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Final Report

FURTHER ANALYSIS OF SCENARIO RESULTS OBTAINED WITH THE RAINS MODEL

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1 Work Element 1: Further Analysis of Model Results

Work element 1 of the study carried out for the French Ministry of the Environment conducts an in-depth analysis of scenario results presented in earlier reports of IIASA to the European Commission (Amann *et al.*, 1999a) and to the UN/ECE Task Force on Integrated Assessment Modelling (Amann *et al.*, 1999b). A previous report (Amann *et al.,* 1999e) to the French Ministry of the Environment provided detailed information on the Reference scenario and scenarios H1, H6/2, J1 and J1/S1. The present report gives further sectoral details of the H1 scenario relevant to France.

Table 1.1 provides information on the sectoral emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOC), and ammonia (NH_3) for the reference (REF) and H1 scenarios for France. This table is prepared in the same fashion as tables presented in section 1.3.3 in the previous report (Amann *et al.,* 1999e) and can be directly compared.

Table 1.2 - Table 1.5 include lists of options taken in France to achieve emission reductions of SO_2, NH_3, NO_x and VOC necessary in the H1 scenario. These tables are complementary to the tables included in section 1.2.4 in the previous report (Amann *et al.*, 1999e) as they give full names of options as well as their 'application level' called *percentage applied.* Similar tables were presented in the previous report for REF (see Annex 1 to 4 in Amann *et al.,* 1999e).

For SO_2 and NO_x the *percentage applied* refers to the capacity on which a given technique is applied. However, for ammonia and VOC this number should be interpreted as the percentage of the maximum potential for a given option. Interpretation of this number as a capacity share becomes rather more difficult when combinations of options are considered as they apply to several stages at which emissions occur (in the case of ammonia, for example). Let us take ammonia emissions from cattle as an example. Assume that the selected option is a combination of animal house adaptation (SA) and high efficiency, low ammonia application (LNA_{high}), and that its *percentage applied* shown in the equivalent to Table 1.3 would be 100 percent. It does not necessarily follow that this option will apply to all cattle. The proportion of cattle to which this option does apply will depend upon the assumed applicability rates for the components of the combination, namely SA and LNA_{high}. (The table with applicability rates for ammonia can be found on the RAINS web site - http://www.iiasa.ac.at/~rains - in the data set for France). These applicability rates can be, for example, 60 percent for SA and 90 percent for LNA_{high}. This would mean that animal house adaptation will be implemented for 60 percent of cattle in a given country, and manure excreted by 90 percent of cattle will be treated with a low ammonia option (for example manure injection).

Table 1.1: Sectoral emissions in France in 2010 for the REF and the H1 scenarios

		Emissions, kilotons		
Country	Sector	REF	H1	REF-H1
Sulphur dioxide (SO_2)	Power plants, of which:	30.7	21.2	9.5
	- existing plants	28.9	19.4	9.5
	- new plants	1.8	1.8	-
	Refineries, other conversion	45.5	26.0	19.5
	Industry, of which:	277.6	93.7	183.9
	- combustion installations	101.3	58.4	42.9
	- processes	176.3	35.3	141.0
	Domestic	60.6	51.4	9.2
	Transport, of which:	18.1	10.3	7.8
	- road	5.8	5.8	-
	- off-road	12.4	4.5	7.9
	Total	448.0	218.2	229.8
Nitrogen oxides (NO_x)	Power plants, of which:	20.1	8.8	11.3
	- existing plants	8.0	4.1	3.9
	- new plants	12.1	1.8	10.3
	Refineries, other conversion	18.2	6.6	11.6
	Industry, of which:	178.7	76.6	102.1
	- combustion installations	88.8	40.6	48.2
	- processes	89.9	35.9	54.0
	Domestic	103.5	87.8	15.7
	Transport, of which:	500.7	461.8	38.9
	- road	281.9	281.9	-
	- off-road	218.8	179.9	38.9
	Total	858.4	678.8	179.6
Volatile organic compounds (VOC)	Energy industry	9.4	9.4	-
	Fuel processing and distribution	149.8	96.2	53.7
	Chemical industry	41.7	27.7	14.0
	Solvent use in industry	206.3	130.0	76.3
	Paint use (excluding DIY)	192.4	135.0	57.4
	Other industry, waste	57.7	57.7	-
	Transport	340.5	274.4	66.1
	Domestic (including paint use-DIY)	224.2	200.8	23.4
	Agriculture	0.8	0.8	-
	Total	1222.8	932.0	290.8
Ammonia (NH_3)	Livestock	606.0	586.0	20.0
	Fertilizer use	144.0	104.5	39.5
	Industry	23.3	23.3	-
	Other	4.1	4.1	-
	Total	777.4	717.9	59.5

Table 1.2: SO_2 control measures for France in the H1 scenario

Fuel/activity	Sector	Technology	Percent applied H1	Percent applied REF
Brown coal/lignite	Refineries and other conversion	Wet flue gases desulphurisation	6	6
	Industry - combustion in boilers	Wet flue gases desulphurisation	6	6
	Industry - other combustion	Wet flue gases desulphurisation	6	6
	Power plants existing, other	Limestone injection	100	100
	Power plants, new	Wet flue gases desulphurisation	100	100
Coke and briquettes	Domestic	Low sulphur coke	100	-
Hard coal	Refineries and other conversion	Wet flue gases desulphurisation	90	-
		Low sulphur coal	10	16
	Domestic	Low sulphur coal	100	-
	Industry - combustion in boilers	Wet flue gases desulphurisation	29	2
		Low sulphur coal	71	16
	Industry - other combustion	Wet flue gases desulphurisation	90	2
		Low sulphur coal	10	16
	Power plants existing, other	Low sulphur coal	100	-
	Power plants, new	Wet flue gases desulphurisation	100	100
Heavy fuel oil	Refineries and other conversion	Low sulphur fuel oil	100	85
	Domestic	Low sulphur fuel oil	100	50
	Industry - combustion in boilers	Low sulphur fuel oil	100	85
	Industry - other combustion	Wet flue gases desulphurisation	90	-
		Low sulphur fuel oil	10	85
	Power plants existing, other	Low sulphur fuel oil	86	86
	Power plants, new	Wet flue gases desulphurisation	100	100
	Other transport - land based	Low sulphur fuel oil	86	86
	Other transport - maritime activities	Low sulphur fuel oil	100	-
Gas oil (diesel, light fuel oil)	Refineries and other conversion	Low sulphur gas oil - 0.2 % S	36	36
		Low sulphur gas oil - 0.05 % S	65	65
	Domestic	Low sulphur gas oil - 0.2 % S	36	36
		Low sulphur gas oil - 0.05 % S	65	65
	Industry - combustion in boilers	Low sulphur gas oil - 0.2 % S	36	36
		Low sulphur gas oil - 0.05 % S	65	65
	Industry - other combustion	Low sulphur gas oil - 0.2 % S	36	36
		Low sulphur gas oil - 0.05 % S	65	65
	Power plants existing, other	Low sulphur gas oil - 0.2 % S	36	36
		Low sulphur gas oil - 0.05 % S	65	65
	Power plants, new	Low sulphur gas oil - 0.2 % S	36	36
		Low sulphur gas oil - 0.05 % S	65	65
	Other transport - land based	Low sulphur gas oil - 0.005 % S	100	100
	Other transport - maritime activities	Low sulphur gas oil - 0.2 % S	100	-
	Road transport	Low sulphur gas oil - 0.005 % S	100	100
	Industry - process emissions	Stage 3 control	100	-

Table 1.3: NH_3 control measures for France in the H1 scenario

Sector	Technology	Percentage applied H1	Percentage applied REF
Fertiliser use - urea	Substitution of urea fertiliser	100	-
Laying hens	Low ammonia application - high efficiency	100	-
Other poultry	Animal house adaptation and low ammonia appl.	5	-
Other poultry	Low ammonia application - high efficiency	95	-

Table 1.4: NO_x control measures for France in the H1 scenario

Fuel/activity	Sector	Technology	Percentage applied H1	Percentage applied REF
Brown coal/lignite	Industry - combustion in boilers	Combustion modification	5	5
	Industry - other combustion	Combustion modification	5	5
	Power plants existing, other	Combustion modification	100	100
	Power plants, new	Selective catalytic reduction	50	50
	Refineries and other conversion	Combustion modification	5	5
Fuelwood and other low S solid	Industry - combustion in boilers	Combustion modification	100	-
	Power plants existing, other	Combustion modification	100	-
Gas oil (diesel, light fuel oil)	Domestic	Combustion modification - commercial boilers	100	-
	Industry - combustion in boilers	Combustion modification	100	-
	Industry - other combustion	Combustion modification	100	-
	Other transport - land based	Euro 1 (1992/93) standards	-	38
		Euro 2 (1995/96) standards	48	35
		Euro 4 (post-2005) standards	24	-
	Other transport - maritime activ. - large ships	Comb. modification + selective cat. reduction	25	-
	Other transport - maritime activ. - medium ships	Combustion modification	25	-
	Power plants existing, other	Combustion modification	100	-
	Refineries and other conversion	Combustion modification	100	-
	Road transp - cars and light duty vehic. 4-stroke	Euro 1 (1992/93) standards	4	4
		Euro 2 (1995/96) standards	20	20
		Euro 3 (2000) standards	36	36
		Euro 4 (post-2005) standards	36	36
	Road transp - heavy duty trucks and buses	Euro 2 (1995/96) standards	6	6
		Euro 3 (2000) standards	54	54
		Euro 4 (post-2005) standards	40	40
Hard coal	Industry - combustion in boilers	Combustion modification	-	16
		Comb. modification + selective non-cat. reduction	100	-
	Industry - other combustion	Combustion modification	-	16
		Comb. modification + selective cat. reduction	80	-
		Comb. modification + selective non-cat. reduction	20	-
	Power plants existing, other	Combustion modification	-	100
		Comb. modification + selective cat. reduction	100	-
	Power plants, new	Selective catalytic reduction	100	50
	Refineries and other conversion	Combustion modification	-	16
		Comb. modification + selective cat. reduction	80	-
		Comb. modification + selective non-cat. reduction	20	-

Fuel/activity	Sector	Technology	Percentage applied	
			H1	REF
Heavy fuel oil	Domestic	Combustion modification - commercial boilers	100	-
	Industry - combustion in boilers	Combustion modification	-	55
		Comb. modification + selective cat. reduction	80	-
		Comb. modification + selective non-cat. reduction	20	-
	Industry - other combustion	Combustion modification	-	55
		Comb. modification + selective cat. reduction	80	-
		Comb. modification + selective non-cat. reduction	20	-
	Other transp. - maritime activ. - large ships	Comb. modification + selective cat. reduction	25	-
	Power plants existing, other	Combustion modification	100	100
	Power plants, new	Selective catalytic reduction	50	50
	Refineries and other conversion	Combustion modification	-	55
		Comb. modification + selective cat. reduction	23	-
		Comb. modification + selective non-cat. reduction	77	-
Light fractions (e.g., gasoline, LPG)	Domestic	Combustion modification - commercial boilers	100	-
	Industry - combustion in boilers	Combustion modification	100	-
	Industry - other combustion	Combustion modification	100	-
	Other transport - land based	Euro 2 (1995/96) standards	35	-
	Road transp - cars and light duty vehic. 4-stroke	Euro 1 (1992/93) standards	2	2
		Euro 2 (1995/96) standards	21	21
		Euro 3 (2000) standards	35	35
		Euro 4 (post-2005) standards	40	40
Natural gas (incl. other gases)	Domestic	Combustion modification - commercial boilers	100	-
	Industry - combustion in boilers	Combustion modification	100	30
	Industry - other combustion	Combustion modification	-	30
		Comb. modification + selective non-cat. reduction	100	-
	Power plants existing, other	Combustion modification	100	100
	Power plants, new	Selective catalytic reduction	100	50
	Refineries and other conversion	Combustion modification	-	30
		Comb. modification + selective non-cat. reduction	100	-
	Road transp - cars and light duty vehic. 4-stroke	Three-way catalytic converter	100	100
	Road transp - heavy duty trucks and buses	Three-way catalytic converter	100	100
Other solid - high S	Power plants existing, other	Combustion modification	100	-
	Power plants, new	Selective catalytic reduction	100	-
	Industry - process emissions	Stage 2 control	100	-

Table 1.5: VOC control measures for France in the H1 scenario

Fuel/activity	Sector	Technology	Percentage applied H1	Percentage applied REF
Crude oil	Refineries - process	Quarterly inspection, covers on oil/water separators, flaring	-	100
		Quarterly inspection, covers on oil/water sep., flaring, incineration	100	-
Light fractions (gasoline,kerosen,naphta,LPG)	Evaporative emissions from cars	Small carbon canister (in cars)	100	100
	Gasoline distribution - service stations	Stage II and IB at service station	5	-
		Stage IB controls at service stations	95	-
	Gasoline distribution - transport and depots	Internal floating covers or secondary seals	-	100
		IFC and Stage IA (single stage) controls	100	-
	Transport other - 2 stroke engines	Oxidation catalyst for 2 stroke engines	100	50
	Transport road - 2 stroke engines	Oxidation catalyst for 2 stroke engines	100	50
Other solid-low S (biomass, wood,..)	Combustion in residential and commercial sector	New, improved small (residential) boiler with accumulation tank	100	100
Hard coal, high quality		New, improved small (residential) boiler with accumulation tank	100	-
Paint and glue produced	Products incorporating solvents	Product reformulation	-	100
		Basic emission management measures, adsorption or incineration	100	-
Paint use	Architectural use of paints	Emulsions, water-based dispersion paints	-	100
		Emulsions, water-based and high-solid paints	100	-
	Domestic use of paints	Emulsions, water-based dispersion paints	-	100
		Emulsions, water-based and high-solid paints	100	-
	Other industrial use of paints	Good housekeeping and improved application (primary measures)	-	30
		Good housekeeping, improved application and substitution	30	-
		Primary measures, end-of-pipe and substitution	70	70
	Vehicle refinishing	Primary measures and 40% high solids, 60% water based paints	90	90
	Vehicle refinishing (new installations)	Substitution with 40% high solids, 60% water based paints	90	90

Fuel/activity	Sector	Technology	Percentage applied H1	Percentage applied REF
Printing inks	Flexography and rotogravure in packaging	Low solvent or water based inks	-	100
		Low solvent/water based inks, enclosure and adsorption	100	-
	Flexography and rotogravure in packaging, new installat	Water based inks, incineration (for new inst. with enclosure)	45	45
		Water based inks	55	55
	Printing, offset	Primary measures (offset), solvent free inks	-	100
		Primary measures (offset), solvent free inks, incineration	100	-
	Printing, offset, new installations	Incineration	100	80
	Rotogravure in publication	Low solvent inks, enclosure and adsorption	100	100
	Rotogravure in publication, new installations	Water based inks	100	-
	Screen printing	Water based inks	100	-
	Screen printing, new installations	Water based inks	100	-
Solvent use	Degreasing	Basic emissions management techniques	-	100
		Basic emissions management techniques and carbon adsorption	100	-
	Degreasing (new installations)	Activated carbon adsorption	100	-
	Pharmaceutical industry	Good Housekeeping and Carbon Adsorption	40	-
		Good housekeeping and cat. or th. incineration	60	60
Emissions of NMVOC	Application of glues and adhesives in industry	Good housekeeping and substitution	100	62
	Organic chemical industry, process	Flaring	-	100
		Quarterly inspection and maintenance, flaring, incineration	100	-
	Other industrial sources	Good housekeeping in steel industry and switch to emulsion bitumen	100	100
	Other industrial use of solvents	Process modification and biofiltration	100	-
	Products not incorporating solvents	Solvent management plan and substitution	100	100
	Stubble burning and other agr. waste	Ban stubble burning	100	100
	Waste treatment and disposal	Improved Landfills	100	100
Textiles (clothing)	Dry cleaning (new installations)	New generation closed circuit machine	40	40
Vehicles	Manufacture of automobiles (new installations)	Adsorption, incineration	100	100

2 Work Element 2: Effects of Reducing the Disparity in the Level of Efforts per Country

2.1 Introduction

It has been shown by earlier work that cost-effectiveness implies differentiated requirements for emission reductions, taking into account regional differences in environmental sensitivities and in meteorological conditions, and differences in the potential for and the costs of further emission controls. The variations of these factors in Europe lead to the finding that the burden of additional emission control measures imposed by cost-optimised strategies may differ considerably between individual European countries. Sensitivity analyses have been performed in order to explore the gains in cost-effectiveness achieved by the optimisation approach when compared to scenarios in which the emission reduction requirements are distributed ‘more evenly’ between the countries. Such sensitivity analyses have been reported for a variety of concepts of even-handedness.

The first definition of equity to be investigated used a 'flat rate' emission control scenario, in which the average reduction rates of the optimised scenario - for each of the four pollutants - were applied uniformly to all the European countries involved. The H9 scenario was constructed for EU-15 countries following this principle and its results compared with those of the optimised H1 scenario (Amann *et al*., 1999c, 1999e). This concept was also examined with a pan-European focus; in the J7 scenario the emissions from each country were fixed - as far as possible - to the value corresponding to the average percentage reduction across all ECE countries obtained for the central, optimised J1 scenario (Amann *et al*., 1999b, 1999e).

The same 'flat rate' approach was also examined in conjunction with the EU-15 environmental targets. Starting from the optimised H1 scenario and maintaining the environmental targets of this scenario, a series of scenarios (H10/1 to H10/5) explored the changes in emission control costs if the deviations from the average emission reduction levels (of the H9 scenario) were gradually restricted (Amann *et al*., 1999c, 1999e). For the ECE region, scenario J8 was developed in which the emission reductions were kept as close as possible to the average reduction level while maintaining the achievement of the J1 environmental targets (Amann *et al*., 1999b, 1999e).

A second concept investigated was to relate international emission reduction requirements to a 'per-capita' indicator for emissions. The rationale for the illustrative 'uniform per-capita' scenario, J11, was to fix - as far as possible - each country’s emissions to the value corresponding to the average per capita emission rates across Europe that were obtained for the J1 scenario (Amann *et al*., 1999d, 1999e).

The 'uniform per-capita' approach was also used to influence the cost optimisation for the J1 environmental targets. Starting from the optimised J1 scenario and maintaining the environmental targets of this scenario, scenario J12 explored the changes in emission control costs if the deviations from the average per-capita emission levels (of the J11 scenario) were reduced as much as possible (Amann *et al*., 1999d).

In scenario J13 a further concept was explored in which the target was to close, for each country and pollutant, the gap between 1990 per-capita emissions and the lowest per-capita emissions of the REF scenario by an equal percentage, in such a way that the overall emissions remained at the J1 scenario level (Amann *et al*., 1999e).

This report presents two more scenarios for the EU-15 countries involving further developments of this latter concept.

2.2 Uniform Gap Closure For Per-Capita Emissions (Scenario H12)

An alternative 'per-capita gap closure' concept has been explored for EU-15 countries in scenario H12. Here, the target is to close, for each country and pollutant, the gap between the per-capita emissions of the 2010 REF scenario and the lowest per-capita emissions of the REF scenario by an equal percentage, so that the overall emissions are the same as in the H1 scenario. This differs from the approach used in scenario J13 in that the gap to be reduced is now defined from the REF scenario per-capita emissions instead of from the corresponding 1990 value as in J13.

The following targets and gap-closure percentages were used:

	Gap closure	Target level (kg/capita)	corresponds to per-capita emissions in REF of
SO_2	36.1 %	4.89	Netherlands
NO_x	46.2 %	13.32	Austria
VOC	82.2 %	14.42	Germany
NH_3	25.9 %	5.19	United Kingdom

If for a particular country these reductions fall below the MFR emissions, then the appropriate MFR value was used instead.

2.3 Uniform Gap Closure For Per-Capita Emissions with Limited Marginal Costs (Scenario H13)

Another type of sensitivity analysis involves limiting the emission control measures to those having marginal costs below a given threshold. Scenario J9 explored the effects of applying marginal cost limits to the emission ceilings of the Europe-wide J1 scenario (Amann *et al.*, 1999d). A further scenario, J10, similarly restricted the set of control measures to those satisfying the J9 marginal cost limits while also maintaining the achievement of the J1 environmental targets (Amann *et al.*, 1999d).

Scenario H13, presented here, applies limits to the marginal costs of scenario H12. The following limits were selected:

SO_2 : 2000 EURO/tonne
NO_x : 2000 EURO/tonne
VOC : 2000 EURO/tonne
NH_3 : 4000 EURO/tonne

These limits were applied to the relevant cost curves except where this procedure would preclude attainment of the Reference scenario emissions, in which cases the emissions were fixed at the Reference levels.

2.4 Comparison with the Central H1 Scenario

The emissions, costs and exposure indices of the H12 and H13 scenarios are compared with those of the central scenario H1 in Table 2.1 - Table 2.8.

Table 2.1: NO_x emissions for the 'per-capita gap closure' emission control scenarios. Percentage changes relate to the year 1990.

	H1 Central case		H12 Per-capita gap closure		H13 With limited marginal costs	
	kt	*Change*	kt	*Change*	kt	*Change*
Austria	91	*-53%*	103	*-46%*	101	*-47%*
Belgium	127	*-64%*	170	*-52%*	170	*-52%*
Denmark	127	*-54%*	100	*-64%*	105	*-62%*
Finland	152	*-45%*	113	*-59%*	116	*-58%*
France	679	*-64%*	810	*-57%*	810	*-57%*
Germany	1051	*-61%*	1122	*-58%*	1142	*-57%*
Greece	264	*-23%*	248	*-28%*	339	*-2%*
Ireland	59	*-48%*	59	*-48%*	59	*-48%*
Italy	869	*-57%*	962	*-53%*	962	*-53%*
Luxembourg	8	*-64%*	8	*-64%*	9	*-59%*
Netherlands	238	*-56%*	243	*-55%*	272	*-50%*
Portugal	144	*-31%*	155	*-25%*	155	*-25%*
Spain	781	*-33%*	685	*-41%*	685	*-41%*
Sweden	152	*-55%*	155	*-54%*	159	*-53%*
UK	1181	*-58%*	991	*-65%*	1093	*-62%*
EU-15	5922	*-55%*	5922	*-55%*	6176	*-53%*

Table 2.2: VOC emissions for the 'per-capita gap closure' emission control scenarios. Percentage changes relate to the year 1990.

	H1 Central case		H12 Per-capita gap closure		H13 With limited marginal costs	
	kt	*Change*	kt	*Change*	kt	*Change*
Austria	129	*-63%*	128	*-64%*	152	*-57%*
Belgium	102	*-73%*	164	*-56%*	164	*-56%*
Denmark	85	*-53%*	76	*-58%*	76	*-58%*
Finland	110	*-48%*	79	*-63%*	79	*-63%*
France	932	*-61%*	889	*-63%*	1018	*-57%*
Germany	924	*-70%*	1137	*-64%*	1137	*-64%*
Greece	173	*-49%*	167	*-50%*	186	*-45%*
Ireland	55	*-50%*	51	*-54%*	51	*-54%*
Italy	962	*-53%*	889	*-57%*	963	*-53%*
Luxembourg	6	*-68%*	6	*-68%*	6	*-68%*
Netherlands	156	*-68%*	218	*-56%*	218	*-56%*
Portugal	102	*-52%*	142	*-33%*	142	*-33%*
Spain	662	*-34%*	562	*-44%*	562	*-44%*
Sweden	219	*-57%*	174	*-66%*	221	*-57%*
UK	964	*-64%*	953	*-64%*	1113	*-58%*
EU-15	5581	*-60%*	5634	*-60%*	6087	*-57%*

Table 2.3: SO_2 emissions for the 'per-capita gap closure' emission control scenarios. Percentage changes relate to the year 1990.

	H1 Central case		H12 Per-capita gap closure		H13 With limited marginal costs	
	kt	*Change*	kt	*Change*	kt	*Change*
Austria	40	*-57%*	39	*-58%*	39	*-58%*
Belgium	76	*-77%*	142	*-58%*	142	*-58%*
Denmark	77	*-58%*	67	*-63%*	67	*-63%*
Finland	116	*-49%*	83	*-63%*	87	*-62%*
France	218	*-83%*	386	*-69%*	386	*-69%*
Germany	463	*-91%*	515	*-90%*	525	*-90%*
Greece	546	*8%*	367	*-27%*	367	*-27%*
Ireland	28	*-84%*	48	*-73%*	48	*-73%*
Italy	566	*-66%*	464	*-72%*	464	*-72%*
Luxembourg	3	*-79%*	3	*-79%*	3	*-79%*
Netherlands	50	*-75%*	73	*-64%*	73	*-64%*
Portugal	141	*-50%*	108	*-62%*	108	*-62%*
Spain	746	*-66%*	561	*-74%*	561	*-74%*
Sweden	67	*-44%*	58	*-51%*	60	*-50%*
UK	497	*-87%*	728	*-81%*	728	*-81%*
EU-15	3637	*-78%*	3641	*-78%*	3657	*-78%*

Table 2.4: NH_3 emissions for the 'per-capita gap closure' emission control scenarios. Percentage changes relate to the year 1990.

	H1 Central case		H12 Per-capita gap closure		H13 With limited marginal costs	
	kt	*Change*	kt	*Change*	kt	*Change*
Austria	67	*-13%*	60	*-22%*	65	*-16%*
Belgium	57	*-41%*	86	*-11%*	86	*-11%*
Denmark	71	*-8%*	60	*-22%*	68	*-12%*
Finland	31	*-23%*	30	*-25%*	30	*-25%*
France	718	*-11%*	652	*-19%*	681	*-16%*
Germany	413	*-45%*	529	*-30%*	533	*-30%*
Greece	74	*-8%*	68	*-15%*	69	*-14%*
Ireland	123	*-3%*	111	*-13%*	126	*-1%*
Italy	430	*-7%*	397	*-14%*	397	*-14%*
Luxembourg	7	*0%*	7	*0%*	7	*0%*
Netherlands	104	*-55%*	121	*-48%*	136	*-42%*
Portugal	67	*-6%*	63	*-11%*	63	*-11%*
Spain	353	*0%*	312	*-11%*	332	*-6%*
Sweden	48	*-21%*	47	*-23%*	48	*-21%*
UK	264	*-20%*	297	*-10%*	297	*-10%*
EU-15	2826	*-21%*	2840	*-21%*	2939	*-18%*

Table 2.5: Control costs on top of the REF scenario for SO_2, NO_x and VOC for the 'per-capita gap closure' emission control scenarios (in million EURO/year)

	NO_x & VOC			SO_2		
	H1 Central case	H12 Per-capita gap closure	H13 Limited marginal costs	H1 Central case	H12 Per-capita gap closure	H13 Limited marginal costs
Austria	119	107	29	0	0	0
Belgium	459	28	28	127	18	18
Denmark	0	32	23	5	10	10
Finland	0	43	36	0	58	48
France	739	493	182	136	22	22
Germany	1048	90	44	244	76	40
Greece	338	532	70	0	29	29
Ireland	4	7	7	20	6	6
Italy	403	429	247	0	29	29
Luxembourg	4	8	2	1	0	0
Netherlands	211	109	19	19	0	0
Portugal	57	4	4	0	14	14
Spain	13	202	202	9	70	70
Sweden	87	408	68	0	21	9
UK	1026	1429	411	299	88	88
EU-15	4508	3922	1373	861	442	384

Table 2.6: Control costs for NH_3 emissions and total costs on top of the REF scenario for the 'per-capita gap closure' emission control scenarios (in million EURO/year)

	NH_3			Total		
	H1 Central case	H12 Per-capita gap closure	H13 Limited marginal costs	H1 Central case	H12 Per-capita gap closure	H13 Limited marginal costs
Austria	0	32	2	119	139	32
Belgium	467	19	19	1053	65	65
Denmark	0	91	6	6	133	39
Finland	0	3	1	0	104	85
France	41	293	136	916	808	340
Germany	854	45	31	2147	211	115
Greece	0	12	6	338	573	106
Ireland	20	455	0	44	468	13
Italy	0	34	34	403	492	310
Luxembourg	0	0	0	4	9	2
Netherlands	741	208	0	971	317	19
Portugal	0	6	6	57	23	23
Spain	0	128	40	22	399	312
Sweden	0	19	0	87	447	77
UK	23	0	0	1348	1517	499
EU-15	2146	1344	281	7514	5707	2037

Table 2.7: Cumulative ozone exposure indices for the 'per-capita gap closure' emission control scenarios

	Population (million persons.ppm.hours)			Vegetation (1000 km^2.excess ppm.hours)		
	H1	H12	H13	H1	H12	H13
	Central case	Per-capita gap closure	Limited marginal costs	Central case	Per-capita gap closure	Limited marginal costs
Austria	2	2	3	213	231	237
Belgium	23	29	30	115	131	133
Denmark	1	2	2	36	38	43
Finland	0	0	0	0	0	0
France	53	68	73	1816	2053	2120
Germany	99	120	125	943	1086	1118
Greece	2	2	2	137	136	155
Ireland	0	0	1	3	4	5
Italy	38	41	45	996	1025	1059
Luxembourg	1	1	1	11	13	13
Netherlands	27	33	34	63	73	74
Portugal	6	6	7	233	242	244
Spain	4	4	4	1093	1023	1036
Sweden	0	0	0	9	9	10
UK	45	56	63	96	112	127
EU-15	300	365	391	5765	6175	6372

Table 2.8: Ecosystems with deposition above critical loads for the 'per-capita gap closure' emission control scenarios (1000 hectares)

	Acidification			Eutrophication		
	H1	H12	H13	H1	H12	H13
	Central case	Per-capita gap closure	Limited marginal costs	Central case	Per-capita gap closure	Limited marginal costs
Austria	99	126	130	2773	3096	3212
Belgium	52	110	115	586	634	647
Denmark	6	7	7	91	71	94
Finland	1150	1095	1105	2163	1884	1990
France	88	109	112	22524	22195	22526
Germany	727	1187	1258	7474	8522	8676
Greece	0	0	0	211	113	207
Ireland	9	9	10	54	28	56
Italy	58	58	59	3452	3436	3461
Luxembourg	1	4	4	66	72	75
Netherlands	76	157	172	278	284	288
Portugal	1	1	1	683	617	620
Spain	17	8	8	964	609	723
Sweden	1420	1429	1460	737	707	791
UK	649	893	937	64	71	97
EU-15	4351	5193	5376	42117	42338	43464

The data in Table 2.1 - Table 2.4 indicate how the emission reductions required by the central scenario H1 would be re-distributed in scenario H12. It may be observed that the H12 emission control requirements in Belgium, the Netherlands and Germany would be relaxed compared to H1 for all four pollutants. In contrast, Denmark, Finland, Greece and Spain would make further reductions in emissions of all four pollutants in H12. For the other countries the direction of change, if any, varies with the pollutant.

Introduction of limits to the marginal costs in scenario H13 makes only a relatively small difference to the SO_2 emissions of the H12 scenario, and then only in Finland, Germany and Sweden. For the other pollutants[†] the impact of the selected marginal cost limits is greater and extends across most of the EU countries. Only in Belgium and Portugal do the emissions of all four pollutants remain unaffected by the application of marginal cost limits.

Table 2.5 and Table 2.6 show the additional control costs (above REF) associated with the H12 and H13 scenarios. In comparison with the central H1 scenario, H12 would reduce overall annual costs to the EU countries by 1.8 billion EURO (-24%), most of this saving being associated with NH_3 emission control. The largest overall cost reductions would be achieved in Belgium, Germany and the Netherlands. The additional restrictions on control measures imposed in H13 would mean that this scenario is 5.5 billion EURO per year cheaper than H1.

The environmental indicators given in Table 2.7 and Table 2.8 suggest that the H12 scenario would have the largest adverse effect on environmental improvements for the population ozone exposure index (+22% compared to H1) and for the ecosystems area with deposition above critical loads for acidification (+19%). Most of this environmental deterioration is expected to occur in Belgium, France, Germany, the Netherlands and the UK. The further changes in environmental indicators associated with the H13 scenario are, in most cases, relatively small in comparison to the differences between H12 and H1.

The overall cost-effectiveness of these EU-15 sensitivity analysis scenarios, including those presented in earlier reports, is displayed graphically in Figure 2.1 to Figure 2.3. These figures show the cost-effectiveness curves obtained for a series of three optimised scenarios of increasing ambition level in terms of environmental improvement, together with sensitivity analysis scenarios represented by square symbols. Filled squares are used for scenarios that meet the targets of the central H1 scenario, while open symbols represent scenarios for which those targets were disregarded. The different scenarios may be identified from the following list:

REF	reference scenario
H2	‘low ambition’
H1	‘medium ambition’
H3	‘high ambition’
H9	‘flat-rate’ emission reductions
H10	‘flat-rate’ emission reductions without violating H1 targets – series of scenarios
H12	gap closure based on per-capita emissions
H13	gap closure based on per-capita emissions with limited marginal costs

From these figures scenario H12 is seen to be somewhat more expensive than the ‘low ambition’ scenario H2, yet performs less well than H2 in terms of the two ozone exposure indices and is comparable to H2 in relation to the area of ecosystems not protected against

[†] An apparent anomaly between the H12 and H13 scenarios in the case of NO_x emissions from Austria may be observed in Table 2.1. The H13 limit on marginal costs restricts the extent of VOC reductions available within the stationary source sector, which necessitates additional control measures for heavy-duty vehicles. These extra controls also reduce NO_x emissions, with the result that total Austrian NO_x emissions are lower in scenario H13 than in H12.

acidification. The considerably cheaper H13 scenario achieves less environmental improvement than either H2 or H12 but appears to be more cost-effective than H12. It must be remembered, of course, that neither H12 nor H13 satisfies the environmental targets of the central H1 scenario.

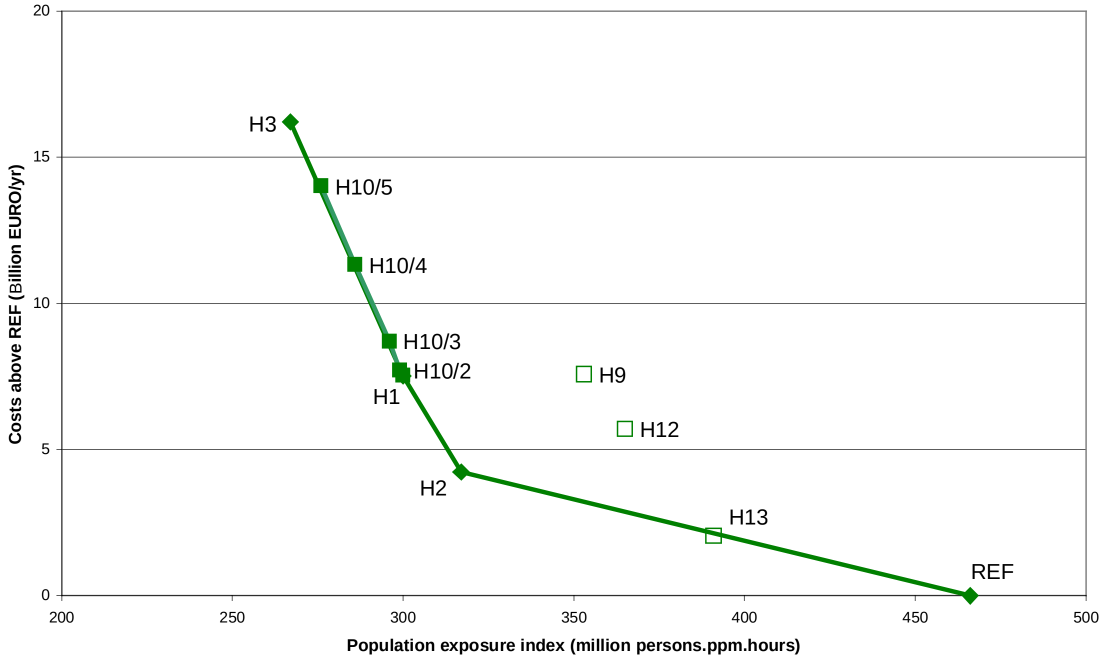

Figure 2.1: Cost-effectiveness of the EU-15 sensitivity analysis scenarios in relation to the population exposure index

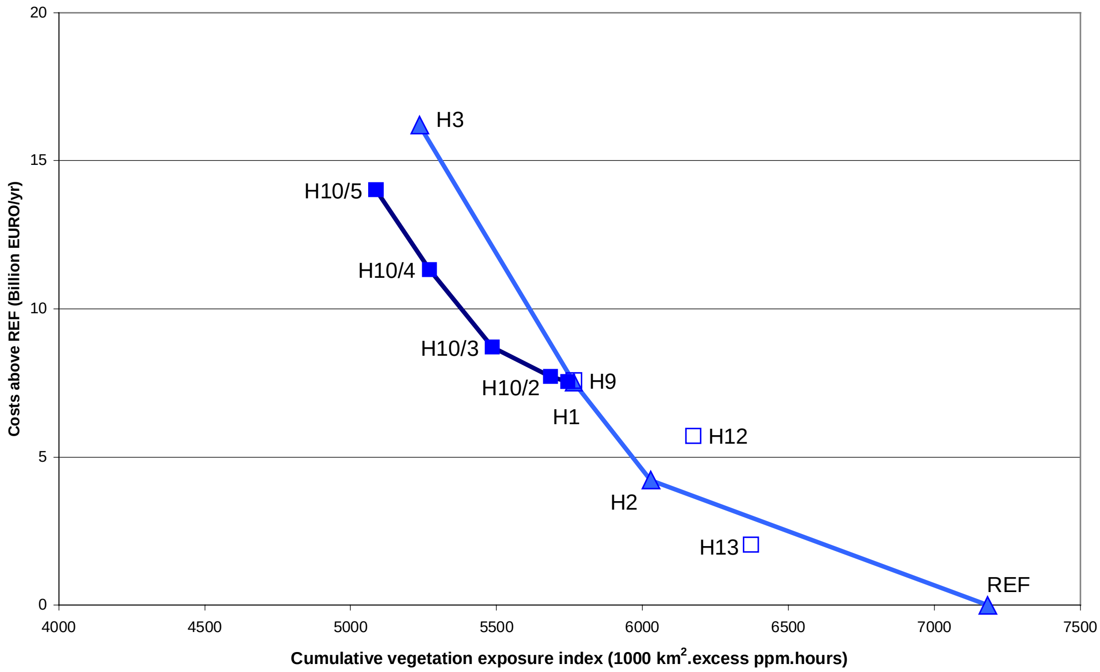

Figure 2.2: Cost-effectiveness of the EU-15 sensitivity analysis scenarios in relation to the vegetation exposure index

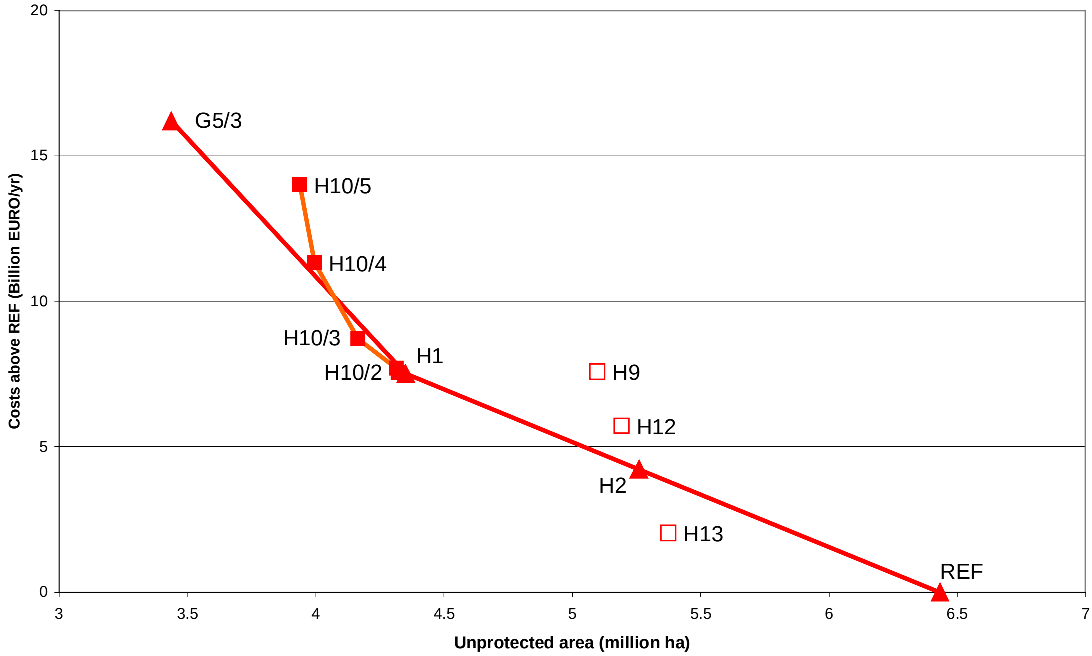

Figure 2.3: Cost-effectiveness of the EU-15 sensitivity analysis scenarios in relation to the area of ecosystems not protected against acidification

3 Work Element 4: Sensitivity to Optimisation Constraints

The scenarios constructed in various IIASA studies for the European Commission and the UN/ECE Task Force on Integrated Assessment Modelling have been effects-based. In these scenarios the optimisation goal has been to identify the cost-optimised set of emission reductions that satisfy a given set of environmental targets. The sensitivity analyses of work element 4 for the French Ministry of the Environment explore the effects of abandoning the effects-based approach in favour of one in which the greatest emphasis is placed on costs. The aim of such an approach would be to achieve environmental improvements first where they cost least.

In principle, one method to tackle this question would be to optimise the set of emission control measures to be taken for a given cost. This multi-criteria optimisation approach is not currently possible with the present version of the RAINS model, however. Instead, two alternative sensitivity analysis scenarios – based on different premises - have been designed for this investigation.

3.1 Scenario J14

The Europe-wide central J1 scenario employed a compensation mechanism that allowed the environmental targets of individual grids to be exceeded (up to a specified limit) provided that such exceedances were balanced by additional environmental improvements (more than meeting the targets) at other grids within the same country. Sensitivity analysis scenario J14 uses the same set of environmental targets for individual grids as J1 but extends the compensation region to include the whole of Europe. In effect, J14 repeats scenario J1 treating Europe as one country for the purposes of the target balancing mechanism.

3.2 Scenario J15

The alternative approach taken in the construction of scenario J15 is a straightforward, non-optimised way of arriving at the costs of scenario J1 without regard for the environmental targets. For each pollutant separately it is assumed that emission control measures are taken in order of their marginal costs starting from the cheapest until the relevant J1 costs have been reached.

3.3 Comparison with the Central J1 Scenario

The emissions, costs and environmental impacts of the J14 and J15 scenarios are compared with those of the central scenario J1 in Table 3.1 - Table 3.8.

Compared to the J1 scenario, scenario J14 reduces the emission control requirements in several countries for one or more pollutants. It is interesting to note that these savings are more evident for SO_2 and NH_3 emissions than for NO_x and, in particular, VOC. Sulphur dioxide emission control requirements are reduced by 10% or more (in terms of 1990 emissions) for fourteen countries; for NH_3 the corresponding number is nine countries. On the same basis, Hungary, Norway, Poland and Romania would be afforded some relief from NO_x control by scenario J14, but only Portugal would benefit to the same relative extent as far as VOC reduction measures are concerned. For the ECE as a whole, the J14 scenario would cost 3.5 billion EURO per year (above REF), a decrease of 59% in comparison to J1.

Table 3.1: NO_x emissions for the J14 and J15 scenarios. Percentage changes relate to the year 1990.

	J1 Central case		J14		J15	
	kt	*Change*	kt	*Change*	kt	*Change*
Austria	91	*-53%*	91	*-53%*	98	*-49%*
Belgium	127	*-64%*	133	*-62%*	158	*-55%*
Denmark	113	*-59%*	125	*-54%*	105	*-62%*
Finland	152	*-45%*	148	*-46%*	118	*-57%*
France	704	*-62%*	706	*-62%*	738	*-60%*
Germany	1081	*-59%*	1131	*-58%*	1147	*-57%*
Greece	344	*0%*	344	*0%*	339	*-2%*
Ireland	55	*-51%*	64	*-43%*	58	*-49%*
Italy	902	*-56%*	902	*-56%*	901	*-56%*
Luxembourg	8	*-64%*	9	*-59%*	9	*-59%*
Netherlands	266	*-51%*	280	*-48%*	275	*-49%*
Portugal	144	*-31%*	154	*-26%*	144	*-31%*
Spain	726	*-38%*	781	*-33%*	653	*-44%*
Sweden	159	*-53%*	158	*-53%*	158	*-53%*
UK	1181	*-58%*	1181	*-58%*	1088	*-62%*
EU-15	6054	*-54%*	6208	*-53%*	5987	*-55%*
Albania	36	*50%*	36	*50%*	33	*38%*
Belarus	290	*-28%*	290	*-28%*	244	*-39%*
Bosnia-H	53	*-34%*	60	*-25%*	51	*-36%*
Bulgaria	266	*-25%*	272	*-23%*	247	*-30%*
Croatia	87	*6%*	91	*11%*	81	*-1%*
Czech Rep.	188	*-66%*	199	*-64%*	219	*-60%*
Estonia	73	*-13%*	71	*-15%*	55	*-35%*
Hungary	137	*-37%*	181	*-17%*	175	*-20%*
Latvia	118	*1%*	116	*-1%*	102	*-13%*
Lithuania	134	*-12%*	130	*-15%*	119	*-22%*
Norway	142	*-35%*	173	*-21%*	142	*-35%*
Poland	654	*-46%*	803	*-34%*	678	*-44%*
R.of Moldova	64	*-26%*	65	*-25%*	50	*-43%*
Romania	328	*-37%*	392	*-24%*	355	*-31%*
Russia	2653	*-24%*	2648	*-24%*	2269	*-35%*
Slovakia	115	*-47%*	122	*-44%*	117	*-47%*
Slovenia	34	*-43%*	36	*-40%*	32	*-47%*
Switzerland	76	*-53%*	76	*-53%*	76	*-53%*
FYR of Mac.	29	*-26%*	29	*-26%*	25	*-36%*
Ukraine	1222	*-35%*	1268	*-33%*	1014	*-46%*
Yugoslavia	132	*-37%*	152	*-28%*	129	*-39%*
Non-EU	6830	*-33%*	7210	*-29%*	6212	*-39%*
Total	12884	*-49%*	13418	*-46%*	12200	*-51%*

Table 3.2: VOC emissions for the J14 and J15 scenarios. Percentage changes relate to the year 1990.

	J1 Central case		J14		J15	
	kt	*Change*	kt	*Change*	kt	*Change*
Austria	142	*-60%*	142	*-60%*	161	*-54%*
Belgium	103	*-72%*	103	*-72%*	154	*-59%*
Denmark	85	*-53%*	85	*-53%*	75	*-59%*
Finland	110	*-48%*	110	*-48%*	74	*-65%*
France	989	*-58%*	1015	*-57%*	1018	*-57%*
Germany	995	*-68%*	990	*-68%*	1102	*-65%*
Greece	261	*-22%*	263	*-22%*	193	*-43%*
Ireland	55	*-50%*	55	*-50%*	52	*-53%*
Italy	1030	*-50%*	983	*-52%*	963	*-53%*
Luxembourg	7	*-63%*	7	*-63%*	7	*-63%*
Netherlands	157	*-68%*	158	*-68%*	190	*-61%*
Portugal	102	*-52%*	122	*-42%*	122	*-42%*
Spain	648	*-36%*	669	*-34%*	596	*-41%*
Sweden	241	*-53%*	219	*-57%*	239	*-53%*
UK	1101	*-59%*	1083	*-59%*	1257	*-53%*
EU-15	6024	*-57%*	6002	*-57%*	6200	*-56%*
Albania	41	*32%*	41	*32%*	28	*-10%*
Belarus	298	*-20%*	298	*-20%*	178	*-52%*
Bosnia-H	48	*-6%*	48	*-6%*	29	*-43%*
Bulgaria	185	*-5%*	188	*-4%*	116	*-41%*
Croatia	86	*-17%*	85	*-17%*	69	*-33%*
Czech Rep.	156	*-65%*	157	*-64%*	224	*-49%*
Estonia	49	*9%*	49	*9%*	32	*-29%*
Hungary	137	*-33%*	139	*-32%*	105	*-49%*
Latvia	56	*-11%*	56	*-11%*	38	*-40%*
Lithuania	105	*-5%*	105	*-5%*	71	*-36%*
Norway	195	*-34%*	195	*-34%*	177	*-40%*
Poland	475	*-40%*	475	*-40%*	513	*-36%*
R.of Moldova	42	*-16%*	42	*-16%*	24	*-52%*
Romania	500	*-1%*	504	*0%*	338	*-33%*
Russia	2723	*-23%*	2723	*-23%*	1495	*-58%*
Slovakia	140	*-7%*	140	*-7%*	114	*-25%*
Slovenia	40	*-27%*	40	*-27%*	30	*-45%*
Switzerland	144	*-48%*	143	*-49%*	129	*-54%*
FYR of Mac.	19	*0%*	19	*0%*	13	*-32%*
Ukraine	770	*-34%*	756	*-35%*	470	*-60%*
Yugoslavia	138	*-3%*	138	*-3%*	78	*-45%*
Non-EU	6345	*-26%*	6342	*-26%*	4269	*-50%*
Total	12370	*-45%*	12344	*-45%*	10469	*-54%*

Table 3.3: SO_2 emissions for the J14 and J15 scenarios. Percentage changes relate to the year 1990.

	J1 Central case		J14		J15	
	kt	*Change*	kt	*Change*	kt	*Change*
Austria	35	*-62%*	40	*-57%*	39	*-58%*
Belgium	76	*-77%*	115	*-66%*	145	*-57%*
Denmark	60	*-67%*	90	*-51%*	60	*-67%*
Finland	116	*-49%*	116	*-49%*	116	*-49%*
France	219	*-82%*	448	*-64%*	318	*-75%*
Germany	463	*-91%*	547	*-90%*	574	*-89%*
Greece	546	*8%*	546	*8%*	333	*-34%*
Ireland	36	*-80%*	66	*-63%*	46	*-74%*
Italy	290	*-83%*	567	*-66%*	295	*-82%*
Luxembourg	3	*-79%*	4	*-71%*	4	*-71%*
Netherlands	50	*-75%*	60	*-70%*	72	*-64%*
Portugal	141	*-50%*	141	*-50%*	79	*-72%*
Spain	747	*-66%*	774	*-65%*	539	*-75%*
Sweden	67	*-44%*	67	*-44%*	66	*-45%*
UK	499	*-87%*	792	*-79%*	718	*-81%*
EU-15	3349	*-80%*	4374	*-73%*	3405	*-79%*
Albania	55	*-24%*	55	*-24%*	23	*-68%*
Belarus	494	*-41%*	487	*-42%*	101	*-88%*
Bosnia-H	162	*-67%*	415	*-15%*	44	*-91%*
Bulgaria	378	*-79%*	846	*-54%*	211	*-89%*
Croatia	23	*-87%*	70	*-61%*	41	*-77%*
Czech Rep.	283	*-85%*	349	*-81%*	301	*-84%*
Estonia	175	*-36%*	175	*-36%*	101	*-63%*
Hungary	296	*-68%*	403	*-56%*	339	*-63%*
Latvia	104	*-14%*	104	*-14%*	44	*-64%*
Lithuania	107	*-50%*	107	*-50%*	78	*-63%*
Norway	18	*-65%*	31	*-40%*	25	*-52%*
Poland	722	*-76%*	1168	*-61%*	1048	*-65%*
R.of Moldova	38	*-81%*	117	*-41%*	38	*-81%*
Romania	148	*-89%*	594	*-55%*	305	*-77%*
Russia	2186	*-56%*	2170	*-57%*	1419	*-72%*
Slovakia	92	*-83%*	137	*-75%*	100	*-82%*
Slovenia	14	*-93%*	71	*-65%*	14	*-93%*
Switzerland	23	*-47%*	26	*-40%*	25	*-42%*
FYR of Mac.	81	*-24%*	81	*-24%*	81	*-24%*
Ukraine	1457	*-61%*	1488	*-60%*	637	*-83%*
Yugoslavia	217	*-63%*	269	*-54%*	255	*-56%*
Non-EU	7071	*-67%*	9161	*-58%*	5230	*-76%*
Total	10419	*-73%*	13535	*-65%*	8635	*-78%*

Table 3.4: NH_3 emissions for the J14 and J15 scenarios. Percentage changes relate to the year 1990.

	J1 Central case		J14		J15	
	kt	*Change*	kt	*Change*	kt	*Change*
Austria	66	*-14%*	66	*-14%*	59	*-23%*
Belgium	60	*-38%*	80	*-18%*	80	*-18%*
Denmark	69	*-10%*	71	*-8%*	65	*-16%*
Finland	31	*-23%*	31	*-23%*	29	*-28%*
France	642	*-20%*	674	*-16%*	635	*-21%*
Germany	413	*-45%*	518	*-32%*	438	*-42%*
Greece	73	*-9%*	73	*-9%*	67	*-16%*
Ireland	116	*-9%*	126	*-1%*	124	*-2%*
Italy	356	*-23%*	356	*-23%*	323	*-30%*
Luxembourg	7	*0%*	7	*0%*	7	*0%*
Netherlands	105	*-55%*	136	*-42%*	136	*-42%*
Portugal	65	*-8%*	67	*-6%*	57	*-20%*
Spain	353	*0%*	353	*0%*	308	*-13%*
Sweden	48	*-21%*	48	*-21%*	48	*-21%*
UK	264	*-20%*	264	*-20%*	251	*-24%*
EU-15	2668	*-25%*	2870	*-20%*	2626	*-27%*
Albania	32	*0%*	34	*6%*	28	*-13%*
Belarus	140	*-36%*	140	*-36%*	128	*-42%*
Bosnia-H	22	*-29%*	22	*-29%*	21	*-32%*
Bulgaria	105	*-26%*	108	*-23%*	98	*-30%*
Croatia	29	*-28%*	37	*-8%*	28	*-30%*
Czech Rep.	101	*-6%*	101	*-6%*	90	*-16%*
Estonia	29	*0%*	26	*-10%*	21	*-28%*
Hungary	77	*-36%*	103	*-14%*	97	*-19%*
Latvia	35	*-19%*	30	*-30%*	25	*-42%*
Lithuania	72	*-10%*	71	*-11%*	63	*-21%*
Norway	21	*-9%*	21	*-9%*	21	*-9%*
Poland	468	*-7%*	477	*-6%*	404	*-20%*
R.of Moldova	41	*-13%*	48	*2%*	35	*-26%*
Romania	227	*-22%*	274	*-6%*	249	*-15%*
Russia	894	*-30%*	827	*-35%*	725	*-43%*
Slovakia	39	*-35%*	40	*-33%*	37	*-38%*
Slovenia	16	*-30%*	19	*-17%*	15	*-35%*
Switzerland	63	*-13%*	64	*-11%*	61	*-15%*
FYR of Mac.	15	*-12%*	15	*-12%*	13	*-24%*
Ukraine	588	*-19%*	589	*-19%*	516	*-29%*
Yugoslavia	64	*-29%*	75	*-17%*	72	*-20%*
Non-EU	3077	*-23%*	3124	*-22%*	2746	*-31%*
Total	5745	*-24%*	5994	*-21%*	5372	*-29%*

Table 3.5: Control costs on top of the REF scenario for SO_2, NO_x and VOC for the J14 and J15 scenarios (in million EURO/year)

	NO_x & VOC			SO_2		
	J1 Central	J14	J15	J1 Central	J14	J15
Austria	70	70	20	5	0	0
Belgium	452	379	48	122	33	17
Denmark	8	1	24	13	0	13
Finland	0	1	36	0	0	0
France	437	371	249	132	0	47
Germany	484	397	66	240	17	4
Greece	2	1	59	0	0	40
Ireland	10	1	7	12	0	7
Italy	245	289	311	87	0	83
Luxembourg	2	1	1	0	0	0
Netherlands	112	87	29	19	6	1
Portugal	57	15	24	0	0	26
Spain	42	9	174	9	0	77
Sweden	45	73	50	0	0	0
UK	353	420	179	295	66	92
EU-15	2318	2114	1276	935	122	407
Albania	0	0	5	0	0	12
Belarus	3	3	64	0	2	149
Bosnia-H	2	0	11	55	0	93
Bulgaria	10	5	58	58	0	123
Croatia	5	4	19	18	0	9
Czech Rep.	235	209	66	36	4	23
Estonia	0	0	22	0	0	27
Hungary	112	12	45	113	34	50
Latvia	0	0	18	0	0	20
Lithuania	0	1	27	0	0	11
Norway	12	0	21	10	0	2
Poland	373	178	284	283	78	119
R.of Moldova	0	0	16	30	0	30
Romania	100	15	91	137	0	65
Russia	0	0	722	54	60	312
Slovakia	11	2	21	25	0	15
Slovenia	1	0	9	23	0	23
Switzerland	2	2	16	1	0	0
FYR of Mac.	0	0	3	0	0	0
Ukraine	44	32	415	8	0	319
Yugoslavia	6	0	34	27	0	5
Non-EU	917	463	1968	879	177	1407
Total	3235	2577	3244	1814	299	1814

Table 3.6: Control costs for NH_3 emissions and total costs on top of the REF scenario for the J14 and J15 scenarios (in million EURO/year)

	NH_3			Total		
	J1 Central	J14	J15	J1 Central	J14	J15
Austria	1	0	39	76	71	60
Belgium	312	43	43	886	455	108
Denmark	2	0	25	22	1	61
Finland	0	0	11	0	1	47
France	367	174	423	936	545	719
Germany	842	53	448	1567	467	518
Greece	0	0	17	2	1	116
Ireland	146	0	11	168	1	25
Italy	85	84	213	417	373	607
Luxembourg	0	0	0	2	1	1
Netherlands	672	0	0	803	93	29
Portugal	2	0	30	59	15	80
Spain	0	0	146	51	9	397
Sweden	0	0	0	45	73	50
UK	23	23	88	671	509	358
EU-15	2450	379	1494	5704	2614	3177
Albania	1	0	7	1	0	24
Belarus	9	9	63	12	14	276
Bosnia-H	1	0	5	58	0	109
Bulgaria	13	7	57	81	12	238
Croatia	3	0	8	26	4	36
Czech Rep.	9	9	71	280	221	160
Estonia	0	1	14	0	1	63
Hungary	319	10	41	545	57	137
Latvia	0	2	16	0	2	54
Lithuania	4	4	39	4	6	77
Norway	3	0	3	25	0	27
Poland	182	116	647	838	371	1050
R.of Moldova	3	0	22	33	0	68
Romania	304	6	103	541	21	259
Russia	0	27	439	54	88	1473
Slovakia	7	3	24	43	4	60
Slovenia	2	0	8	25	0	40
Switzerland	6	4	17	9	6	33
FYR of Mac.	1	0	8	1	0	11
Ukraine	30	27	344	82	59	1078
Yugoslavia	94	5	18	128	5	56
Non-EU	991	231	1953	2787	872	5328
Total	3442	610	3447	8490	3486	8505

Table 3.7: Cumulative ozone exposure indices for the J14 and J15 scenarios

	Population (million persons.ppm.hours)			Vegetation (1000 km^2.excess ppm.hours)		
	J1 Central	J14	J15	J1 Central	J14	J15
Austria	1	2	2	194	202	210
Belgium	22	23	27	115	115	127
Denmark	1	1	2	30	33	36
Finland	0	0	0	0	0	0
France	54	55	65	1865	1889	2001
Germany	91	95	110	901	923	1021
Greece	3	3	2	146	150	130
Ireland	0	0	1	3	4	5
Italy	40	39	39	993	994	990
Luxembourg	1	1	1	11	11	12
Netherlands	26	27	31	63	62	71
Portugal	6	6	6	229	247	230
Spain	3	4	3	1046	1126	981
Sweden	0	0	0	7	8	8
UK	49	49	64	111	110	138
EU-15	298	304	352	5714	5874	5959
Albania	0	0	0	0	47	42
Belarus	0	0	0	44	48	23
Bosnia-H	0	0	0	126	134	128
Bulgaria	0	0	0	228	242	207
Croatia	1	2	1	173	182	177
Czech Rep.	5	6	7	218	229	244
Estonia	0	0	0	0	0	0
Hungary	6	8	7	290	326	310
Latvia	0	0	0	2	2	1
Lithuania	0	0	0	9	11	2
Norway	0	0	0	1	1	1
Poland	18	21	21	529	591	560
R.of Moldova	0	0	0	43	46	33
Romania	1	2	1	458	515	442
Russia	5	5	2	861	875	521
Slovakia	3	4	4	153	168	161
Slovenia	1	1	1	78	79	79
Switzerland	1	1	1	70	70	73
FYR of Mac.	0	0	0	33	35	29
Ukraine	6	7	2	971	1019	739
Yugoslavia	1	2	1	195	208	193
Non-EU	48	58	48	4481	4829	3965
Total	346	362	400	10194	10703	9924

Table 3.8: Ecosystems with deposition above critical loads for the J14 and J15 scenarios (1000 hectares)

	Acidification			Eutrophication		
	J1 Central	J14	J15	J1 Central	J14	J15
Austria	68	118	86	2477	2932	2438
Belgium	52	110	109	572	627	617
Denmark	5	7	5	85	97	76
Finland	756	762	409	1738	1871	1333
France	84	111	104	21632	22266	21220
Germany	567	1147	890	7312	8393	7802
Greece	0	0	0	85	105	49
Ireland	8	10	9	29	56	54
Italy	51	58	51	2508	2631	2313
Luxembourg	1	4	4	63	70	67
Netherlands	76	164	155	278	287	285
Portugal	1	1	1	580	752	517
Spain	17	18	7	850	985	546
Sweden	1166	1436	1172	620	746	594
UK	636	895	752	62	65	56
EU-15	3486	4841	3754	38890	41883	37967
Albania	0	0	0	160	181	123
Belarus	686	886	65	924	966	773
Bosnia-H	0	0	0	460	559	461
Bulgaria	0	0	0	1263	2140	1307
Croatia	0	0	0	10	17	9
Czech Rep.	81	216	115	1983	2140	1891
Estonia	8	9	5	598	592	546
Hungary	37	42	39	125	133	129
Latvia	0	0	0	1417	1402	1130
Lithuania	5	76	0	894	900	841
Norway	1928	2274	1967	35	60	34
Poland	173	566	256	14894	15385	13718
R.of Moldova	10	29	10	0	0	0
Romania	17	50	18	1770	1943	1801
Russia	1026	917	98	23123	22228	16324
Slovakia	149	223	168	939	1133	932
Slovenia	4	6	4	87	99	85
Switzerland	35	44	37	1468	1616	1468
FYR of Mac.	0	0	0	108	130	91
Ukraine	237	363	194	3859	3976	3612
Yugoslavia	0	0	0	1280	1801	1399
Non-EU	4397	5701	2976	55396	57399	46674
Total	7883	10542	6730	94287	99282	84641

Scenario J15 places the emphasis on making use of the cheapest control measures wherever they may be available. This scenario has been constructed so that total emission control costs for each pollutant match those of the central J1 scenario. As a result, overall emission reductions are greater than in J1; in general, J15 shifts some of the control burden away from the EU into non-EU countries.

Table 3.7 and Table 3.8 show that scenario J14 would generally result in a lower environmental improvement – for the ECE as a whole - than the J1 scenario. For the population exposure index, however, the difference between J14 and J1 is less than 5% (and only 2% within the EU where most of the health-related ozone exceedances occur). This concurs with the relatively small differences in VOC emissions between the J14 and J1 scenarios, noted earlier.

In contrast to J14, scenario J15 would generally result in a better environmental improvement than J1, particularly for the non-EU area, since J15 would achieve greater overall emissions reductions than J1. However, J15 would be noticeably less effective than either J1 or J14 in terms of health-related ozone exposure, with a 16% increase in the cumulative population exposure index compared to J1 (+18% within the EU).

A graphical comparison of the changes in the environmental indicators in relation to emission control costs is provided in Figure 3.1, Figure 3.4, Figure 3.7 and Figure 3.10. These show the cost-effectiveness curves obtained for a series of three optimised scenarios of increasing ambition level in terms of environmental improvement, together with the Europe-wide sensitivity analysis scenarios, including those presented in earlier reports, represented by square symbols. Filled squares are used for scenarios that meet the J1 targets, while open symbols represent scenarios for which these targets were disregarded. Brief descriptions of the various scenarios are provided for identification purposes in the following list:

REF	reference scenario
G5/1	‘low ambition’
J1	‘medium ambition’ central scenario
G5/3	‘high ambition’
J7	‘flat-rate’ emission reductions
J8	‘flat-rate’ emission reductions without violating J1 targets
J9	limited marginal costs
J10	limited marginal costs without violating J1 targets
J11	uniform per-capita emissions
J12	uniform per-capita emissions without violating J1 targets
J13	gap closure based on per-capita emissions
J14	Europe treated as a single region for the purposes of the compensation mechanism
J15	cheapest measures taken regardless of environmental benefits

These figures illustrate the observations made above in relation to the environmental indicators provided in Table 3.7 and Table 3.8. Scenario J14 is considerably cheaper than J1 and is less effective than the central scenario in relation to all four indicators shown. It appears to be comparable to, but more cost-effective than, the ‘low ambition level’ scenario G5/1. Scenario J15, constructed on an entirely different basis, achieves a greater environmental improvement than J1 for three of the indicators but is noticeably worse in relation to the health-related population exposure index. In interpreting and drawing conclusions from these figures, it should be borne in mind, of course, that neither J14 nor J15 would meet the environmental targets of the central J1 scenario.

Maps indicating the spatial differences in environmental improvement between the J14/J15 and J1 scenarios are provided in Figure 3.2, Figure 3.3, Figure 3.5, Figure 3.6, Figure 3.8, Figure 3.9, Figure 3.11 and Figure 3.12.

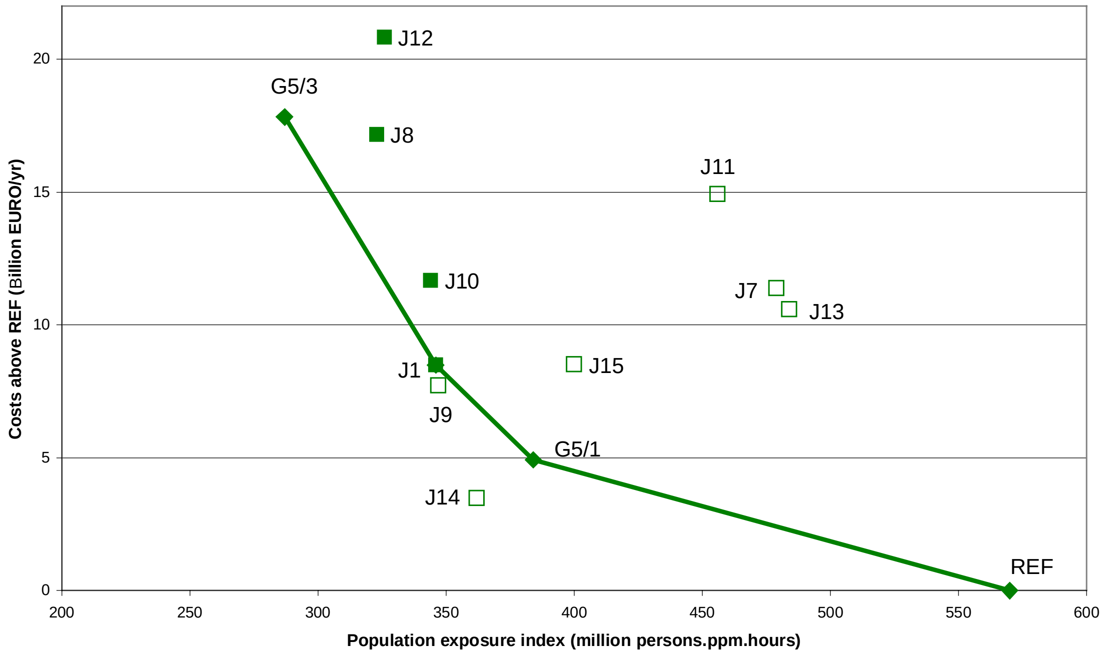

Figure 3.1: Cost-effectiveness of the Europe-wide sensitivity analysis scenarios in relation to the population exposure index

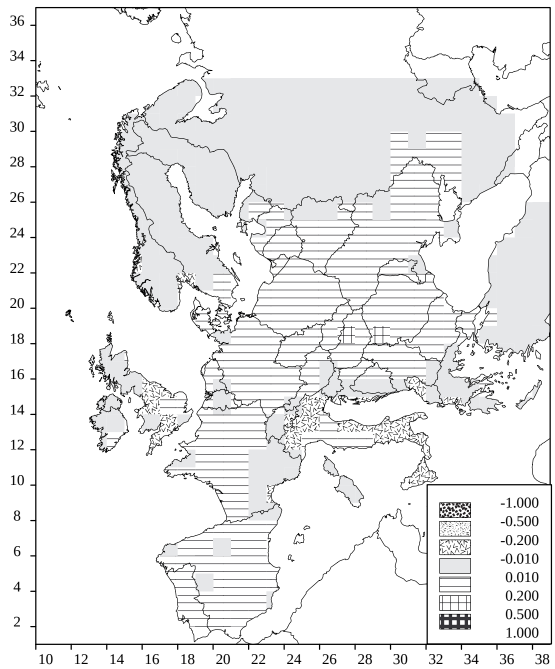

Figure 3.2: Differences in AOT60 (ppm.hours) for the second highest year between scenario J14 and the central J1 scenario

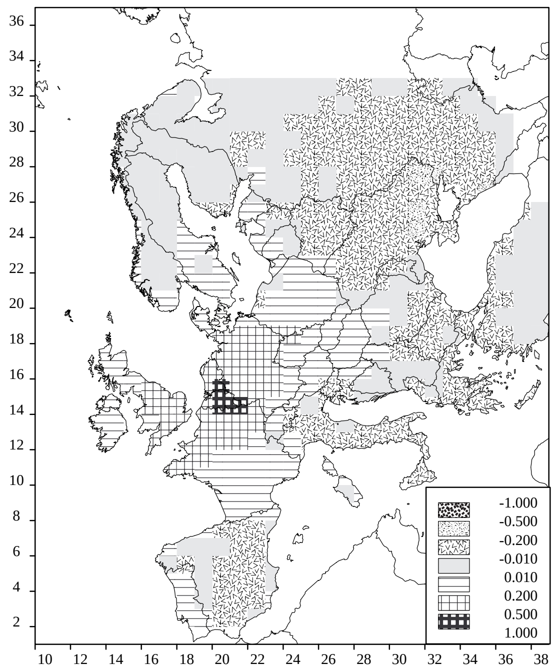

Figure 3.3: Differences in AOT60 (ppm.hours) for the second highest year between scenario J15 and the central J1 scenario

These two maps show (AOT60_J14 – AOT60_J1) and (AOT60_J15 – AOT60_J1).

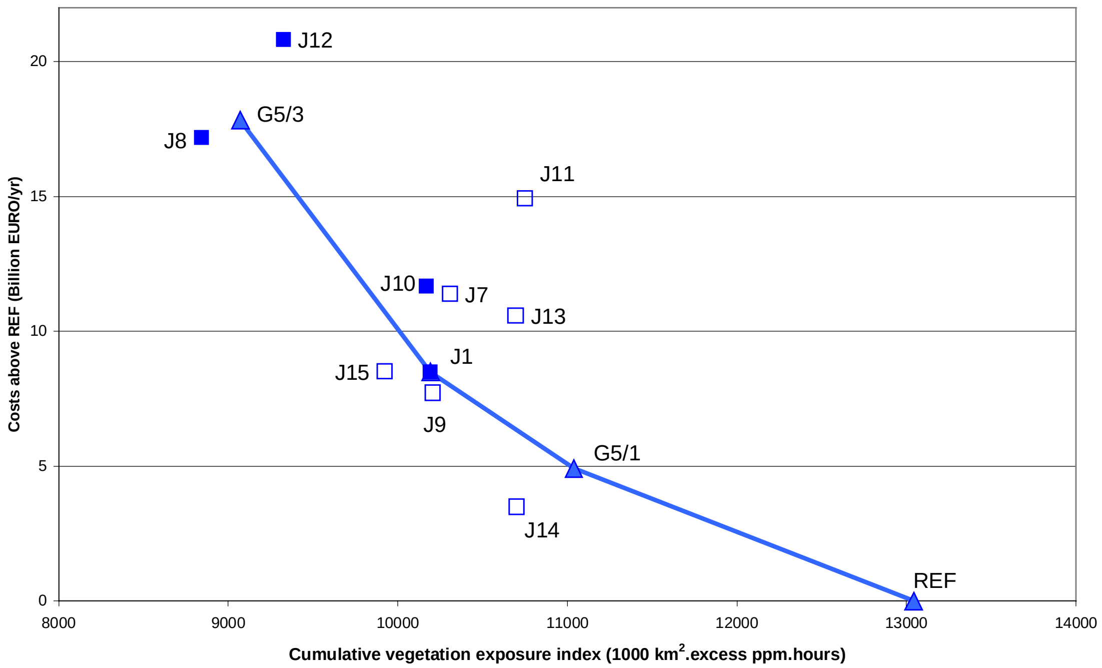

Figure 3.4: Cost-effectiveness of the Europe-wide sensitivity analysis scenarios in relation to the vegetation exposure index

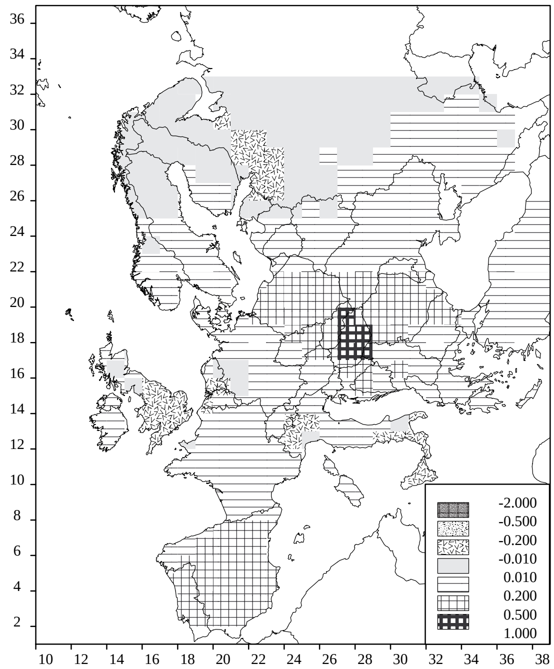

Figure 3.5: Differences in mean AOT40 (ppm.hours) between scenario J14 and the central J1 scenario

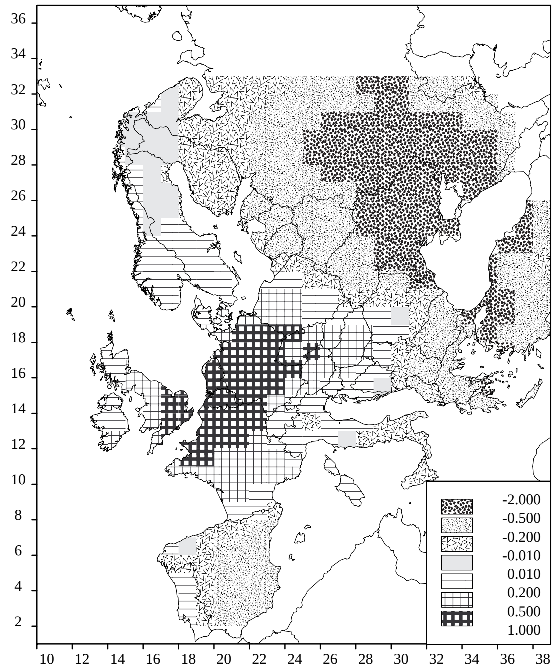

Figure 3.6: Differences in mean AOT40 (ppm.hours) between scenario J15 and the central J1 scenario

These two maps show (AOT40_J14 – AOT40_J1) and (AOT40_J15 – AOT40_J1).

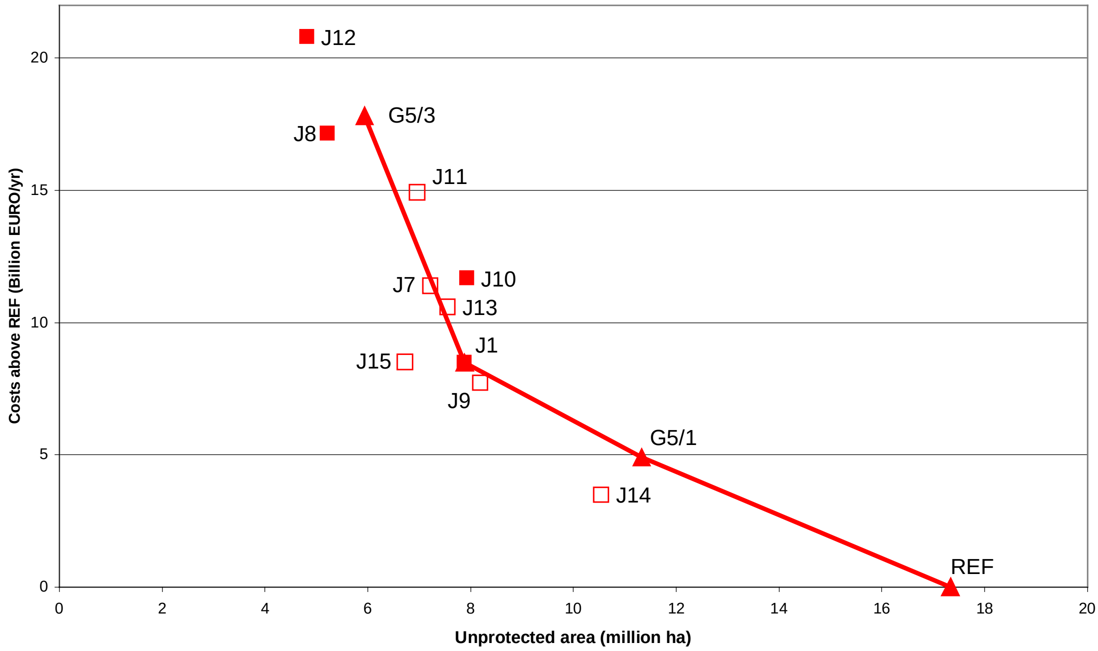

Figure 3.7: Cost-effectiveness of the Europe-wide sensitivity analysis scenarios in relation to the area of ecosystems not protected against acidification

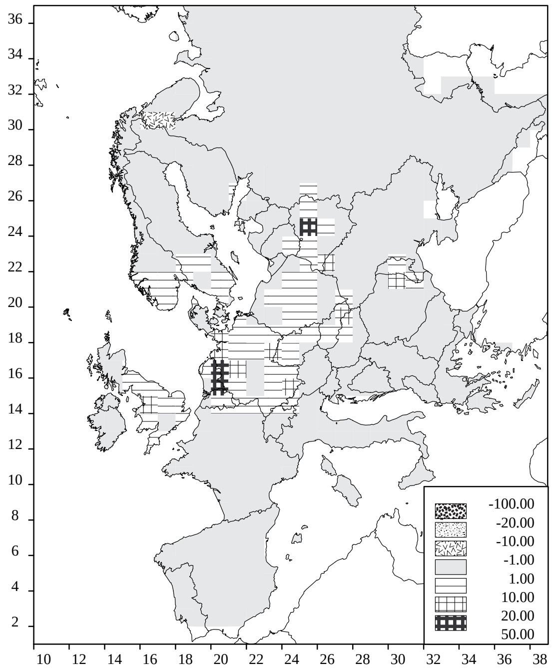

Figure 3.8: Differences in percentage area of ecosystems unprotected against acidification between scenario J14 and the central J1 scenario

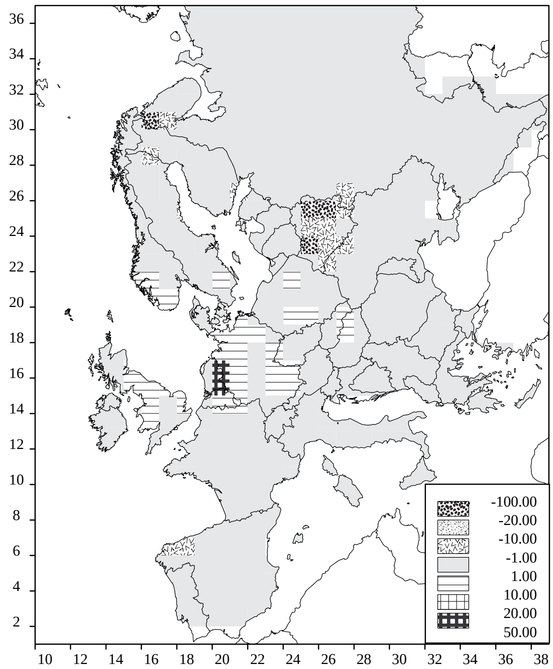

Figure 3.9: Differences in percentage area of ecosystems unprotected against acidification between scenario J15 and the central J1 scenario

These two maps show (Area%_J14 – Area%_J1) and (Area%_J15 – Area%_J1).

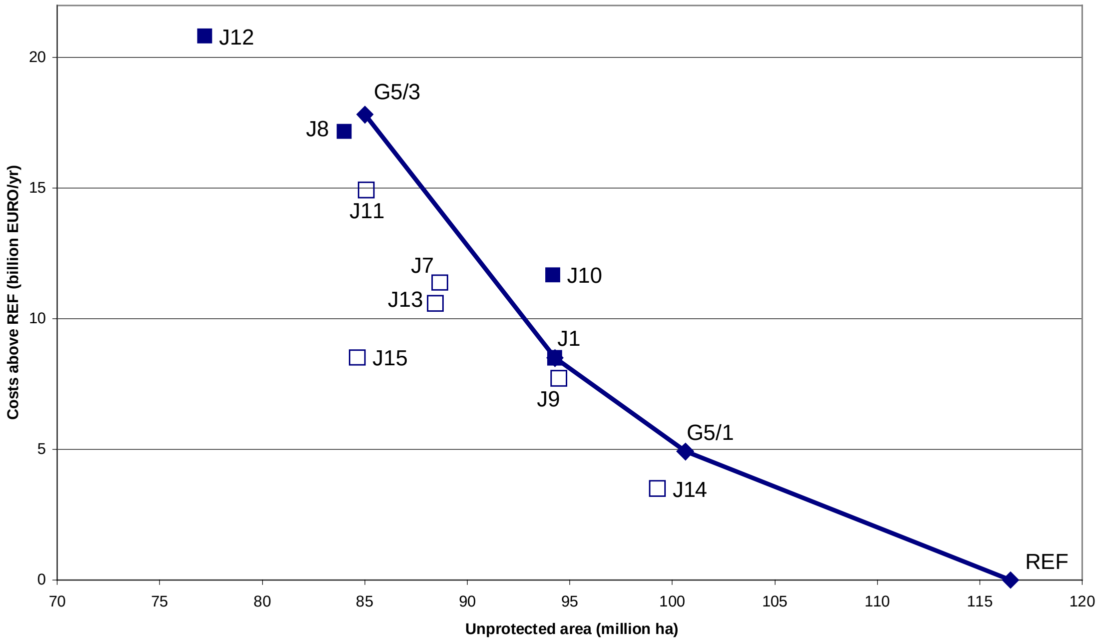

Figure 3.10: Cost-effectiveness of the Europe-wide sensitivity analysis scenarios in relation to the area of ecosystems not protected against eutrophication

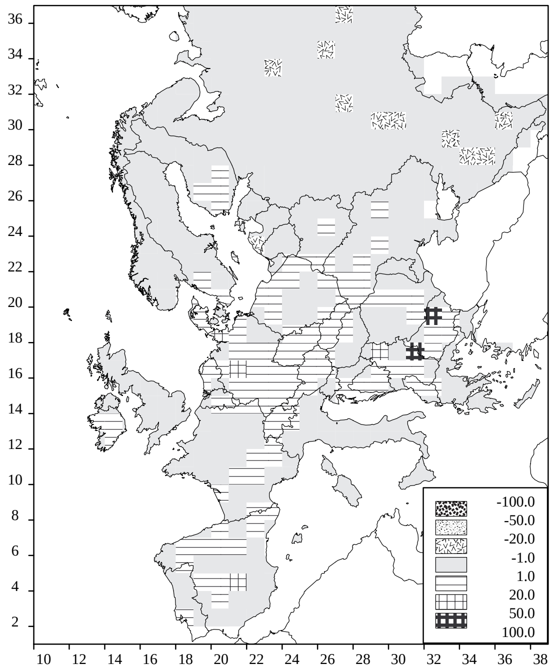

Figure 3.11: Differences in percentage area of ecosystems unprotected against eutrophication between scenario J14 and the central J1 scenario

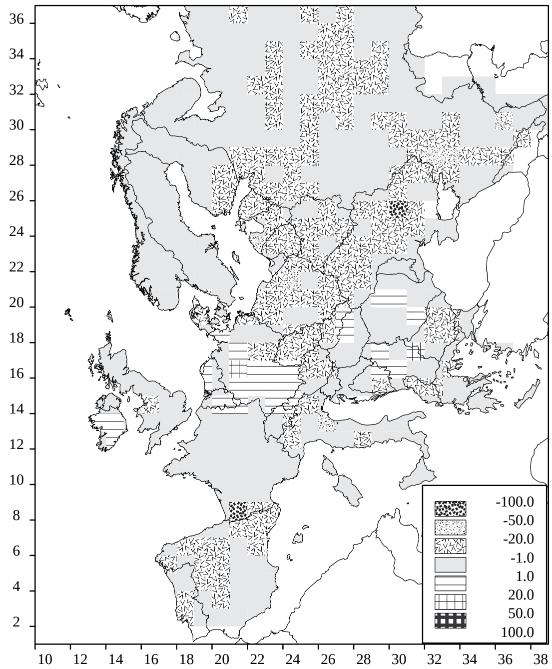

Figure 3.12: Differences in percentage area of ecosystems unprotected against eutrophication between scenario J15 and the central J1 scenario

These two maps show (Area%_J14 – Area%_J1) and (Area%_J15 – Area%_J1).

4 References

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