explores the feasible ranges of future emissions of air pollutants for

- a "climate policy" scenario, which assumes for the year 2020 a carbon price of 20 €/ton CO_2 , achieving a stabilization of the EU-25 CO_2 emissions in 2020 compared to 2000 (the "climate policy" CAFE baseline scenario), and
- an "illustrative climate" scenario developed with the PRIMES energy model, assuming a carbon price of 90 €/ton CO_2 in 2020. This scenario results in a reduction of the EU-25 CO_2 emissions by 20 percent.

For both projections, the RAINS model estimated the air pollutant emissions for

- the "current legislation" (CLE) baseline case, which assumes the implementation of all presently decided emission-related legislation in all countries of the EU-25, and
- the "maximum feasible reduction" (MFR) case, which assumes full implementation of the presently available most advanced technical emission control measures in the year 2020, although excluding premature retirement of existing equipment before the end of its technical life time.

The initial analysis presented in this paper focuses on the year 2020.

Table 2.1: Current legislation and measures assumed for the maximum feasible reduction scenario for SO_2 emissions

Legislation considered in the Current Legislation (CLE) scenario	
Large combustion plant directive	
Directive on the sulphur content in liquid fuels	
Directives on quality of petrol and diesel fuels	
IPPC legislation on process sources	
National legislation and national practices (if stricter)	
Measures assumed for the Maximum Feasible Reduction (MFR) scenario	
Sector	Technology
Power plant boilers - coal, oil and waste fuels	High efficiency FGD
Power plants, biomass	Combustion modification on small biomass boilers
Residential/commercial boilers	Low sulphur coal and oil
Industrial boilers and furnaces	FGD on larger boilers, in-furnace controls for smaller boilers
Industrial processes	Stage 3 controls
Transport (land-based sources)	Sulphur-free gasoline and diesel
Sea transport	Low sulphur marine oils (heavy fuel oil and diesel)

Table 2.2: Current legislation and measures assumed for the maximum feasible reduction scenario for NO_x emissions

Legislation considered in the Current Legislation (CLE) scenario	
Large combustion plant directive	
Auto/Oil EURO standards	
Emission standards for motorcycles and mopeds	
Legislation on non-road mobile machinery	
Implementation failure of EURO-II and Euro-III for heavy duty vehicles	
IPPC legislation for industrial processes	
National legislation and national practices (if stricter)	
Measures assumed for the Maximum Feasible Reduction (MFR) scenario	
Sector	Technology
Power plant boilers - coal, oil and gas	SCR
Power plants, biomass	Combustion modification on small biomass boilers, SCR on large boilers
Residential/commercial boilers	Combustion modification
Industrial boilers and furnaces	SCR on larger boilers, SNCR on smaller boilers
Industrial processes	Stage 3 controls
Non-road diesel vehicles (construction, agriculture, inland waterways, railways)	Equivalent to EURO VI on HDVs (post-stage III or IV, depending on a sector and rated power)
Non-road gasoline vehicles (construction, agriculture, inland waterways, railways)	3-way catalytic converters
Motorcycles	Stage 3 controls
Mopeds	Stage 3 controls
Heavy-duty trucks - diesel	Post-Euro V (Euro VI)
Heavy-duty trucks - gasoline	Post-Euro V (Euro VI)
Light-duty vehicles (gasoline and diesel)	Post-EURO IV (Euro VI)

Table 2.3: Current legislation and measures assumed for the maximum feasible reduction scenario for VOC emissions

Legislation considered in the Current Legislation (CLE) scenario	
Stage I directive	
Directive 91/441 (carbon canisters)	
Auto/Oil EURO standards	
Fuel directive (RVP of fuels)	
Solvents directive	
Product directive (paints)	
National legislation, e.g., Stage II	
Measures assumed for the Maximum Feasible Reduction (MFR) scenario	
Sector	Technology
Residential boilers and stoves, coal	New boilers or stoves, possibly equipped with oxidation catalysts
Residential stoves and fireplaces, wood	Catalytic inserts
Extraction and distribution of liquid fuels	Vapour balancing on tankers
Process emissions in oil refineries	Leak detection and repair program and covers on oil-water separators
Evaporative emissions from gasoline vehicles	Small carbon canister
Gasoline service stations	Stage I and II controls
Storage and distribution of gasoline	Internal floating covers and Stage I controls
Dry cleaning	New closed circuit machine, hydrocarbon machines and water-based cleaning
Degreasing	Closed (sealed) degreaser; use of chlorinated solvents (or use of A3 solvents and activated carbon filter), water based cleaning
Domestic (personal usage) use of solvents	Reformulation of products
Decorative paints	Simulation of possible developments beyond Product Directive
Vehicle refinishing	Primary measures and substitution
Wood coating	Very high solids systems (5% solvent content) (additionally small share of low [80% solvents], medium [55%], and high [20%] solid coating systems), application process with an efficiency of 75%
Coil coating	Powder coating system (solvent free), thermal oxidation
Automobile production	Process modification, substitution, end-of-pipe (adsorption, thermal oxidation)
Leather coating	Use of water based coating, bio-filtration
Winding wire coating	Primary (lower solvent content of enamel and reduced fugitive emissions) and secondary measures (increased efficiency of the oven)
Other industrial paint use (continuous processes, plastic, general)	Use of current standard solvent based paints (60% solvent content); Use of improved solvent based paints (55%) - application efficiency 65%; Use of water based paints (4-5%) - application efficiency 65 to 98%; Use of powder coatings; application efficiency 90 to 96%
Production of paints, inks and adhesives	Upgrade of the condensation units or carbon adsorption and solvent recovery
Printing	Low solvent/water based inks and incineration/adsorption (Packaging and Publication); Primary measures, solvent free inks, incineration (Offset); Water based inks, enclosure and incineration (Screen printing)

Table 2.4: Current legislation and measures assumed for the maximum feasible reduction scenario for VOC emissions, continued

Measures assumed for the Maximum Feasible Reduction (MFR) scenario	
Sector	Technology
Industrial glue application	Emulsions, hot melts or UV cross-linking acrylates or electron beam curing systems, adsorption, incineration
Wood preservation	Use of water based preservatives (conventional application methods) and improved application technique (vacuum impregnation system)
Steam cracking (ethylene and propylene production) and downstream units - chem. ind.	Leak detection and repair program, stage IV
Polystyrene processing	6% pentane expandable beads (85%) and recycled EPS waste (15%) and incineration
PVC production	Stripping and vent gas treatment plus optimization of emission treatment including leak and detection program
Pharmaceutical industry	Primary measures and high level employment of end-of-pipe measures (incl. thermal incineration, carbon adsorption, condensation, and other)
Storage and handling of chemical products	Internal floating covers/sec. seals, vapour recovery (double stage)
Synthetic rubber production	Use of 30% solvent based additives and 70% low solvent additives (90% vulcanized rubber and 10% thermoplastic rubber produced) and incineration
Food and drink industry	Thermal oxidation
Tyre production	New process
Manufacturing of shoes	Good housekeeping and substitution plus automatic application, biofiltration
Fat, edible and non-edible oil extraction	Schumacher type desolventiser-toaster-dryer-cooler plus "a new" hexane recovery section and process optimization
Other industrial sources	Good housekeeping in steel industry and switch to emulsion bitumen
Open burning of agricultural and municipal waste	Ban

Table 2.5: Current legislation and measures assumed for the maximum feasible reduction scenario for NH_3 emissions

Legislation considered in the Current Legislation (CLE) scenario	
No EU-wide legislation	
National legislations	
Current practice	
Measures assumed for the Maximum Feasible Reduction (MFR) scenario	
Sector	Technology
Cattle	Low nitrogen feed, housing adaptation, low nitrogen application (specifically distinguishing between options for liquid slurry and solid manure)
Pigs	Low nitrogen feed, housing adaptation and closed storage, low nitrogen application (specifically distinguishing between options for liquid slurry and solid manure)
Poultry	Low nitrogen feed, housing adaptation and closed storage, bio-filtration, low nitrogen application and incineration of poultry manure (limited number of countries)
Sheep	Low nitrogen application
N-fertilizer application	Substitution of urea with ammonium nitrate
Fertilizer production	BAT to control end-of-pipe emissions from fertilizer plants

Table 2.6: Current legislation and measures assumed for the maximum feasible reduction scenario for PM2.5 emissions

Legislation considered in the Current Legislation (CLE) scenario	
Large combustion plant directive	
Auto/Oil EURO standards for vehicles	
Emission standards for motorcycles and mopeds	
Legislation on non-road mobile machinery	
IPPC legislation on process sources	
National legislation and national practices (if stricter)	
Measures assumed for the Maximum Feasible Reduction (MFR) scenario	
Sector	Technology
Power plant boilers - coal, oil and gas	High efficiency de-dusters (ESP or fabric filters)
Power plants, biomass	Combustion modification on small biomass boilers
Power plants, oil	Fabric filters on large boilers, good housekeeping for smaller boilers
Commercial boilers, coal	High efficiency de-dusters (cyclons, fabric filters)
Residential boilers and stoves, coal	New boilers or stoves
Residential/commercial boilers (oil)	Good housekeeping
Residential stoves and fireplaces, wood	Catalytic inserts
Industrial processes	High efficiency de-dusters (ESP or fabric filters), good practices for fugitive emissions
Agriculture	Good practices, feed modifications, low till farming and alternative cereal harvesting
Construction	Spraying water at construction places
Flaring in oil and gas industry	Good practices

Table 2.7: SO_2 emissions for 2000 and 2020, for the "Climate policy" and the "Illustrative climate" scenarios, for current legislation (CLE) and maximum technically feasible reduction (MFR) cases (kt SO_2)

	2000	"Climate policy" scenario 2020		"Illustrative climate" scenario 2020	
		CLE	MFR	CLE	MFR
Austria	38	26	22	23	20
Belgium	187	83	51	71	47
Cyprus	46	8	3	7	2
Czech Rep.	250	53	26	36	17
Denmark	28	13	10	13	9
Estonia	91	10	3	7	2
Finland	77	62	46	56	43
France	654	345	148	322	149
Germany	643	332	220	259	177
Greece	481	110	40	100	34
Hungary	487	88	32	77	29
Ireland	132	19	10	18	10
Italy	747	281	117	243	102
Latvia	16	8	2	8	2
Lithuania	43	22	11	19	11
Luxembourg	4	2	1	2	1
Malta	26	2	1	1	1
Netherlands	84	64	41	62	40
Poland	1515	554	223	385	178
Portugal	230	81	33	74	30
Slovakia	124	33	13	25	9
Slovenia	97	16	8	14	7
Spain	1489	335	155	315	153
Sweden	58	50	39	49	38
UK	1186	209	102	202	100
EU-25	8735	2805	1357	2387	1211
Atlantic Ocean	397	657	146	657	146
Baltic Sea	243	225	90	225	90
Black Sea	84	138	31	138	31
Mediterranean	1244	2082	464	2082	464
North Sea	461	424	169	424	169
Sea regions	2430	3526	900	3526	900

Table 2.8: NO_x emissions for 2000 and 2020, for the "Climate policy" and the "Illustrative climate" scenarios, for current legislation (CLE) and maximum technically feasible reduction (MFR) cases (kt NO_x)

	2000	"Climate policy" scenario 2020		"Illustrative climate" scenario 2020	
		CLE	MFR	CLE	MFR
Austria	192	127	91	117	88
Belgium	333	190	112	173	104
Cyprus	26	18	10	17	10
Czech Rep.	318	113	60	90	51
Denmark	207	105	65	101	63
Estonia	37	15	8	12	7
Finland	212	117	63	110	58
France	1447	819	461	778	450
Germany	1645	808	600	753	550
Greece	322	209	120	194	109
Hungary	188	83	42	76	38
Ireland	129	63	39	56	34
Italy	1389	663	363	622	338
Latvia	35	15	9	15	9
Lithuania	49	27	15	25	15
Luxembourg	33	18	11	16	10
Malta	9	4	2	3	2
Netherlands	399	240	166	227	158
Poland	843	364	209	309	177
Portugal	263	156	97	141	86
Slovakia	106	60	34	53	31
Slovenia	58	24	16	22	15
Spain	1335	681	398	627	375
Sweden	251	150	75	143	70
UK	1753	817	474	746	439
EU-25	11581	5888	3540	5427	3288
Atlantic Ocean	575	954	488	954	488
Baltic Sea	354	592	302	592	302
Black Sea	120	199	102	199	102
Mediterranean	1837	3095	1582	3095	1582
North Sea	670	1111	568	1111	568
Sea regions	3557	5951	3042	5951	3042

Table 2.9: VOC emissions for 2000 and 2020, for the "Climate policy" and the "Illustrative climate" scenarios, for current legislation (CLE) and maximum technically feasible reduction (MFR) cases (kt VOC)

	2000	"Climate policy" scenario 2020		"Illustrative climate" scenario 2020	
		CLE	MFR	CLE	MFR
Austria	190	139	94	139	94
Belgium	242	147	109	146	108
Cyprus	13	6	4	6	4
Czech Rep.	242	120	74	119	75
Denmark	128	58	39	58	38
Estonia	34	17	11	17	11
Finland	171	97	63	96	62
France	1542	924	660	935	667
Germany	1528	777	618	767	612
Greece	280	144	79	139	76
Hungary	169	91	53	90	52
Ireland	88	47	29	46	29
Italy	1738	735	552	740	552
Latvia	52	28	16	26	15
Lithuania	75	44	22	44	22
Luxembourg	13	8	6	7	6
Malta	5	2	1	2	1
Netherlands	265	204	145	202	144
Poland	582	321	215	314	210
Portugal	260	164	116	162	115
Slovakia	88	65	32	67	33
Slovenia	54	21	12	20	12
Spain	1121	702	492	697	489
Sweden	305	179	136	177	134
UK	1474	880	652	871	645
EU-25	10661	5918	4230	5889	4205
Atlantic Ocean	21	35	35	35	35
Baltic Sea	13	22	22	22	22
Black Sea	4	7	7	7	7
Mediterranean	68	114	114	114	114
North Sea	25	41	41	41	41
Sea regions	131	219	219	219	219

Table 2.10: NH_3 emissions for 2000 and 2020, for the "Climate policy" and the "Illustrative climate" scenarios, for current legislation (CLE) and maximum technically feasible reduction (MFR) cases (kt NH_3)

	2000	"Climate policy" scenario 2020		"Illustrative climate" scenario 2020	
		CLE	MFR	CLE	MFR
Austria	54	54	27	54	27
Belgium	81	76	47	76	47
Cyprus	6	6	3	6	3
Czech Rep.	74	65	36	65	36
Denmark	91	78	40	78	40
Estonia	10	12	5	12	5
Finland	35	32	22	32	22
France	728	702	387	702	386
Germany	638	603	441	599	437
Greece	55	52	34	51	34
Hungary	78	85	39	85	39
Ireland	127	121	84	121	83
Italy	432	399	248	398	246
Latvia	12	16	7	16	7
Lithuania	50	57	39	57	39
Luxembourg	7	6	4	6	4
Malta	1	1	1	1	1
Netherlands	157	140	103	139	103
Poland	309	333	150	332	147
Portugal	68	67	40	67	39
Slovakia	32	33	17	32	16
Slovenia	18	20	9	20	9
Spain	394	370	197	370	197
Sweden	53	49	33	48	33
UK	315	310	206	310	203
EU-25	3824	3686	2221	3679	2203

Table 2.11: Primary PM2.5 emissions for 2000 and 2020, for the "Climate policy" and the "Illustrative climate" scenarios, for current legislation (CLE) and maximum technically feasible reduction (MFR) cases (kt PM2.5)

	2000	"Climate policy" scenario 2020		"Illustrative climate" scenario 2020	
		CLE	MFR	CLE	MFR
Austria	37	27	20	27	20
Belgium	43	24	16	22	16
Cyprus	2	2	1	2	1
Czech Rep.	66	18	12	13	8
Denmark	22	13	10	13	9
Estonia	22	6	2	6	2
Finland	36	27	16	27	16
France	290	167	101	167	102
Germany	171	111	83	107	79
Greece	49	41	23	37	21
Hungary	60	22	8	22	8
Ireland	14	9	6	9	6
Italy	209	100	69	95	66
Latvia	7	4	2	4	2
Lithuania	17	12	5	12	5
Luxembourg	3	2	2	2	2
Malta	1	0	0	0	0
Netherlands	36	26	20	26	20
Poland	215	102	53	92	48
Portugal	46	37	21	38	21
Slovakia	18	14	6	12	5
Slovenia	15	6	3	5	3
Spain	169	91	56	87	54
Sweden	67	40	23	40	22
UK	129	68	48	66	47
EU-25	1749	971	604	931	582
Atlantic Ocean	34	57	57	57	57
Baltic Sea	21	35	35	35	35
Black Sea	7	12	12	12	12
Mediterranean	108	182	182	182	182
North Sea	40	66	66	66	66
Sea regions	210	352	352	352	352

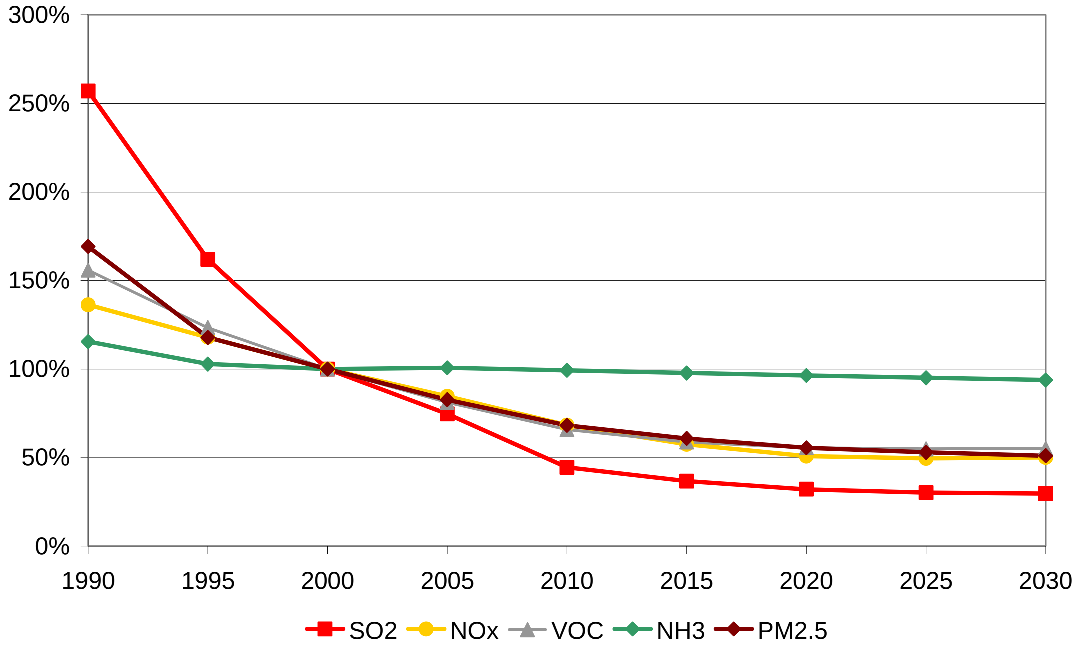

Figure 2.1: Long-term trends in EU-25 emissions relative to the year 2000

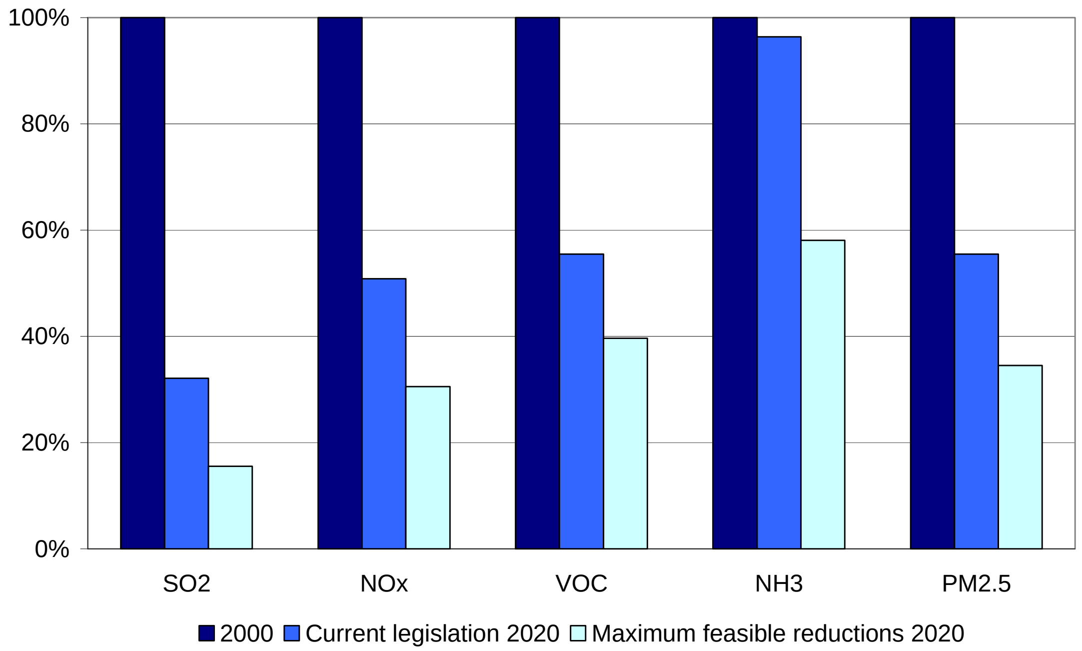

Figure 2.2: Scope for further technical emission control measures in 2020 in the EU-25 (2000 = 100%)

3 Environmental impacts

For the purpose of exploring the cost-effectiveness of further emission control measures, this paper analyses the impacts of the emission reductions outlined in the preceding sections on a range of health and environmental endpoints.

While inter-annual meteorological variability is an important aspect that must be considered in the design of cost-effective air quality management strategies, the provisional analysis presented in this paper is carried out for the meteorological conditions of a single year (1997). This simplification is caused by the high computational demand of developing atmospheric source-receptor relationships, which form one backbone in the RAINS optimization approach. Due to constraints in computer time, up to now source-receptor relationships could only be developed for one meteorological year. The assessment of the CAFE baseline scenario has considered the meteorological conditions of four years (1997, 1999, 2000 and 2003), finding that at least for particulate matter 1997 did not represent extreme conditions. Thus, to provide a background for setting environmental targets for the first round of the RAINS optimization analyses, this paper evaluates the environmental impacts in a way that is fully compatible with the (provisional) RAINS optimization framework, i.e., for 1997. Eventually, when refining the assessment, the inter-annual meteorological variability has to be taken into account.

With decreasing emissions from European sources, European air quality is increasingly influenced by hemispheric background pollution. The atmospheric computations of the EMEP model conducted for the CAFE analysis consider present background levels as boundary conditions to their calculations. For ozone, however, a wide range of scientific literature hints at increasing background concentrations resulting from intercontinental and hemispheric transport, essentially caused by global increases in methane emissions and steep growth in Asian emissions of NO_x and VOC. Thus, any considerations of future environmental air quality targets for Europe should not forget the ongoing increases in background pollution, in order to set European emission control efforts into a realistic context. For this purpose, the analysis presented in this paper assumes for the year 2020 a 3 ppb increase in hemispheric background levels of ozone compared to the year 2000.

As an initial analysis, this paper presents the environmental impacts for the "Climate policy" scenario. Due to time constraints it was not possible to finalize the impacts assessment for the "Illustrative climate" scenario before the meeting of the Working Group on Target Setting and Policy Advice. However, the emission estimates listed in the preceding section for the "Illustrative climate" scenario provide some indication of the additional scope for air quality improvements resulting from more aggressive greenhouse gas control strategies.

3.1 Anthropogenic contributions to ambient PM2.5 concentrations

The EMEP Eulerian model has been used to calculate changes in the anthropogenic contribution to ambient concentrations of PM2.5 in Europe resulting from the changes in the precursor emissions (primary PM2.5, SO_2, NO_x, and NH_3).

However, at the moment, the scientific peers do not consider the modelling of total particulate mass of the EMEP model (and of all other reviewed state-of-the-art models) as sufficiently accurate and robust for policy analysis. Thus, one should not base an integrated assessment on estimates of total PM mass concentrations (http://www.unece.org/env/documents/2004/eb/ge1/eb.air.ge.1.2004.6.e.pdf). The largest deficiencies have been identified in the quantification of the contribution from natural sources (e.g., mineral dust, organic carbon, etc.) and water. Equally, the quantification of secondary organic aerosols (SOA) is not considered mature enough to base policy analysis on. A certain fraction of SOA is definitely caused by anthropogenic emissions, but some estimates suggest that the contribution from natural sources might dominate total SOA. Clarification of this question is urgent to judge whether the inability of contemporary atmospheric chemistry models to quantify SOA is a serious deficiency for modelling the anthropogenic fraction of total PM mass.

In contrast, the modelling of secondary inorganic aerosols is considered reliable within the usual uncertainty ranges. This applies especially to sulphur aerosols. The lack of formal validation of the nitrate calculations is explained by insufficient monitoring data with known accuracy; the model performs reasonably well for other nitrogen-related compounds.

Figure 3.1 presents the model estimates of the identified anthropogenic fraction of PM2.5 for the three emission scenarios.

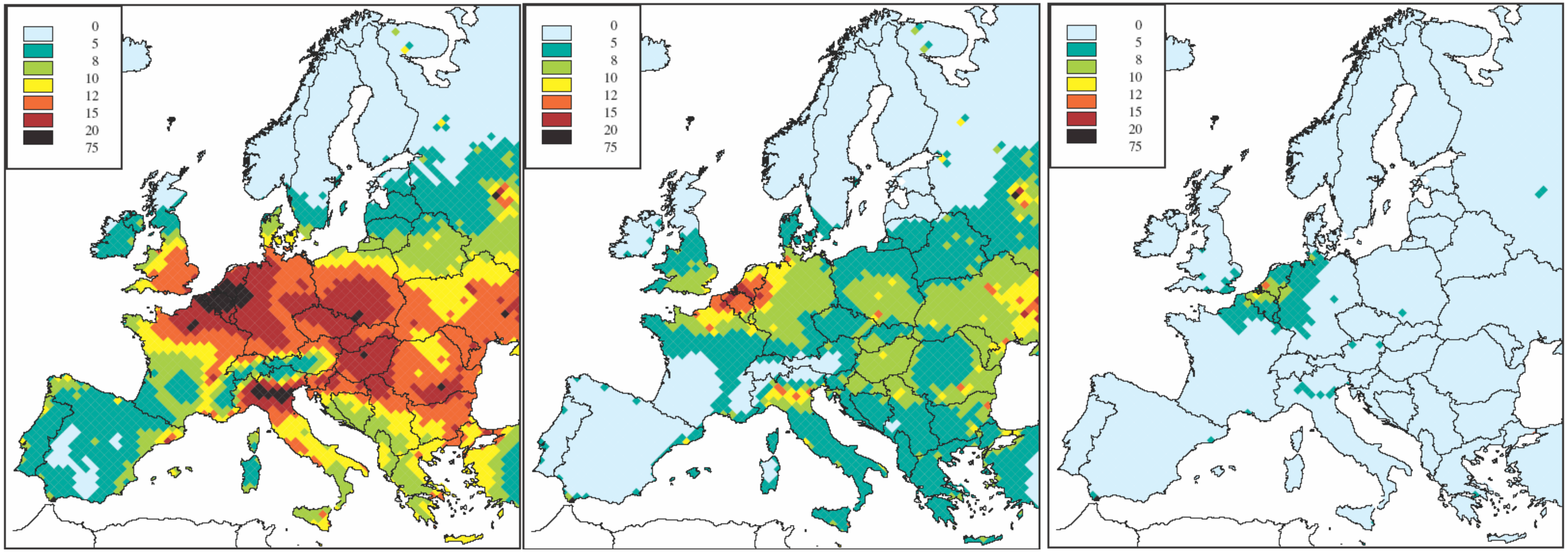

Figure 3.1: Identified anthropogenic contribution to modelled grid-average PM2.5 concentrations (annual mean, μg/m^3) for the emissions of the year 2000 (left panel), the current legislation case of the "Climate policy" scenario in 2020 (centre panel) and the maximum feasible reduction case for 2020 (right panel). Calculation results for the meteorological conditions of 1997.

3.2 Loss in life expectancy attributable to the exposure to fine particulate matter

With the methodology described in Amann *et al.* (2004), the RAINS model estimates changes in the loss in statistical life expectancy that can be attributed to changes in anthropogenic emissions (ignoring the role of secondary organic aerosols). This calculation is based on the assumption that health impacts can be associated with changes in PM2.5 concentrations. Following the advice of the joint World Health Organization/UNECE Task Force on Health (http://www.unece.org/env/documents/2004/eb/wg1/eb.air.wg1.2004.11.e.pdf), RAINS applies a linear concentration-response function and associates all changes in the identified anthropogenic fraction of PM2.5 with health impacts. Thereby, no health impacts are calculated for PM from natural sources and for secondary organic aerosols. It transfers the rate of relative risk for PM2.5 identified by Pope *et al.* (2002) for 500.000 individuals in the United States to the European situation and calculates mortality for the population older than 30 years. Thus, the assessment in RAINS does not quantify infant mortality and thus underestimates overall effects. Awaiting results from the City-Delta project, the provisional estimates presented in this report assume PM2.5 concentrations originating from primary emissions in urban areas to be 25 percent higher than in the surrounding rural areas.

Table 3.1: Loss in statistical life expectancy that can be attributed to the identified anthropogenic contributions to PM2.5 (in months), for the emissions of the year 2000, the current legislation case of the "Climate policy" scenario in 2020 and the maximum feasible reduction case for 2020. Calculation results for the meteorological conditions of 1997. Provisional calculations based on generic assumptions on urban increments in PM2.5, awaiting City-Delta results.

	2000	*Current legislation 2020*	*Maximum feasible reduction 2020*
Austria	8.1	4.4	2.4
Belgium	14.9	9.3	5.5
Czech Rep.	10.4	5.0	2.5
Denmark	6.8	4.6	2.5
Estonia	3.7	2.9	1.3
Finland	2.6	2.0	0.9
France	9.3	5.3	2.7
Germany	10.7	6.3	3.6
Greece	7.0	4.5	1.6
Hungary	12.5	6.4	2.3
Ireland	4.6	3.0	1.8
Italy	9.1	5.0	2.2
Latvia	4.4	3.1	1.2
Lithuania	6.2	4.3	1.7
Luxembourg	11.0	6.4	3.5
Malta	7.4	6.7	3.9
Netherlands	13.4	9.2	5.7
Poland	10.8	5.8	2.6
Portugal	5.4	3.3	1.8
Slovakia	10.6	5.4	2.2
Slovenia	9.5	5.1	2.1
Spain	5.4	3.1	1.6
Sweden	3.9	2.8	1.5
UK	7.6	4.9	2.8
Total EU-15	8.7	5.2	2.8
Total NMS	10.3	5.5	2.4
Total EU-25	9.0	5.3	2.7

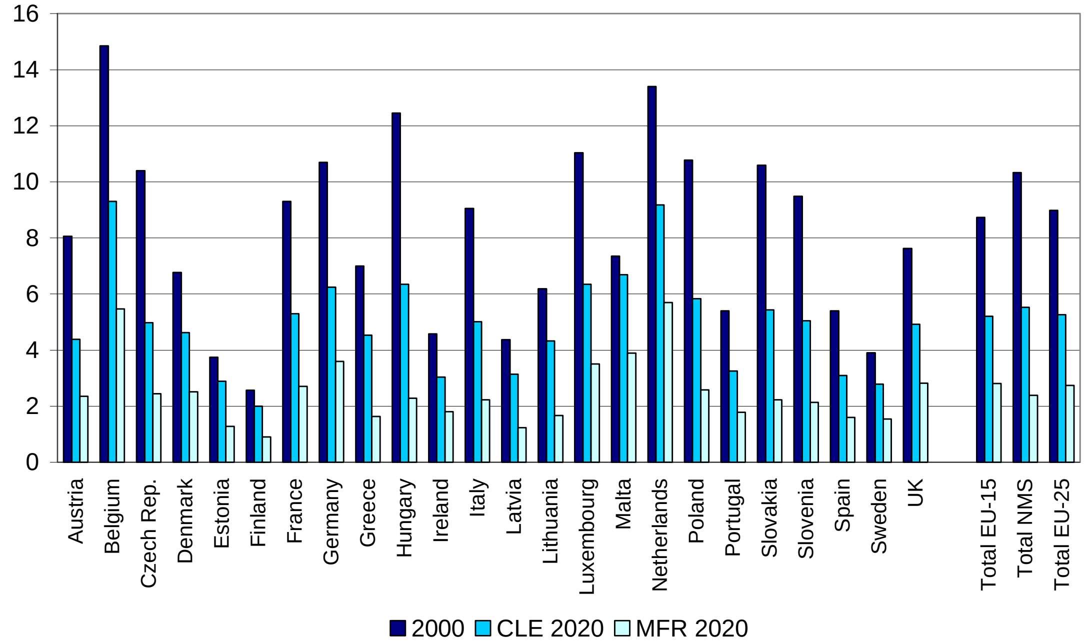

Figure 3.2: Loss in statistical life expectancy that can be attributed to the identified anthropogenic contributions to PM2.5 (in months), for the emissions of the year 2000, the current legislation case of the "Climate policy" scenario in 2020 and the maximum feasible reduction case for 2020. Calculation results for the meteorological conditions of 1997. Provisional calculations based on generic assumptions on urban increments in PM2.5, awaiting City-Delta results.

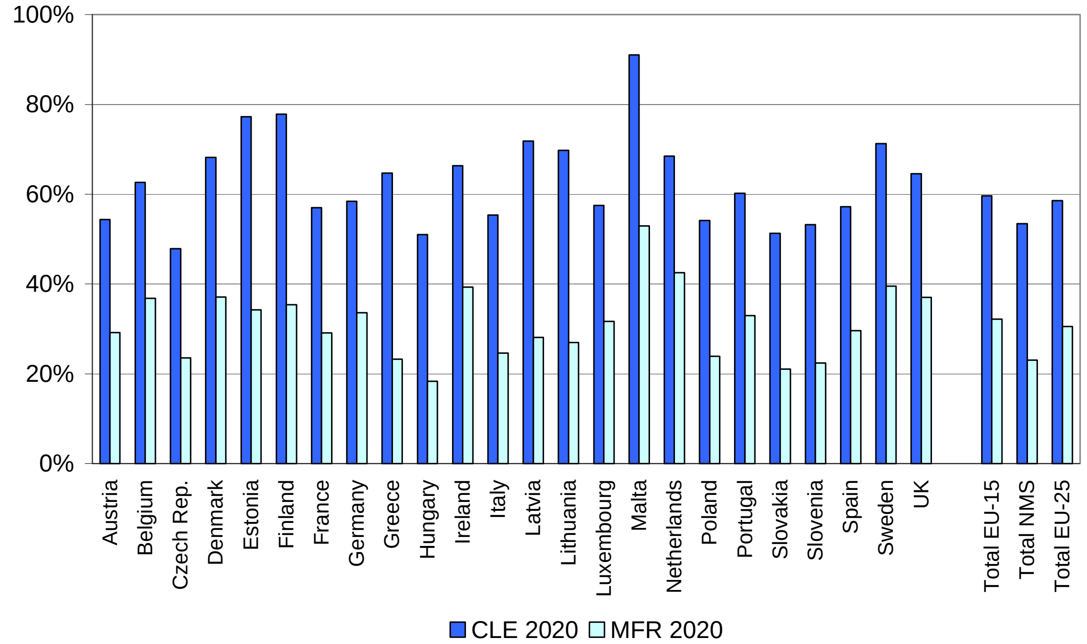

Figure 3.3: Remaining "gap" in life expectancy losses of the CLE and MFR scenarios (loss in 2000 = 100% gap)

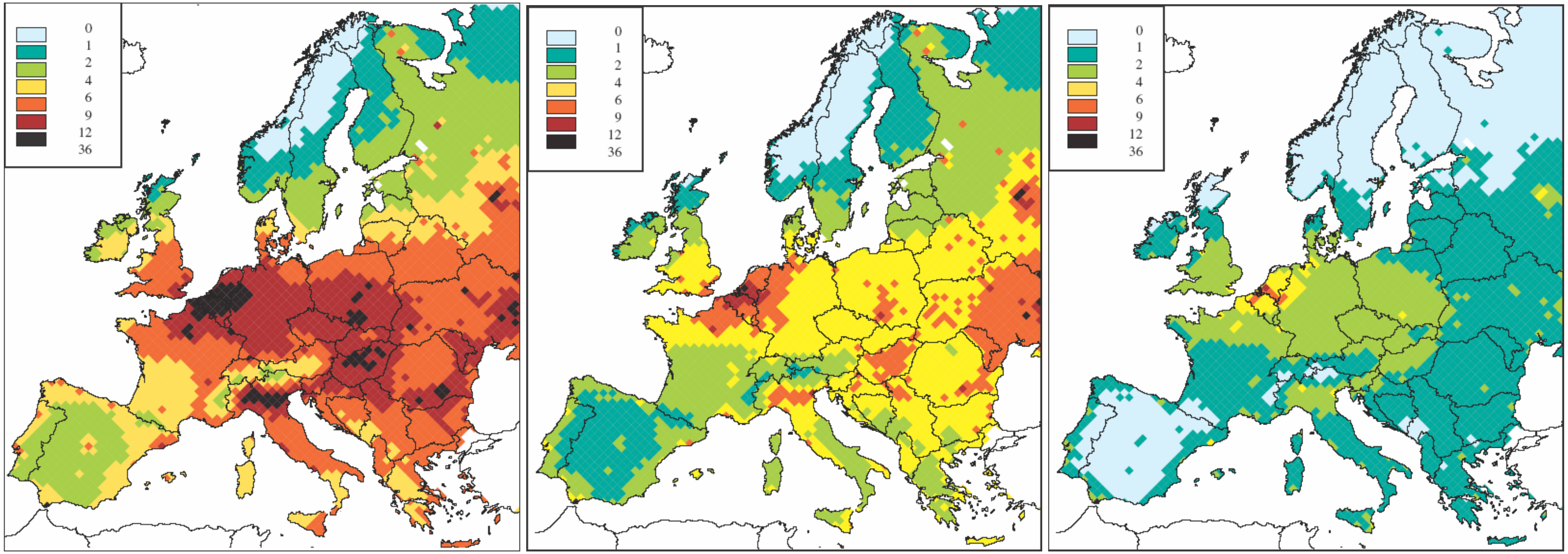

Figure 3.4: Loss in statistical life expectancy that can be attributed to the identified anthropogenic contributions to PM2.5 (in months), for the emissions of the year 2000 (left panel), the current legislation case of the "Climate policy" scenario in 2020 (centre panel) and the maximum feasible reduction case for 2020 (right panel). Calculation results for the meteorological conditions of 1997. Provisional calculations based on generic assumptions on urban increments in PM2.5, awaiting City-Delta results.

3.3 Premature deaths attributable to the exposure to ground-level ozone

The joint WHO/UNECE Task Force at its 7th Meeting developed specific recommendations concerning the inclusion of ozone-related mortality into RAINS. Key points of these recommendations are summarised below:

- The relevant health endpoint is mortality, even though several effects of ozone on morbidity are also well documented and causality established; however, available input data (e.g., on base rates) to calculate the latter on a European scale are often either lacking or not comparable.
- The relative risk for all-cause mortality is taken from the recent meta-analysis of European time-series studies, which was commissioned by WHO and performed by a group of experts of St. George's Hospital in London, UK (WHO, 2004). The relative risk taken from this study is 1.003 for a 10 µg/m^3 increase in the daily maximum 8-hour mean (CI 1.001 and 1.004).
- In agreement with the recent findings of the WHO Systematic Review, a linear concentration-response function is applied.
- The effects of ozone on mortality are calculated from the daily maximum 8-hour mean. This is in line with the health studies used to derive the summary estimate used for the meta-analysis mentioned above.
- Even though current evidence was insufficient to derive a level below which ozone has no effect on mortality, a cut-off at 35 ppb, considered as a daily maximum 8-hour mean ozone concentration, is used. This means that for days with ozone concentration above 35 ppb as maximum 8-hour mean, only the increment exceeding 35 ppb is used to calculate effects. No effects of ozone on health are calculated on days below 35 ppb as maximum 8-hour mean. This exposure parameter is called SOMO35 (sum of means over 35) and is the sum of excess of daily maximum 8-h means over the cut-off of 35 ppb calculated for all days in a year. This is illustrated in the following figure.

The Eulerian EMEP model has been used to calculate the SOMO35 exposure indicator referred to above for the baseline emission projections. RAINS applies the SOMO35 based methodology to quantify the changes in premature mortality that are attributable to the projected reductions in ozone precursor emissions. However, these estimates are loaded with considerable uncertainties of different types, and further analysis is necessary to explore the robustness of these figures. In particular, these numbers are derived from time series studies assessing the impacts of daily changes in ozone levels on daily mortality rates. By their nature, such studies cannot provide any indication on how much the deaths have been brought forward, and some of these deaths are considered as "harvesting effects" followed by reduced mortality few days later. At present it is not possible to quantify the importance of this effect for these estimates. Also the influence of the selected cut-off value (35 ppb) on the outcome needs to be further explored in the future.

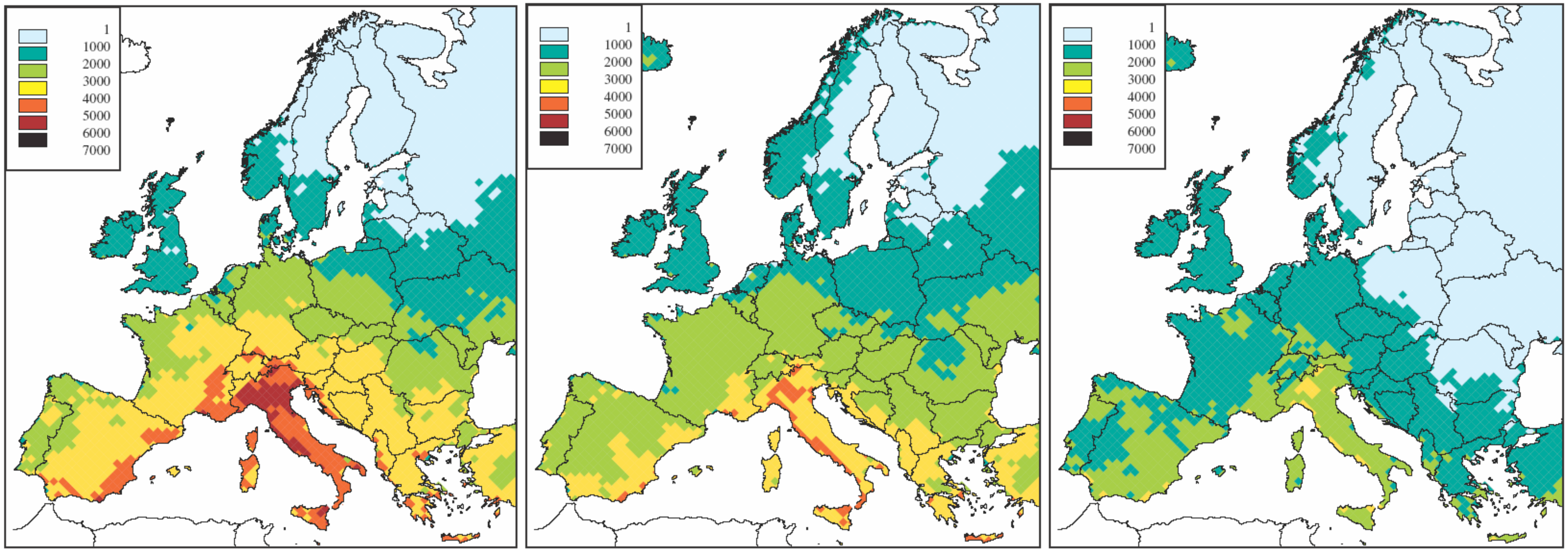

Figure 3.5: Grid-average ozone concentrations expressed as SOMO35 for the year 2000 (left panel), the current legislation case of the “Climate policy” scenario in 2020 (centre panel) and the maximum feasible reduction case for 2020 (right panel), in ppb.days. Calculation results for the meteorological conditions of 1997.

Table 3.2: Provisional estimates of premature mortality attributable to ozone for the "no further climate measures" CAFE baseline scenario (cases of premature deaths per year). These calculations are based on regional scale ozone calculations (50*50 km) and apply the meteorological conditions of 1997. No estimates have been performed for Cyprus and Malta.

	2000	*CLE 2020*	*MFR 2020*
Austria	422	316	220
Belgium	381	340	309
Denmark	179	160	126
Finland	58	60	39
France	2663	2180	1655
Germany	4258	3306	2535
Greece	627	567	334
Ireland	74	80	68
Italy	4507	3581	2583
Luxembourg	31	26	20
Netherlands	416	362	336
Portugal	450	443	350
Spain	2002	1705	1271
Sweden	197	189	135
UK	1423	1698	1554
Total EU-15	18110	15307	11711
Czech Rep.	535	390	257
Estonia	21	22	13
Hungary	748	574	300
Latvia	65	66	35
Lithuania	66	65	29
Poland	1399	1117	609
Slovakia	239	177	99
Slovenia	112	82	52
Total NMS	3215	2516	1418
Total	21429	17938	13288

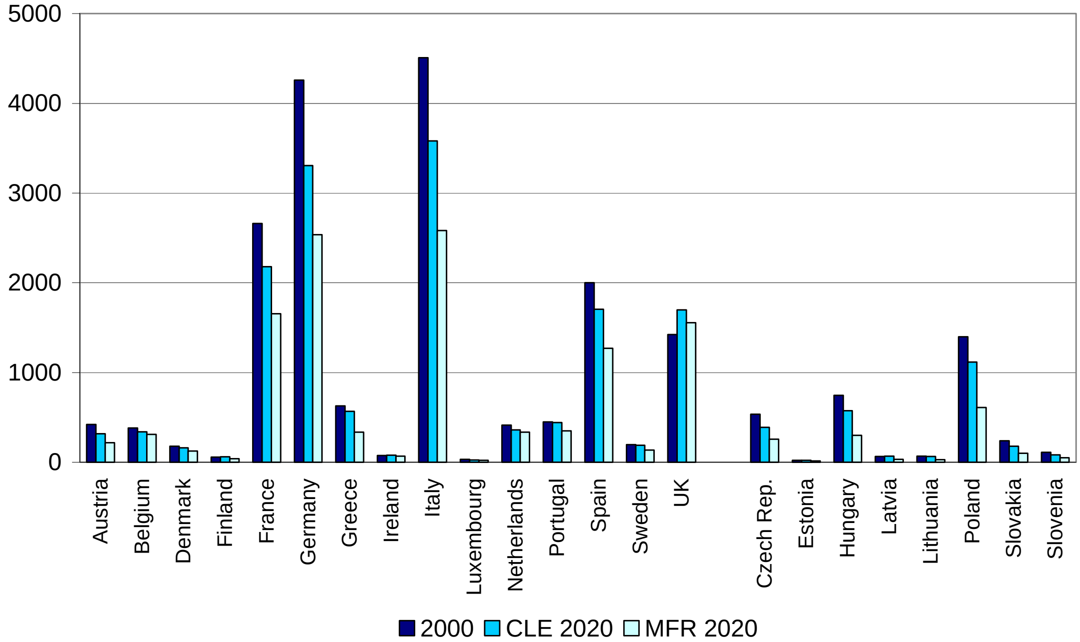

Figure 3.6: Provisional estimates of premature mortality attributable to ozone for the "no further climate measures" CAFE baseline scenario (cases of premature deaths per year). These calculations are based on regional scale ozone calculations (50*50 km) and apply the meteorological conditions of 1997. No estimates have been performed for Cyprus and Malta.

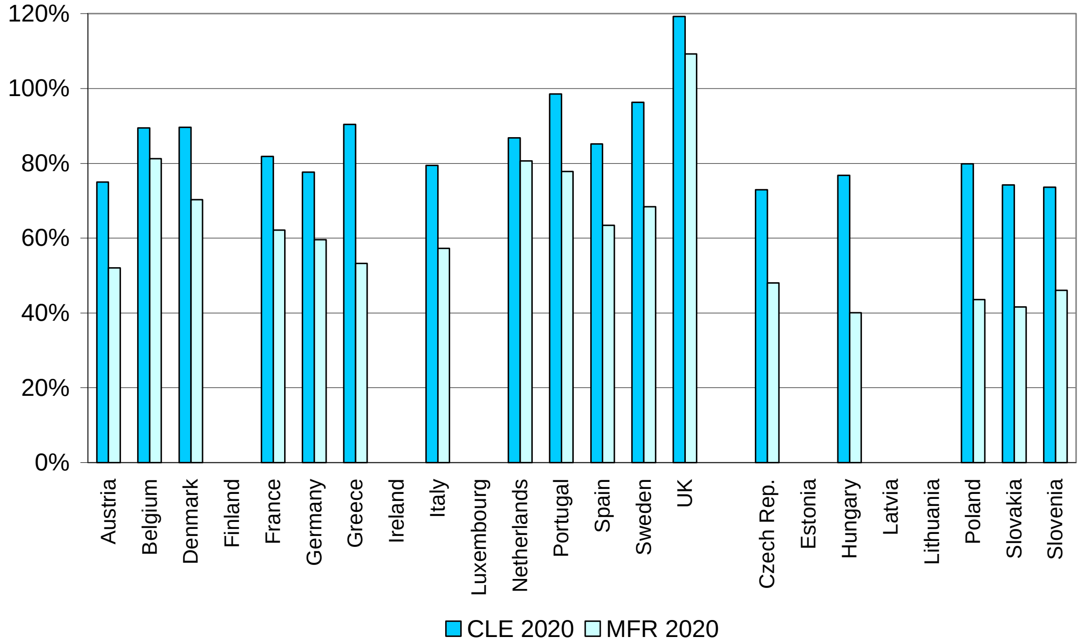

Figure 3.7: Remaining "gaps" in premature deaths attributable to ozone of the CLE and MFR scenarios (loss in 2000 = 100% gap)

3.4 Vegetation damage from ground-level ozone

The RAINS model applies the concept of critical levels to quantify progress towards the environmental long-term target of full protection of vegetation from ozone damage. At the UNECE workshop in Gothenburg in November 2002 (Karlsson *et al.*, 2003) it was concluded that the effective ozone dose, based on the flux of ozone into the leaves through the stomatal pores, represents the most appropriate approach for setting future ozone critical levels for forest trees. However, uncertainties in the development and application of flux-based approaches to setting critical levels for forest trees are at present too large to justify their application as a standard risk assessment method at a European scale.

Consequently, the UNECE Working Group on Effects retains in its Mapping Manual the AOT40 (accumulated ozone over a threshold of 40 ppb) approach as the recommended method for integrated risk assessment for forest trees, until the ozone flux approach will be sufficiently refined. However, such AOT40 measures are not considered suitable for quantifying vegetation damage, but can only be used as indicators for quantifying progress towards the environmental long-term targets.

The Mapping Manual defines critical levels for crops, forests and semi-natural vegetation in terms of different levels of AOT40, measured over different time spans. From earlier analysis of ozone time series for various parts of Europe, the critical level for forest trees (5 ppm.hours over the full vegetation period, April 1- September 30 is recommended as default) appears as the most stringent constraint. For most parts of Europe, the other critical levels will be automatically achieved if the 5 ppm.hours over six months condition is satisfied. Thus, if used for setting environmental targets for emission reduction strategies, the critical levels for forest trees would imply protection of the other receptors.

Figure 3.8 presents the evolution of the excess ozone that is considered harmful for forest trees, using the AOT40 (accumulated ozone over a threshold of 40 ppb) as a metric. The updated manual for critical levels (UNECE, 2004) specifies a no-effect critical level of 5 ppm.hours for trees. Related to this quantity, significant excess ozone is calculated for 2000 for large parts of the European Union. Baseline emission reductions will improve the situation, but will not be sufficient to eliminate the risk even by 2020.

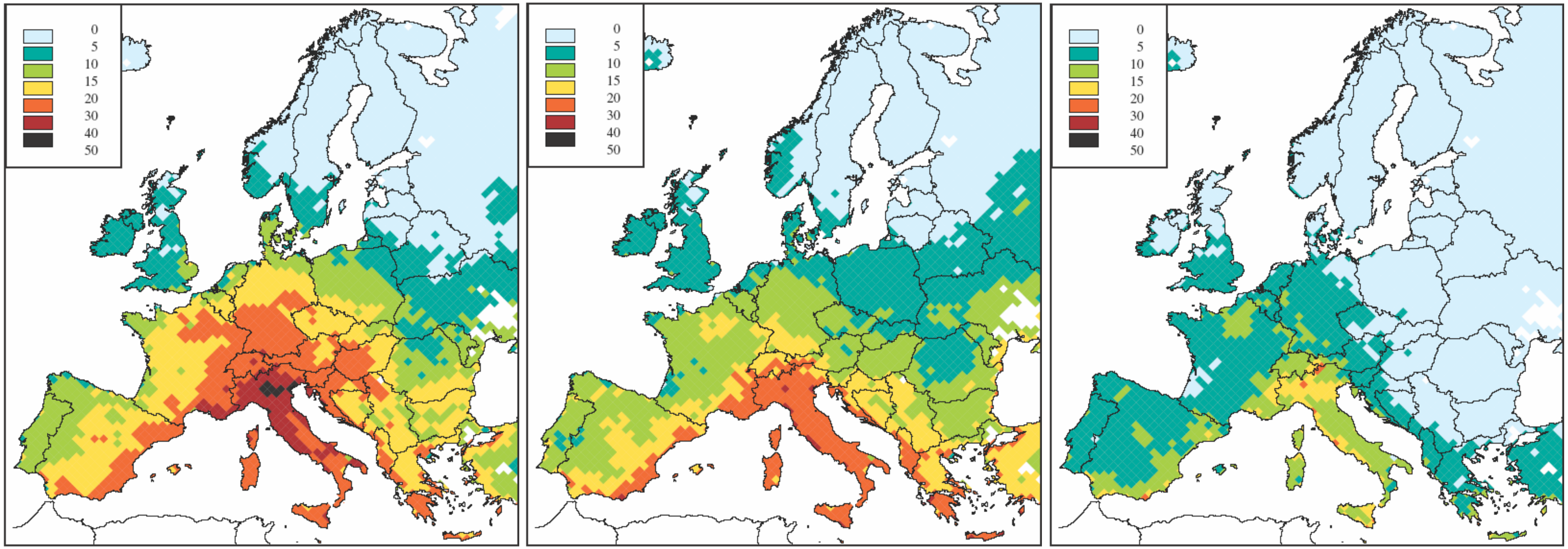

Figure 3.8: AOT40 for the year 2000 (left panel), the current legislation case of the "Climate policy" scenario in 2020 (centre panel) and the maximum feasible reduction case for 2020 (right panel), in ppm.hours. Calculation results for the meteorological conditions of 1997. The critical level for forests is set at 5 ppm.hours.

3.5 Acid deposition to forest ecosystems

RAINS used the concept of critical loads as a quantitative indicator for sustainable levels of sulphur and nitrogen deposition. The analysis using is based on the critical loads databases compiled by the Coordination Centre on Effects under the UNECE Working Group on Effects. This database combines quality-controlled critical loads estimates of the national focal centres for more than 1.6 million ecosystems (Posch *et al*., 2004). National focal centres have selected a variety of ecosystem types as receptors for calculating and mapping critical loads. For most ecosystem types (e.g., forests), critical loads are calculated for both acidity and eutrophication. Other receptor types, such as streams and lakes, have only critical loads for acidity, on the assumption that eutrophication does not occur in these ecosystems. The RAINS analysis groups ecosystems into three classes (forests, semi-natural vegetation such as nature protection areas and freshwater bodies) and performs separate analyses for each class. The RAINS analysis compares for a given emission scenario the resulting deposition to these ecosystems with the critical loads and thus provides an indication to what extent the various types of ecosystems are still at risk of acidification. This indicator cannot be directly interpreted as the actual damage occurring at such ecosystems. To derive damage estimates, the historic rate of acid deposition as well as dynamic chemical processes in soils and lakes need to be considered, which can lead to substantial delays in the occurrence of acidification as well as in the recovery from acidification.

Table 3.3: Percentage of forest area receiving acid deposition above the critical loads for the baseline emissions for 2000, the current legislation case of the “Climate policy” scenario in 2020 and the maximum feasible reduction case for 2020. Calculation results for the meteorological conditions of 1997, using ecosystem-specific deposition for forests. Critical loads data base of 2004.

	2000	*CLE*	*MFR*
Austria	15.2	5.0	0.5
Belgium	55.4	31.6	13.3
Denmark	31.8	8.5	0.3
Finland	1.6	1.5	0.4
France	12.4	4.8	0.7
Germany	72.3	41.6	12.9
Greece	0.6	0.0	0.0
Ireland	47.0	19.2	9.1
Italy	2.3	1.0	0.3
Luxembourg	35.1	11.6	0.0
Netherlands	88.3	80.4	52.3
Portugal	2.6	0.2	0.0
Spain	1.0	0.0	0.0
Sweden	23.7	18.7	8.4
UK	49.0	17.6	6.0
Total EU-15	17.7	10.5	3.7
Czech Rep.	80.8	42.0	1.8
Estonia	0.3	0.0	0.0
Hungary	3.9	1.5	0.0
Latvia	0.6	0.5	0.0
Lithuania	2.9	1.0	0.0
Poland	59.0	21.8	0.2
Slovakia	22.7	7.7	0.4
Slovenia	2.8	0.1	0.0
Total NMS	35.7	14.2	0.3
Total EU-25	20.8	11.1	3.1

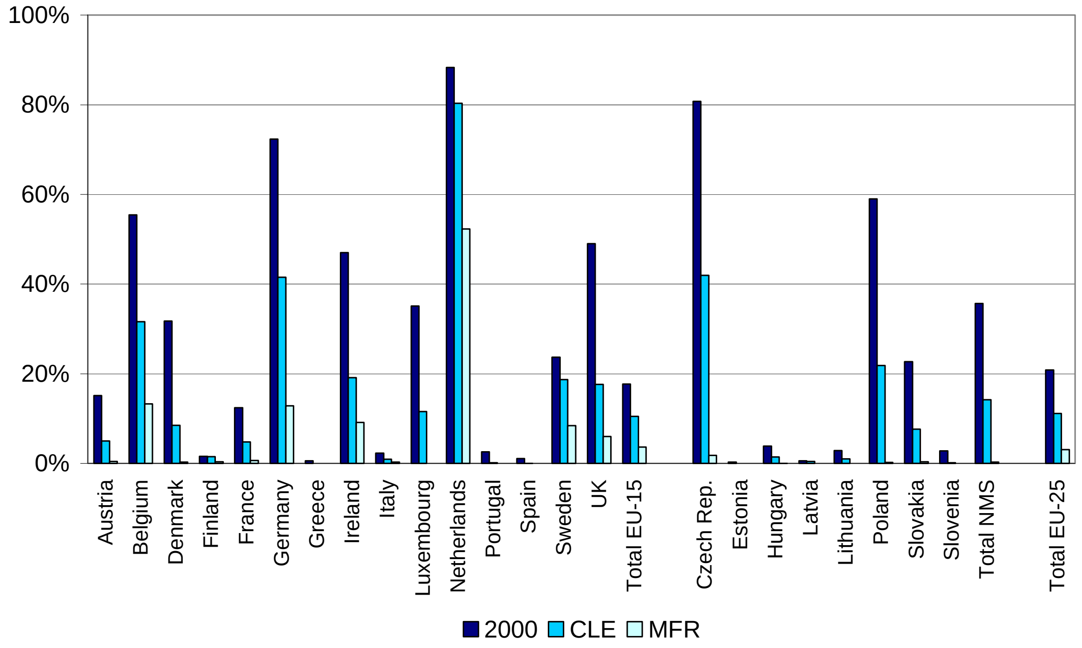

Figure 3.9: Percentage of forest area receiving acid deposition above the critical loads for the baseline emissions for 2000, the current legislation case of the "Climate policy" scenario in 2020 and the maximum feasible reduction case for 2020. Calculation results for the meteorological conditions of 1997, using ecosystem-specific deposition for forests. Critical loads data base of 2004.

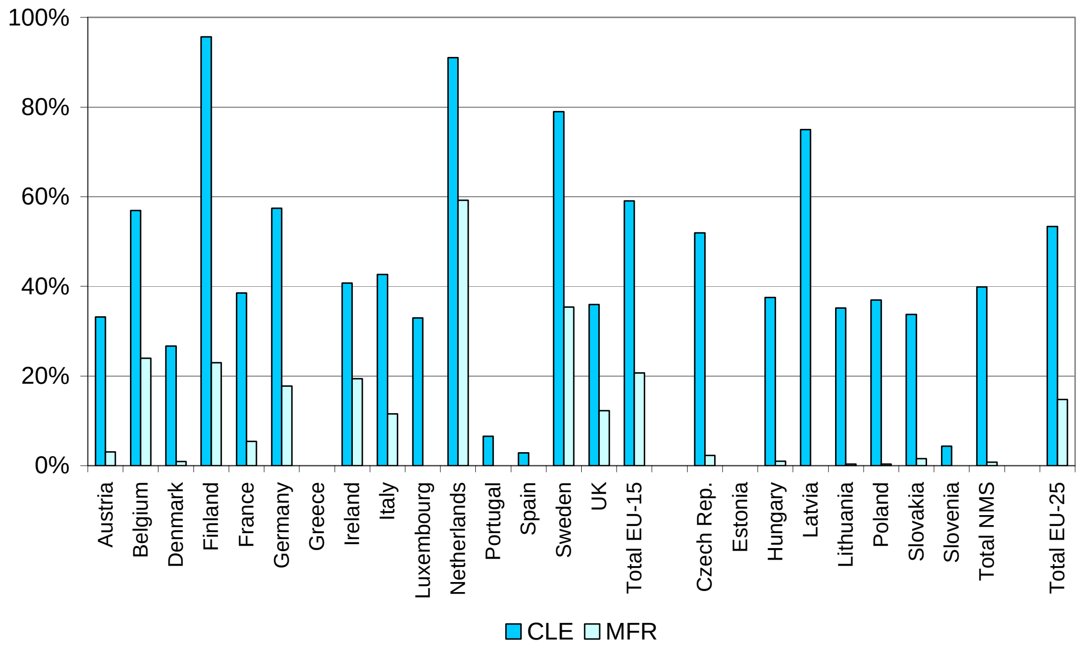

Figure 3.10: Remaining "gaps" in unprotected forest ecosystems of the CLE and MFR scenario related to the situation in 2000 (2000 = 100% gap)

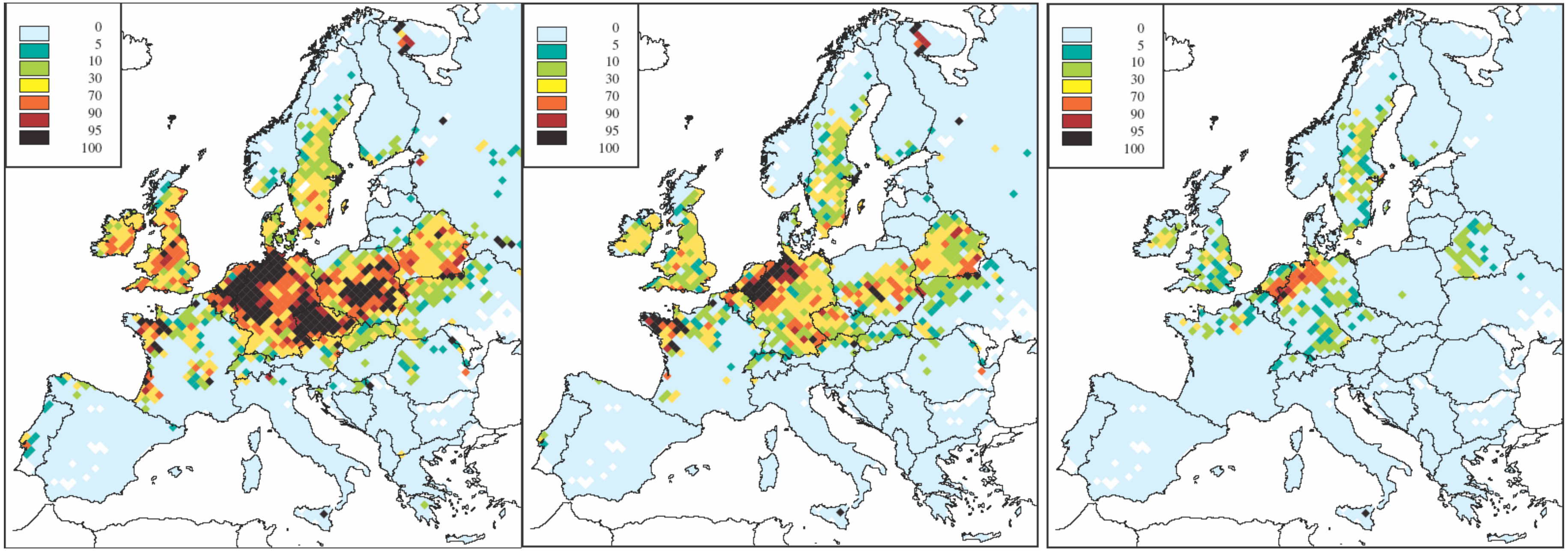

Figure 3.11: Percentage of forest area receiving acid deposition above the critical loads for the baseline emissions for 2000 (left panel), the current legislation case of the “Climate policy” scenario in 2020 (centre panel) and the maximum feasible reduction case for 2020 (right panel). Calculation results for the meteorological conditions of 1997, using ecosystem-specific deposition for forests. Critical loads data base of 2004.

3.6 Acid deposition to semi-natural ecosystems

A number of countries have provided estimates of critical loads for so-called "semi-natural" ecosystems. This group typically contains nature and landscape protection areas, many of them designated as "Natura2000" areas of the EU Habitat directive. While this group of ecosystems includes open land and forest areas, RAINS uses as a conservative estimate grid-average deposition rates for the comparison with critical loads, which systematically underestimates deposition for forested land.

Table 3.4: Area with semi-natural ecosystems with acid deposition above critical loads (in km^2) for the "no further climate measures" scenario. The analysis reflects average meteorological conditions of 1997

	Percent of semi-natural ecosystems area			*Semi-natural ecosystems area with acid deposition above critical loads*		
	2000	*CLE 2020*	*MFR 2020*	*2000*	*CLE 2010*	*MFR 2020*
France	37.6	9.0	0.6	376032	90328	6008
Germany	68.1	40.9	11.3	268750	161487	44752
Ireland	10.3	2.3	0.4	47429	10786	1982
Italy	0.0	0.0	0.0	261	0	0
Netherlands	63.0	47.8	17.8	81711	61970	23111
UK	30.8	9.3	1.3	1528760	459721	65106
Total	24.1	8.2	1.5	2302941	784291	140960

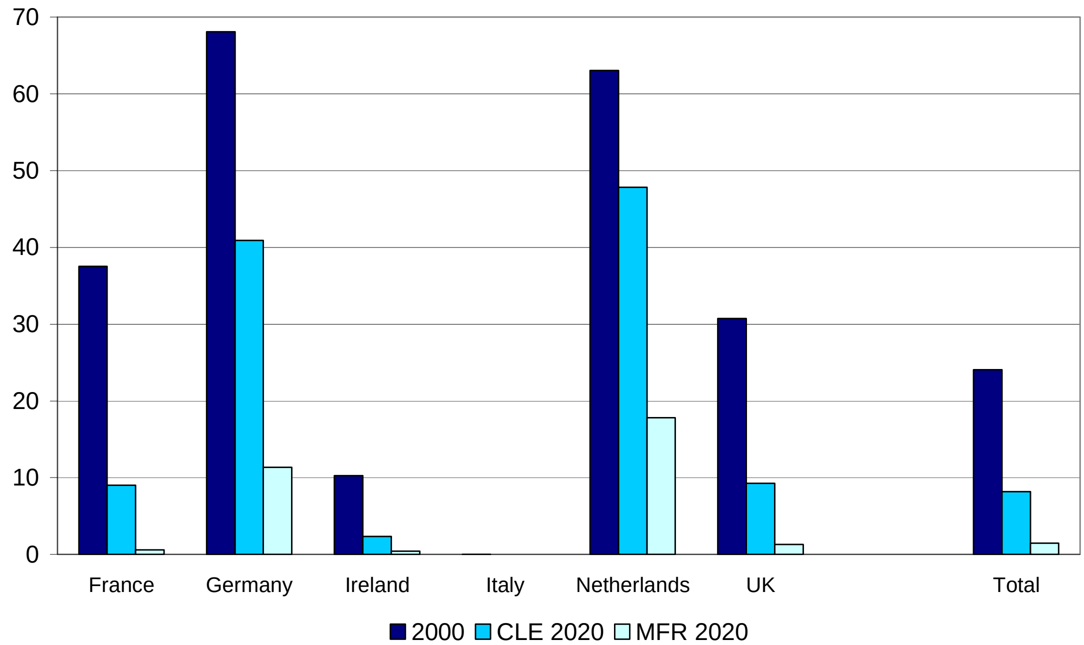

Figure 3.12: Percentage of the area of semi-natural ecosystems receiving acid deposition above the critical loads, for the baseline emissions for 2000, the CLE case in 2020 and the MFR case for 2020. Calculation results for the meteorological conditions of 1997, using grid-average deposition.

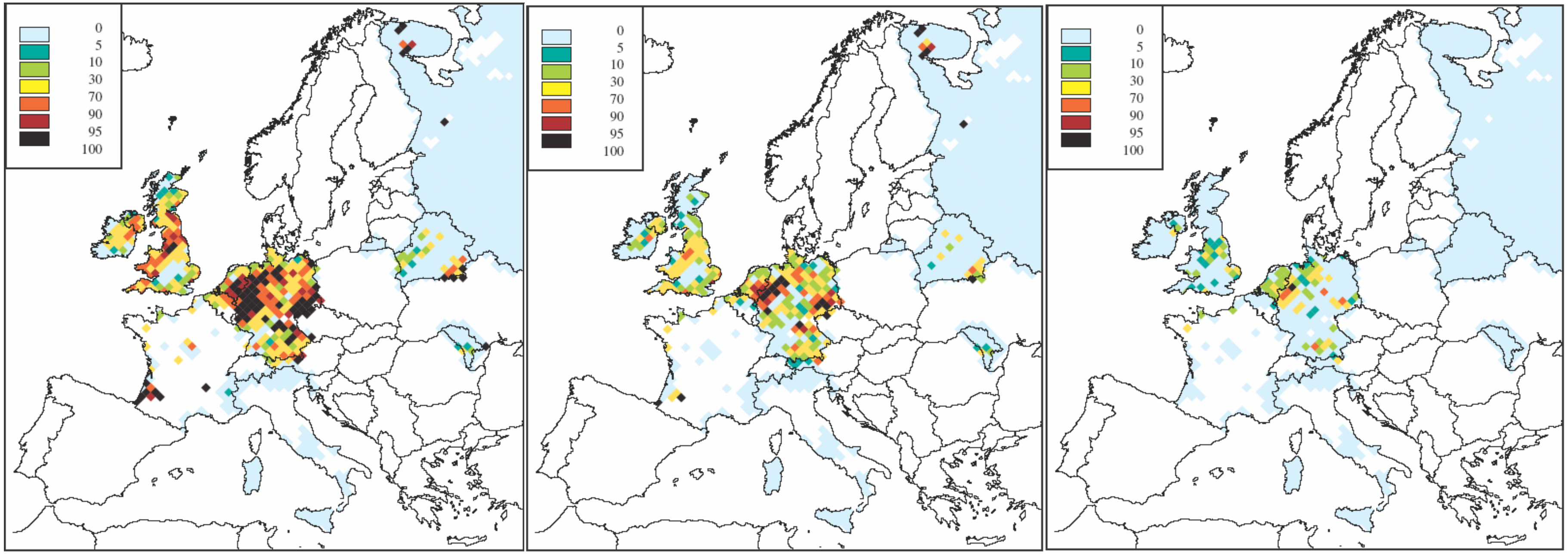

Figure 3.13: Percentage of the area of semi-natural ecosystems receiving acid deposition above the critical loads, for the baseline emissions for 2000 (left panel), the current legislation case of the "Climate policy" scenario in 2020 (centre panel) and the maximum feasible reduction case for 2020 (right panel). Calculation results for the meteorological conditions of 1997, using grid-average deposition. Critical loads data base of 2004. For areas shown in white no critical loads estimates have been provided.

3.7 Acid deposition to freshwater bodies

In a number of countries critical loads have been estimated for the catchments areas of freshwater bodies (lakes and streams), which experienced significant acidification in the past. The baseline emission projections suggest a significant decline of acid deposition at many of these catchments areas, in many cases even below their critical loads. As indicated above, recovery from acidification requires acid deposition to stay some time below the critical loads.

Table 3.5: Percentage of freshwater ecosystems area receiving acid deposition above the critical loads for the baseline emissions for 2000, the current legislation case of the "Climate policy" scenario in 2020 and the maximum feasible reduction case for 2020. Calculation results for the meteorological conditions of 1997, using grid-average deposition. Critical loads data base of 2004.

	2000	*CLE*	*MFR*
Finland	0.7	0.7	0.2
Sweden	14.9	10.5	5.2
UK	8.1	3.7	1.3

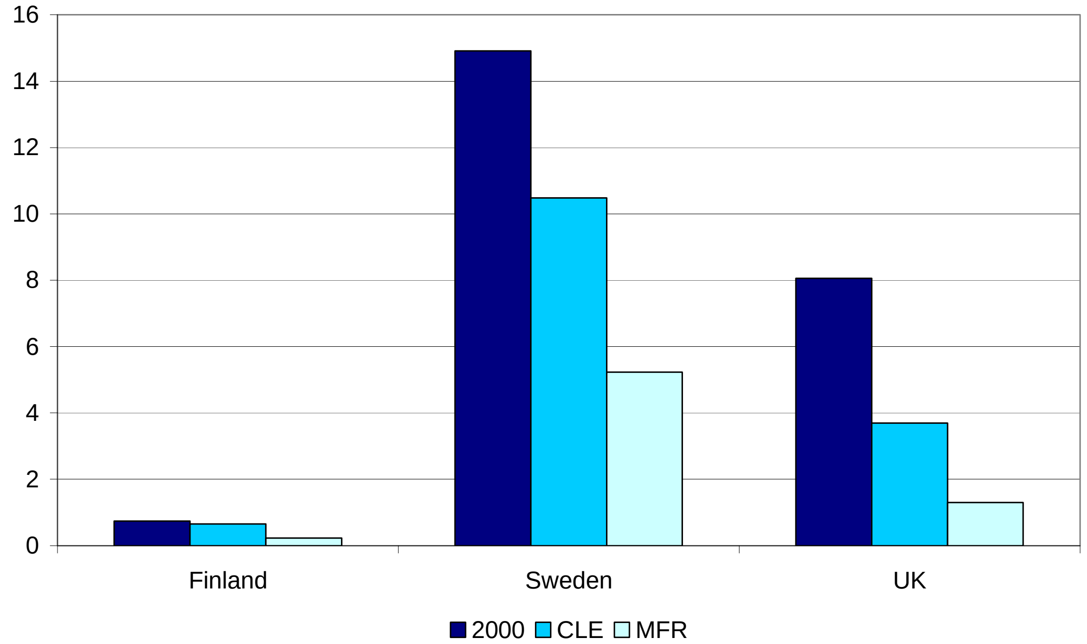

Figure 3.14: Percentage of freshwater ecosystems area receiving acid deposition above the critical loads for the baseline emissions for 2000, the current legislation case of the "Climate policy" scenario in 2020 and the maximum feasible reduction case for 2020. Calculation results for the meteorological conditions of 1997, using grid-average deposition. Critical loads data base of 2004.

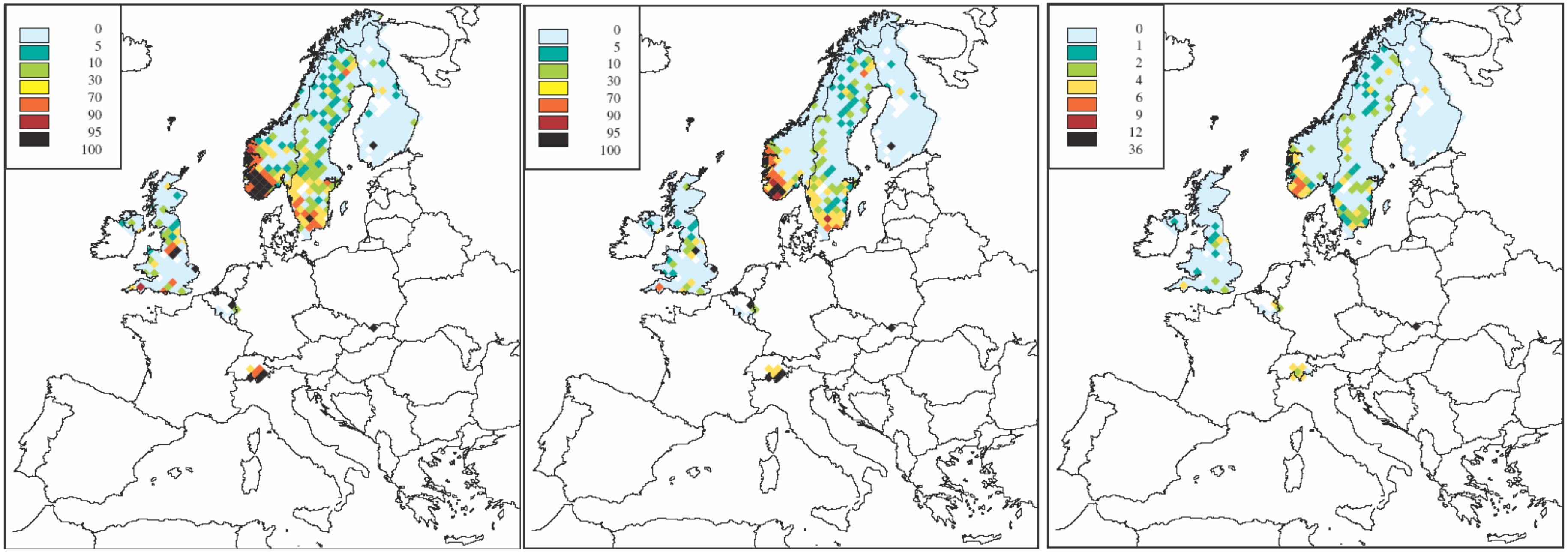

Figure 3.15: Percentage of freshwater ecosystems area receiving acid deposition above the critical loads for the baseline emissions for 2000 (left panel), the current legislation case of the “Climate policy” scenario in 2020 (centre panel) and the maximum feasible reduction case for 2020 (right panel). Calculation results for the meteorological conditions of 1997, using grid-average deposition. Critical loads data base of 2004. For areas shown in white no critical loads estimates have been provided.

3.8 Excess nitrogen deposition

Excess nitrogen deposition poses a threat to a wide range of ecosystems endangering their bio-diversities through changes in the plant communities. Critical loads indicating the maximum level of nitrogen deposition that can be absorbed by ecosystems without eutrophication have been estimated throughout Europe. As a conservative estimate, the assessment presented in this report uses grid-average deposition for all ecosystems, resulting in a systematic underestimate of nitrogen deposition to forests.

Table 3.6: Percentage of total ecosystems area receiving nitrogen deposition above the critical loads for eutrophication for the baseline emissions for 2000, the current legislation case of the "Climate policy" scenario in 2020 and the maximum feasible reduction case for 2020. Calculation results for the meteorological conditions of 1997, using grid-average deposition. Critical loads data base of 2004.

	2020	*CLE 2020*	*MFR 2020*
Austria	96.0	86.4	52.9
Belgium	92.7	60.8	23.3
Denmark	52.7	37.2	0.8
Finland	25.1	14.4	0.0
France	95.8	79.1	20.2
Germany	96.2	94.4	85.5
Greece	75.8	72.9	2.0
Ireland	11.6	3.3	0.0
Italy	62.3	47.7	12.8
Luxembourg	96.4	82.1	39.6
Netherlands	66.5	60.8	26.7
Portugal	29.7	12.0	0.0
Spain	64.6	50.1	6.7
Sweden	26.1	16.1	0.6
UK	13.3	5.5	0.0
Total EU-15	54.3	43.0	16.0
Czech Rep.	95.2	76.6	11.9
Estonia	11.7	5.8	0.0
Hungary	30.7	24.4	4.6
Latvia	54.3	38.0	0.5
Lithuania	85.0	80.8	4.4
Poland	86.0	78.8	17.8
Slovakia	88.8	60.2	4.4
Slovenia	94.3	88.0	20.8
Total NMS	71.2	60.3	10.1
Total EU-25	57.1	45.9	15.1

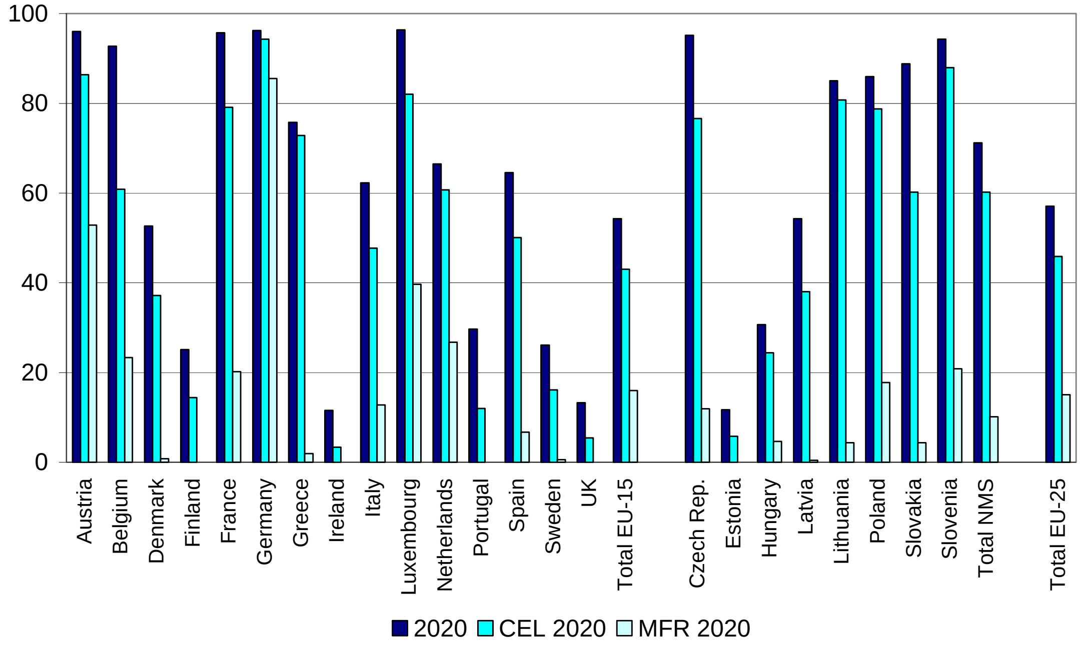

Figure 3.16: Percentage of total ecosystems area receiving nitrogen deposition above the critical loads for eutrophication for the baseline emissions for 2000, the current legislation case of the "Climate policy" scenario in 2020 and the maximum feasible reduction case for 2020. Calculation results for the meteorological conditions of 1997, using grid-average deposition. Critical loads data base of 2004.

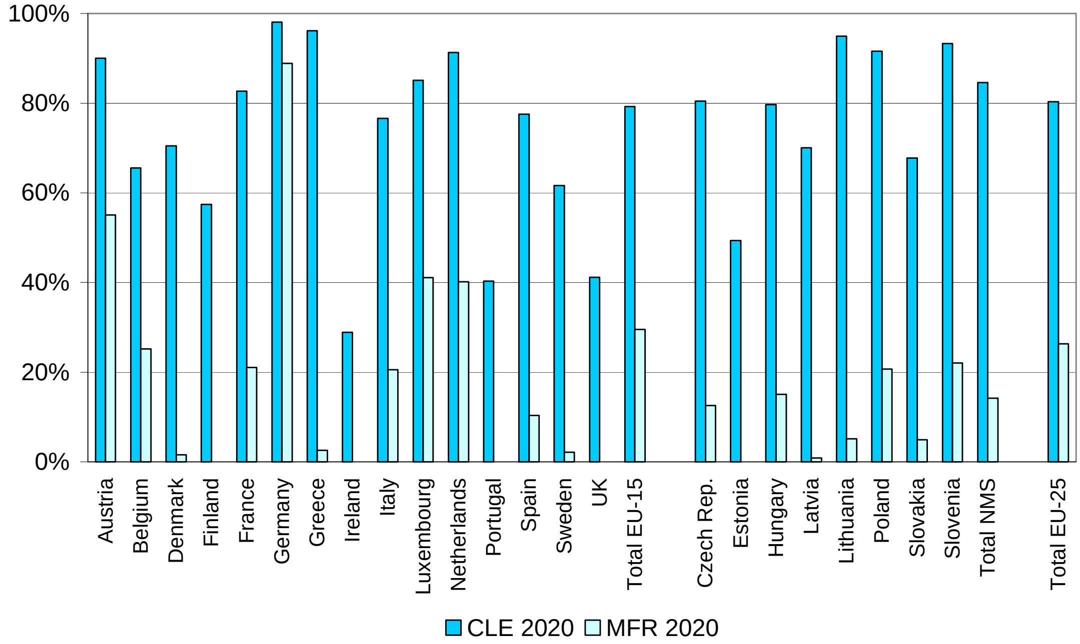

Figure 3.17: Remaining "gaps" for excess nitrogen deposition of the CLE and MFR scenario related to the situation in 2000 (2000 = 100% gap)

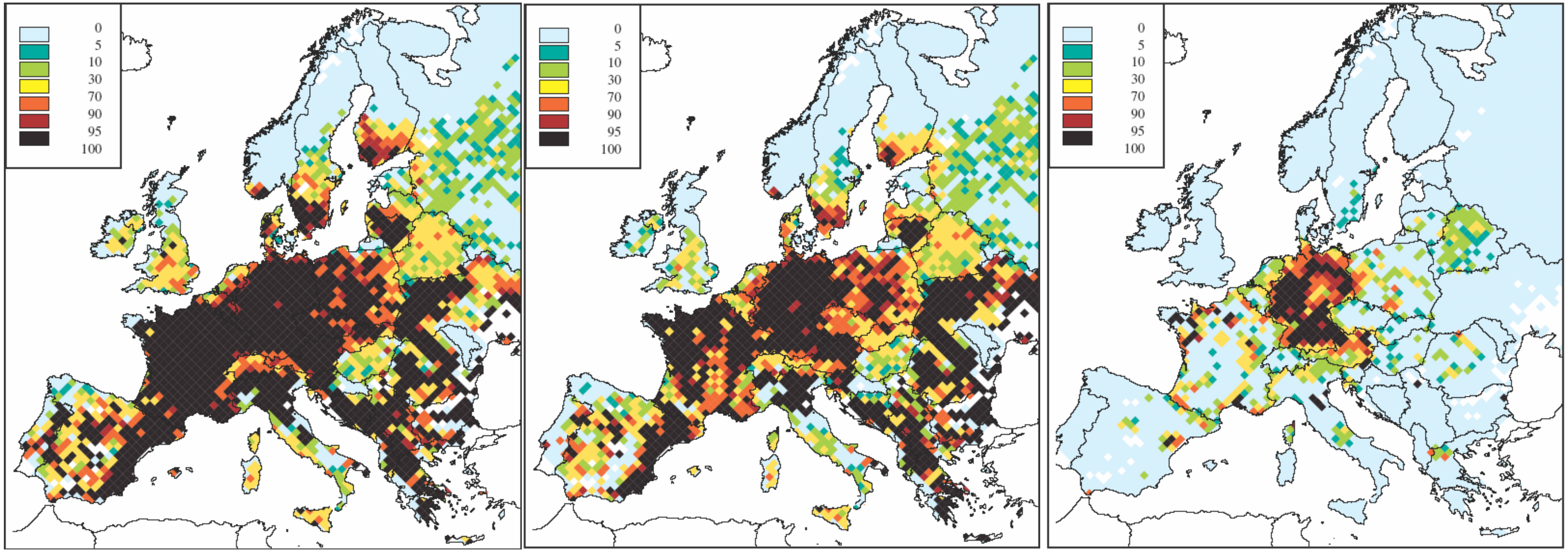

Figure 3.18: Percentage of total ecosystems area receiving nitrogen deposition above the critical loads for eutrophication for the baseline emissions for 2000 (left panel), the current legislation case of the “Climate policy” scenario in 2020 (centre panel) and the maximum feasible reduction case for 2020 (right panel). Calculation results for the meteorological conditions of 1997, using grid-average deposition. Critical loads data base of 2004. For areas shown in white no critical loads estimates have been provided.

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