TEXTE
40/2013

Gridded European Emission Data for the project years 2010, 2015 and 2020

based on the IIASA GAINS NEC scenarios

Umwelt Bundes Amt
Für Mensch und Umwelt

| TEXTE | 40/2013

ENVIRONMENTAL RESEARCH OF THE
FEDERAL MINISTRY OF THE ENVIRONMENT,
NATURE CONSERVATION AND NUCLEAR SAFETY

Project No. (FKZ) 206 43 200/01
Report No. (UBA-FB) 001524/ANH,2,E

Gridded European emission data for the projection years 2010, 2015 and 2020 based on the IIASA GAINS NEC scenarios

Teilbericht zum F&E-Vorhaben „Strategien zur Verminderung der Feinstaubbelastung - PAREST“

by

Hugo Denier van der Gon
Antoon Visschedijk
Hans van den Brugh

TNO Earth, Environment and Life Sciences, Utrecht (The Netherlands)

On behalf of the Federal Environment Agency (Germany)

UMWELTBUNDESAMT

This publication is only available online. It can be downloaded from
http://www.uba.de/uba-info-medien-e/4515.html

ISSN 1862-4804

Study performed by: TNO Earth, Environment
and Life Sciences
P.O.Box 80015
3508 TA Utrecht, The Netherlands

Study completed in: December 2009

Publisher: Federal Environment Agency (Umweltbundesamt)
Wörlitzer Platz 1
06844 Dessau-Roßlau
Germany
Phone: +49-340-2103-0
Fax: +49-340-2103 2285
Email: info@umweltbundesamt.de
Internet: http://www.umweltbundesamt.de
http://fuer-mensch-und-umwelt.de/

Edited by: Section II 4.1 General Aspects of Air Quality Control
Johanna Appelhans

Dessau-Roßlau, June 2013

Table of contents

1 Introduction

In its Thematic Strategy on Air Pollution, the European Commission outlined the strategic approach towards cleaner air in Europe (EC, 2005) and established interim environmental objectives for the year 2020. As one of the main policy instruments, the Thematic Strategy announced the revision of the Directive on National Emission Ceilings (2001/81/EC) with new emission ceilings that should lead to the achievement of the agreed interim objectives. To support the EC in defining the 2020 NEC the International Institute for Applied System Analysis (IIASA) (Amann et al., 2007; 2008) developed various scenarios. These so-called NEC scenarios examine cost-effective emission ceilings for the air pollutant SO_2, NO_x, $PM_{2.5}$, NH_3 and VOC to achieve the environmental objectives of the Thematic Strategy on Air Pollution in 2020. The NEC scenarios are in line with energy projections that correspond to the recent Climate & Energy Package of the European Commission and the national projections of agricultural activities.

In the UBA PAREST project it was agreed that the national emissions for projection years should be in line with the EC environmental objectives for the year 2020. Therefore, the national emissions for the projection years will be based on the NEC Scenario Analysis done by IIASA as described by Amann et al. (2007, 2008). The selected scenarios are described in the next chapter. The approach was such that the national emissions by source sector match the NEC scenario analysis but the starting point of the scaling and spatial distribution of the emissions is the high resolution European emission database for the base year 2005 developed partly in the frame work of the PAREST project and described in detail by Denier van der Gon et al. (2009).

2 Projected emissions for Europe used in PAREST

An overview of the most relevant scenarios as presented in the NEC report 6 (Amann et al., 2008) is presented here. For a more detailed description we refer to the original documentation by Amann et al. (2008).

2.1 Available NEC emission scenarios

C&E package, current policy
Baseline for NECD plus Climate and Energy Package (-20% GHG, 20% share of renewables+ JI/CDM at 30 €/t CO_2+ full renewable trade on top of baseline), February 2008. Current control policies. They include: - 'Current legislation' in all sectors - ELVs on combustion sources in industry and power sector from the IPPC Directive (less strict interpretation) - Euro VI on heavy-duty vehicles - Ceilings from the NEC Directive.

- Scenario described in the NEC Report Nr 6, Amann et al. (2008)
- Available years: 2010, 2015, 2020

C&E package, current legislation
This is the "current legislation" projection for the Climate and Energy Package. Compared with "C&E current policy" case it does not include the implementation of EURO VI standards for heavy-duty vehicles (CEC, 2007a) and the revision of the IPPC Directive (CEC, 2007b).

- Scenario described in the NEC Report Nr 6, Amann et al. (2008)
- Available years: 2010, 2015, 2020

C&E package, OPTV5
This is an optimized emission scenario that assumes an energy projection that is consistent with the Climate and Energy Package of the European Commission. The projection relies on option 4 of the Impact Assessment of the Climate & Energy Package (CEC, 2008b, CEC, 2008c) since it assumes redistribution of non-ETS targets, access to CDM (limiting carbon prices to €30/t CO_2 in both the ETS and non-ETS sectors) and meeting the 20% renewable target in a cost-efficient way through trade and agricultural projection that reflects national perspectives on the development of the agricultural sector that have been provided to IIASA. The scenario meets in 2020 the environmental objectives of the Thematic Strategy on Air Pollution.

- Scenario described in the NEC Report Nr 6, Amann et al. (2008)
- Available years: 2020

C&E package, MRRV5
This MRR (Maximum emissions Reductions in the RAINS model) scenario is based on the activity projections of the Climate and Energy Package and estimates the potential for further emission reductions that are achievable through a full application of the most advanced technical (add-on) emission control measures that are on the market today. This scenario does not consider premature scrapping of existing capital stock before the end of its technical life time; it excludes the potential for emission reductions from fuel substitution and energy efficiency improvements, and it does not assume changes in personal behaviour or in the demand for energy services (e.g., smaller cars, lower room temperature, heating of less living space, changes in diets, etc.). This "MRR" scenario

reflects the “Maximum technically feasible emission reduction” (MTFR) case as it was frequently computed with the RAINS model before, but it does not include the additional potential for emission reductions through structural changes and efficiency improvements that is quantified in the new GAINS model setup.

– Scenario described in the NEC Report Nr 6, Amann et al. (2008)
– Available years: 2020

2.2 Selected scenarios and approach

In consultation with UBA, the following scenarios were selected as a base to make European emission projections for 2010, 2015 and 2020 for the PAREST project.

Table 1 Selected scenarios for projection of emissions to 2010, 2015 and 2020.

Scenario name	Years	Reference
C(limate)& E(nergy) package, Current Policy	2010, 2015, 2020	Amann et al. (2008)
C&E package, OPTV5	2020	Amann et al. (2008)
C&E package, MRRV5	2020	Amann et al. (2008)
“NEC_NAT_EUVI_HDV_V4”[a)]	2010, 2015, 2020	Amann et al. (2007)

a) This scenario is based on national activity projections (and in addition to the NEC_NAT_CLE scenario in NEC Report No.4 (Amann et al. 2007) it assumes the implementation of EURO VI on heavy duty vehicles).

The NEC_NAT_EUVI_HDV_V4 scenario is described in NEC Report No. 4 (June 2007) and in GAINS online. Data is available for the years 2000, 2005, 2010, 2015 and 2020. It was selected because it is based on national energy projections, while the C&E scenarios employ the PRIMES baseline projection of November 2007.

TNO scaled the emissions for Europe w/o Germany from PAREST base year 2005 to the projection years at the source sector level (SNAP01) following the scenarios listed in Table 1. The 2005 distribution pattern per source sector has been assumed for the spatial distribution of the projected years. This implies that national sector total emissions in the PAREST projections are in line with the respective NEC reports prepared by Amann et al. (2007; 2008).

2.3 Projected emissions and distribution

As indicated before absolute emission totals are scaled to IIASA NEC reports to be in line with “accepted” projections as available on http://www.iiasa.ac.at/rains/gains-online.html. Emission projections following the selected scenarios are made for the substances CH_4, NH_3, NMVOC, NO_x, PM_{10}, $PM_{2.5}$ and SO_2. The NO_x and PM_{10} emissions for the EU(27) and other European countries is presented in Table 2. The values for other substances are presented in appendix S1.

Table 2 NO_x and PM_{10} emissions in the EU(27) and "other" Europe for the PAREST base year 2005 and selected emission projections.

SCENARIO		EU(27)				Other Europe			
		2005	2010	2015	2020	2005	2010	2015	2020
		ktonnes/yr							
PAREST 2005	**NO_x**	10656				6231			
GAINS 2005		10655				6185			
NEC4_NAT_EUVI_HDV_V4			9067	7787	6255		6437	6561	6641
NEC6_current_policy			8088	6818	5359		6336	6486	6587
NEC6_OPTV5					4885				6535
NEC6_MRRV5					4224				6483
PAREST 2005	**PM_{10}**	2125				2978			
GAINS 2005		2033				2315			
NEC4_NAT_EUVI_HDV_V4			1780	1753	1570		2223	2299	2376
NEC6_current_policy			1882	1767	1658		2151	2242	2353
NEC6_OPTV5					1407				2256
NEC6_MRRV5					1032				2174

The GAINS projections are not made for all European countries but apply to the EU27, Romania and Bulgaria. Therefore we have presented the emission totals in Table 2 for two country groups. EU(27) and "other Europe. The small changes over the years in "other Europe" occur only because Romania and Bulgaria are included in this group, The other countries are kept constant over these years. Obviously this is not realistic but good emission projections were not available. The group "other Europe" in Table 2 excludes a number of eastern former soviet countries (e.g. Azerbaijan, Armenia, Georgia) but these countries are present in the gridded emission totals. Also for these countries emissions do not deviate from 2005 as no good projection data were readily available.
The Current Policy scenario has higher emissions than the OPTV5 scenario which in turn has higher emissions than the MRVV5 scenario (Table 2). This is to be expected as OPTV5 is an optimized emission scenario and the MRRV5 (Maximum emissions Reductions in the RAINS model) scenario estimates the potential for further emission reductions that are achievable through a full application of the most advanced technical (add-on) emission control measures on the market today.
The comparison of the C&E Current Policy scenario with NEC4 national projections gives a mixed impressions as sometimes the national projection is lower than GAINS "Current Policy" but for "other Europe" it is often higher.

The projected emissions are distributed using the TNO gridding tools (partly) developed in the PAREST project. It should be noted that in all projections the distribution is "PAREST" but the country SNAP totals are from IIASA GAINS NEC reports. We refer to these reports to explain country differences. In the emission distribution maps Germany will be replaced by the projections prepared by IER within the PAREST project. So, although Germany is visible in the next figures the emissions presented are not relevant for the Parest project.

2.3.1 *Distributed NO_x emissions*

The projected NO_x in emission in 2020 following the C&E Current Policy scenario are presented in Figure 1. Emissions vary between 0 – 50.000 tonnes / yr with an indicative average value ranging from 5-100 tonne/cell/yr. The difference between this scenario and the OPTV5 and MRRV5 scenarios is presented in Figure 2 and Figure 3, respectively. The legend scale in both figures is the same, illustrating the lower emissions of the MRRV5 scenario. Again as an indication and for reference to the CP scenario, OPTV5 reduction average ranges from 1 – 10 tonnes/cell/yr with few extremes for point sources whereas MRRV5 reduction average ranges from 1 – 20 tonnes/cell/yr with some extremes for point sources and major cities.

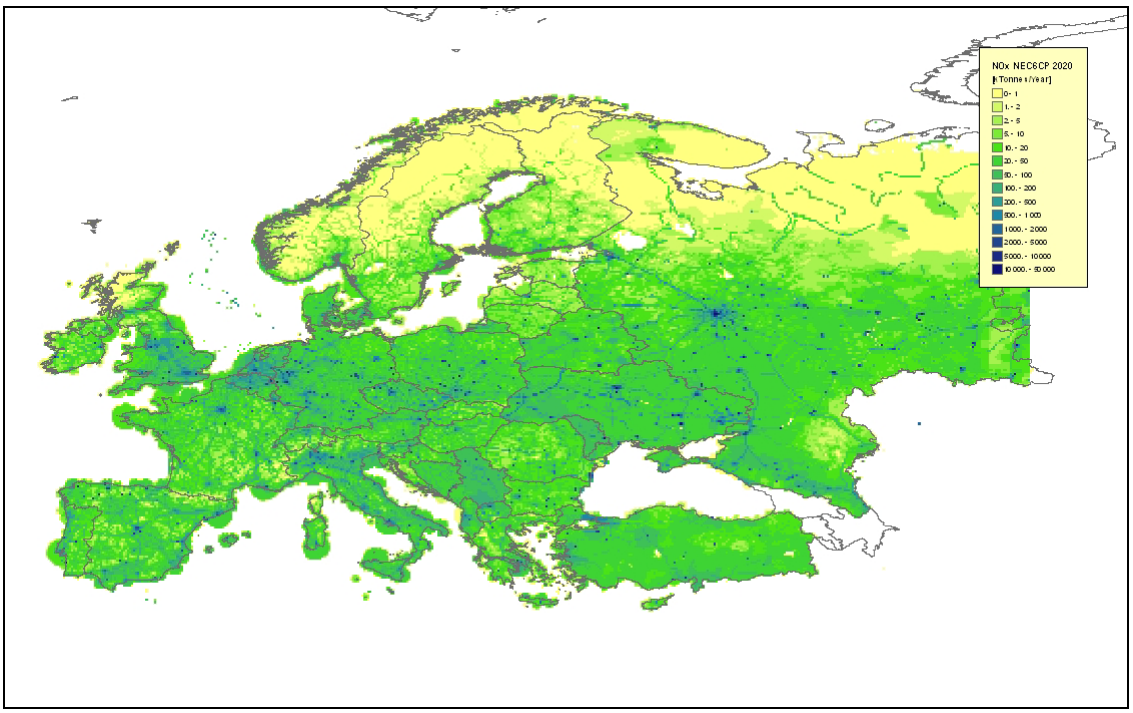


Figure 1 Distribution of NO_x emission in 2020 according to NEC6_current_policy (Table 2).

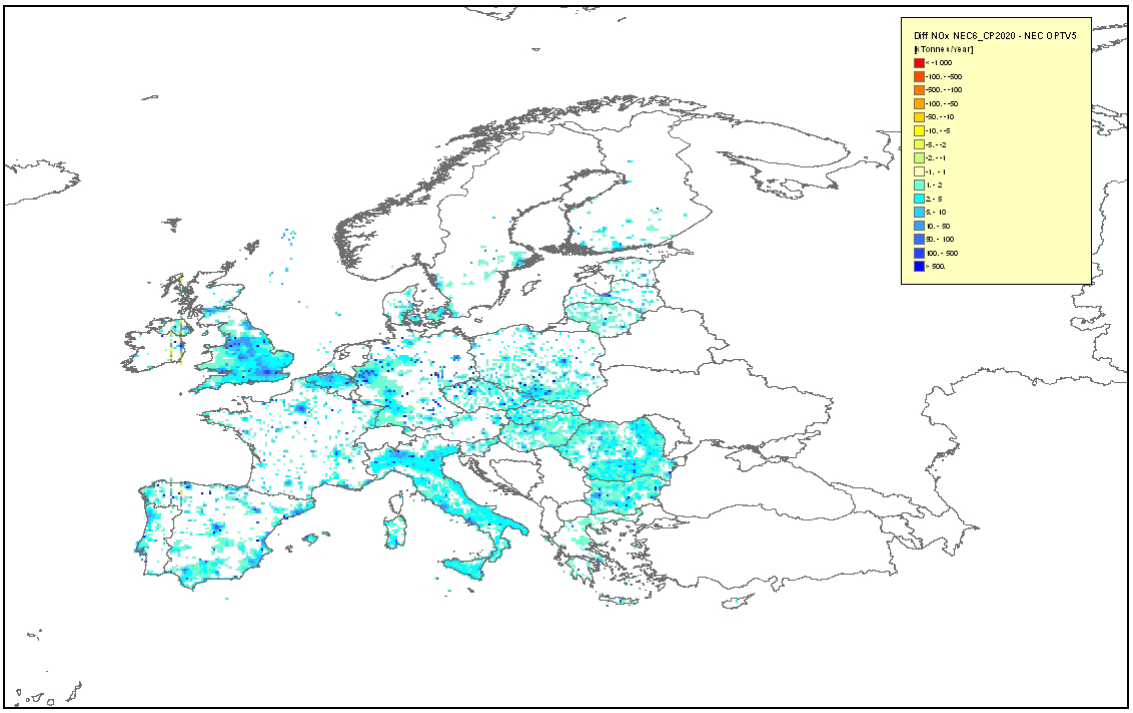


Figure 2 Difference in NO_x emission in 2020 between CP and OPTV5 scenarios – blue indicates OPTV5 is lower.

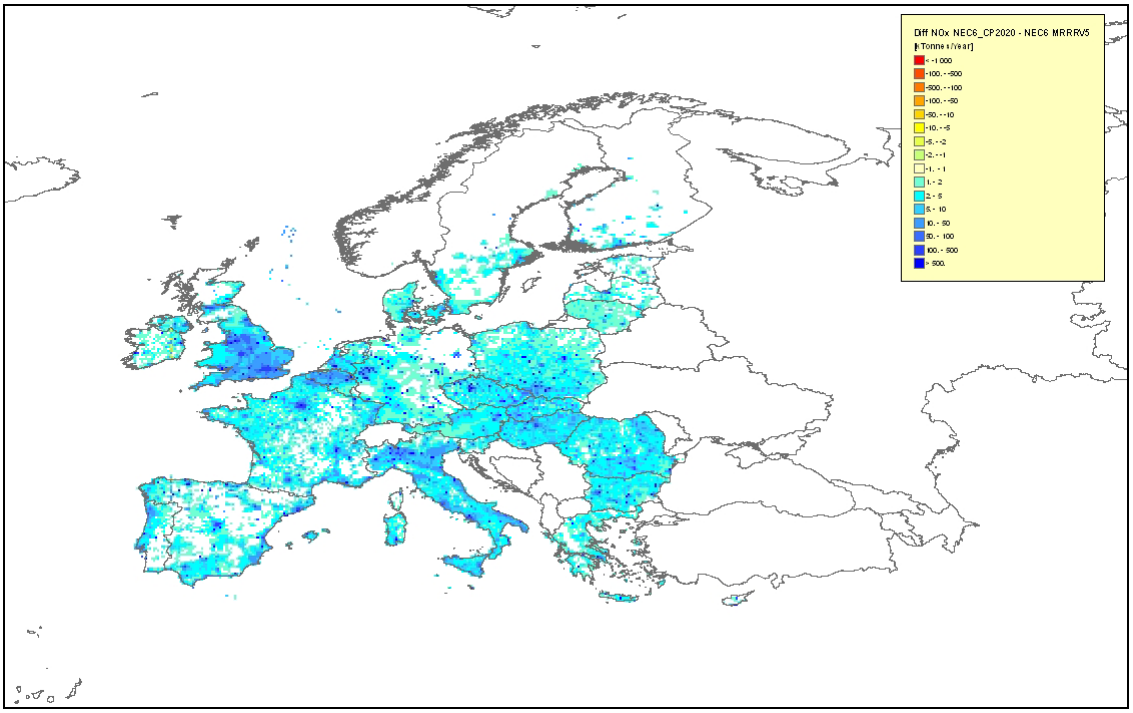


Figure 3 Difference in NO_x emission in 2020 between CP and MRRV5 scenarios – blue indicates MRRV5 is lower.

2.3.2 *Distributed PM_{10} emissions*

The projected PM_{10} emission in 2020 following the C&E Current Policy scenario is presented in Figure 4. Emissions vary between 0 – 50.000 tonnes / yr with an indicative average value ranging from 5-20 tonne/cell/yr. The difference between this scenario and the OPTV5 and MRRV5 scenarios is presented in Figure 2 and Figure 6, respectively. The legend scale in both figures is the same, again illustrating the lower emissions of the MRRV5 scenario. The OPTV5 reduction average ranges from 1 – 10 tonnes/cell/yr with some extremes for point sources and major cities; the MRRV5 reduction average ranges from 2 – 20 tonnes/cell/yr with some extremes for point sources and major cities and urban areas. Figure 7 illustrates the difference between the C&E Current Policy scenario and the NEC_NAT_EUVI_HDV_V4 scenario for 2010 emissions. This shows mixed results because national and IIASA GAINS projections differ by country. The difference ranges from -5 – 10 tonnes/cell/yr.

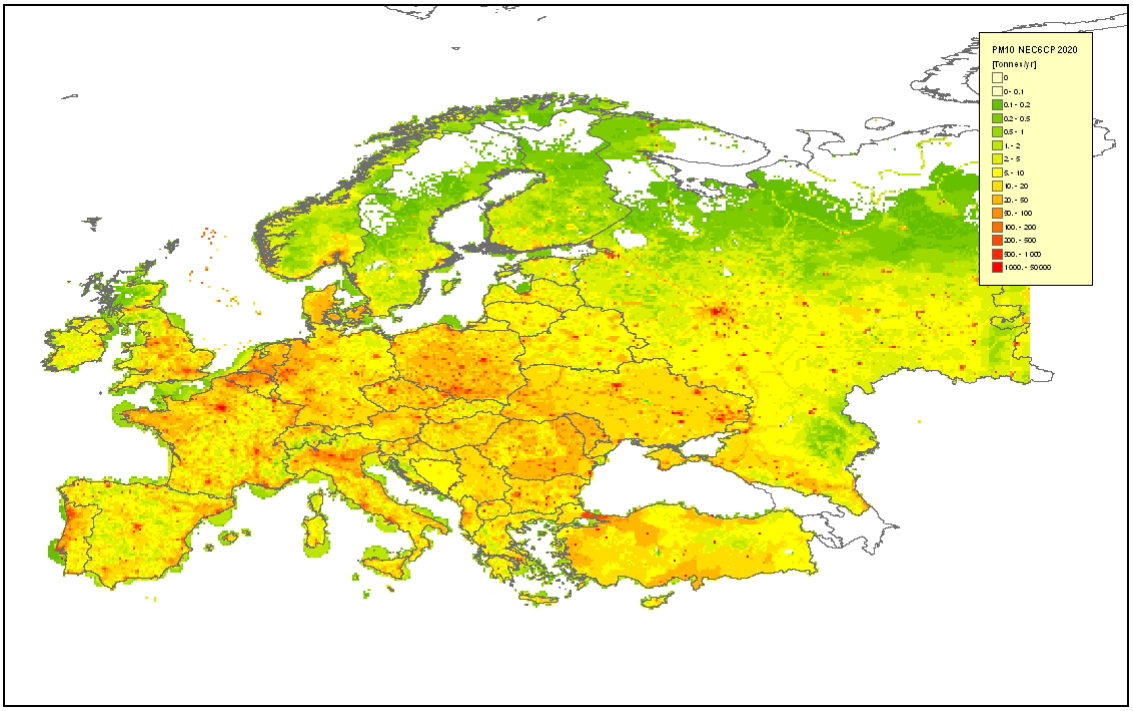


Figure 4 Distribution of PM_{10} emission in 2020 according to NEC6_current_policy (Table 2).

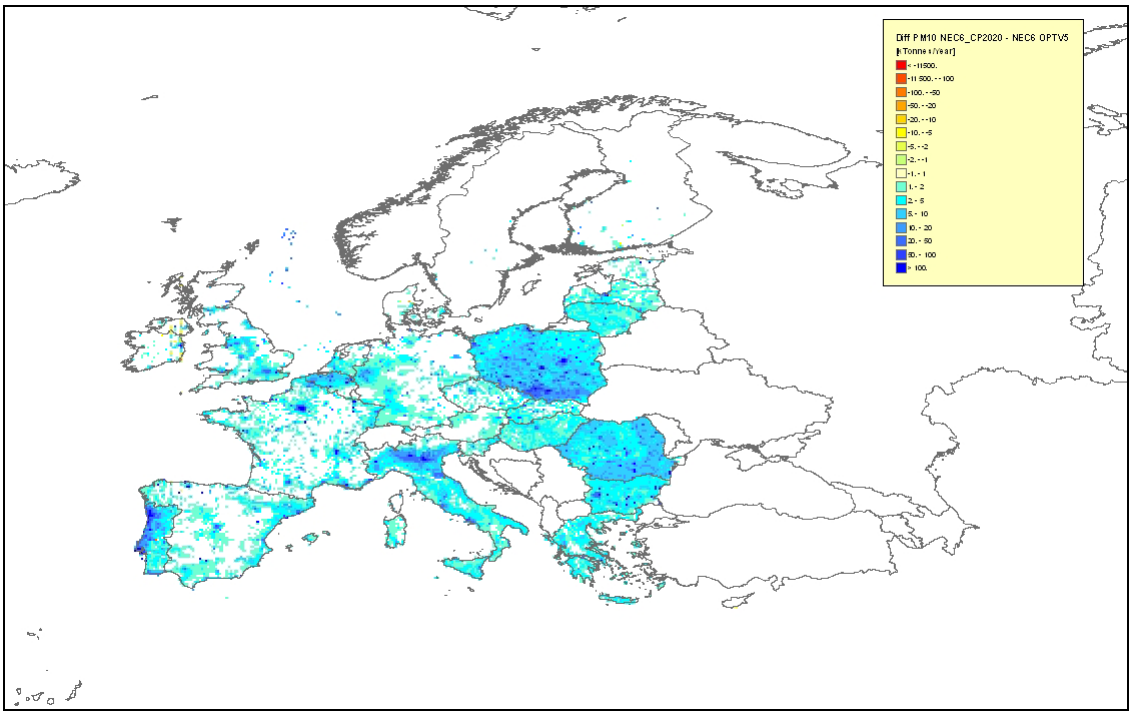


Figure 5 Difference in PM_{10} emission in 2020 between CP and OPTV5 scenarios – blue indicates OPTV5 is lower.

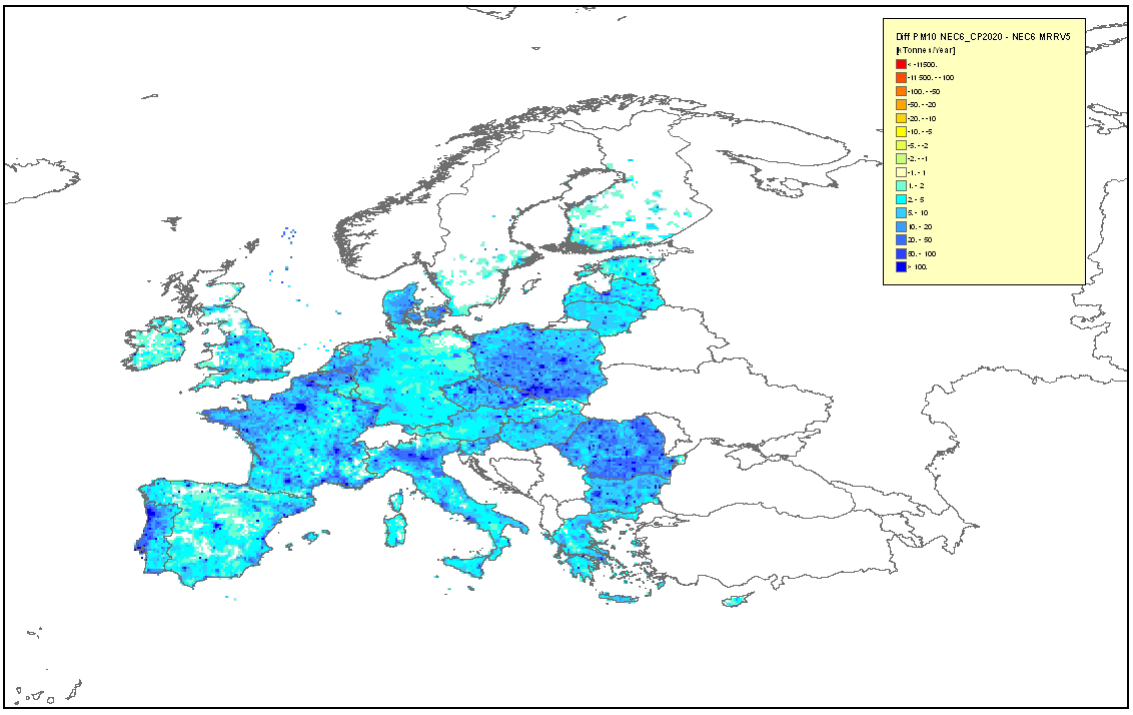


Figure 6 Difference in PM_{10} emission in 2020 between CP and MRRV5 scenarios – blue indicates MRRV5 is lower.

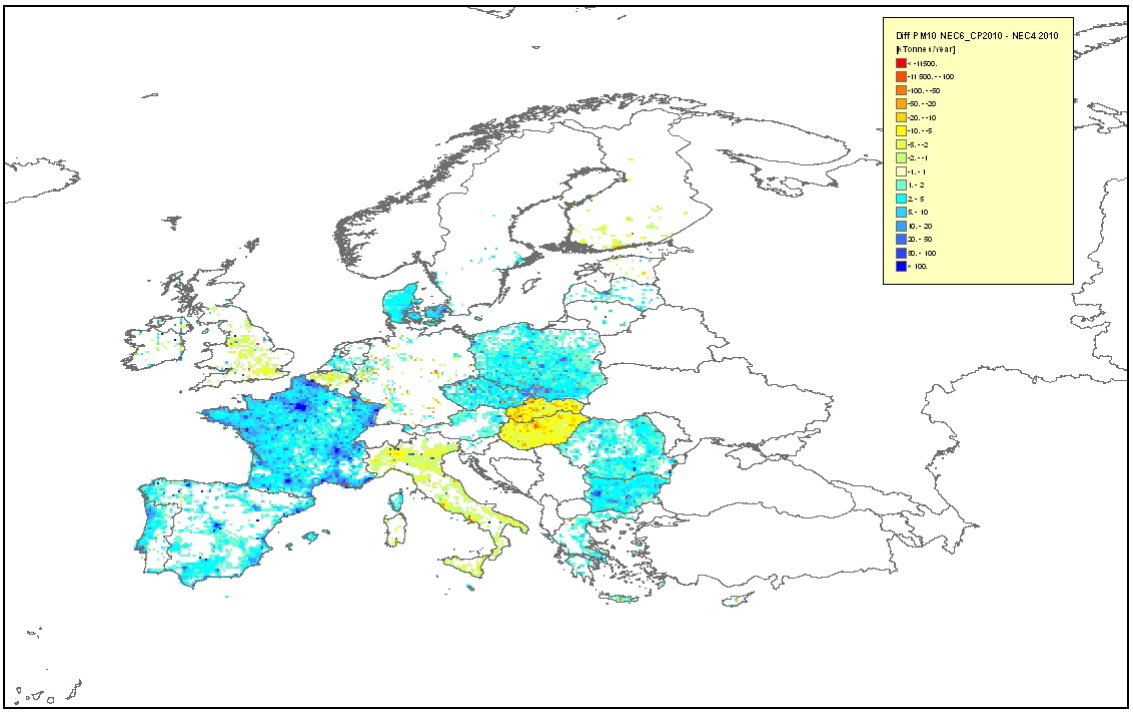


Figure 7 Difference in PM_{10} emission in 2010 between CP and NEC4_national projection scenarios – blue indicates national projection is lower.

3 Summary and Conclusions

Projected emissions for selected scenarios for the years 2010, 2015 and 2020 were obtained from the GAINS NEC scenario reports and distributed on a high resolution over Europe using the TNO gridding tools. These emission maps are available as model input in the PAREST project to model the contribution of Europe to air quality in Germany in 2010, 2015 and 2020 (see note Rainer Stern, May 2009).

The scenarios have a significant influence on absolute emission levels for the countries that were covered by IIASA GAINS. This suggests that emission changes in countries were no scenarios were available (Armenia, Azerbaijan, Georgia) or where only a projection year baseline is available (all non-EU) may be subject to significant changes as well (but these are quite far from Germany). For future projects it is recommended to make simple and transparent scenarios for these other countries, as well as for International Shipping.

The change in emissions from the base year 2005 to the projection year 2010 needs to be interpreted with care. This because some methodology differences between 2005 official emission data as used in the PAREST base year 2005 emission set and GAINS 2010 data exist. It is expected that the emission reduction steps towards 2020 are more realistic.

4 References

Amann, M., W. Asman, I. Bertok, J. Cofala, C. Heyes, Z. Klimont, W. Schöpp, F. Wagner, Updated Baseline Projections for the Revision of the Emission Ceilings Directive of the European Union, NEC Scenario Analysis Report Nr. 4, International Institute for Applied Systems Analysis (IIASA), 2007a

Amann, M., I. Bertok, J. Cofala, C. Heyes, Z. Klimont, P. Rafaj, W. Schöpp, F. Wagner, NEC Scenario Analysis Report Nr. 6, National Emission Ceilings for 2020 based on the 2008 Climate & Energy Package International Institute for Applied Systems Analysis (IIASA), Laxenburg, Final version July 2008.

Denier van der Gon, HAC, AJH Visschedijk, H. van der Brugh, R. Droge, A high resolution European emission data base for the year 2005, TNO report (in prep.), 2009.

European Commission, 2005. Communication from the commission to the council and the European parliament. Thematic Strategy on air pollution COM(2005) 446 final.

Stern, R., Auswirkungen der verschiedenen NEC-Abschätzungen auf die Immissionen in Deutschland, Internal Note PAREST project, May 2009.

5 Authentication

Name and address of the principal

Frau Johanna Appelhans
Umweltbundesamt - Federal Environment Agency
General Aspects of Air Quality Control
Wörlitzer Platz 1, D-06844 Dessau-Roßlau
Germany

Names and functions of the cooperators

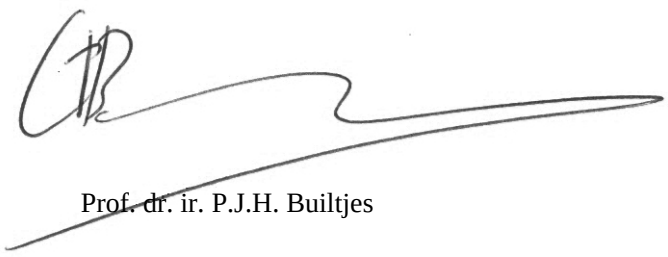
A.J.H. Visschedijk
H.A.C. Denier van der Gon
H. van der Brugh

Names and establishments to which part of the research was put out to contract

-

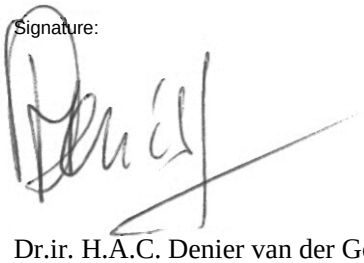
Date upon which, or period in which the research took place

Name and signature reviewer:



Prof. dr. ir. P.J.H. Builtjes

Signature:



Dr.ir. H.A.C. Denier van der Gon
project leader

Release:

Ir. R.A.W. Albers MPA
team manager

1 Overview of Emission Projections by substance

Table 3 Emissions in the EU(27) and "other" Europe for the PAREST base year 2005 and selected emission projections.

		EU(27)				Other Europe			
SUBSTANCE	**SCENARIO**	**2005**	**2010**	**2015**	**2020**	**2005**	**2010**	**2015**	**2020**
CH4	PAREST base year	18229				**34504**			
	GAINS 2005	25161				18606			
	NEC4_NEC_NAT_EUVI_HDV_V4		25309	25677	28360		19529	19440	20113
	NEC6_current_policy		14465	13970	13675		19788	19735	20431
	NEC6_OPTV5				24086				23073
	NEC6_MRRV5				23937				23049
NH3	PAREST base year	3842				**2379**			
	GAINS 2005	3622				1745			
	NEC4_NEC_NAT_EUVI_HDV_V4		3385	3373	3354		1833	1868	1912
	NEC6_current_policy		3472	3469	3465		1846	1880	1924
	NEC6_OPTV5				2936				1882
	NEC6_MRRV5				2255				1817
NMVOC	PAREST base year	9334				**5660**			
	GAINS 2005	8333				6349			
	NEC4_NEC_NAT_EUVI_HDV_V4		6761	6147	5886		6352	6299	6213
	NEC6_current_policy		6743	6114	5724		6304	6275	6222
	NEC6_OPTV5				5674				6194
	NEC6_MRRV5				3959				5975
NOx	PAREST base year	10656				**6231**			
	GAINS 2005	10655				6185			
	NEC4_NEC_NAT_EUVI_HDV_V4		9067	7787	6255		6437	6561	6641
	NEC6_current_policy		8088	6818	5359		6336	6486	6587
	NEC6_OPTV5				4885				6535
	NEC6_MRRV5				4224				6483
PM10	PAREST base year	2125				**2978**			
	GAINS 2005	2033				2315			
	NEC4_NEC_NAT_EUVI_HDV_V4		1780	1753	1570		2223	2299	2376
	NEC6_current_policy		1882	1767	1658		2151	2242	2353
	NEC6_OPTV5				1407				2256
	NEC6_MRRV5				1032				2174
PM2_5	PAREST base year	1351				**1881**			
	GAINS 2005	1384				1587			
	NEC4_NEC_NAT_EUVI_HDV_V4		1178	1086	979		1526	1576	1619
	NEC6_current_policy		1289	1178	1075		1499	1558	1623
	NEC6_OPTV5				894				1548
	NEC6_MRRV5				614				1476
SO2	PAREST base year	6990				**8555**			
	GAINS 2005	6444				7617			
	NEC4_NEC_NAT_EUVI_HDV_V4		4707	4226	3820		7388	7108	7198
	NEC6_current_policy		3157	2919	2624		7292	7111	7250
	NEC6_OPTV5				2093				7186
	NEC6_MRRV5				1634				7064

2 National total emissions for different emission Projection

Table 4 European emissions for the PAREST base year 2005 (ktonnes/yr).

Region	CH_4	CO	NH_3	NMVOC	NO_x	PM_{10}	PM_{2_5}	SO_2
Albania	178	113	24	32	25	9	7	32
Armenia	153	74	15	27	9	7	5	10
Austria	336	720	64	157	226	46	26	26
Azerbaijan	442	174	51	281	113	27	18	185
Belgium	373	876	74	201	295	43	29	147
Bulgaria	489	740	57	158	234	92	56	900
Bosnia and Herzegovina	155	182	17	47	52	45	19	427
Belarus	737	532	135	189	159	36	25	77
Switzerland	168	335	55	106	86	19	9	17
Cyprus	47	41	5	15	17	3	2	14
Czech Republic	521	511	68	183	278	34	21	219
Germany	2268	4043	619	1243	1469	195	112	562
Denmark	268	611	93	120	186	39	28	22
Spain	1730	2297	430	1070	1497	209	141	1341
Estonia	89	158	9	36	32	27	20	77
Finland	214	522	36	131	177	51	34	69
France	2681	5677	735	1443	1207	508	329	465
United Kingdom	2357	2417	318	978	1627	150	95	706
Georgia	151	347	38	53	52	10	7	14
Greece	404	637	73	361	317	71	54	537
Croatia	150	311	44	93	69	24	17	60
Hungary	370	587	80	177	204	57	39	485
Ireland	624	222	113	62	116	22	15	70
Italy	1905	4207	426	1258	1173	166	116	497
Lithuania	160	190	39	82	58	20	17	44
Luxembourg	17	41	5	13	15	4	3	3
Latvia	86	337	14	65	41	16	14	10
Republic of Moldova	219	140	27	38	66	46	25	124
Macedonia	91	104	7	25	39	19	9	105
Malta	17	0	1	9	12	1	0	8
Netherlands	796	603	135	176	347	40	21	62
Norway	219	446	23	221	197	56	50	24
Poland	1824	3333	326	880	721	289	138	1222
Portugal	514	627	72	288	271	47	37	213
Romania	1226	1405	194	402	309	152	103	686
Russia	22855	13019	764	2728	2743	1516	947	2743
Slovak Republic	197	299	27	79	98	25	16	89
Slovenia	100	83	18	43	58	9	7	42
Sweden	267	602	52	196	205	53	33	40
Turkey	2350	2825	410	785	932	372	268	1792
Ukraine	5140	2923	553	703	1183	507	305	1193
Serbia and Montenegro	527	315	68	146	165	86	43	375
Total Europe	**53417**	**53628**	**6318**	**15301**	**17080**	**5147**	**3258**	**15738**
International Shipping	0	333	0	113	3304	267	253	2316

Table 5 European emissions for the NEC4_NAT_EUVI_HDV_V4 2010 scenario (ktonnes/yr).

Region	**CH_4**	**CO**	**NH_3**	**NMVOC**	**NO_x**	**PM_{10}**	**PM_{2_5}**	**SO_2**
Albania	132	145	26	38	28	9	8	30
Austria	1024	667	58	136	172	36	25	21
Belgium	924	710	80	141	259	53	29	98
Bulgaria	228	1088	67	133	156	97	62	441
Bosnia and Herzegovina	129	119	18	45	54	36	17	411
Belarus	691	647	126	246	217	62	47	173
Switzerland	311	210	45	103	66	13	8	19
Cyprus	29	92	7	6	18	2	2	18
Czech Republic	650	591	79	194	297	68	49	236
Germany	5018	2592	471	1039	1212	194	115	470
Denmark	300	477	58	92	168	30	20	19
Spain	2431	1556	360	815	1161	162	105	501
Estonia	67	110	10	28	37	25	16	76
Finland	177	374	31	111	169	34	26	66
France	3791	4061	655	949	1187	241	168	494
United Kingdom	1949	1685	270	920	1204	132	80	458
Greece	326	395	49	171	233	58	41	175
Croatia	104	287	30	74	73	21	15	67
Hungary	493	302	82	122	140	48	32	144
Ireland	746	158	105	57	100	16	10	35
Italy	1488	3240	395	870	1074	187	134	340
Lithuania	125	104	37	53	51	15	12	39
Luxembourg	40	80	6	8	25	3	2	2
Latvia	57	336	14	58	42	22	17	22
Republic of Moldova	145	140	45	40	64	33	20	117
Macedonia	85	99	15	31	41	16	8	82
Netherlands	1651	467	127	158	287	41	21	48
Norway	250	411	21	139	204	61	54	25
Poland	3108	4778	314	400	683	257	173	1165
Portugal	320	406	71	175	211	81	52	132
Romania	883	2293	165	417	334	200	142	331
Russia	9645	12943	509	3323	3001	836	584	2842
Slovak Republic	251	388	31	62	95	30	20	68
Slovenia	76	58	21	35	52	14	10	27
Sweden	260	557	51	156	182	29	19	43
Turkey	3334	2572	449	664	795	353	249	1145
Ukraine	3315	4038	246	946	1237	409	273	1429
Serbia and Montenegro	394	128	71	151	168	75	39	277
Armenia [a)]	153	74	15	27	9	7	5	10
Azerbaijan [a)]	442	174	51	281	113	27	18	185
Georgia [a)]	151	347	38	53	52	10	7	14
Total Europe	**45693**	**49902**	**5318**	**13470**	**15670**	**4046**	**2734**	**12296**
International Shipping [a)]	0	333	0	113	3304	267	253	2316

[a)] PAREST year 2005 value, no scenario applied

Table 6 European emissions for the NEC4_NAT_EUVI_HDV_V4 2015 scenario (ktonnes/yr).

Region	**CH_4**	**CO**	**NH_3**	**NMVOC**	**NO_x**	**PM_{10}**	**PM_{2_5}**	**SO_2**
Albania	131	144	26	40	32	9	8	30
Austria	1017	593	59	124	138	34	22	20
Belgium	781	663	79	132	221	52	27	95
Bulgaria	202	976	67	108	131	91	58	158
Bosnia and Herzegovina	108	93	18	47	56	35	16	395
Belarus	706	670	128	244	227	62	47	177
Switzerland	306	155	43	93	55	12	7	18
Cyprus	27	76	7	6	16	2	2	18
Czech Republic	640	430	78	161	235	57	39	197
Germany	5194	2209	460	922	1016	182	105	460
Denmark	296	365	56	78	145	27	17	21
Spain	2466	1248	365	803	1014	149	92	499
Estonia	65	87	10	24	29	29	17	48
Finland	186	314	30	99	145	33	25	58
France	4167	3503	660	868	1010	315	170	592
United Kingdom	1758	1552	267	872	1059	119	69	361
Greece	304	324	48	146	211	53	37	104
Croatia	111	215	31	56	62	20	14	64
Hungary	478	272	86	119	111	50	34	53
Ireland	719	113	102	54	85	14	8	36
Italy	1451	2619	389	739	929	174	120	335
Lithuania	119	85	38	46	45	15	11	41
Luxembourg	44	53	6	7	18	3	2	2
Latvia	54	300	15	47	37	22	17	22
Republic of Moldova	154	139	45	40	63	26	16	109
Macedonia	74	104	15	33	42	15	8	77
Netherlands	1759	389	132	159	252	39	19	49
Norway	244	345	21	108	188	57	49	26
Poland	3227	4357	311	351	593	240	159	960
Portugal	303	309	70	161	180	70	47	105
Romania	792	2116	169	358	283	197	140	131
Russia	9637	13034	518	3349	3151	876	611	3071
Slovak Republic	269	388	32	61	87	31	21	74
Slovenia	78	50	21	32	44	14	10	26
Sweden	265	497	51	134	161	28	17	42
Turkey	3618	2267	472	585	761	380	263	1026
Ukraine	3123	4631	243	1085	1338	441	298	1603
Serbia and Montenegro	349	73	72	152	170	78	40	221
Armenia [a)]	153	74	15	27	9	7	5	10
Azerbaijan [a)]	442	174	51	281	113	27	18	185
Georgia [a)]	151	347	38	53	52	10	7	14
Total Europe	**45968**	**46351**	**5341**	**12803**	**14515**	**4095**	**2692**	**11535**
International Shipping [a)]	0	333	0	113	3304	267	253	2316

Table 7 European emissions for the NEC4_NAT_EUVI_HDV_V4 2020 scenario (ktonnes/yr).

Region	CH_4	CO	NH_3	NMVOC	NO_x	PM_{10}	PM_{2_5}	SO_2
Albania	136	142	27	43	36	9	7	31
Austria	1089	518	59	113	110	32	21	20
Belgium	831	633	77	125	185	51	26	86
Bulgaria	188	862	68	85	105	61	42	115
Bosnia and Herzegovina	117	88	18	51	58	34	16	380
Belarus	768	699	131	252	239	62	47	182
Switzerland	287	137	41	88	49	12	7	18
Cyprus	29	61	7	5	14	2	2	8
Czech Republic	495	377	77	148	183	48	32	178
Germany	5773	2046	448	850	850	175	99	438
Denmark	291	308	53	71	123	25	15	21
Spain	2672	1088	368	832	819	142	83	446
Estonia	68	77	11	22	23	28	16	48
Finland	191	265	30	90	125	32	24	59
France	5630	3164	651	855	816	201	129	493
United Kingdom	1738	1319	267	827	791	108	60	274
Greece	306	309	47	138	187	51	36	96
Croatia	118	151	32	42	53	19	13	62
Hungary	498	273	90	116	97	58	39	67
Ireland	828	89	98	51	69	13	7	36
Italy	1439	2347	385	699	740	165	110	345
Lithuania	128	78	40	42	40	15	11	39
Luxembourg	50	45	6	6	13	3	2	2
Latvia	53	284	15	43	30	21	16	19
Republic of Moldova	155	140	45	41	63	20	13	102
Macedonia	76	109	15	36	43	15	8	72
Netherlands	1913	354	138	166	209	38	17	50
Norway	242	310	21	90	178	51	44	26
Poland	3411	3946	312	316	412	221	144	857
Portugal	289	265	70	156	152	67	43	86
Romania	810	1883	173	296	249	204	141	139
Russia	9852	13123	524	3363	3297	911	635	3125
Slovak Republic	276	388	32	61	74	32	21	81
Slovenia	77	45	21	30	34	13	9	23
Sweden	276	469	51	121	149	27	17	41
Turkey	4012	1949	491	474	731	426	289	911
Ukraine	3100	5266	253	1196	1368	471	315	1866
Serbia and Montenegro	364	76	73	155	173	82	42	168
Armenia [a)]	153	74	15	27	9	7	5	10
Azerbaijan [a)]	442	174	51	281	113	27	18	185
Georgia [a)]	151	347	38	53	52	10	7	14
Total Europe	**49323**	**44282**	**5367**	**12456**	**13064**	**3990**	**2627**	**11220**
International Shipping [a)]	0	333	0	113	3304	267	253	2316

Table 8 European emissions for the NEC6 C&E package, Current Policy2010 scenario (ktonnes/yr).

Region	CH_4	CO	NH_3	NMVOC	NO_x	PM_{10}	PM_{2_5}	SO_2
Albania	131	145	27	38	28	9	8	30
Austria	270	750	58	144	171	39	27	19
Belgium	344	717	80	138	218	50	27	94
Bulgaria	341	1346	67	117	131	63	47	518
Bosnia and Herzegovina	122	119	18	45	54	36	17	411
Belarus	664	647	128	246	217	62	47	173
Switzerland	174	210	45	89	66	13	8	19
Cyprus	23	81	7	7	15	2	2	9
Czech Republic	414	668	80	229	258	67	52	110
Germany	1719	2911	563	1050	1096	192	115	397
Denmark	233	514	58	94	136	34	24	16
Spain	1575	1720	344	760	1158	191	128	539
Estonia	78	114	10	28	30	13	11	19
Finland	134	390	31	111	159	29	21	52
France	2322	4579	654	893	907	360	276	225
United Kingdom	1646	1675	270	939	1026	127	76	254
Greece	317	428	50	177	228	53	39	169
Croatia	149	287	31	73	73	21	15	67
Hungary	278	273	82	111	133	36	25	139
Ireland	540	152	105	56	90	17	10	38
Italy	1360	2969	400	856	1042	182	128	282
Lithuania	142	110	38	63	47	16	12	26
Luxembourg	24	86	6	9	34	4	2	1
Latvia	54	339	15	56	38	23	19	9
Republic of Moldova	145	140	46	40	64	33	20	117
Macedonia	77	99	15	31	41	16	8	82
Netherlands	608	470	127	158	278	42	22	43
Norway	180	402	21	139	190	61	54	25
Poland	1431	5260	316	422	525	265	183	514
Portugal	406	466	71	181	188	79	51	88
Romania	1190	2485	169	423	272	162	130	158
Russia	10025	12943	524	3296	3001	836	584	2842
Slovak Republic	239	215	31	55	75	20	12	48
Slovenia	93	60	21	36	53	10	8	16
Sweden	208	496	52	167	174	30	19	40
Turkey	2741	2572	428	667	795	353	249	1145
Ukraine	3589	4038	255	948	1237	409	273	1429
Serbia and Montenegro	377	128	72	151	168	75	39	277
Armenia [a)]	153	74	15	27	9	7	5	10
Azerbaijan [a)]	442	174	51	281	113	27	18	185
Georgia [a)]	151	347	38	53	52	10	7	14
Total Europe	**35110**	**51598**	**5419**	**13405**	**14591**	**4076**	**2817**	**10650**
International Shipping [a)]	0	333	0	113	3304	267	253	2316

Table 9 European emissions for the NEC6 C&E package, Current Policy2015 scenario (ktonnes/yr).

Region	CH_4	CO	NH_3	NMVOC	NO_x	PM_{10}	$PM_{2.5}$	SO_2
Albania	131	144	27	40	32	9	8	30
Austria	266	694	59	132	136	37	25	19
Belgium	330	676	79	131	179	49	25	89
Bulgaria	312	1290	67	101	112	60	45	138
Bosnia and Herzegovina	105	93	18	47	56	35	16	395
Belarus	690	670	130	244	227	62	47	177
Switzerland	174	155	43	82	55	12	7	18
Cyprus	22	91	7	6	12	2	1	6
Czech Republic	400	566	79	199	216	60	46	88
Germany	1591	2576	564	938	931	187	109	394
Denmark	227	403	56	80	112	31	20	16
Spain	1572	1406	349	696	1008	177	112	543
Estonia	75	88	10	24	27	12	10	19
Finland	155	321	31	97	132	26	18	39
France	2318	4155	659	820	713	338	252	201
United Kingdom	1499	1627	267	898	875	117	68	244
Greece	269	349	49	149	191	44	33	72
Croatia	157	215	32	55	62	20	14	64
Hungary	279	237	86	103	112	34	22	61
Ireland	539	105	105	53	72	15	9	36
Italy	1295	2355	395	727	879	171	115	295
Lithuania	127	90	39	58	42	15	11	28
Luxembourg	24	57	6	8	21	3	2	1
Latvia	53	311	15	48	34	22	18	10
Republic of Moldova	152	139	46	40	63	26	16	109
Macedonia	70	104	15	34	42	15	8	77
Netherlands	628	392	124	157	230	40	20	44
Norway	172	331	21	107	168	57	49	26
Poland	1416	4982	313	393	486	255	177	512
Portugal	395	389	70	170	156	72	48	87
Romania	1086	2501	173	378	247	170	136	153
Russia	10019	13034	533	3318	3151	876	611	3071
Slovak Republic	189	202	32	52	68	20	12	48
Slovenia	90	53	21	33	44	9	7	14
Sweden	206	391	51	138	139	27	16	47
Turkey	2981	2267	451	590	761	380	263	1026
Ukraine	3458	4631	253	1086	1338	441	298	1603
Serbia and Montenegro	341	73	73	152	170	78	40	221
Armenia [a)]	153	74	15	27	9	7	5	10
Azerbaijan [a)]	442	174	51	281	113	27	18	185
Georgia [a)]	151	347	38	53	52	10	7	14
Total Europe	**34559**	**48761**	**5449**	**12746**	**13474**	**4052**	**2766**	**10236**
International Shipping [a)]	0	333	0	113	3304	267	253	2316

Table 10 European emissions for the NEC6 C&E package, Current Policy2020 scenario (ktonnes/yr).

Region	CH_4	CO	NH_3	NMVOC	NO_x	PM_{10}	PM_{2_5}	SO_2
Albania	136	142	27	43	36	9	7	31
Austria	264	621	60	120	103	35	23	17
Belgium	323	650	77	128	148	48	24	84
Bulgaria	318	1238	68	87	97	61	45	139
Bosnia and Herzegovina	113	88	18	51	58	34	16	380
Belarus	753	699	133	252	239	62	47	182
Switzerland	174	137	41	79	49	12	7	18
Cyprus	22	89	7	6	10	2	1	4
Czech Republic	366	516	77	181	181	53	40	81
Germany	1452	2442	566	868	790	186	106	403
Denmark	227	341	53	73	95	28	18	17
Spain	1568	1181	353	663	719	160	96	362
Estonia	74	81	11	21	21	11	8	16
Finland	132	259	30	88	107	24	16	36
France	2313	3729	650	756	541	311	227	188
United Kingdom	1415	1412	267	856	615	108	60	210
Greece	257	317	48	138	165	42	30	63
Croatia	167	151	33	42	53	19	13	62
Hungary	285	213	90	96	89	32	20	55
Ireland	540	80	104	50	56	14	8	34
Italy	1245	2090	390	681	700	166	109	290
Lithuania	136	82	40	54	35	15	11	29
Luxembourg	23	44	6	7	13	3	2	1
Latvia	52	279	15	42	29	21	17	10
Republic of Moldova	153	140	46	41	63	20	13	102
Macedonia	72	109	15	36	43	15	8	72
Netherlands	662	356	130	161	178	39	18	45
Norway	167	292	21	90	152	51	44	26
Poland	1414	4502	313	361	424	235	160	498
Portugal	401	360	70	167	130	71	47	65
Romania	1104	2509	177	339	228	181	143	167
Russia	10271	13123	539	3329	3297	911	635	3125
Slovak Republic	195	199	32	52	58	20	12	50
Slovenia	90	46	21	31	34	9	6	15
Sweden	211	329	51	123	115	26	15	49
Turkey	3304	1949	468	481	731	426	289	911
Ukraine	3459	5266	263	1198	1368	471	315	1866
Serbia and Montenegro	355	76	75	155	173	82	42	168
Armenia [a)]	153	74	15	27	9	7	5	10
Azerbaijan [a)]	442	174	51	281	113	27	18	185
Georgia [a)]	151	347	38	53	52	10	7	14
Total Europe	**34959**	**46735**	**5490**	**12304**	**12117**	**4054**	**2728**	**10081**
International Shipping [a)]	0	333	0	113	3304	267	253	2316

Table 11 European emissions for the NEC6 C&E package, OPTV5 2020 scenario (ktonnes/yr).

Region	CH_4	CO	NH_3	NMVOC	NO_x	PM_{10}	PM_{2_5}	SO_2
Albania	136	142	27	43	36	9	7	31
Austria	666	592	55	120	99	33	21	17
Belgium	596	641	73	127	135	40	20	65
Bulgaria	306	1156	63	85	81	35	25	136
Bosnia and Herzegovina	113	88	18	51	58	34	16	380
Belarus	753	699	133	252	239	62	47	182
Switzerland	174	137	41	79	49	12	7	18
Cyprus	43	89	6	6	10	2	1	4
Czech Republic	611	504	69	181	156	49	37	65
Germany	3312	2323	444	865	711	174	97	386
Denmark	426	337	52	73	88	27	17	16
Spain	2170	1166	297	652	625	137	81	263
Estonia	93	80	10	20	16	10	7	16
Finland	516	259	28	88	100	22	14	34
France	3272	3717	536	756	507	275	200	162
United Kingdom	2595	1377	236	855	554	95	52	175
Greece	370	314	41	130	161	35	24	61
Croatia	167	151	33	42	53	19	13	62
Hungary	625	209	65	94	74	27	17	23
Ireland	686	74	95	50	53	13	7	28
Italy	2222	2054	331	669	648	138	85	224
Lithuania	173	80	34	50	30	12	8	24
Luxembourg	38	44	6	7	13	3	2	1
Latvia	75	277	11	40	23	15	12	10
Republic of Moldova	153	140	46	41	63	20	13	102
Macedonia	72	109	15	36	43	15	8	72
Netherlands	1403	354	125	161	177	37	16	44
Norway	855	292	21	90	152	51	44	26
Poland	2141	3446	267	358	391	174	117	327
Portugal	679	360	60	167	118	41	29	50
Romania	3071	2473	141	314	192	110	87	107
Russia	10271	13123	539	3329	3297	911	635	3125
Slovak Republic	338	198	28	51	49	15	8	35
Slovenia	129	46	17	30	33	8	6	10
Sweden	891	329	46	123	110	26	14	49
Turkey	3304	1949	468	481	731	426	289	911
Ukraine	3459	5266	263	1198	1368	471	315	1866
Serbia and Montenegro	355	76	75	155	173	82	42	168
Armenia [a)]	153	74	15	27	9	7	5	10
Azerbaijan [a)]	442	174	51	281	113	27	18	185
Georgia [a)]	151	347	38	53	52	10	7	14
Total Europe	**48001**	**45272**	**4918**	**12226**	**11591**	**3706**	**2472**	**9488**
International Shipping [a)]	0	333	0	113	3304	267	253	2316

Table 12 European emissions for the NEC6 C&E package, MRRV5 2020 scenario (ktonnes/yr).

Region	CH_4	CO	NH_3	NMVOC	NO_x	PM_{10}	PM_{2_5}	SO_2
Albania	136	142	27	43	36	9	7	31
Austria	654	382	35	77	90	26	16	16
Belgium	595	610	68	109	121	35	17	58
Bulgaria	302	460	53	44	65	20	13	51
Bosnia and Herzegovina	113	88	18	51	58	34	16	380
Belarus	753	699	133	252	239	62	47	182
Switzerland	174	137	41	79	49	12	7	18
Cyprus	43	22	5	5	8	2	1	1
Czech Republic	599	268	56	78	139	27	17	52
Germany	3305	2046	338	596	643	156	88	349
Denmark	423	226	47	47	82	15	8	13
Spain	2163	961	210	523	546	109	65	191
Estonia	92	50	7	13	13	5	3	9
Finland	514	224	25	57	88	12	7	32
France	3237	2654	379	489	435	173	113	135
United Kingdom	2592	1304	198	657	445	83	46	144
Greece	365	232	34	78	133	23	15	29
Croatia	167	151	33	42	53	19	13	62
Hungary	620	175	49	52	57	17	8	18
Ireland	685	67	84	28	42	10	6	20
Italy	2215	1738	252	506	556	114	71	126
Lithuania	170	35	24	30	23	6	3	12
Luxembourg	38	41	4	6	12	3	2	1
Latvia	71	121	8	16	21	5	4	8
Republic of Moldova	153	140	46	41	63	20	13	102
Macedonia	72	109	15	36	43	15	8	72
Netherlands	1403	347	118	129	153	30	15	39
Norway	855	292	21	90	152	51	44	26
Poland	2118	2206	203	206	340	120	71	280
Portugal	671	180	42	110	104	24	14	32
Romania	3051	902	86	135	157	43	28	70
Russia	10271	13123	539	3329	3297	911	635	3125
Slovak Republic	337	167	17	34	37	12	7	23
Slovenia	123	21	13	15	32	5	3	8
Sweden	890	280	37	98	102	21	11	36
Turkey	3304	1949	468	481	731	426	289	911
Ukraine	3459	5266	263	1198	1368	471	315	1866
Serbia and Montenegro	355	76	75	155	173	82	42	168
Armenia [a)]	153	74	15	27	9	7	5	10
Azerbaijan [a)]	442	174	51	281	113	27	18	185
Georgia [a)]	151	347	38	53	52	10	7	14
Total Europe	**47829**	**38488**	**4173**	**10293**	**10879**	**3249**	**2120**	**8908**
International Shipping [a)]	0	333	0	113	3304	267	253	2316