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Emission scenarios for non-CO_2 greenhouse gases in the EU-27

Mitigation potentials and costs in 2020

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Executive Summary

To provide quantitative information for the debate on the burden sharing of the European Union target to reduce greenhouse gas emissions in 2020 by 20 percent, this report assesses the potential and costs for further mitigation of the non-CO_2 greenhouse gas emissions beyond the currently agreed policies. It addresses the non-CO_2 gases included in the Kyoto protocol, i.e., methane (CH_4), nitrous oxide (N_2O), and the three F-gases hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6).

The study employs the GAINS (Greenhouse and Air pollution Interactions and Synergies) model to project future emissions and to assess the remaining mitigation potentials and costs. A baseline projection quantifies the impacts of present expectations on economic development and of the currently agreed mitigation policies. This baseline assessment adopts the national projections of future activity data that have been provided by Member States to IIASA in the course of the revision of the National Emission Ceilings (NEC) directive. In a further step, the analysis derives cost curves that rank, for each Member State and greenhouse gas, remaining mitigation measures by increasing marginal mitigation costs.

The assessment maintains full consistency with the greenhouse gas emission inventories that have been submitted by the Member States to the UNFCCC.

The analysis finds that in the baseline, assuming the national projections of future activity data and full implementation of current legislation, total emissions of non-CO_2 greenhouse gases would decline in the EU-27 by 58 Mt CO_2eq or 6 percent between 2005 and 2020. This includes a 19 percent reduction in CH_4, a 4 percent increase in N_2O, and a 12 percent increase in F-gases. Additional reductions of 286 Mt CO_2eq are considered technically feasible. This could achieve a decline in total non-CO_2 gases of 36 percent between 2005 and 2020, and would come at a total cost of € 21 billion per year. 44 Mt CO_2eq of this potential could be implemented through measures for which cost savings exceed over the technical life time investments and operating costs. These measures include farm-scale anaerobic digestion for large farms and leakage reduction at compressor stations in gas transmission pipelines. Mitigation of the remaining 242 Mt CO_2eq would involve costs of € 21 billion per year. Among the control options that have marginal cost of less than € 25/t CO_2eq, substantial reductions can be attained from reducing N_2O through catalytic reduction in nitric acid production, reduced application of fertilizers on agricultural lands, and combustion modifications in fluidized bed combustion.

About the authors

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1 Introduction

In March 2007 the European Council decided to set as an autonomous objective for domestic EU climate policy a 20 percent reduction in greenhouse gas emissions for 2020 compared to 1990. It also agreed that an essential point that needs to be addressed is the sharing of the burden of these emission reductions across Member States and sectors. Estimates of the available potentials for and costs of further mitigation measures in each Member State can provide one essential input to the policy discussion on the distribution of the overall reduction commitment.

This study provides for the year 2020 quantitative assessments of mitigation potentials for non-CO_2 greenhouse gas emissions and associated costs for all Member States of the European Union. Based on the GAINS (Greenhouse and Air pollution Interactions and Synergies) model, this report develops a projection of future baseline emissions of the non-CO_2 gases. Furthermore, the potential for further emission reductions beyond what is required by current legislation is assessed for each country, and the costs of the additional measures are estimated.

This report addresses emissions of the five non-CO_2 greenhouse gases that are included in the Kyoto protocol, i.e., methane (CH_4), nitrous oxide (N_2O), and the three F-gases hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). It covers all 27 EU Member States and targets the year 2020.

Thereby, through quantifying the technical potentials for mitigation measures and the associated costs for all Member States, the study provides relevant information that should assist the policy process in reaching a fair and effective burden sharing agreement. A companion study is conducted by the Technical University of Athens to assess the mitigation potentials and costs for CO_2 emissions.

The report is organized as follows: Section 2 summarizes the methodology of the GAINS model that is used for the baseline emission projection and the assessment of the potentials and costs for further mitigation measures. It discusses how information provided by Member States in their national emission inventories reported to the UNFCCC has been taken into account. Section 3 compared the emission estimates for the years 2000 and 2005 derived by the GAINS model with the recent numbers that have been reported by Member States to the UNFCCC. Section 4 develops a baseline projection of future non-CO_2 greenhouse gas emissions that outlines the likely development of emissions based on national perspectives on economic development and considering the impacts of current legislation for mitigation measures. Section 5 summarizes the potential and costs for further mitigation measures, for the EU-27 as a whole and for each Member State individually. Conclusions are drawn in Section 5.

2 Methodology: The GAINS model

The Greenhouse and Air pollution Interactions and Synergies (GAINS) model explores cost-effective strategies to reduce emissions of greenhouse gases and conventional air pollutants. The GAINS model (http://www.iiasa.ac.at/web-apps/apd/rainsonline/EU/) produces emission scenarios for all major air pollutants for any exogenously supplied projection of future economic activities, abatement potentials, and costs as well as interactions in abatement between various pollutants (Klaassen *et al.*, 2004).

2.1 Emission calculations

Emissions of each pollutant *p* are calculated as the product of the activity levels, the "uncontrolled" emission factor in absence of any emission control measures, a factor adjusting for the efficiency of emission control measures and the application rate of such measures:

$$E_{i,p} = \sum_{j,a,t} E_{i,j,a,t,p} = \sum_{j,a,t} A_{i,j,a} * ef_{i,j,a,p} * s_{t,p} * X_{i,j,a,t}$$ Equation 2.1

where

i,j,a,t,p	country, sector, activity, abatement technology, pollutant
E_{ip}	emissions of pollutant *p* in country *i*,
A_{ija}	activity in sector *j* and activity *a* in country *i*,
ef_{ijap}	"uncontrolled" emission factor for sector *j* and activity *a*,
S_{tp}	fraction of emissions remaining after application of control technology *t*, and
X_{ijat}	implementation rate of control technology *t*.

For calculating total greenhouse gas emissions, the GAINS model uses the global warming potentials defined in the Kyoto protocol (Table 2-1).

Table 2-1: Global warming potentials (GWPs) over 100 years used in GAINS emission calculations (UNFCCC, 1997)

Gas/sector	*Gas*	*Average GWP*
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
HCFC-22 production	HFC	11700
Industrial refrigeration	HFC	2600
Commercial refrigeration	HFC	2726
Transport refrigeration	HFC	2000
Domestic refrigeration	HFC	1300
Stationary air conditioning	HFC	1670
Mobile air conditioning	HFC	1300
Aerosols	HFC	1300
Other HFC	HFC	815-1300
Primary aluminium production	PFC	6500-9200
Semiconductor industry	PFC	6500
High and mid voltage switches	SF_6	23900
Magnesium production and casting	SF_6	23900
Other use of SF_6	SF_6	23900

The methodology used for the non-CO_2 greenhouse gas modules in GAINS has been documented in detail for CH_4 in Höglund-Isaksson and Mechler, 2005a, for N_2O in Winiwarter, 2005, and for F-gases in Tohka, 2005. Since these publications all three modules have been subject to revisions. The following changes are most relevant for the analysis of the burden sharing agreement presented in this report:

- The treatment of CH_4 emissions from solid waste and wastewater has been revised to better reflect emissions from the various types of biodegradable waste as well as the long time lag of up to a few decades between solid waste deposition and emissions. The detailed account of different waste types and wastewater sources and their treatment in Europe became possible with the publication of detailed waste and wastewater statistics by EUROSTAT, 2005.
- CH_4 emission factors from gas transmission pipelines are now based on the energy content of the gas transported following the recommendations of the revised IPCC guidelines (IPCC, 2006). In GAINS Version 1.0, these emission factors were related to the amounts of gas produced in Eastern Europe and the amounts of gas consumed in Western Europe following the IPCC guidelines (IPCC, 1997).
- In GAINS Version 1.0, CH_4 emissions from combustion included only emissions from biomass burning (as the main source for CH_4 combustion emissions). This has now been revised to include CH_4 emissions from the combustion of biomass and non-biomass fuels as well as from stationary and mobile sources.
- The F-gas directive (2006/842/EC) and the directive on air-conditioning systems in motor vehicles (2006/40/EC) have been included in the current legislation baseline scenario.

- The actual penetration of HCF-134a-based mobile air conditioning (MAC) has been adjusted to correspond to the emissions reported to the UNFCCC for 2005 and the saturation of HCF-134a-based MAC was protracted by five years.

2.2 Mitigation measures considered in GAINS

GAINS considers more than 60 different measures to control CH_4, 10 measures to control N_2O and 15 measures to control different F-gases. Table 2-2 presents a summary of these measures. Technical and economic features of the available mitigation measures are documented in Höglund-Isaksson and Mechler, 2005a, Winiwarter, 2005, and Tohka, 2005.

For CH_4, significant amounts of emissions can be mitigated by diverting biodegradable solid waste away from landfills through recycling, composting or incineration, and through controlling and recovery of landfills emissions. Many of these options are already adopted in the EU as a result of the Landfill Directive. CH_4 from domestic and industrial wastewater can be controlled through increased collection of wastewater and extended use of aerobic treatment procedures or anaerobic treatment with gas recovery and flaring or utilization of the gas for energy purposes. Control measures in the energy sector include extended gas recovery from coal mines, gas and oil production and refineries. Fugitive emissions from gas distribution networks can be controlled by replacing grey cast iron networks with PE or PVC networks, and through increased frequency of leakage controls. Agricultural emissions of CH_4 can be controlled through anaerobic digestion of animal manure. Farm-scale anaerobic digesters are assumed economically feasible for larger farms (with at least 100 dairy cows, 200 beef cattle or 1000 pigs). Larger community-scale anaerobic digesters are assumed feasible in areas with intensive farming per land area. Use of alternative rice strains and improved aeration of rice fields are measures that can reduce emissions from rice cultivation.

Important options for controlling N_2O emissions from soils include various ways to modify fertilizer application, e.g., by reducing fertilizer use and/or improved timing. More expensive options include the use of advanced agro-chemicals (e.g., nitrification inhibitors) and precision farming. N_2O emissions in the energy sector can be controlled through combustion modifications in plants with fluidized beds. Catalytic reduction can mitigate N_2O emissions from adipic and nitric acid production. The release of N_2O can also be reduced through optimized operating conditions in wastewater treatment plants and improved control of direct use of N_2O, e.g., for anaesthetic purposes.

HFC mitigation measures include various good practice options such as leakage control, improved components, and end-of-life recollection of refrigeration and air-conditioning equipment. Further reductions can be attained by using alternative agents to HFC in mobile air conditioning, aerosols, and in one- and more-component foams. HFC emissions from HCFC-22 production can be reduced through post-combustion of HFC-23.

PFC emissions from primary aluminium industry can be reduced through retrofitting or conversion of side-worked prebake (SWPB) or Vertical Stud Söderberg (VSS) technology to point feeder prebake (PFPB) technology. PFC emissions can also be reduced in the semi-conductor industry by using NF_3 as alternative solvent.

SF_6 emissions from magnesium production and casting can be reduced by using SO_2 as alternative protection gas and by banning the use of SF_6 in e.g., soundproof windows or sports equipment.

Emissions from high and mid voltage switches can be controlled through good practice measures, i.e., leakage control, improved components, and end-of-life recollection.

Table 2-2: Summary of mitigation measures for non-CO_2 greenhouse gases included in European version of GAINS

Gas	Sector	Abatement technology description
CH_4	Agriculture	Farm-scale and community-scale anaerobic digestion of animal manure
		Dietary changes for dairy cows and cattle
		Alternative rice strains and improved aeration of rice fields.
		Ban on agricultural waste burning
	Waste	Waste diversion options: recycling of paper and wood waste, composting and biogasification of food waste, and waste incineration
		Landfill options: gas recovery with flaring or gas utilization
	Wastewater	Domestic urban wastewater collection with aerobic or anaerobic treatment with or without gas recovery.
		Domestic rural wastewater treatment in latrines or septic tanks.
		Industrial wastewater treatment –aerobic or anaerobic with or without gas recovery utilization
	Coal mining	Recovery with flaring or utilization of gas
	Gas distribution	Replacement of grey cast iron networks and increased network control frequency
	Gas and oil prod.& processing	Recovery and flaring of gas
N_2O	Agriculture	Reduced and/or improved timing of fertilizer application
		Use of advanced agro-chemicals (e.g., nitrification inhibitors)
		Precision farming
	Energy combustion	Combustion modifications in fluidized beds
	Industrial processes	Catalytic reduction in nitric and adipic acid production
	Wastewater	Optimization of operating conditions in wastewater plants
	Direct N_2O use	Replacement/reduction in use of N_2O for anaesthetic purposes
HFC	Aerosols	Alternative propellant
	Stationary air conditioning and refrigeration	Good practice: leakage control, improved components, and end-of-life recollection
		Process modifications for commercial and industrial refrigeration
	Mobile air conditioning and refrigeration	Alternative refrigerant: pressurized CO_2
		Good practice: leakage control, improved components, and end-of-life recollection
	HCFC-22 production	Incineration: post combustion of HFC-23
	Foams	Alternative blowing agent for one component and other foams
PFC	Primary aluminium production	Conversion of SWPB or VSS to PFPB and
		Retrofitting of VSS and SWPB
	Semiconductor Industry	Alternative solvent use: NF_3
SF_6	Magnesium prod. and casting	Alternative protection gas: SO_2
	High and mid voltage switches	Good practice: leakage control, improved components, and end-of-life recollection
	Other SF_6 use	Ban of use

2.3 Mitigation costs

The GAINS model calculates the costs for each country and mitigation option taking into account technology- and country-specific circumstances. It applies a social cost concept to the calculations of mitigation costs. The model attempts to quantify the values to society of the resources diverted to reduce emissions. In practice, these values are approximated by estimating costs at the production level rather than at the level of consumer prices. Therefore, any mark-ups charged over production costs by manufacturers or dealers do not represent actual resource use and are ignored. Any taxes added to production costs are similarly ignored as subsidies as they are transfers and not resource costs. All costs are given in Euros at the 2005 price level.

A central assumption in the GAINS cost calculation is the existence of a free market for (abatement) equipment throughout Europe that is accessible to all countries at the same conditions. Thus, the capital investments for a certain technology can be specified as being independent of the country. Simultaneously, the calculation routine takes into account several country-specific parameters that characterise the situation in a given region e.g., labour costs and emission factors. Expenditures for emission controls are differentiated into:

- investments,
- operating and maintenance costs, and
- cost savings.

From these elements GAINS calculates annual costs per unit of activity level in year *t* as:

$$C_{it} = I_t^{an} + OM_{it} - CS_{it}$$ Equation 2.2,

where I_t^{an} is the annualized investment cost, OM_{it} is the country-specific operation and maintenance cost, and CS_{it} is the country-specific cost-saving. Each cost part is specified in more detail below. All cost data was taken from literature and are referenced in detail in the reports by Höglund-Isaksson and Mechler, 2005a, Winiwarter, 2005, and Tohka, 2005.

Investments cover expenditures accumulated until the start-up of a mitigation technology. These costs include, e.g., delivery of the installation, construction, civil works, ducting, engineering and consulting, license fees, land requirement and capital. The GAINS model uses investment functions where these cost components are aggregated into one function.

For all pollutants, investments are annualised over the technical lifetime of the plant *lt* by using the interest rate *q* (as %/100):

$$I^{an} = I * \frac{(1+q)^{lt} * q}{(1+q)^{lt} - 1}$$ Equation 2.3.

An interest rate of nine percent was used for the cost calculations in this report. While this is in contrast to the (social) interest rate of four percent that is conventionally used in GAINS, it matches the (private) interest rates used by the PRIMES model that has been applied for the CO_2-related aspects of the burden sharing proposal. Since the PRIMES model is used in conjunction with the GAINS to model the contribution of EU emissions trading market vis-à-vis other sectors as part of the EU's Climate & Energy Package the private interest rate is the one to determine the carbon prices and renewable subsidies needed to meet the given objectives (20% reduction in

GHG emissions in 2020 compared to 1990 and a 20% share of renewable energy in final energy deman) of the EU's climate and energy package [1].

Operating and maintenance costs (*OM*) include all variable costs associated with a control measure. These include e.g., operating costs of paper recycling plants, farm-scale anaerobic digestion plants, large-scale composts, and waste incineration plants, as well as costs for operating installations for recovery and utilization or flaring of gas. Apart from costs for operating control equipment, the *OM* costs also include costs for upgrading recovered gas and waste separation and collection costs. The annual operating and maintenance cost per activity unit is defined as:

$$OM_{it} = M + E * p_{electr} + \frac{h}{1920} \times W_{it} \qquad \text{Equation 2.4}$$

where M is the non-labour and non-energy related operation and maintenance cost e.g., costs for material, E is the energy required, p_{electr} is the price of electricity, h are the annual work hours required, and W_{it} is the average annual wage for skilled workers. The material costs are not assumed to vary between countries, while labour costs are country-specific.

Cost-savings occur primarily in CH_4 control options. These include different forms of utilization of recovered gas or reduced gas leakages. Cost-saving may also appear as productivity increases in milk or beef production as changes in animal feeds reduce emissions from enteric fermentation. Other sources of cost-savings arise in the waste sector, where virgin pulp in paper production can be substituted for cheaper recycled pulp, good quality compost may be sold in the market, and any diversion of waste away from landfills implies saved costs from avoided landfill deposition.

Recovered gas e.g., from landfills, sewage plants, or anaerobic digestion plants, is assumed to be flared or utilized for energy purposes. When utilized, the gas can be upgraded to the quality of natural gas or utilized directly as electricity or heat. Cost-savings arising from utilization of recovered gas or from reduced gas leakages are defined as follows:

$$CS_{it} = \lfloor N * p_{gas} \rfloor + \lfloor 0.75 * R * p_{electr} \rfloor \qquad \text{Equation 2.5,}$$

where N is the amount of gas recovered and upgraded to the quality of natural gas or saved through reduced leakages, p_{gas} is the price of natural gas, R is the amount of energy recovered and utilized as electricity or heat, and p_{electr} is the price of electricity. From the energy recovered and utilized as electricity or heat, 50 percent is assumed to be utilized as electricity and 50 percent as heat and the price of heat energy is assumed to be 50 percent of the electricity price. The prices of gas and electricity were retrieved from the GAINS model and are for the past based on International Energy Agency (IEA) statistics and for the future on the price index of the baseline projection used by the PRIMES energy model.

Cost-savings from dietary changes that reduce emissions from enteric fermentation in dairy cows and beef cattle arise because the diet change often increases productivity. With a constant production of milk and meat, the productivity increase is reflected in a reduced animal stock where

[1] See: Impact Assessment Package of Implementation Measures for the EU's objectives on climate change and renewable energy for 2020 (SEC(2008))85/3, Commission Staff Working Document, European Commission, Brussels

each animal produces more milk or meat. The value of the extra milk or beef produced per animal is measured using country-specific producer prices for milk and meat for the year 2000 from FAOSTAT (2004). These prices are assumed to remain constant in real terms in the projections.

$$CS_{it} = y_{it} * p_i * \eta \qquad \text{Equation 2.6,}$$

where y_{it} is the average milk or meat yield per animal, p_i is the producer price for milk or meat, and η is the percentage increase in productivity per animal resulting from the change in diet.

3 Base year emissions

The GAINS model estimates historic emissions on the basis of (i) statistics of activity levels of emission generating activities, (ii) country- and sector-specific emission factors reflecting country-specific conditions without mitigation measures, and (iii) the penetration of mitigation measures over time and their effectiveness.

3.1 Activity data

As a starting point for the calculation of current and future emissions, GAINS uses statistics on energy consumption, industrial production and agricultural activities. To minimize artefacts resulting from different national accounting schemes, activity statistics in GAINS for 2000 and 2005 have been predominantly derived from international statistics and harmonized to the extent possible with the information provided in the CRFs and the National Inventory Reports (NIRs) to UNFCCC. The GAINS database has been validated in a series of bilateral consultations with national experts in the course of the preparation of the revised NEC directive. Table 3-1 to Table 3-3 summarize total energy consumption and livestock numbers for the 27 EU Member States for the year 2000.

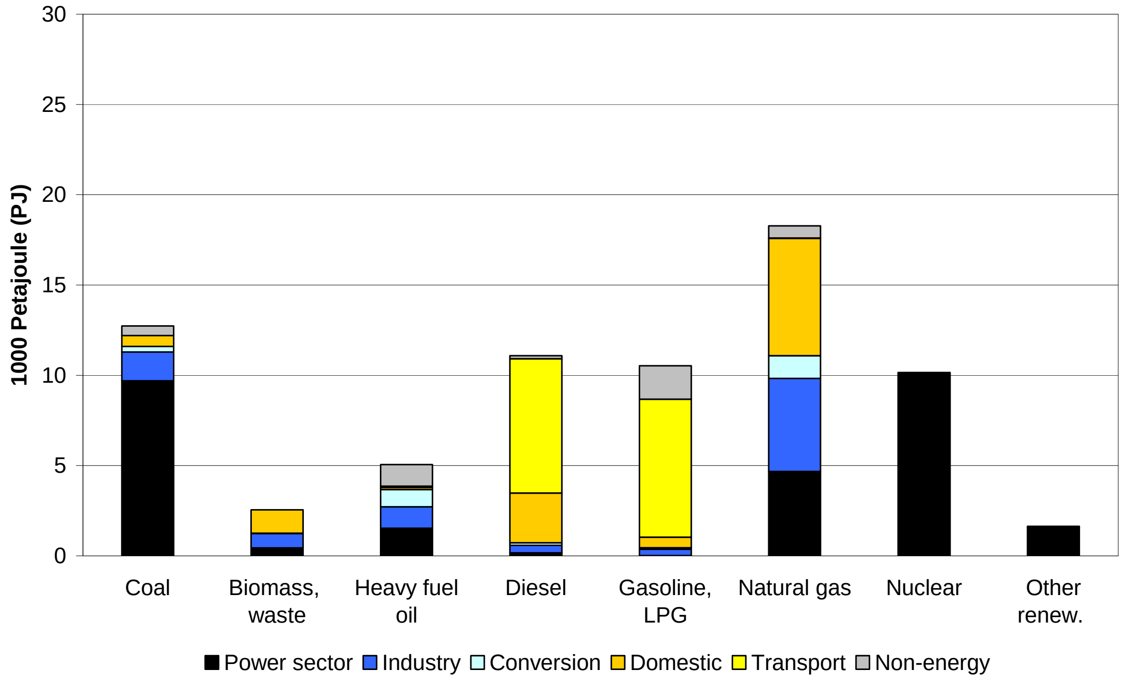

Figure 3-1: Energy consumption by fuel and sector in 2000

Table 3-1: Primary energy consumption in 2000 [PJ]. Source: GAINS (based on national and EUROSTAT energy balances)

	Coal	*Biomass, waste*	*Heavy fuel oil*	*Diesel*	*Gasoline, LPG*	*Natural gas*	*Nuclear*	*Other renew.*	*Electr. import*[1)]	*Total*
Austria	119	128	114	253	114	332	0	153	-5	1208
Belgium	257	49	78	497	447	655	496	2	15	2496
Bulgaria	268	23	52	60	63	136	196	10	-17	792
Cyprus	1	0	47	22	25	1	0	1	0	99
Czech Rep.	823	28	58	147	112	385	147	6	-38	1668
Denmark	165	70	72	152	125	205	0	19	2	811
Estonia	120	21	10	16	14	31	0	0	-3	208
Finland	207	237	80	171	117	189	236	47	39	1324
France	494	448	452	1811	1351	1727	4538	259	-250	10830
Germany	3327	221	741	2469	2252	3334	1851	117	11	14322
Greece	382	40	170	279	223	96	0	19	0	1208
Hungary	156	16	94	87	107	423	153	1	12	1049
Ireland	117	8	70	160	97	144	0	5	0	600
Italy	426	139	1262	1213	1335	2473	0	339	150	7337
Latvia	3	49	9	19	16	41	0	10	16	164
Lithuania	3	23	43	26	24	86	93	1	-14	286
Luxembourg	5	2	1	55	40	28	0	1	21	152
Malta	0	0	19	6	9	0	0	0	-1	34
Netherlands	269	60	112	504	569	1542	39	4	68	3167
Poland	2279	166	210	320	296	557	0	8	-23	3812
Portugal	155	133	247	220	175	99	0	44	3	1076
Romania	271	119	171	138	98	636	59	54	-3	1542
Slovakia	136	47	22	33	28	315	178	17	-10	766
Slovenia	57	17	6	51	39	35	52	15	-11	263
Spain	830	155	610	1027	853	800	672	125	16	5087
Sweden	95	294	131	237	263	57	619	286	14	1997
UK	1771	58	176	1119	1735	3983	822	88	51	9802
EU-27	12734	2552	5057	11093	10528	18308	10151	1629	45	72098

[1)] Exports are indicated by negative numbers.

Table 3-2: Energy consumption of the EU-27 by fuel and sector in 2000 [PJ] Source: GAINS (based on national and EUROSTAT energy balances)

	Coal	*Biomass, waste*	*Heavy fuel oil*	*Diesel*	*Gasoline LPG*	*Natural gas*	*Nuclear*	*Other renew.*	*Electr.*[1)]	*Total*
Power sector	9695	437	1533	172	18	4675	10151	1595	-10549	17728
Industry	1588	802	1180	414	354	5149	0	1	3741	13230
Conversion	319	15	957	134	77	1260	0	0	1607	4369
Domestic	594	1298	117	2757	590	6497	0	33	5011	16896
Transport	0	0	72	7443	7635	54	0	0	234	15439
Non-energy	539	0	1197	173	1854	673	0	0	0	4435
Total	12734	2552	5057	11093	10528	18307	10151	1629	45	72098

[1)] Power sector - gross power generation (reported with negative sign); the conversion sector includes own use of energy industries as well as transmission and distribution losses; Total - net electricity import. Exports are indicated by negative numbers.

Table 3-3: Agricultural activity data for the year 2000

	Cattle	*Pigs*	*Chicken and poultry*	*Sheep and goats*	*Horses*	*Fertilizer consumption*	*Fertilizer production*
	1000 animal heads					kt N	
Austria	2155	3348	11787	395	82	121	185
Belgium	3001	7266	39728	176	73	145	1440
Bulgaria	652	1512	14963	3595	374	145	404
Cyprus	54	408	3310	625	7	8	0
Czech Rep.	1609	3315	32043	118	26	213	306
Denmark	1868	11922	21831	91	150	252	133
Estonia	253	300	2366	32	4	22	38
Finland	1057	1298	12570	107	57	167	245
France	20310	14930	270989	10788	444	2571	1494
Germany	14568	25767	118447	2305	520	1848	1308
Greece	566	936	28193	14449	140	285	216
Hungary	805	4834	31244	1219	79	320	290
Ireland	6558	1732	15338	7957	80	408	248
Italy	7245	8307	176722	12464	337	786	428
Latvia	367	394	3105	39	20	29	0
Lithuania	898	936	6373	39	75	98	530
Luxembourg	200	83	70	8	2	17	0
Malta	19	80	830	17	1	0	0
Netherlands	4070	13118	104972	1487	118	339	1300
Poland	5723	15447	111900	337	550	896	1497
Portugal	1172	2359	41195	4145	80	170	125
Romania	2532	4797	70076	8195	865	239	872
Slovakia	647	1488	12446	399	10	82	286
Slovenia	493	604	5107	118	14	34	0
Spain	6074	24367	169133	26892	499	1255	899
Sweden	1684	1918	16900	437	300	189	94
UK	11134	6482	168973	42340	291	1036	490
EU-27	95714	157948	1490610	138774	5198	11674	12827

Data source: GAINS, based on EUROSTAT statistics, FAO, IFA, national statistical yearbooks, and bilateral consultations with national experts

For the year 2005, not all activity statistics were available in mid 2007 when the analysis has been conducted. Therefore, the analysis employs for the year 2005 the most recent projections for the year 2005, which however might differ to some degree from numbers provided in the final statistics. Activity data used for the calculation of emissions in 2005 are provided in Table 3-4 to Table 3-6.

Table 3-4: Primary energy consumption in 2005 [PJ]. Source: GAINS

	Coal	*Biomass, waste*	*Heavy fuel oil*	*Diesel*	*Gasoline, LPG*	*Natural gas*	*Nuclear*	*Other renew.*	*Electr. import*[1)]	*Total*
Austria	107	133	66	337	114	359	0	160	-3	1273
Belgium	252	55	71	529	447	722	488	4	23	2591
Bulgaria	271	28	49	72	82	121	183	12	-22	795
Cyprus	1	1	51	23	28	1	0	2	0	108
Czech Rep.	776	50	36	197	120	394	279	13	-46	1820
Denmark	210	109	57	157	129	204	0	30	-20	875
Estonia	139	27	6	25	15	32	0	1	-7	238
Finland	192	272	76	178	119	233	237	48	24	1380
France	501	534	426	2203	1270	1873	4809	287	-216	11687
Germany	3239	260	645	2534	1942	3610	1732	185	5	14152
Greece	404	33	167	364	257	125	0	25	13	1387
Hungary	92	41	0	146	113	455	134	1	25	1007
Ireland	122	11	49	199	114	160	0	10	2	667
Italy	657	221	856	1430	1287	2982	0	321	193	7947
Latvia	3	50	29	28	19	60	0	11	17	216
Lithuania	8	30	30	38	28	125	115	1	-13	361
Luxembourg	2	2	2	59	45	35	0	1	21	167
Malta	0	0	24	7	10	0	0	0	0	40
Netherlands	294	64	124	576	607	1544	39	22	62	3331
Poland	2160	195	227	348	274	610	0	13	-25	3800
Portugal	144	131	264	241	173	158	0	62	-17	1156
Romania	372	135	145	194	129	675	61	61	-3	1769
Slovakia	170	34	21	56	33	272	134	19	-8	730
Slovenia	65	20	6	62	38	41	63	16	-13	298
Spain	719	334	518	1232	767	1467	649	229	8	5924
Sweden	84	338	125	225	258	73	673	254	-14	2017
UK	1793	131	110	1235	1640	3898	762	147	34	9751
EU-27	12777	3239	4181	12696	10058	20227	10358	1933	20	75489

[1)] Exports are indicated by negative numbers.

Table 3-5: Energy consumption of the EU-27 by fuel and sector in 2005 [PJ]

	Coal	*Biomass, waste*	*Heavy fuel oil*	*Diesel*	*Gasoline LPG*	*Natural gas*	*Nuclear*	*Other renew.*	*Electr.*[1)]	*Total*
Power sector	10024	878	1055	177	22	5533	10358	1866	-11325	18587
Industry	1484	951	1104	502	329	5503	0	1	3976	13850
Conversion	247	93	762	301	117	1204	0	0	1582	4305
Domestic	488	1318	96	2815	539	7090	0	66	5540	17953
Transport	0	0	77	8751	7246	59	0	0	247	16380
Non-energy	533	0	1087	151	1803	839	0	0	0	4414
Total	12777	3239	4181	12696	10058	20227	10358	1933	20	75489

[1)] Power sector - gross power generation (reported with negative sign); the conversion sector includes own use of energy industries as well as transmission and distribution losses; Total - net electricity import. Exports are indicated by negative numbers.

Table 3-6: Agricultural activity data for the year 2005

	Cattle	*Pigs*	*Chicken and poultry*	*Sheep and goats*	*Horses*	*Fertilizer consumption*	*Fertilizer production*
	1000 animal heads					kt N	
Austria	1989	3204	13007	380	87	94	225
Belgium	2907	7266	39728	132	73	147	1440
Bulgaria	630	931	19495	2411	373	135	350
Cyprus	54	441	4403	633	7	8	0
Czech Rep.	1450	3500	34200	154	25	230	250
Denmark	1500	13079	18146	91	157	202	0
Estonia	249	354	2042	45	4	23	38
Finland	959	1401	14025	97	64	158	230
France	19468	15885	258076	10333	458	2346	1300
Germany	13550	25218	108890	2038	650	1790	1000
Greece	553	967	26895	14519	140	238	200
Hungary	758	4059	41330	1397	82	361	250
Ireland	6211	1695	16057	6434	82	352	0
Italy	7039	8508	186411	12234	337	841	428
Latvia	378	444	4368	54	16	35	0
Lithuania	834	1041	7862	34	65	115	500
Luxembourg	200	87	73	7	2	17	0
Malta	18	73	1010	20	2	1	0
Netherlands	3781	12107	103646	1568	129	300	1100
Poland	5150	15357	169000	330	327	908	1450
Portugal	1294	2348	35434	4088	95	170	148
Romania	2507	6604	86552	8297	826	299	800
Slovakia	688	1623	12447	372	10	93	270
Slovenia	492	658	5425	142	17	34	0
Spain	5871	25348	175333	26971	498	1170	881
Sweden	1570	2204	18450	416	300	180	65
UK	10378	4847	175620	33898	291	1016	500
EU-27	90477	159250	1577925	127093	5115	11261	11425

Data source: GAINS, based on projections of agricultural activities for 2005

3.2 Emission factors

For the purpose of the EU burden sharing analysis this report attempts to assures, as far as possible, that the assessment of future mitigation potentials would be fully consistent with the inventories reported by Member States to the UNFCCC. At the outset of this project, preliminary emission inventories for year 2005 had not been submitted to the UNFCCC for all 27 Member States. The review process of the 2005 submissions was still underway during 2007 and final inventories for 2005 are only expected to be completed in the first months of 2008. Due to the incompleteness of the 2005 submissions at the starting time of the project and the five years intervals built into the structure of the GAINS model, the year 2000 was chosen as the latest year for which complete comparisons could be made between the Member States' submissions to the UNFCCC and the emissions calculated in the GAINS model. Therefore the analysis employs implied emission factors that reproduce - with the GAINS activity statistics for the year 2000 and taking into account the implementation of specific mitigation measures - sectoral CH_4 and N_2O emissions as they have been listed in the 2007 submissions for the year 2000 at the UNFCCC web site as of May 30, 2007 (UNFCCC, 2007)[2]..

Cyprus and Malta are not required to provide detailed reports of their inventories to the UNFCCC, and Luxemburg only reported incomplete data for N_2O. Therefore, for these countries the GAINS emission factors that have been derived according to the IPCC methodology with country-specific adjustments have been used instead (Höglund-Isaksson and Mechler, 2005a, Winiwarter, 2005).

Because many national F-gas inventories for the year 2000 are incomplete and do not allow deriving meaningful implied emission factors, the analysis for the burden sharing agreement uses for F-gases the GAINS emission factors as described in Tohka, 2005.

These 'uncontrolled' emission factors that have been derived for the year 2000 as described above are assumed constant for the future. For 2005, emissions are estimated on the basis of the activity statistics/projections (summarized in Table 3-4 to Table 3-6) and considering progressing implementation of mitigation measures in each Member State as provided in the "Policies and Measures" chapters of the latest National Communications to UNFCCC.

All emission factors and penetration rates of mitigation measures that have been used for this study can be extracted from the GAINS online version (www.iiasa.ac.at/gains, select the "Burden Sharing" scenario group and then the "NEC_NAT_CLEV4_FCCC2000B" scenario).

3.3 Emission estimates for 2000 and 2005

As a result of the approach described above, the GAINS model reproduces for the year 2000 CH_4 and N_2O emissions exactly as they have been presented on the UNFCCC web site on May 30, 2007 (Table 3-7 and Table 3-8). Comparisons of estimates of F-gas emissions have only limited meaning because many national inventories for the year 2000 are incomplete or not detailed enough for meaningful comparisons.

[2] Since at the time of the analysis for this report the Greek submission for 2007 has not been made public on the UNFCCC web site, the 2006 submission was used for Greece instead.

For 2005, current GAINS estimates deviate to some degree from numbers given in the recent (and still preliminary) national inventories available on the UNFCCC web site as of November 30, 2007. For the EU-27 as a whole, GAINS overestimates CH_4 emissions by four percent and N_2O emissions by five percent, while it matches with total emissions reported for F-gases. Differences are larger for some Member States. For methane, GAINS estimates deviate by more than 10 percent for 11 Member States (details are provided in Annex 1). Major factors leading to discrepancies are (i) employed activity data for 2005 that do not always match with the statistical data used by countries for their national inventories, and (ii) that some countries have updated the emission calculation methodologies in the meantime. For N_2O, estimates differ for 15 Member States by more than 10 percent, not at least since more than five Member States provided updated inventories between May and November 2007. Furthermore, the GAINS estimates are derived from general information on the implementation of mitigation measures in 2005 as given in the National Communications; more details are required for an exact quantification. For a number of countries, revised information that emerged from the recent inventory review has not been incorporated into the currently available 2007 inventories, but will only influence the 2008 submissions.

For 18 Member States, differences in estimated 2005 emissions between the GAINS calculations and the preliminary submissions of Member States to the UNFCCC are smaller than 10 percent (Tables 3-7 and 3-8). It is important to note that discrepancies between emissions estimated by GAINS and those reported to the UNFCCC do not necessarily compromise the robustness of the projections for 2020. GAINS projections are based on activity forecasts, on country-specific emission factors and on the scope for mitigation measures in 2020. Given the exogenous projections of emission generating activities (which are consistent with historic time series), resulting changes in future emissions are mainly influenced by changes in emissions factors (either due to revised emission factors in the base year or a different application of mitigation measures). Therefore in general, discrepancies in the estimates for 2005 due to different base year emission factors will not have major impacts on the *relative* change in emissions over time, although it could obviously influence the estimate of the *absolute* levels of future emissions.

Table 3-7: Estimates of CH_4 and N_2O emissions for 2000 and 2005 (in million tons CO_2eq).

	CH_4			N_2O		
	2000	2005		2000	2005	
	UNFCCC[1)]	GAINS	UNFCCC[2)]	UNFCCC[1)]	GAINS	UNFCCC[2)]
Austria	7.6	6.8	7.1	6.3	5.9	5.3
Belgium	9.4	8.9	7.8	12.7	13.3	11.0
Bulgaria	11.6	11.1	10.3	4.9	4.7	4.4
Cyprus	0.7	0.7	1.0	0.4	0.4	1.1
Czech Rep.	11.4	9.7	11.0	8.1	9.0	8.0
Denmark	5.9	5.2	5.6	8.6	8.0	7.0
Estonia	2.0	2.1	1.9	0.7	0.8	0.8
Finland	5.4	3.5	4.5	6.9	6.8	6.8
France	63.6	57.9	56.9	82.3	80.7	72.3
Germany	64.7	48.6	47.6	59.7	59.5	66.1
Greece	9.0	7.7	8.5	13.4	14.0	13.1
Hungary	8.3	7.5	7.8	11.3	12.9	9.7
Ireland	13.4	12.9	13.1	10.2	12.0	8.8
Italy	44.3	44.1	39.7	43.2	38.0	40.4
Latvia	1.7	2.0	1.8	1.3	1.4	1.5
Lithuania	3.3	2.8	3.3	3.5	3.6	5.0
Luxembourg	0.4	0.4	0.3	0.3	0.3	0.4
Malta	0.3	0.3	0.4	0.1	0.2	0.0
Netherlands	18.9	16.0	16.7	19.9	19.6	17.6
Poland	39.3	39.0	38.3	31.4	31.1	31.1
Portugal	12.4	11.9	11.1	6.2	6.4	6.1
Romania	25.7	28.0	25.7	15.0	15.9	16.8
Slovakia	4.5	5.0	4.2	4.1	4.5	3.7
Slovenia	2.1	2.1	2.1	1.3	1.3	1.3
Spain	35.3	35.2	37.3	32.6	32.7	29.6
Sweden	6.1	5.4	5.6	8.0	8.1	7.6
UK	68.5	59.9	49.5	43.5	45.7	39.6
Sum EU-27	476.0	434.9	419.2	436.0	436.8	415.1

Notes:

1) as of May 30, 2007

2) as of October 18, 2007

Table 3-8: Estimates of F-gas and total non-CO_2 emissions for 2000 and 2005 (in million tons CO_2eq).

	F-gases			Total Non-CO_2 emissions		
	2000	2005		2000	2005	
	GAINS	GAINS	UNFCCC[2)]	UNFCCC[1)]	GAINS	UNFCCC[2)]
Austria	1.6	2.1	1.3	15.4	14.8	13.6
Belgium	1.0	1.4	1.6	23.1	23.6	20.5
Bulgaria	0.1	0.2	0.4	16.6	16.0	15.0
Cyprus	0.1	0.1	0.1	1.2	1.2	2.1
Czech Rep.	0.3	0.5	0.7	19.8	19.2	19.7
Denmark	0.7	0.9	0.8	15.2	14.1	13.5
Estonia	0.1	0.2	0.0	2.9	3.0	2.7
Finland	0.4	0.9	0.9	12.7	11.1	12.2
France	11.2	12.8	14.1	157.2	151.4	143.2
Germany	9.9	14.5	14.8	134.3	122.6	128.5
Greece	5.5	5.5	6.0	27.9	27.1	27.6
Hungary	0.4	0.5	0.9	19.9	20.9	18.4
Ireland	0.7	0.9	0.7	24.3	25.8	22.7
Italy	4.2	6.6	6.1	91.7	88.7	86.2
Latvia	0.1	0.1	0.0	3.1	3.4	3.3
Lithuania	0.1	0.2	0.0	6.9	6.6	8.4
Luxembourg	0.1	0.2	0.1	0.8	0.9	0.9
Malta	0.0	0.1	0.0	0.4	0.5	0.4
Netherlands	4.0	2.7	2.0	42.8	38.3	36.2
Poland	0.9	1.8	3.0	71.6	72.0	72.4
Portugal	0.4	0.9	0.4	19.0	19.2	17.6
Romania	0.2	0.3	0.6	40.9	44.3	43.1
Slovakia	0.1	0.2	0.2	8.8	9.7	8.1
Slovenia	0.1	0.2	0.2	3.5	3.6	3.6
Spain	7.6	5.7	5.5	75.5	73.7	72.4
Sweden	1.2	1.3	1.2	15.3	14.8	14.4
UK	10.2	11.7	10.7	122.2	117.3	99.9
Sum EU-27	61.0	72.3	72.5	973.0	944.0	906.8

Notes:

[1)] as of May 30, 2007

[2)] as of October 18, 2007

4 Emission projections for 2020

4.1 Activity projections

For the purpose of the EU burden sharing agreement, GAINS employs projections of future volumes of energy consumption and agricultural activities that have been supplied by Member States to IIASA in the course of the preparations for the revision of the NEC directive (i.e., the "National projections" of the NEC analysis, see Amann *et al.*, 2007a). All data can be extracted from the GAINS online version (www.iiasa.ac.at/gains, select under "Activity data" the "Burden Sharing" scenario group and then the "NEC_NAT_CLEV4_FCCC2000B" scenario).

For the revision of the NEC directive, DG Environment of the European Commission requested in 2005 all Member States to provide official activity projections up to 2020. These projections must reflect national policies as laid down, e.g., in governmental energy plans. Furthermore, these projections must include all necessary measures to comply with the Kyoto targets on greenhouse gas emissions and the burden sharing agreement for 2012. For 2020, it should be assumed as a minimum that the Kyoto emission caps remain unchanged. With these requirements the national energy projections for the revision of the NEC Directive should, in principle, be consistent with the energy projections presented by the Member States to UNFCCC in their Fourth National Communications in 2006.

While these national projections are supposed to reflect governmental views of the individual Member States in 2006 on future energy and agricultural development, there is no guarantee for Europe-wide consistency in terms of assumptions on economic development trends, the world energy prices, electricity imports and exports, the availability of natural gas or on European agricultural policies. Unfortunately, Member States did not supply sufficient detail to judge the EU-wide consistency of the underlying assumptions.

4.1.1 Energy projections

In the course of the bilateral consultations for the NEC directive in 2005-2006, 23 Member States supplied national energy projections to IIASA for implementation into the GAINS model (Table 4-1). Collectively, these national projections constitute the "National projections" baseline scenario for the revision of the NEC directive. For those Member States that have not provided their own energy projection, the "National projections" baseline case assumes by default the energy development as outlined by the "PRIMES €20" energy projection presented in Amann *et al.*, 2007b.

Table 4-1: Data sources for the “National projections” NEC baseline scenario as of July 2007

	Data source	*Date of last information exchange*
Austria	National projection (2006)	04 July 2006
Belgium	National projection (2006)	31 August 2006
Bulgaria	PRIMES €20 (2006)	No national inputs
Cyprus	PRIMES €20 (2006)	No national inputs
Czech Rep.	National projection (2006)	01 August 2006
Denmark	National projection (2006)	11 November 2006
Estonia	National projection (2006)	30 October 2006
Finland	National projection (2006)	23 February 2007
France	National projection (2006)	30 June 2006
Germany	National projection (2006)	05 May 2006
Greece	National projection (2006)	18 April 2007
Hungary	National projection (2006)	13 April 2007
Ireland	National projection (2006)	05 December 2006
Italy	National projection (2006)	07 July 2006
Latvia	National projection (2006)	09 December 2005
Lithuania	National projection (2006)	20 January 2007
Luxembourg	PRIMES €20 (2006)	No national inputs
Malta	National projection (2006)	24 January 2007
Netherlands	National projection (2006)	17 April 2007
Poland	National projection (2006)	25 August 2006
Portugal	National projection (2006)	31 August 2006
Romania	PRIMES €20 (2006)	No national inputs
Slovakia	National projection (2006)	16 November 2006
Slovenia	National projection (2006)	06 October 2006
Spain	National projection (2006)	31 January 2007
Sweden	National projection (2006)	22 January 2007
UK	National projection (2006)	20 September 2006
Croatia	RAINS projection from 1996	No national inputs
Turkey	PRIMES €20 (2006)	No national inputs
Norway	National projection (2006)	23 January 2007
Switzerland	National projection (2006)	23 January 2007

The perceived evolution of fuel consumption in the various Member States is summarized for the year 2020 in Table 4-2. Overall, EU-27 Member States expect an increase in total primary energy use by 16 percent between 2000 and 2020. Coal consumption is projected to decrease by six percent, while for natural gas a 46 percent increase is envisaged. Member States anticipate a five percent drop in gasoline consumption and a 33 percent increase in diesel and light fuel oil. According to these projections, the EU-27 net electricity imports would increase by about 80 percent until 2020.

Table 4-2: Primary energy consumption of the national energy projections in 2020 [PJ] Source: GAINS, based on national submissions to IIASA.

	Coal	*Biomass, waste*	*Heavy fuel oil*	*Diesel*	*Gasoline LPG*	*Natural gas*	*Nuclear*	*Other renew.*	*Electr. import*[1)]	*Total*
Austria	129	179	53	389	86	463	0	201	0	1500
Belgium	160	82	53	567	449	933	338	15	17	2614
Bulgaria	139	48	47	112	134	214	215	19	-20	909
Cyprus	1	3	68	26	33	1	0	4	0	135
Czech Rep.	718	84	87	184	180	467	318	17	-25	2031
Denmark	114	122	54	174	146	315	0	45	-8	962
Estonia	173	27	13	30	16	45	0	3	-9	298
Finland	180	336	74	173	118	288	345	56	21	1591
France	484	711	540	2464	1113	2185	5093	360	-139	12811
Germany	3550	306	510	2616	1492	4041	693	363	8	13579
Greece	393	46	140	274	343	423	0	65	6	1690
Hungary	124	103	0	182	128	615	161	1	21	1334
Ireland	63	26	35	277	172	326	0	34	6	940
Italy	657	406	507	1501	1314	3410	0	483	304	8580
Latvia	47	60	24	50	40	72	0	16	17	324
Lithuania	4	51	62	54	38	258	45	4	-14	503
Luxembourg	1	5	2	71	47	59	0	1	23	209
Malta	0	1	21	14	13	0	0	0	0	50
Netherlands	402	154	130	665	762	1736	39	96	12	3997
Poland	2046	305	297	566	387	1121	0	50	-19	4753
Portugal	96	149	224	349	172	358	0	100	-108	1339
Romania	392	182	125	319	214	988	125	94	-3	2435
Slovakia	259	55	28	65	49	399	89	28	-8	966
Slovenia	47	29	4	86	24	70	59	21	-23	317
Spain	516	335	417	1562	825	3381	626	394	0	8056
Sweden	84	430	122	242	247	196	448	275	-11	2033
UK	1170	160	100	1605	1465	4495	268	406	35	9704
EU-27	11948	4395	3739	14617	10005	26858	8862	3153	82	83658
Croatia	31	17	80	68	55	187	25	21	4	487
Turkey	935	325	483	662	1128	1790	0	417	-10	5731
Norway	49	59	13	213	178	276	0	467	27	1282
Switzerland	9	91	23	291	197	115	308	151	-23	1161

[1)] Exports are indicated by negative numbers.

Table 4-3: Energy consumption of the EU-27 by fuel and sector for the national energy projections for 2020 [PJ]

	Coal	*Biomass, waste*	*Heavy fuel oil*	*Diesel*	*Gasoline LPG*	*Natural gas*	*Nuclear*	*Other renew.*	*Electr.*[1)]	*Total*
Power sector	9387	1577	599	136	12	9236	8862	2987	-14033	18763
Industry	1419	1321	963	522	306	6663	0	3	4884	16081
Conversion	248	134	931	183	118	1422	0	0	1705	4742
Domestic	388	1358	84	2538	472	8138	0	151	7226	20354
Transport	0	0	71	11073	7418	119	0	12	301	18993
Non-energy	507	4	1091	166	1678	1279	0	0	0	4726
Total	11948	4395	3739	14617	10005	26858	8862	3153	82	83658

Note: Gross power generation in the power sector is reported with negative sign. The conversion sector includes own use of energy industries as well as transmission and distribution losses. Totals exclude net electricity imports.

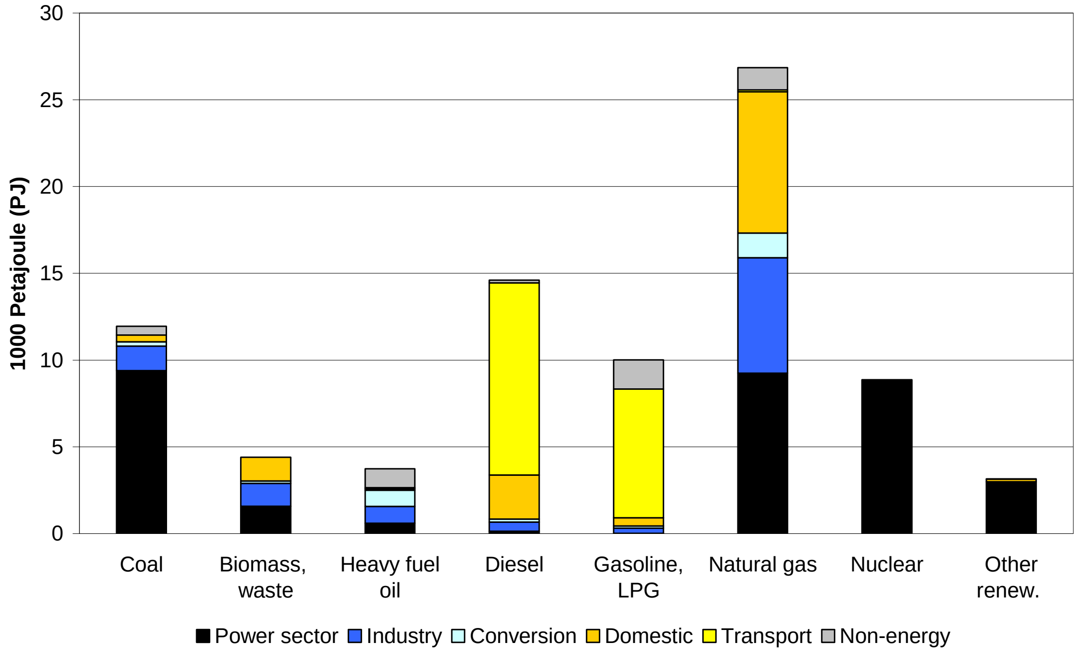

Figure 4-1: National projections of the energy consumption of the EU-27 for 2020

4.1.2 Agricultural projections

In addition to the request for energy projections, DG Environment of the European Commission invited all Member States to provide official national projections of their agricultural activities up to 2020 as a basis for the revision of the NEC Directive. These projections should reflect national agricultural policies as laid down, e.g., in governmental plans. Furthermore, these projections must include all necessary measures to comply with the Kyoto targets on greenhouse gas emissions and the burden sharing agreement for 2012.

In the course of the bilateral consultations in 2006, 19 Member States have supplied national agricultural projections to IIASA for implementation into the GAINS model (Table 4-4). For those Member States that have not provided their own agricultural projection, the baseline case assumes by default the agricultural development as outlined by the CAPRI (EEA, 2004) and EFMA (EFMA, 2005) agricultural and fertilizer projections. For Member States for which CAPRI and/or EFMA projections are unavailable, projections developed by the Food and Agricultural Organization (FAO) have been used (Bruinsma, 2003).

For the EU-27 as a whole (Table 4-5) these national projections anticipate between 2000 and 2020 for cattle a 12 percent decline in livestock numbers. The number of dairy cows drops by about 16 percent and that of beef cattle by about 10 percent. For sheep a reduction by 11 percent is anticipated, and increases of four and eight percent in the numbers of pigs and poultry, respectively. Use of nitrogen fertilizers is estimated to decline in the EU-27 by about six percent.

Table 4-4: Data sources for the “National projections” NEC baseline scenario as of July 2007

	Data source	*Date of last information exchange*	*Comments*
Austria	National (2006)	9 January 2006	
Belgium	National (2007)	30 April 2007	
Bulgaria	FAO (2003)		Update using CRONOS database
Cyprus	FAO (2003), EFMA (2005)		
Czech Rep.	National (2005)	26 June 2006	
Denmark	National (2006)	10 November 2006	
Estonia	National (2006)	4 May 2006	
Finland	National (2006)	1 March 2007	
France	National (2004)	18 May 2004	
Germany	CAPRI (2004), EFMA (2005)		
Greece	CAPRI (2004), EFMA (2005)		
Hungary	National (2006)		Projection submitted to UNECE
Ireland	National (2006)	20 November 2006	
Italy	National (2006)	31 August 2006	
Latvia	National (2006)	7 February 2006	
Lithuania	CAPRI (2004), EFMA (2005)		
Luxembourg	CAPRI (2004), EFMA (2005)		
Malta	National (2006)	27 January 2007	For some categories discrepancies for historical years, supplementary data from FAO, IFA , and CRONOS database used
Netherlands	National (2006)	14 September 2006	
Poland	National (2005)	19 October 2005	
Portugal	National (2006)	16 October 2006	
Romania	FAO (2003), National (2007)	26 January 2007	For some categories discrepancies for historical years, supplementary data from FAO and IFA used
Slovakia	CAPRI (2004), EFMA (2005)		
Slovenia	National (2006)	6 September 2006	
Spain	National (2007)	24 May 2007	
Sweden	National (2006)	2 July 2006	
UK	National (2006)	27 July 2006	
Croatia	FAO (2003)		
Turkey	FAO (2003)		Update using CRONOS database
Norway	National (2005)	10 February 2005	
Switzerland	National (2006)	10 January 2007	

Table 4-5: National projections of agricultural activities for the year 2020. Source: GAINS, based on national submissions to IIASA.

	Cattle	*Pigs*	*Chicken and poultry*	*Sheep and goats*	*Horses*	*Fertilizer consumption*	*Fertilizer production*
	1000 animal heads					kt N	
Austria	1896	3228	13007	389	87	102	225
Belgium	2586	7266	39728	129	73	142	1440
Bulgaria	677	1100	22958	2411	373	151	350
Cyprus	48	457	4830	655	7	7	0
Czech Rep.	1400	3800	36234	260	28	230	310
Denmark	1310	14728	18146	95	168	176	0
Estonia	222	448	2640	87	4	21	38
Finland	791	1270	13113	97	65	145	210
France	19145	16327	226966	9971	458	2313	1374
Germany	12216	22490	89767	1592	770	1688	1000
Greece	520	994	23923	14819	140	202	200
Hungary	907	7000	43000	1600	82	398	250
Ireland	4937	1503	13200	4941	85	320	0
Italy	6418	9181	197983	11320	337	799	428
Latvia	350	508	5091	55	16	35	0
Lithuania	766	1208	12782	38	65	119	500
Luxembourg	189	94	86	7	2	16	0
Malta	19	82	1010	26	3	1	0
Netherlands	3506	11181	108629	1951	165	272	1000
Poland	4850	15598	171500	340	355	963	1450
Portugal	1256	2064	38699	3992	40	170	152
Romania	2630	7300	90000	8297	800	391	800
Slovakia	693	1901	11602	359	10	101	270
Slovenia	527	665	5552	142	17	33	0
Spain	6173	26447	227461	26119	733	995	650
Sweden	1455	2490	20000	395	300	170	65
UK	8317	4835	175620	33813	291	976	500
EU-27	83804	164165	1613525	123900	5474	10936	11212
Croatia	566	1273	12589	916	14	116	300
Turkey	14561	4	344710	32000	664	1200	600
Norway	907	633	14290	1416	55	90	630
Switzerland	1403	1357	7490	485	72	50	15

Data sources: GAINS, based on national submissions to IIASA

4.2 Climate measures included in the baseline projections

The baseline projection considers changes in the sector activity levels and assumes that in absence of targeted mitigation measures the country- and sector-specific emission factors derived for the year 2000 would prevail. Actual emissions, however, will be determined by the degree to which mitigation measures penetrate in a country. The baseline projection explores the consequences of the temporal penetration of mitigation measures that follows from the implementation of current EU and national legislation. For each sector, the penetration of mitigation measures over time, as required by current EU and national legislation, has been derived from information provided in the "Policies and Measures" chapters of the latest available National Communications to UNFCCC.

The penetration of mitigation measures assumed in the baseline projection for 2020 is listed in Table 4-6.

Table 4-6: Abatement measures assumed for the “current legislation” baseline projection for 2020.

Gas	*Sector*	*Countries*	*Technology description*
CH_4	Agriculture	Denmark	Community-scale anaerobic digestion for manure applied to 3.2% of dairy cows, 1.6% of other cattle, and 32% of pigs
	Coal mining	Several countries	Gas recovery with flaring applied to between 28% and 63% of emissions from mining
	Gas distribution networks	EU-15	Replacement of 60% of grey cast iron networks and increased leakage control
	Gas transmission pipelines	Estonia, Lithuania	Reduced leakage at compressor stations, applied to 20%
	Gas and oil production & processing	EU-15	Flaring of emissions from oil and gas production and processing in EU-15
	Energy combustion	Several countries	Wood burning in domestic sector -replacement and change of boilers to more energy and emission efficient boilers
	Transport	Several countries	Fuel efficiency enhancements
	Municipal solid waste	Several countries	Treatment through large-scale composting, recycling, incineration, or landfill with gas recovery, meeting the Landfill directive
	Industrial wastewater	EU-27	Extended aerobic treatment of industrial wastewater from food-, paper-, and organic chemical manufacturing industries
	Domestic wastewater	EU-27	Extended collection and treatment of domestic wastewater partly with gas recovery
N_2O	Use of N_2O gas, e.g. as anaesthetics	Applied in 10 countries	Reduced application of N_2O as anesthetics
	Chemical processes	France, Germany, Italy, Romania, UK	Catalytic reduction in adipic acid production
	Industrial combustion	Austria, Belgium	Modifications in fluidized bed combustion
F-gases	Aerosols	EU-27	Alternative propellant (applied to 8% of emissions)
	Stationary air condition	EU-27	Good practice: leakage control, improved components, and end-of-life recollection
	Commercial refrigeration	EU-27	Good practice: leakage control, improved components, and end-of-life recollection
	Domestic refrigerators	EU-27	Good practice: end-of-life recollection
	Industrial refrigeration	EU-27	Good practice: leakage control, improved components, and end-of-life recollection
	Mobile air conditioning	EU-27	Alternative refrigerant: HFC-134a replaced by pressurized CO_2 and Good practice: end-of-life recollection
	Transport refrigeration	EU-27	Good practice: leakage control, improved components, and end-of-life recollection
	Production of HCFC-22	France, Germany, Greece, Italy, Netherlands, Spain, UK	Incineration: post-combustion of HFC-23 (application full in all countries except 20% in Greece)
	One component foams	EU-15	Alternative blowing agent
	Other foams	Austria, Germany	Alternative blowing agent (application 32% in Austria and 2% in Germany)

Table 4-6, ctd.: Abatement measures assumed for the "current legislation" baseline projection for 2020.

Gas	*Sector*	*Countries*	*Technology description*
F-gases	Aluminium production	Germany, Netherlands, Romania, Spain	Conversion of SWPB or VSS to PFPB (full application in Germany and Netherlands, 80% in Romania and 90% in Spain)
	Semiconductor industry	Belgium, Finland, France, Germany	Use of NF3 as alternative solvent (85-90% application)
	Magnesium production and casting	Several countries	Use of SO_2 as alternative protection gas to SF_6
	High and mid voltage switches	EU-27	Good practice: leakage control and end-of-life recollection and recycling
	Soundproof windows	Several countries	Ban of F-gas use
	Other SF6 use	Several countries	Ban of F-gas use

4.3 Baseline emission projection for 2020

With the assumptions on future activity levels, emission factors and penetration of mitigation measures, emissions as they are expected to emerge in 2020 as a consequence of the current legislation can be calculated. In such a baseline case, total non-CO_2 greenhouse gas emissions in the EU-27 are projected for the national activity projections to decline by six percent between 2005 and 2020 (Table 4-7). This reduction is composed of a 19 percent cut in CH_4, a four percent increase in N_2O, and a 12 percent increase in F-gases. Compared to the 1990 emission levels reported to the UNFCCC, the overall decline in non-CO_2 emissions until 2020 amounts to 26 percent.

It should be noted that emission reductions in the baseline case may not always result from targeted implementation of regulations to control non-CO_2 greenhouse gases. Some reductions are a consequence of changes in activity levels, they might result from national voluntary measures, or emerge as side-effects of regulations for other pollutants such as for waste disposal.

Major factors that contribute to the expected decline in CH_4 emissions in 2020 include the full implementation of the Landfill directive (with increased diversion of biodegradable waste away from landfills and increased gas recovery from landfills) and the replacement of old gas distribution networks in the EU-15. The increased recovery of coal mine gas coupled with the phase-out of coal mining in many countries constitutes an additional factor.

N_2O, emissions decreased between 1990 and 2005 mainly as a consequence of voluntary measures that reduce emissions from adipic acid production as well as the consumption of N_2O for anaesthetic purposes. For the future, the expected increase follows the envisaged growth in the volumes of N_2O-emitting activities.

The implementation of the F-gas directive and the directive on air-conditioning systems in vehicles is expected to lead to better practices for the handling of F-gases. In particular, leakages should be better controlled and refrigeration and air conditioning equipment containing F-gases will be recollected at the end of its lifetime. Nevertheless, F-gas emissions are expected to increase by 12 percent between 2005 and 2020. In particular, HFC emissions are expected to increase from different types of refrigeration and air conditioning. This development is a combined effect of the ongoing replacement of CFCs by HFCs in accordance with the Montreal Protocol and the expected increase in demand for refrigeration and air conditioning.

Table 4-7: Baseline projections of non-CO_2 greenhouse gas emissions for the national energy projections for 2020 (in million tons CO_2eq)

	CH_4			N_2O			F-gases			Total		
	2005	2020	2005-2020	2005	2020	2005-2020	2005	2020	2005-2020	2005	2020	2005-2020
Austria	6.8	6.5	-5.4%	5.9	6.0	0.3%	2.1	1.8	-13%	14.8	14.2	-4.1%
Belgium	8.9	8.0	-10%	13.3	16.8	27%	1.4	1.7	22%	23.6	26.6	13%
Bulgaria	11.1	5.7	-49%	4.7	4.9	4.5%	0.2	0.2	0.0%	16.0	10.8	-33%
Cyprus	0.7	0.6	-15%	0.4	0.4	3.0%	0.1	0.1	-13%	1.2	1.1	-9.0%
Czech Rep.	9.7	6.6	-32%	9.0	10.0	11%	0.5	0.7	24%	19.2	17.2	-10%
Denmark	5.2	4.6	-11%	8.0	7.7	-3.4%	0.9	1.1	19%	14.1	13.5	-4.7%
Estonia	2.1	1.8	-14%	0.8	0.8	0.8%	0.2	0.2	31%	3.0	2.8	-7.7%
Finland	3.5	3.2	-9.7%	6.8	6.5	-4.2%	0.9	0.9	7.0%	11.1	10.6	-5.1%
France	57.9	47.6	-18%	80.7	81.7	1.3%	12.8	13.2	3.4%	151.4	142.6	-5.8%
Germany	48.6	37.1	-24%	59.5	58.8	-1.2%	14.5	15.6	7.5%	122.6	111.5	-9.1%
Greece	7.7	6.1	-21%	14.0	13.5	-3.5%	5.5	3.9	-28%	27.1	23.5	-13%
Hungary	7.5	6.6	-12%	12.9	16.1	25%	0.5	0.5	-12%	20.9	23.2	11%
Ireland	12.9	10.2	-21%	12.0	10.9	-9.5%	0.9	1.0	18%	25.8	22.1	-14%
Italy	44.1	38.1	-14%	38.0	39.3	3.2%	6.6	9.3	41%	88.7	86.6	-2.3%
Latvia	2.0	1.7	-12%	1.4	3.1	128%	0.1	0.2	50%	3.4	5.0	46%
Lithuania	2.8	2.7	-1.4%	3.6	4.1	13%	0.2	0.2	47%	6.6	7.1	7.6%
Luxembourg	0.4	0.3	-4.2%	0.3	0.3	-0.9%	0.2	0.2	-6.3%	0.9	0.8	-3.3%
Malta	0.3	0.2	-34%	0.2	0.2	20%	0.1	0.0	-20%	0.5	0.5	-12%
Netherlands	16.0	12.8	-20%	19.6	20.1	2.5%	2.7	3.8	39%	38.3	36.7	-4.1%
Poland	39.0	33.6	-14%	31.1	32.3	3.9%	1.8	2.0	7.1%	72.0	67.8	-5.7%
Portugal	11.9	9.2	-23%	6.4	6.7	4.9%	0.9	1.1	19%	19.2	17.0	-12%
Romania	28.0	25.8	-8.0%	15.9	18.5	16%	0.3	0.5	32%	44.3	44.7	1.0%
Slovakia	5.0	5.2	3.0%	4.5	4.9	9.7%	0.2	0.2	33%	9.7	10.3	6.6%
Slovenia	2.1	1.8	-15%	1.3	1.3	-0.2%	0.2	0.2	0.0%	3.6	3.3	-9.2%
Spain	35.2	34.1	-3.2%	32.7	33.2	1.3%	5.7	8.6	49%	73.7	75.8	2.9%
Sweden	5.4	4.1	-24%	8.1	7.9	-1.9%	1.3	2.0	49%	14.8	14.0	-5.3%
UK	59.9	37.2	-38%	45.7	47.6	4.3%	11.7	11.8	0.9%	117.3	96.7	-18%
EU-27	434.9	351.4	-19%	436.8	453.8	3.9%	72.3	80.8	12%	944.0	885.9	-6.2%

4.4 Sensitivity analysis for the PRIMES energy baseline projections

The baseline projections in Table 4-7 were derived based on national energy projections that have been supplied by Member States to IIASA in 2006. In December 2007, EU-wide baseline energy projections from the PRIMES energy model became available. Table 4-8 presents the baseline projections for non-CO_2 greenhouse gases in 2020 that emerge from the recent PRIMES baseline energy activity data.

For most Member States there is close agreement between the baseline emission projections using national and PRIMES energy activity data. Significant differences, however, occur for Latvia and Lithuania. For Latvia, national energy projections, which assume expansion of power generation from coal result in much higher N_2O emissions than the PRIMES baseline projections, which do not consider the same increase in coal use. The difference in future N_2O emissions is then a consequence of the additional fluidized bed combustion plants that are implied in the national projections. For Lithuania, the activity data for nitric acid production increase by more than 100 percent between 2005 and 2020 in the PRIMES baseline, while the increase is only 20 percent in the national projections. In absence of specific information on nitric acid production, the growth rate in GAINS has been derived from the aggregated production levels provided in the PRIMES model for chemical industry. However, the national projection for nitric acid production may be considered more accurate.

Table 4-8: Baseline projections of non-CO_2 greenhouse gas emissions for the PRIMES baseline (December 2007) energy projections for 2005 and 2020 (in Mt CO_2-eq).

	CH_4			N_2O			F-gases			Total non-CO_2 GHG		
	2005	2020	2005-2020	2005	2020	2005 2020	2005	2020	2005-2020	2005	2020	2005-2020
Austria	7.5	6.6	-12%	6.1	6.3	4%	2.1	1.8	-13%	15.6	14.7	-6%
Belgium	9.7	8.7	-11%	12.6	15.1	20%	1.4	1.7	22%	23.8	25.5	7%
Bulgaria	12.3	7.2	-42%	4.6	5.5	18%	0.2	0.2	0%	17.1	12.8	-25%
Cyprus	0.8	0.6	-20%	0.4	0.4	4%	0.1	0.1	-13%	1.3	1.1	-11%
Czech Rep.	10.2	7.0	-32%	8.9	10.5	17%	0.4	0.5	15%	19.6	18.0	-8%
Denmark	5.8	4.9	-16%	8.0	7.7	-4%	0.9	1.1	18%	14.8	13.7	-7%
Estonia	2.3	1.7	-27%	0.8	0.8	3%	0.2	0.2	31%	3.2	2.7	-17%
Finland	4.1	3.7	-10%	9.4	9.6	2%	0.9	0.9	7%	14.3	14.2	-1%
France	61.8	52.4	-15%	75.8	75.5	-1%	12.8	12.2	-4%	150.4	140.1	-7%
Germany	53.3	37.0	-31%	56.9	58.8	3%	14.5	15.6	7%	124.7	111.4	-11%
Greece	8.3	6.4	-23%	13.9	14.1	2%	5.5	3.9	-28%	27.6	24.4	-12%
Hungary	8.4	7.1	-15%	11.8	13.7	16%	0.5	0.7	41%	20.6	21.5	4%
Ireland	14.1	11.7	-17%	11.2	12.7	14%	0.9	1.0	18%	26.2	25.4	-3%
Italy	51.1	40.7	-20%	38.2	41.5	9%	6.6	9.3	41%	95.9	91.4	-5%
Latvia	2.1	1.8	-16%	1.4	1.5	7%	0.1	0.2	50%	3.6	3.4	-6%
Lithuania	3.1	3.2	4%	4.4	7.0	60%	0.2	0.2	47%	7.6	10.4	37%
Luxembourg	0.4	0.4	-7%	0.3	0.3	-3%	0.2	0.2	-6%	0.9	0.8	-5%
Malta	0.3	0.2	-30%	0.2	0.2	18%	0.1	0.0	-20%	0.6	0.5	-12%
Netherlands	17.6	13.7	-22%	21.6	23.6	10%	2.7	3.8	39%	41.9	41.1	-2%
Poland	46.0	36.4	-21%	31.0	34.4	11%	1.8	2.0	10%	78.8	72.8	-8%
Portugal	12.7	9.5	-26%	6.4	6.7	6%	0.9	1.1	19%	20.0	17.3	-14%
Romania	31.1	27.8	-11%	16.2	20.5	27%	1.0	1.2	23%	48.3	49.6	2%
Slovakia	4.9	4.8	-1%	4.4	5.2	18%	0.2	0.3	30%	9.5	10.3	8%
Slovenia	2.3	2.1	-10%	1.5	1.6	11%	0.2	0.2	35%	3.9	3.9	0%
Spain	38.1	36.6	-4%	33.5	34.7	4%	5.8	8.5	47%	77.3	79.8	3%
Sweden	6.1	4.6	-24%	8.3	8.7	4%	1.4	2.1	51%	15.8	15.4	-3%
UK	64.8	40.2	-38%	43.4	45.2	4%	11.8	12.0	1%	120.1	97.3	-19%
EU-27	479.5	377.0	-21%	431.0	461.8	7%	73.1	81.0	11%	983.6	919.7	-6%

5 The scope for further GHG mitigation in 2020

The GAINS model has been used to estimate the scope for further mitigation measures that will be available in 2020 in addition to the measures that are required by current legislation (Table 4-6). The mitigation potential has been determined for the activity levels in 2020 of the National projections. For non-CO_2 emissions, the analysis considers the end-of-pipe measures listed in Section 2.2 that are not required by current legislation. However, the analysis does not account for possible changes in activity levels that could lead to further reductions in greenhouse gas emissions. For each Member State, GAINS ranks the available mitigation measures according to the cost-effectiveness.

5.1 EU-27

For the EU-27 as a whole, the analysis reveals a technical mitigation potential for non-CO_2 greenhouse gas emissions of 50 percent (or 600 Mt CO_2eq) below the 1990 level. 40 percent of this potential (i.e., 176 Mt CO_2eq) has been realized by 2005. The baseline projection envisages for 2020 a further reduction by 60 Mt CO_2eq (i.e., by seven percent compared to 2005 or five percent relative to 1990) as a consequence of structural changes and targeted mitigation measures required by current legislation. This leaves in 2020 a further mitigation potential of 285 Mt CO_2eq, so that with all available technical measures non-CO_2 emissions in the EU-27 could be further reduced by 32 percent below the baseline projection (Table 5-1).

The full set of additional measures involves marginal costs of up to € 300 per ton of CO_2eq, with average costs of approximately € 30/t CO_2eq. Out of the total potential, 44 Mt CO_2eq is would be available at no additional cost if the cost accounting is performed over the full technical life time with a nine percent interest rate (at 2005 price levels)[3]. For a carbon price of € 20/t CO_2, non-CO_2 emissions could be reduced by 21 percent compared to 2005. Average costs would amount to € 2.4/t CO_2eq. Beyond this level, costs for further measures increase sharply. For a carbon price of € 50/t CO_2eq, the mitigation potential increases to 25 percent, and average costs grow up to € 10/t CO_2eq. The maximum reduction of 37 percent would incur costs of € 21 billion/year. The marginal cost curve is displayed in graphical form in Figure 5-1.

[3] In the interest of comparing the mitigation potentials and costs with the results for CO_2 emissions obtained with the PRIMES model, this calculation applies a nine percent interest rate. In contrast, standard calculations with GAINS (e.g., for the emission ceilings directive) assume a social interest rate of four percent, and use prices of the year 2000.

Table 5-1: Reduction potentials, marginal costs and total costs for the mitigation of non-CO_2 greenhouse gases in 2020 in the EU-27

	CH_4			N_2O			F-gases			Total non-CO_2 emissions			
		Change relative to			Change relative to			Change relative to			Change relative to		Costs
	kt	1990	2005	kt	1990	2005	Mt CO2eq	1990	2005	Mt CO2eq	1990	2005	[M €/yr]
1990 UNFCCC	28747			1727			59690			1198801			
2005 GAINS	20708	-28.0%		1409	-18.4%		72340	21.2%		944026	-21.3%		
2020 Baseline	16733	-41.8%	-19.2%	1463	-15.3%	3.8%	80779	35.3%	11.7%	885797	-26.1%	-6.2%	0
2020 Least-cost solutions for a carbon price of													
€0	14945	-48.0%	-27.8%	1447	-16.2%	2.7%	79239	32.8%	9.5%	841673	-29.8%	-10.8%	0
€5	14845	-48.4%	-28.3%	1241	-28.1%	-11.9%	78967	32.3%	9.2%	775393	-35.3%	-17.9%	49
€10	14801	-48.5%	-28.5%	1183	-31.5%	-16.0%	77876	30.5%	7.7%	755499	-37.0%	-20.0%	187
€15	14702	-48.9%	-29.0%	1183	-31.5%	-16.0%	77876	30.5%	7.7%	753290	-37.2%	-20.2%	216
€20	14542	-49.4%	-29.8%	1173	-32.1%	-16.7%	77745	30.2%	7.5%	746790	-37.7%	-20.9%	330
€25	14534	-49.4%	-29.8%	1170	-32.3%	-17.0%	75212	26.0%	4.0%	743213	-38.0%	-21.3%	409
€30	14499	-49.6%	-30.0%	1166	-32.5%	-17.2%	71262	19.4%	-1.5%	737154	-38.5%	-21.9%	579
€35	14484	-49.6%	-30.1%	1154	-33.2%	-18.1%	71153	19.2%	-1.6%	732900	-38.9%	-22.4%	722
€40	14479	-49.6%	-30.1%	1132	-34.5%	-19.7%	64071	7.3%	-11.4%	719012	-40.0%	-23.8%	1238
€45	14442	-49.8%	-30.3%	1131	-34.5%	-19.7%	64071	7.3%	-11.4%	717864	-40.1%	-24.0%	1286
€50	14394	-49.9%	-30.5%	1112	-35.6%	-21.1%	63066	5.7%	-12.8%	710173	-40.8%	-24.8%	1643
€55	14310	-50.2%	-30.9%	1109	-35.8%	-21.3%	59676	0.0%	-17.5%	703887	-41.3%	-25.4%	1977
€60	14240	-50.5%	-31.2%	1104	-36.1%	-21.6%	59676	0.0%	-17.5%	700859	-41.5%	-25.8%	2148
€65	14184	-50.7%	-31.5%	1104	-36.1%	-21.6%	59676	0.0%	-17.5%	699681	-41.6%	-25.9%	2220
€70	14112	-50.9%	-31.9%	1076	-37.7%	-23.6%	59676	0.0%	-17.5%	689691	-42.5%	-26.9%	2892
€75	13998	-51.3%	-32.4%	1059	-38.7%	-24.8%	59005	-1.1%	-18.4%	681234	-43.2%	-27.8%	3494
€100	13915	-51.6%	-32.8%	1030	-40.4%	-26.9%	42345	-29.1%	-41.5%	653848	-45.5%	-30.7%	5674
€125	13901	-51.6%	-32.9%	1023	-40.8%	-27.4%	39200	-34.3%	-45.8%	648301	-45.9%	-31.3%	6288
€150	13899	-51.7%	-32.9%	1005	-41.8%	-28.7%	39145	-34.4%	-45.9%	642430	-46.4%	-31.9%	7154

Continued on next page

Table 5-1, continued: Reduction potentials, marginal costs and total costs for the mitigation of non-CO_2 greenhouse gases in 2020 in the EU-27

	CH_4			N_2O			F-gases			Total non-CO_2 emissions			
		Change relative to			Change relative to			Change relative to			Change relative to		Costs
	kt	1990	2005	kt	1990	2005	Mt CO2eq	1990	2005	Mt CO2eq	1990	2005	[M €/yr]
€175	13857	-51.8%	-33.1%	999	-42.2%	-29.1%	39145	-34.4%	-45.9%	639851	-46.6%	-32.2%	7584
€200	13828	-51.9%	-33.2%	992	-42.6%	-29.6%	39145	-34.4%	-45.9%	637172	-46.8%	-32.5%	8104
€225	13772	-52.1%	-33.5%	961	-44.4%	-31.8%	39061	-34.6%	-46.0%	626292	-47.8%	-33.7%	10382
€250	13737	-52.2%	-33.7%	940	-45.6%	-33.3%	31872	-46.6%	-55.9%	611592	-49.0%	-35.2%	13906
€275	13658	-52.5%	-34.0%	938	-45.7%	-33.4%	31872	-46.6%	-55.9%	609318	-49.2%	-35.5%	14496
€300	13563	-52.8%	-34.5%	936	-45.8%	-33.6%	31872	-46.6%	-55.9%	606786	-49.4%	-35.7%	15229
€20,000	13533	-52.9%	-34.6%	917	-46.9%	-34.9%	31052	-48.0%	-57.1%	599438	-50.0%	-36.5%	20955

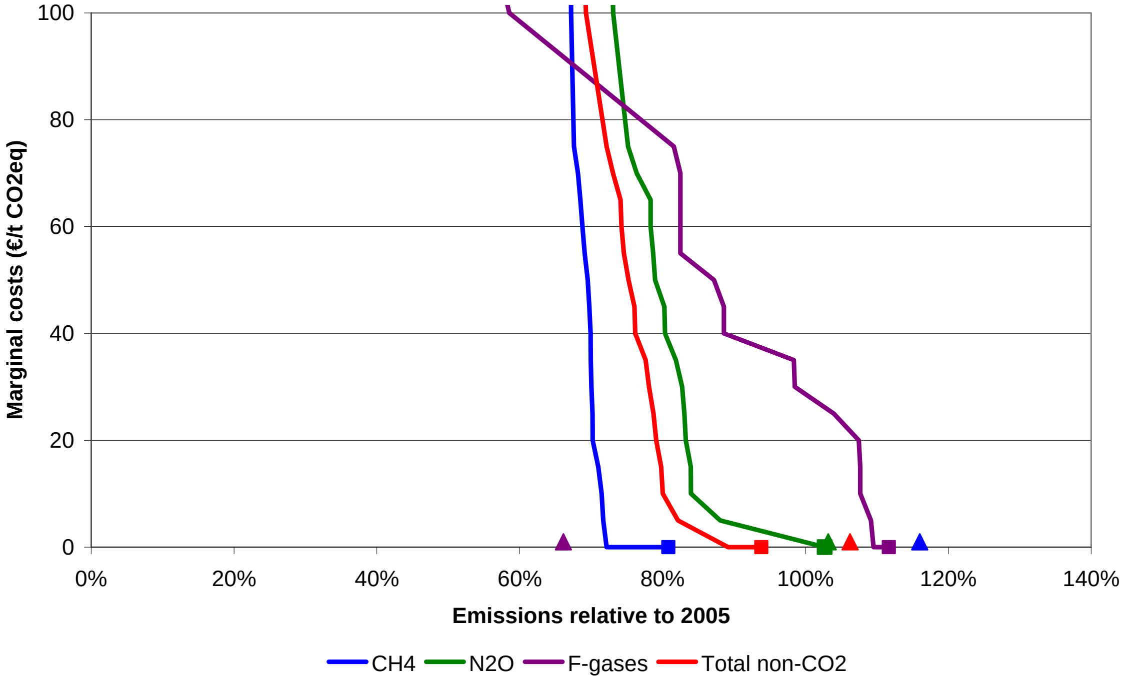

Figure 5-1: Cost curve for the mitigation of the non-CO_2 greenhouse gases in the EU-27 in the year 2020. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

Under the assumption of a nine percent interest rate, a few options are available that can reduce non-CO_2 greenhouse gas emissions in 2020 by additionally 44 Mt CO_2eq per year at no cost or even with negative costs, i.e., cost savings (Table 5-2). This means that over the technical life time cost savings (e.g., from reduced energy demand) outweigh the costs of the measure. Following the definition of the mitigation potential given in the Fourth Assessment Report of the IPCC, such measures form part of the "economic potential". The economic potential - in contrast to the "market potential" - refers to the mitigation potential that takes into account social costs and benefits and social discount rates, assuming that market efficiency is improved by policies and measures and that barriers are removed.

For CH_4, the reduction potential at no cost is estimated at 38 Mt CO_2eq per year. This includes 26 Mt CO_2eq from extended use of farm-scale anaerobic digestion and from dietary changes to enhance productivity and reduce emissions from enteric fermentation in dairy cows and cattle. About 10 Mt CO_2eq of CH_4 can be reduced at no cost through reducing leakage at compressor stations in gas transmission pipelines. A reduction of 1.6 Mt CO_2eq is attainable from extended wastewater treatment in urban areas, particularly in the new Member States. The latter option is accounted for as a no cost option for GHG mitigation as it is considered to be primarily implemented for other reasons, e.g., as a measure to reduce eutrophication. The reduction in CH_4 is therefore considered as a co-benefit of reducing eutrophication. It should, however, be pointed out that as a pure CH_4 reducing measure, improved wastewater treatment would be immensely expensive, see Höglund-Isaksson and Mechler, 2005b for a discussion.

N_2O emissions can be reduced by ~4 Mt CO_2eq at no costs by using less N_2O for anaesthetic purposes or by optimizing operating conditions in wastewater plants. About 1.5 Mt CO_2eq of F-gas emissions can be reduced through improved practices for transport refrigeration using alternative blowing agent in one component foams, or extending the ban on SF_6 use.

It should be noted that, as a conservative assumption, the calculation of total costs in Table 5-2 does not account for cost savings from such measures, but assumes net costs of zero in order to represent transaction costs that currently prevent implementation of such measures.

Table 5-2: No-cost mitigation options for greenhouse gas emissions that are not applied in the baseline projection in 2020

Gas	Sector	Countries	Technology description	Emission reduction		Total cost
				kt	kt CO_2eq	M€/yr
CH_4	Agriculture	Several countries	Dietary changes for dairy cows and cattle and farm-scale anaerobic digestion for large cattle farms	644	13531	0
		Several countries	Farm-scale anaerobic digestion for large pig farms	616	12926	0
	Gas transmission pipelines	Several countries	Reduced leakage at compressor stations	454	9534	0
	Domestic wastewater	Several countries	Extended collection and treatment with gas recovery of wastewater in urban areas	74	1557	0
N_2O	Use of N_2O gas, e.g. as anaesthetics	Several countries	Reduced application of N_2O as anaesthetic	1	347	0
	Domestic wastewater	Several countries	Optimization of operating conditions in waste water plant	15	4687	0
F-gases	Foams	NMS	Alternative blowing agent in one component foams	307	307	0
	Other SF_6 use	Several countries	Ban of SF_6 use not covered by F-gas directive, e.g., laboratory equipment	114	114	0
	Transport refrigeration	Several countries	Alternative refrigerant: use of open CO_2 system	1122	1122	0
Total					44124	0

Table 5-3 presents control options that are available to reduce non-CO_2 greenhouse gases beyond the baseline projection at additional costs. According to the definition of the IPCC AR4, these measures represent the “market potential”, which is the mitigation potential based on private costs and private discount rates that might be expected to occur under forecast market conditions. The table ranks these measures by increasing marginal costs. For each range of marginal costs, the set of options and the corresponding countries are displayed together with their mitigation potential and costs.

Table 5-3 was obtained as follows: First, the total range of marginal costs was divided into 25 equal steps (intervals of € 5/t CO_2eq for marginal costs less than € 75/t CO_2eq, € 25/t CO_2eq steps for marginal costs between € 75 and € 300/t CO_2eq, and one step for marginal costs exceeding € 300/t CO_2eq). For each step the cost-minimizing GAINS optimization was run (see Wagner *et al.*,

2007) with an EU-27-wide carbon "tax" to identify those options whose marginal cost is equal or lower than the "tax" level. This procedure is the well-known dual formulation of an emission constraint in linear programming (LP) problems. The optimization identified the least cost solution with the given carbon price and delivered the corresponding reductions in greenhouse gas emissions (for each gas) and the total costs associated with these measures. Obviously, the procedure could have been performed for any number of steps. The more steps chosen, the more detailed marginal cost ranges can be obtained. However, in order to keep the presentation of results relatively compact, the 25 steps have even been grouped together into twelve steps in Table 5-3.

Table 5-3: Mitigation options that are available in 2020 in addition to the measures assumed in the baseline projections and the no-cost measures. Options are ordered by increasing marginal costs.

Marginal cost range €/t CO_2eq	Gas	Sector	Countries	Technology description	Emission reduction kt	Emission reduction kt CO_2eq	Total costs Million €/yr
0 to 5 €/t CO_2eq	CH_4	Coal mining	Bulgaria, France, Romania, Slovakia, Slovenia	Upgraded recovery and utilization	75	1574	5.7
		Gas & oil prod and processing	Estonia, Hungary, Lithuania, Romania, Slovakia	Increased flaring at oil refineries	24	506	0.7
		Agriculture	Poland, Portugal	Enforced ban on agric. waste burning	1	22	0.1
	N_2O	Agriculture	Several countries	Reduced fertilizer application	28	8595	16.8
		Energy combustion	Several countries	Combustion modifications in fluidized bed combustion	20	6353	11.6
		Chemical processes	Several countries	Catalytic reduction in nitric acid production	158	48958	16.5
	F-gases	Transport refrigeration	Germany	Alternative refrigerant: use of open CO_2 system	272	272	2.2

Table 5-3, contd.: Mitigation options that are available in 2020 in addition to the measures assumed in the baseline projections and the no-cost measures. Options are ordered by increasing marginal costs.

Marginal cost range €/t CO_2eq	Gas	Sector	Countries	Technology description	Emission reduction kt	kt CO_2eq	Total costs Million €/yr
5 to 10 €/t CO_2eq	CH_4	Coal mining	Estonia, Germany, Greece, Hungary, Romania	Upgraded recovery and utilization	33	697	4.1
		Gas & oil prod and processing	Bulgaria, Slovakia	Increased flaring	2	51	0.3
		Agriculture	Bulgaria, Italy, Portugal, Romania	Alternative rice strains	8	163	1.1
		Agriculture	Austria, Bulgaria	Enforced ban on agric. waste burning	1	14	0.1
	N_2O	Agriculture	several countries	Reduced fertilizer application	33	10320	59.0
		Energy combustion	several countries	Combustion modifications in fluidized bed combustion	24	7557	64.2
	F-gases	Foams	Several countries	Alternative blowing agent in other than one component foams	1091	1091	9.4

Table 5-3, contd.: Mitigation options that are available in 2020 in addition to the measures assumed in the baseline projections and the no-cost measures. Options are ordered by increasing marginal costs.

Marginal cost range €/t CO_2eq	Gas	Sector	Countries	Technology description	Emission reduction kt	kt CO_2eq	Total costs Million €/yr
10 to 15	CH_4	Agriculture	Bulgaria, France, Greece, Hungary	Alternative rice strains	2	34	0.4
		Agriculture	Spain	Enforced ban on agric. waste burning	2	39	0.5
		Coal mining	Bulgaria	Upgraded recovery and utilization	0	2	0.02
		Gas & oil prod and processing	Czech Rep.	Increased flaring at oil refineries	0	9	0.14
		Gas distribution networks	Poland, Estonia	Doubling of leak control frequency	96	2009	27.0
	N_2O	Agriculture	Lithuania, Luxembourg	Reduced fertilizer application	0	86	1.0
		Energy combustion	Austria, Bulgaria	Combustion modifications in fluidized bed combustion	0	29	0.3
15 to 20	CH_4	Agriculture	Romania, Spain	Alternative rice strains	2	40	0.7
		Gas & oil prod and processing	Romania	Increased flaring at gas production	133	2789	46.2
		Gas distribution networks	Bulgaria, Latvia	Doubling of leak control frequency	20	422	8.1
	N_2O	Energy combustion	Several countries	Combustion modifications in fluidized bed combustion	10	3019	58.7
	F-gases	Aluminium production	Hungary, Poland, Sweden, UK	VSS retrofitting	131	131	2.1

Table 5-3, contd.: Mitigation options that are available in 2020 in addition to the measures assumed in the baseline projections and the no-cost measures. Options are ordered by increasing marginal costs.

Marginal cost range €/t CO_2eq	Gas	Sector	Countries	Technology description	Emission reduction kt	kt CO_2eq	Total costs Million €/yr
20 to 25	CH_4	Agriculture	Hungary, Portugal	Alternative rice strains	3	54	1.2
		Agriculture	Greece	Enforced ban on agric. waste burning	1	16	0.4
		Coal mining	Czech Rep., Poland	Upgraded recovery and utilization	4	90	1.8
		Gas & oil prod and processing	Slovenia	Increased flaring at oil refineries	0	1	0.01
	N_2O	Agriculture	Greece	Improved timing of fertilizer application	1	368	8.8
		Energy combustion	Austria, Italy, Denmark	Combustion modifications in fluidized bed combustion	2	515	12.9
	F-gases	Aluminium production	France	SWPB retrofitting	537	537	11.9
		HCFC-22 prod	Greece	Incineration: post combustion of HFC-23	1778	1778	38.1
		Industrial refrigeration	Finland	Process modifications including alternative refrigerants	1	1	0.02
		Transport refrigeration	Germany	Good practice on top of alternative refrigerant replacement	217	217	4.9
25 to 30	CH_4	Agriculture	Italy	Alternative rice strains introduced and/or increased aeration of fields	20	422	11.1
		Coal mining	Germany	Upgraded recovery and utilization	16	330	9.3
	N_2O	Agriculture	Romania, Slovakia	Improved timing of fertilizer application	2	733	20.8
		Energy combustion	Austria, Slovakia, Spain	Combustion modifications in fluidized bed combustion	2	625	16.2
	F-gases	Industrial refrigeration	Several countries	Process modifications including alternative refrigerants	52	52	1.4
		Semiconductor manufacture	Several countries	Alternative solvent: use of NF3	3898	3898	111

Table 5-3, contd.: Mitigation options that are available in 2020 in addition to the measures assumed in the baseline projections and the no-cost measures. Options are ordered by increasing marginal costs.

Marginal cost range €/t CO_2eq	Gas	Sector	Countries	Technology description	Emission reduction kt	kt CO_2eq	Total costs Million €/yr
30 to 35	CH_4	Gas distribution networks	Hungary	Doubling of leak control frequency	15	308	10.5
		Agriculture	Bulgaria	Use of alternative rice strains, increased aeration and use of sulfate-containing amendments	0	8	0.3
	N_2O	Agriculture	France, Spain	Improved timing of fertilizer application	11	3522	119
		Energy combustion	Slovenia, Netherlands, Portugal	Combustion modifications in fluidized bed combustion	1	308	10.7
	F-gases	Industrial refrigeration	several countries	Process modifications including alternative refrigerants	109	109	3.7
35 to 40	CH_4	Agriculture	France, Greece	Use of alternative rice strains and increased aeration and use of sulphate-containing amendments	2.7	57	2.2
		Agriculture	Romania	Enforced ban on agric. waste burning	1.4	28	1.1
	N_2O	Agriculture	several countries	Improved timing of fertilizer application	18	5622	210
		Agriculture	Finland	Ban agricultural use of histosols	4	1094	43.4
	F-gases	Industrial refrigeration	Several countries	Process modifications including alternative refrigerants	7082	7082	258
40 to 45	CH_4	Agriculture	Romania	Use of alternative rice strains and increased aeration and/or use of sulphate-containing amendments	0	5	0.2
		Gas & oil prod and processing	Poland, Hungary	Increased flaring at gas and oil production	7	146	6.1
		Gas distribution networks	Romania	Doubling of leak control frequency	30	633	26.4
	N_2O	Agriculture	Ireland	Improved timing of fertilizer application	1	297	12.6
		Energy combustion	Ireland	Combustion modifications in fluidized bed combustion	0.2	68	2.9

Table 5-3, contd.: Mitigation options that are available in 2020 in addition to the measures assumed in the baseline projections and the no-cost measures. Options are ordered by increasing marginal costs.

Marginal cost range €/t CO_2eq	Gas	Sector	Countries	Technology description	Emission reduction Kt	Emission reduction Kt CO_2eq	Total costs Million €/yr
45 to 50	CH_4	Coal mining	UK	Upgraded recovery and utilization	36	754	34.2
		Gas & oil prod and processing	Poland	Increased flaring at gas production	12	257	12.3
		Gas distribution networks	Cyprus	Doubling of leak control frequency	0	1	0.04
	N_2O	Agriculture	Estonia, Greece	Improved timing of fertilizer application	3	913	43.8
		Agriculture	Germany	Ban agricultural use of histosols	15	4762	217
	F-gases	Commercial refrigeration	Finland	Process modifications including alternative refrigerants	41	41	2.0
		Industrial refrigeration	France	Process modifications including alternative refrigerants	964	964	47.5
50 to 55	CH_4	Gas and oil production and processing	Hungary, Bulgaria	Increased flaring at gas and oil production	2	36	1.8
		Gas distribution networks	Czech Rep., Denmark, Italy, Slovakia	Doubling of leak control frequency	82	1730	89.3
	N_2O	Agriculture	Sweden, Poland, Slovakia	Improved timing of fertilizer application	4	1087	57.7
		Energy combustion		Combustion modifications in fluidized bed combustion	0	45	2.2
	F-gases	Aluminium production	France, Germany, Netherlands, Romania	Conversion of SWPB to PFPB	1466	1466	80.8
		Commercial refrigeration	Several countries	Process modifications including alternative refrigerants	1924	1924	102

Table 5-3, contd.: Mitigation options that are available in 2020 in addition to the measures assumed in the baseline projections and the no-cost measures. Options are ordered by increasing marginal costs.

Marginal cost range €/t CO_2eq	Gas	Sector	Countries	Technology description	Emission reduction kt	Emission reduction Kt CO_2eq	Total costs Million €/yr
55 and above	CH_4	Agriculture	Several countries	Dietary changes for dairy cows and cattle combined with community-scale anaerobic digestion for the manure	242	5085	1784
		Agriculture	Belgium, Denmark, Netherlands, Malta	Community-scale anaerobic digestion for pig manure	37	782	120
		Agriculture	Several countries	Use of alternative rice strains and increased aeration, use of sulphate-containing amendments	33	685	73.3
		Agriculture	Italy	Enforced ban on agric. waste burning	0.3	7	1.1
		Coal mining	Czech Rep., Poland, Spain	Upgraded recovery and utilization	147	3078	232
		Gas & oil prod and processing	Czech Rep., Bulgaria, Lithuania, Romania, Slovakia	Increased flaring at gas and oil production	1	19	15.6
		Gas & oil prod and processing	Poland	Increased flaring at oil refinery	0.01	0	0.5
		Gas distribution networks	Several countries	Replacement of grey cast iron networks	315	6608	684
	N_2O	Agriculture	Several countries	Advanced agro-chemicals (e.g., nitrification inhibitors), and/or precision farming	161	49787	7123
		Agriculture	Several countries	Ban agricultural use of histosols	18	5529	925
		Energy combustion	Estonia, Finland, Belgium, Denmark	Comb. modifications in fluidized bed combustion	1	403	82.5
		Use of N_2O, e.g., as anaesthetic	Several countries	Full replacement of N_2O application	12	3791	3992
	F-gases	Stationary air conditioning	EU-27	Process modifications incl. alternative refriger.	8147	8147	2128
		Commercial refrigeration	Several countries	Process modifications incl. alternative refriger.	19918	19918	1688
		Magnesium production	Germany	Alternative protection gas: SF_6 replaced by SO_2	95	95	10.4
		Aluminium production	Several countries	Conversion of VSS to PFPB	462	462	37.8
	Total					242200	20950

5.2 Mitigation potentials and costs by country

The results that are summarized in the preceding section for the EU-27 as a whole have been derived for each Member State individually. Table 5-4 presents for each Member State the potentials for further mitigation of the non-CO_2 greenhouse gases in 2020 and the associated costs. The table provides under the "2020 Baseline" entry costs for implementing the current legislation in 2020. The subsequent rows show – for increasing carbon prices - costs for additional measures on top of the costs of current legislation. The € 0 case presents emission levels that would result from an implementation of all measures for which the GAINS cost calculation (with a 9 percent discount rate) produces negative costs over the full technical life time. However, as explained before, these cost savings are neglected in the further calculation for this analysis. Detailed information on all measures considered in each Member State can be derived from the on-line version of the GAINS model (www.iiasa.ac.at/gains, choose the "Costs" menu, specify the pollutant in the combo box at the top and select "National cost curves" at the bottom of the left menu bar). National cost curves are displayed in graphical form in the Annex.

Table 5-4: Reduction potentials and costs for non-CO_2 greenhouse gases in 2020 by Member State. Relative reductions are measured against the 1990 emission level reported by countries to UNFCCC.

		Remaining CH_4 emissions (kt CH_4)	*Remaining N_2O emissions (kt N_2O)*	*Remaining F-gas emissions (kt CO2eq)*	*Remaining total non-CO_2 emissions (kt CO_2eq)*	*Reduction relative to 1990*	*Reduction relative to 2005*	*Total costs for all gases (million €/yr)*
Austria	1990	437	20	1605	17135	0.0%		
	2005	325	19	2050	14811		0.0%	
	2020 Baseline	307	19	1789	14198	-17.1%	-4.1%	
	2020 - 0 €	278	19	1758	13476	-21.4%	-9.0%	0
	2020 - 10 €	278	15	1758	12385	-27.7%	-16.4%	1
	2020 - 20 €	278	15	1758	12337	-28.0%	-16.7%	2
	2020 - 50 €	278	15	1541	11922	-30.4%	-19.5%	17
	2020 Max.	271	12	981	10381	-39.4%	-29.9%	280
Belgium	1990	515	39	3850	26684	0.0%		
	2005	425	43	1430	23611		0.0%	
	2020 Baseline	382	54	1744	26587	-0.4%	12.6%	
	2020 - 0 €	324	54	1697	25147	-5.8%	6.5%	0
	2020 - 10 €	324	37	1667	19989	-25.1%	-15.3%	3
	2020 - 20 €	324	37	1667	19989	-25.1%	-15.3%	3
	2020 - 50 €	324	36	1453	19572	-26.7%	-17.1%	18
	2020 Max.	297	33	793	17237	-35.4%	-27.0%	428
Bulgaria	1990	945	34	47	30348	0.0%		
	2005	529	15	170	16009		0.0%	
	2020 Baseline	269	16	168	10756	-64.6%	-32.8%	
	2020 - 0 €	247	16	150	10207	-66.4%	-36.2%	0
	2020 - 10 €	239	11	148	8728	-71.2%	-45.5%	3
	2020 - 20 €	224	11	148	8385	-72.4%	-47.6%	10
	2020 - 50 €	223	11	103	8200	-73.0%	-48.8%	17
	2020 Max.	210	9	61	7295	-76.0%	-54.4%	142

Table 5-4, contd.: Reduction potentials and costs for non-CO_2 greenhouse gases in 2020 by Member State. Relative reductions are measured against the 1990 emission level reported by countries to UNFCCC.

		Remaining CH_4 emissions (kt CH_4)	*Remaining N_2O emissions (kt N_2O)*	*Remaining F-gas emissions (kt CO2eq)*	*Remaining total non-CO_2 emissions (kt CO_2eq)*	*Reduction relative to 1990*	*Reduction relative to 2005*	*Total costs for all gases (million €/yr)*
Cyprus	1990	34	2	1	1394	0.0%		
	2005	34	1	80	1214		0.0%	
	2020 Baseline	29	1	74	1110	-20.4%	-8.6%	
	2020 - 0 €	28	1	63	1072	-23.1%	-11.8%	0
	2020 - 10 €	28	1	63	1050	-24.7%	-13.5%	0
	2020 - 20 €	23	1	63	949	-31.9%	-21.8%	2
	2020 - 50 €	23	1	58	930	-33.3%	-23.4%	3
	2020 Max.	21	1	30	785	-43.7%	-35.4%	41
Czech R.	1990	877	41	0	31012	0.0%		
	2005	462	29	540	19205		0.0%	
	2020 Baseline	315	32	665	17236	-44.4%	-10.3%	
	2020 - 0 €	288	32	608	16531	-46.7%	-13.9%	0
	2020 - 10 €	288	22	600	13549	-56.3%	-29.5%	11
	2020 - 20 €	287	22	600	13540	-56.3%	-29.5%	11
	2020 - 50 €	287	21	372	13066	-57.9%	-32.0%	27
	2020 Max.	245	17	191	10705	-65.5%	-44.3%	422
Denmark	1990	271	34	44	16333	0.0%		
	2005	248	26	920	14131		0.0%	
	2020 Baseline	221	25	1092	13466	-17.6%	-4.7%	
	2020 - 0 €	193	25	1072	12831	-21.4%	-9.2%	0
	2020 - 10 €	193	24	1051	12493	-23.5%	-11.6%	2
	2020 - 20 €	193	24	1051	12493	-23.5%	-11.6%	2
	2020 - 50 €	193	23	944	12108	-25.9%	-14.3%	16
	2020 Max.	166	19	496	9868	-39.6%	-30.2%	343
Estonia	1990	157	6	0	5154	0.0%		
	2005	99	3	160	3039		0.0%	
	2020 Baseline	86	3	210	2806	-45.6%	-7.7%	
	2020 - 0 €	72	3	205	2504	-51.4%	-17.6%	0
	2020 - 10 €	66	2	204	2351	-54.4%	-22.6%	1
	2020 - 20 €	61	2	204	2246	-56.4%	-26.1%	2
	2020 - 50 €	61	2	165	2178	-57.7%	-28.3%	5
	2020 Max.	57	2	58	1842	-64.3%	-39.4%	49
Finland	1990	299	25	94	14261	0.0%		
	2005	167	22	860	11126		0.0%	
	2020 Baseline	151	21	922	10561	-25.9%	-5.1%	
	2020 - 0 €	144	21	910	10354	-27.4%	-6.9%	0
	2020 - 10 €	144	16	894	8933	-37.4%	-19.7%	2
	2020 - 20 €	144	16	894	8933	-37.4%	-19.7%	2
	2020 - 50 €	144	13	732	7677	-46.2%	-31.0%	51
	2020 Max.	137	11	320	6477	-54.6%	-41.8%	295

Table 5-4, contd.: Reduction potentials and costs for non-CO_2 greenhouse gases in 2020 by Member State. Relative reductions are measured against the 1990 emission level reported by countries to UNFCCC.

		Remaining CH_4 emissions (kt CH_4)	*Remaining N_2O emissions (kt N_2O)*	*Remaining F-gas emissions (kt CO2eq)*	*Remaining total non-CO_2 emissions (kt CO_2eq)*	*Reduction relative to 1990*	*Reduction relative to 2005*	*Total costs for all gases (million €/yr)*
France	1990	3291	310	10021	175132	0.0%		
	2005	2758	260	12800	151398		0.0%	
	2020 Baseline	2267	264	13235	142543	-18.6%	-5.8%	
	2020 - 0 €	2013	262	13062	136464	-22.1%	-9.9%	0
	2020 - 10 €	2013	235	12887	127858	-27.0%	-15.5%	19
	2020 - 20 €	2013	234	12887	127815	-27.0%	-15.6%	19
	2020 - 50 €	2011	226	10991	123393	-29.5%	-18.5%	177
	2020 Max.	1988	190	5305	106095	-39.4%	-29.9%	3364
Germany	1990	4727	273	11861	195758	0.0%		
	2005	2312	192	14510	122588		0.0%	
	2020 Baseline	1764	190	15600	111479	-43.1%	-9.1%	
	2020 - 0 €	1619	187	15299	107243	-45.2%	-12.5%	0
	2020 - 10 €	1617	146	14944	94261	-51.8%	-23.1%	57
	2020 - 20 €	1617	146	14944	94261	-51.8%	-23.1%	57
	2020 - 50 €	1602	126	12084	84808	-56.7%	-30.8%	438
	2020 Max.	1491	101	5516	67993	-65.3%	-44.5%	3624
Greece	1990	437	46	1196	24483	0.0%		
	2005	365	45	5480	27108		0.0%	
	2020 Baseline	289	43	3934	23480	-4.1%	-13.4%	
	2020 - 0 €	278	43	3913	23090	-5.7%	-14.8%	0
	2020 - 10 €	261	33	3896	19691	-19.6%	-27.4%	10
	2020 - 20 €	261	33	3896	19681	-19.6%	-27.4%	10
	2020 - 50 €	259	29	1868	16354	-33.2%	-39.7%	108
	2020 Max.	254	27	640	14292	-41.6%	-47.3%	497
Hungary	1990	452	49	311	24945	0.0%		
	2005	358	42	510	20911		0.0%	
	2020 Baseline	315	52	454	23158	-7.2%	10.7%	
	2020 - 0 €	282	52	400	22313	-10.6%	6.7%	0
	2020 - 10 €	275	37	393	17733	-28.9%	-15.2%	4
	2020 - 20 €	275	37	393	17732	-28.9%	-15.2%	4
	2020 - 50 €	255	36	333	16931	-32.1%	-19.0%	33
	2020 Max.	243	31	169	14998	-39.9%	-28.3%	388
Ireland	1990	633	31	36	22821	0.0%		
	2005	616	39	850	25819		0.0%	
	2020 Baseline	484	35	1002	22068	-3.3%	-14.5%	
	2020 - 0 €	440	35	971	21043	-7.8%	-18.5%	0
	2020 - 10 €	440	26	959	18406	-19.3%	-28.7%	4
	2020 - 20 €	440	26	959	18406	-19.3%	-28.7%	4
	2020 - 50 €	440	25	583	17610	-22.8%	-31.8%	34
	2020 Max.	420	21	315	15615	-31.6%	-39.5%	419

Table 5-4, contd.: Reduction potentials and costs for non-CO_2 greenhouse gases in 2020 by Member State. Relative reductions are measured against the 1990 emission level reported by countries to UNFCCC.

		Remaining CH_4 emissions (kt CH_4)	*Remaining N_2O emissions (kt N_2O)*	*Remaining F-gas emissions (kt CO2eq)*	*Remaining total non-CO_2 emissions (kt CO_2eq)*	*Reduction relative to 1990*	*Reduction relative to 2005*	*Total costs for all gases (million €/yr)*
Italy	1990	1992	131	2492	84857	0.0%		
	2005	2100	123	6570	88715		0.0%	
	2020 Baseline	1814	126	9284	86577	2.0%	-2.4%	
	2020 - 0 €	1673	125	9174	83096	-2.1%	-6.3%	0
	2020 - 10 €	1666	112	9027	78631	-7.3%	-11.4%	18
	2020 - 20 €	1666	109	9027	77884	-8.2%	-12.2%	32
	2020 - 50 €	1646	105	6828	74030	-12.8%	-16.6%	158
	2020 Max.	1556	89	3692	63985	-24.6%	-27.9%	1940
Latvia	1990	167	12	0	7328	0.0%		
	2005	93	4	100	3419		0.0%	
	2020 Baseline	82	10	146	4984	-32.0%	45.8%	
	2020 - 0 €	79	10	138	4890	-33.3%	43.0%	0
	2020 - 10 €	79	6	137	3617	-50.6%	5.8%	1
	2020 - 20 €	73	6	137	3502	-52.2%	2.4%	3
	2020 - 50 €	73	6	72	3437	-53.1%	0.5%	5
	2020 Max.	69	4	49	2864	-60.9%	-16.3%	122
Lithuania	1990	293	20	0	12409	0.0%		
	2005	132	12	150	6551		0.0%	
	2020 Baseline	130	13	224	7045	-43.2%	7.5%	
	2020 - 0 €	118	13	213	6763	-45.5%	3.2%	0
	2020 - 10 €	116	9	211	5400	-56.5%	-17.6%	0
	2020 - 20 €	116	9	211	5321	-57.1%	-18.8%	1
	2020 - 50 €	116	9	112	5222	-57.9%	-20.3%	5
	2020 Max.	103	7	75	4551	-63.3%	-30.5%	174
Luxemb.	1990	17	1	17	604	0.0%		
	2005	17	1	160	857		0.0%	
	2020 Baseline	16	1	146	825	36.7%	-3.7%	
	2020 - 0 €	12	1	142	744	23.2%	-13.2%	0
	2020 - 10 €	12	1	140	741	22.8%	-13.5%	0
	2020 - 20 €	12	1	140	733	21.4%	-14.5%	0
	2020 - 50 €	12	1	128	721	19.4%	-15.9%	1
	2020 Max.	12	1	69	613	1.4%	-28.5%	23
Malta	1990	14	0	0	319	0.0%		
	2005	14	1	50	539		0.0%	
	2020 Baseline	9	1	36	469	47.1%	-13.1%	
	2020 - 0 €	9	1	32	455	42.8%	-15.6%	0
	2020 - 10 €	9	1	31	444	39.2%	-17.8%	0
	2020 - 20 €	9	1	31	442	38.6%	-18.1%	0
	2020 - 50 €	9	1	28	429	34.6%	-20.4%	1
	2020 Max.	8	1	16	352	10.4%	-34.8%	20

Table 5-4, contd.: Reduction potentials and costs for non-CO_2 greenhouse gases in 2020 by Member State. Relative reductions are measured against the 1990 emission level reported by countries to UNFCCC. Costs in *italics* indicate estimated total costs for measures included in baseline.

		Remaining CH_4 emissions (kt CH_4)	*Remaining N_2O emissions (kt N_2O)*	*Remaining F-gas emissions (kt CO2eq)*	*Remaining total non-CO_2 emissions (kt CO_2eq)*	*Reduction relative to 1990*	*Reduction relative to 2005*	*Total costs for all gases (million €/yr)*
Netherl.	1990	1211	68	6914	53574	0.0%		
	2005	760	63	2720	38315		0.0%	
	2020 Baseline	611	65	3781	36721	-31.5%	-4.2%	
	2020 - 0 €	541	64	3707	34951	-34.8%	-8.8%	0
	2020 - 10 €	541	45	3657	28936	-46.0%	-24.5%	5
	2020 - 20 €	541	45	3657	28936	-46.0%	-24.5%	5
	2020 - 50 €	541	43	2976	27628	-48.4%	-27.9%	49
	2020 Max.	490	35	1908	22932	-57.2%	-40.1%	1065
Poland	1990	2347	127	832	89383	0.0%		
	2005	1859	100	1840	71957		0.0%	
	2020 Baseline	1600	104	1967	67824	-24.1%	-5.7%	
	2020 - 0 €	1451	103	1816	64134	-28.2%	-10.9%	0
	2020 - 10 €	1450	87	1790	59246	-33.7%	-17.7%	8
	2020 - 20 €	1360	83	1768	56095	-37.2%	-22.0%	56
	2020 - 50 €	1341	83	1539	55478	-37.9%	-22.9%	80
	2020 Max.	1149	58	660	42630	-52.3%	-40.8%	2204
Portugal	1990	541	17	3	16745	0.0%		
	2005	568	21	910	19240		0.0%	
	2020 Baseline	439	22	1084	17014	1.6%	-11.6%	
	2020 - 0 €	384	21	1064	15603	-6.8%	-18.9%	0
	2020 - 10 €	383	19	1050	15013	-10.3%	-22.0%	2
	2020 - 20 €	383	19	1050	15013	-10.3%	-22.0%	2
	2020 - 50 €	380	18	763	14443	-13.7%	-24.9%	20
	2020 Max.	373	16	346	13060	-22.0%	-32.1%	233
Romania	1990	2128	94	2116	76083	0.0%		
	2005	1334	51	340	44281		0.0%	
	2020 Baseline	1227	60	447	44712	-41.2%	1.0%	
	2020 - 0 €	935	59	393	38270	-49.7%	-13.6%	0
	2020 - 10 €	855	48	393	33362	-56.2%	-24.7%	8
	2020 - 20 €	722	48	393	30320	-60.1%	-31.5%	58
	2020 - 50 €	690	46	261	28922	-62.0%	-34.7%	108
	2020 Max.	659	37	164	25526	-66.4%	-42.4%	568
Slovakia	1990	278	20	271	12284	0.0%		
	2005	240	14	150	9682		0.0%	
	2020 Baseline	247	16	197	10315	-16.0%	6.5%	
	2020 - 0 €	230	16	175	9935	-19.1%	2.6%	0
	2020 - 10 €	217	12	172	8556	-30.4%	-11.6%	2
	2020 - 20 €	217	12	172	8556	-30.4%	-11.6%	2
	2020 - 50 €	217	12	140	8326	-32.2%	-14.0%	8
	2020 Max.	200	10	74	7301	-40.6%	-24.6%	197

Table 5-4, contd.: Reduction potentials and costs for non-CO_2 greenhouse gases in 2020 by Member State. Relative reductions are measured against the 1990 emission level reported by countries to UNFCCC.

		Remaining CH_4 emissions (kt CH_4)	*Remaining N_2O emissions (kt N_2O)*	*Remaining F-gas emissions (kt CO2eq)*	*Remaining total non-CO_2 emissions (kt CO_2eq)*	*Reduction relative to 1990*	*Reduction relative to 2005*	*Total costs for all gases (million €/yr)*
Slovenia	1990	109	4	268	3775	0.0%		
	2005	102	4	170	3630		0.0%	
	2020 Baseline	86	4	168	3296	-12.7%	-9.2%	
	2020 - 0 €	78	4	156	3075	-18.6%	-15.3%	0
	2020 - 10 €	77	4	153	2997	-20.6%	-17.4%	0
	2020 - 20 €	77	4	153	2997	-20.6%	-17.4%	0
	2020 - 50 €	77	4	141	2926	-22.5%	-19.4%	3
	2020 Max.	72	3	81	2574	-31.8%	-29.1%	78
Spain	1990	1320	90	3353	58848	0.0%		
	2005	1677	106	5740	73681		0.0%	
	2020 Baseline	1624	107	8563	75813	28.8%	2.9%	
	2020 - 0 €	1334	105	8450	69030	17.3%	-6.3%	0
	2020 - 10 €	1334	94	8374	65481	11.3%	-11.1%	8
	2020 - 20 €	1331	94	8374	65412	11.2%	-11.2%	9
	2020 - 50 €	1331	89	7436	63124	7.3%	-14.3%	81
	2020 Max.	1281	74	2662	52365	-11.0%	-28.9%	2045
Sweden	1990	319	28	551	15918	0.0%		
	2005	259	26	1340	14839		0.0%	
	2020 Baseline	197	26	2003	14052	-11.7%	-5.3%	
	2020 - 0 €	182	25	1957	13636	-14.3%	-8.1%	0
	2020 - 10 €	182	22	1926	12558	-21.1%	-15.4%	3
	2020 - 20 €	182	22	1829	12461	-21.7%	-16.0%	4
	2020 - 50 €	182	21	1654	12132	-23.8%	-18.2%	15
	2020 Max.	176	18	746	9985	-37.3%	-32.7%	410
UK	1990	4936	205	13807	181088	0.0%		
	2005	2855	147	11740	117350		0.0%	
	2020 Baseline	1773	154	11844	96704	-46.6%	-17.6%	
	2020 - 0 €	1712	152	11715	94815	-47.6%	-19.2%	0
	2020 - 10 €	1712	115	11352	83091	-54.1%	-29.2%	15
	2020 - 20 €	1712	113	11340	82351	-54.5%	-29.8%	28
	2020 - 50 €	1676	109	9761	78605	-56.6%	-33.0%	166
	2020 Max.	1585	91	5635	67120	-62.9%	-42.8%	1584
EU27	1990	28747	1727	59690	1198801	0.0%		
	2005	20708	1409	72340	944026		0.0%	
	2020 Baseline	16733	1463	80779	885797	-26.1%	-6.2%	
	2020 - 0 €	14945	1447	79239	841673	-29.8%	-10.8%	0
	2020 - 10 €	14801	1183	77876	755499	-37.0%	-20.0%	187
	2020 - 20 €	14542	1173	77745	746790	-37.7%	-20.9%	330
	2020 - 50 €	14394	1112	63066	710173	-40.8%	-24.8%	1643
	2020 Max.	13533	917	31052	599438	-50.0%	-36.5%	20955

6 Conclusions

This report presents emission projections for the EU-27 for the year 2020 together with the potentials and costs for further mitigation of the non-CO_2 greenhouse gases. These include methane (CH_4), nitrous oxide (N_2O), and the three F-gases hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). The study was undertaken under contract for the European Commission DG Environment to provide the European Commission a quantitative basis for their proposal on the burden sharing of a 20 percent reduction in greenhouse gases in the EU.

The Greenhouse and Air pollution Interactions and Synergies (GAINS) model was used to generate national cost curves for the mitigation of non-CO_2 greenhouse gases for each Member State. The analysis employs projections of activity data provided by Member States to IIASA for the revision of the National Ceilings (NEC) directive. The analysis has been aligned as far as possible with based on the national emission inventories of greenhouse gases in 2000 that have been submitted by the Member States to the UNFCCC.

A baseline projection has been developed that explores the likely level of non-CO_2 emissions in 2020 as they can be expected as a consequence of the national projections of activity levels and the implementation of current legislation on greenhouse gas mitigation. This baseline projection suggests for 2020 a reduction in the total non-CO_2 greenhouse gases by 59 Mt CO_2eq or six percent in comparison to 2005. This includes a 19 percent reduction in CH_4, a four percent increase in N_2O, and a 12 percent increase in F-gases. Major factors contributing to the reductions in CH_4 are the implementation of the Landfill directive, the replacement of old gas distribution networks, and enhanced recovery of coal mine gas coupled with the envisaged phase-out of coal mining in some countries. For N_2O emissions, the effects of the implementation of catalytic reduction in adipic acid production is balanced out by increasing activity volumes. Despite the implementations of the F-gas directive and the directive on air-conditioning systems in motor vehicles, total F-gas emissions are expected to increase considerably. This is primarily a combined effect of replacing the use of CFCs with HFCs in accordance with the Montreal Protocol and the expected increase in demand for refrigeration and air conditioning.

In addition to what is required by current legislation, technical mitigation measures are available that could reduce by 2020 non-CO_2 emissions in the EU-27 by additional 286 Mt CO_2eq, so that total non-CO_2 gas emissions could be cut by almost 50 percent compared to 1990.

44 Mt CO_2eq of this potential could be implemented through measures for which cost savings exceed over the technical life time investments and operating costs. These measures include farm-scale anaerobic digestion for large farms and leakage reduction at compressor stations in gas transmission pipelines. Mitigation of the remaining 242 Mt CO_2eq would involve costs of € 21 billion per year. Among the control options that have marginal costs of less than € 25/t CO_2eq, substantial reductions can be attained from reducing N_2O through catalytic reduction in nitric acid production, reduced application of fertilizers on agricultural lands, and combustion modifications in fluidized bed combustion.

Annex 1: Comparison of GAINS emission estimates for 2005 with the available national inventories

As explained in Section 3, this study employs emission factors that have been derived from the year 2000 inventories as submitted by Member States to the UNFCCC. With the activity data of the GAINS model and information on the implementation of mitigation measures in the year 2000, this approach reproduces exactly CH_4 and N_2O emissions that have been reported by countries for 2000.

For 2005, GAINS emission estimates consider changes in activity levels and progressing implementation of mitigation measures, but keep the country-specific “uncontrolled” emission factor derived for the year 2000 constant. While estimates from such an approach come close to the national inventories for many countries, there are some notable discrepancies. This annex lists the major reasons that lead to significant deviations between the GAINS estimates for 2005 and the national inventories as provided at the UNFCCC web site on November 30, 2007.

As explained in Section 3, one important reasons for discrepancies in the 2005 estimates routes back to the fact that GAINS activity data for 2005 do not necessarily reflect the actual statistics for 2005 since such statistics are not yet fully available at the international level. Instead, GAINS activity data have been derived from the latest projections for 2005, while presumably national inventory agencies could make use of recent actual statistics.

CH_4 emissions

While for the EU-27 as a whole 2005 estimates of CH_4 emissions differ by less than four percent, larger discrepancies occur for some Member states, e.g., Belgium (+14%), Czech Republic (-12%), Finland (-22%), Italy (+11%), Slovakia (+21%), and the UK (+21%). Table 6-1 lists for all EU Member States the differences in emission estimates and provides the most important reasons for these differences.

Table 6-1: Reasons for major discrepancies in GAINS emission estimates for 2005 and preliminary emissions reported to UNFCCC for 2005.

Country	GAINS estimate (kt CH_4)	Emissions reported to UNFCCC as of Nov 30, 2007	Difference	Reasons for major discrepancies
Austria	325	336	-3%	
Belgium	425	373	14%	GAINS activity data for non-dairy cattle and pigs are 20 and 15 percent higher than data in UNFCCC. In the UNFCCC inventory the implied emission factor for municipal solid waste is 39 percent higher in 2005 than in 2000.
Bulgaria	529	489	8%	In the UNFCCC inventory the implied emission factor for municipal solid waste is 15 % higher in 2000 than in 2005.
Cyprus	34			
Czech Rep.	462	524	-12%	GAINS activity data for coal mining is 27 % lower in 2005 than that used in the report to UNFCCC
Denmark	248	268	-7%	In the UNFCCC inventory the implied emission factor for municipal solid waste is 26 % lower in 2000 than in 2005.

Table 6-1, contd.: Reasons for major discrepancies in GAINS emission estimates for 2005 and preliminary emissions reported to UNFCCC for 2005.

Country	GAINS estimate (kt CH_4)	Emissions reported to UNFCCC as of Nov 30, 2007	Difference	Reasons for major discrepancies
Estonia	99	90	10%	In the UNFCCC inventory the implied emission factor for municipal solid waste is 4 % lower in 2000 than in 2005.
Finland	167	214	-22%	GAINS emissions from municipal solid waste are lower than those in the UNFCCC emissions probably due to discrepancies in the assumptions about the implementation of mitigation measures in 2005.
France	2758	2709	2%	
Germany	2312	2268	2%	
Greece	365	405	-10%	The implied emission factor for non-dairy cattle in the UNFCCC inventory is 32 % lower in 2000 than in 2005. The activity level in GAINS for municipal solid waste is 31 % lower in 2005 than that reported to UNFCCC.
Hungary	358	370	-3%	
Ireland	616	624	-1%	
Italy	2100	1891	11%	For 2005, livestock numbers in GAINS for sheep/goats and non-dairy cattle are 54 and 16 % higher, respectively, than those reported to UNFCCC. GAINS activity data for municipal solid waste is 10 % higher than that reported to UNFCCC.
Latvia	93	86	8%	The implied emission factor for fugitive and combustion emissions from natural gas distribution and use in the UNFCCC inventory is 95 % higher in 2000 than in 2005.
Lithuania	132	159	-17%	In the UNFCCC inventory the implied emission factor for dairy cows is 15 % lower in 2000 than in 2005. GAINS emissions from municipal solid waste and wastewater are lower than those reported to UNFCCC, probably because of differences in assumptions about the implementation of mitigation measures in 2005.
Luxembg.	17	17	1%	
Malta	14		-21%	
Nether-lands	760	796	-4%	In the UNFCCC inventory the implied emission factors for dairy cows and oil refineries are 9 and 97 % lower, respectively, in 2000 than in 2005.
Poland	1859	1824	2%	GAINS emission estimates for domestic wastewater are higher than those reported to UNFCCC, probably because of different assumptions about the implementation of mitigation measures in 2005.

Table 6-1, contd.: Reasons for major discrepancies in GAINS emission estimates for 2005 and preliminary emissions reported to UNFCCC for 2005.

Country	GAINS estimate (kt CH_4)	Emissions reported to UNFCCC as of Nov 30, 2007	Difference	Reasons for major discrepancies
Portugal	568	531	7%	Emissions from industrial wastewater are higher in GAINS than those reported to UNFCCC. The reason could not be clarified since there is no common activity unit.
Romania	1334	1226	9%	GAINS activity data for coal mining and gas production in 2005 are 18 and 17 % higher, respectively, than those reported to UNFCCC.
Slovakia	240	198	21%	GAINS activity data for non-dairy cattle, coal mining, and solid fuel use in industrial combustion are higher by 56, 59, and 65 %, respectively, than activity data reported to UNFCCC for 2005.
Slovenia	102	100	2%	
Spain	1677	1775	-5%	The implied emission factor for municipal solid waste in the UNFCCC inventory is 14 percent lower in 2000 than in 2005.
Sweden	259	267	-3%	
UK	2855	2357	21%	The implied emission factors for coal mining and municipal solid waste in the UNFCCC inventory are 14 and 44 % higher in 2000 than in 2005. The implementation of mitigation measures in 2005 needs to be analyzed.
EU-25 (excl. Cyprus and Malta)	20643	19880	4%	

It turns out that many discrepancies relate to the solid waste sector. For this sector the calculation of emissions is particularly complex since it requires information, e.g., on the amount and composition of waste in the past as CH_4 emissions from landfills are released over several decades after disposal. Using the same methodology for all countries, GAINS projections apply historical statistics of waste amounts, compositions and control measures provided by EUROSTAT (2005). In contrast, national inventories compiled by Member States employed different methodologies for this sector since the IPCC (1997) guidelines do not provide detailed guidelines. In addition, important mitigation measures have been adopted in this sector over the last decades, including extensive diversion of waste away from landfills through recycling or recovery and improved control at landfills. Incomplete information on the extent of applied mitigation measures and their effectiveness may explain some of the discrepancies in inventories.

Comparison of N_2O emission estimates for 2005

For the EU-27 as a whole, 2005 estimates of N_2O emissions differ by less than five percent. However, larger discrepancies occur for some Member states (Table 6-1).

Table 6-2: Reasons for major discrepancies between the 2005 GAINS estimates of N_2O emissions and the inventories reported by Member States to UNFCCC for 2005.

Country	GAINS estimate (kt N_2O)	Emissions reported to UNFCCC as of Nov 30, 2007	Difference	Reasons for major discrepancies
Austria	19	17	13%	Inconsistency in the degree of N_2O mitigation for nitric acid production in 2005
Belgium	43	36	20%	Inconsistency in the degree of N_2O mitigation for nitric acid production in 2005
Bulgaria	15	14	8%	
Cyprus	1	3	-61%	Incomplete reporting in the UNFCCC inventory
Czech R.	29	26	11%	Different N_2O emissions from fluidized bed combustion
Denmark	26	23	13%	Different N_2O emissions from fluidized bed combustion
Estonia	3	2	4%	Different N_2O emissions from fluidized bed combustion
Finland	22	22	-1%	
France	260	233	12%	
Germany	192	213	-10%	Higher nitric acid production than projected by GAINS for 2005
Greece	45	42	7%	
Hungary	42	31	33%	Change of emission factors for “Fuel combustion – other sectors” between 2000 and 2005 in the UNFCCC inventory
Ireland	39	29	36%	
Italy	123	130	-6%	Higher adipic acid production than projected by GAINS for 2005
Latvia	4	5	-8%	
Lithuania	12	16	-28%	Higher nitric acid production than projected by GAINS for 2005
Luxembg.	1	1	-20%	Incomplete reporting in the UNFCCC inventory
Malta	1	0		Incomplete reporting in the UNFCCC inventory
Netherl.	63	57	12%	
Poland	100	100	0%	
Portugal	21	20	5%	
Romania	51	54	-5%	
Slovakia	14	12	20%	The national inventories for 2000 and 2005 use different emission factors for agricultural soils
Slovenia	4	4	2%	
Spain	106	95	11%	
Sweden	26	24	7%	
UK	147	128	15%	Higher nitric acid production than projected by GAINS for 2005
EU-27	1409	1339	5%	

Major discrepancies between GAINS estimates and the national inventories for 2005 emerge where national reports show distinct changes between 2000 and 2005. Such changes may be due to actual transformations that have taken place, but can also be a consequence of incomplete knowledge of the inventory agency. Most of the differences originate in three sectors:

- The GAINS projections of activity data assume an increasing share of fluidized bed combustion of solid fuels in energy industries, which will lead to higher N_2O emissions from this sector. Some national inventories for 2005 do not reveal such an increase in fluidized bed combustion, either because it has not happened or because such a change has not been considered when calculating N_2O emissions.
- Some countries have increased the production of nitric acid (Germany, Lithuania, UK) or adipic acid (Italy) more than assumed in the GAINS activity data for 2005.
- Some countries report for 2005 higher impacts of N_2O mitigation measures than foreseen by GAINS (e.g., Austria, Belgium, etc.).
- For some countries, nitrogen application to agricultural soils in 2005 is different in the national inventories from what was assumed in the GAINS activity database.

F-gas emissions

Due to incomplete reporting in the national inventories, the analysis for this report could not derive meaningful implied emission factors. Instead, the default factors of the GAINS model have been used. These two circumstances, i.e., often incomplete national inventories and the use of generic emission factors, lead to sometimes considerable differences between national and GAINS estimates for individual sectors and gases (Table 6-3). In general, estimates agree within a ±20 percent range for HFC for 14 countries and for PFC and SF6 for 12 countries, respectively. Even larger discrepancies occur for SF_6. Due to high aggregation of the national inventories there is limited scope for sectoral comparisons for F-gas emissions.

Table 6-4 identifies for each country the main reasons for major discrepancies between the GAINS estimates and the inventories reported to UNFCCC. Systematic differences that occur for certain sectors for several countries are listed in Table 6-5.

Table 6-3: Comparison of the estimates of individual F-gas emissions for the year 2005 between the UNFCCC inventory (as of November 30, 2007) and the GAINS model (in Mt CO_2eq)

	HFC		PFC		SF_6		Total	
	UNFCCC	GAINS	UNFCCC	GAINS	UNFCCC	GAINS	UNFCCC	GAINS
Austria	0.90	1.15	0.12	0.03	0.29	0.87	1.31	2.05
Belgium	1.45	1.15	0.14	0	0.04	0.25	1.63	1.40
Bulgaria	0.38	0.17	0	0	0	0	0.38	0.17
Cyprus	0.05	0.06	0	0	0	0.02	0.05	0.08
Czech R.	0.58	0.44	0.01	0.07	0.09	0.02	0.68	0.53
Denmark	0.80	0.88	0.01	0.03	0.02	0.02	0.83	0.93
Estonia	0.01	0.15	0	0	0.01	0	0.01	0.15
Finland	0.85	0.83	0.01	0.02	0.02	0.02	0.88	0.87
France	10.95	9.60	1.80	1.67	1.35	1.56	14.10	12.83
Germany	9.35	10.05	0.72	0.58	4.74	3.91	14.81	14.54
Greece	5.90	5.33	0.07	0.14	0	0	5.97	5.47
Hungary	0.52	0.30	0.21	0.17	0.20	0.02	0.93	0.49
Ireland	0.43	0.62	0.17	0.24	0.10	0	0.70	0.86
Italy	5.27	5.37	0.36	0.74	0.46	0.45	6.09	6.56
Latvia	0.02	0.10	0	0	0.01	0.01	0.03	0.11
Lithuania	0.02	0.14	0	0	0	0.01	0.02	0.15
Luxembourg.	0.08	0.14	0	0	0	0.01	0.08	0.15
Netherlands	1.35	2.14	0.26	0.38	0.34	0.20	1.95	2.72
Malta	0.03	0.02	0	0	0	0.02	0.03	0.04
Poland	2.72	1.72	0.26	0.11	0.02	0.02	3.00	1.85
Portugal	0.39	0.91	0	0	0.01	0.01	0.40	0.92
Romania	0	0.31	0.57	0	0	0.02	0.57	0.33
Spain	5.01	5.22	0.24	0.27	0.27	0.26	5.52	5.75
Slovakia	0.17	0.13	0.02	0	0.02	0.02	0.21	0.15
Slovenia	0.09	0.10	0.12	0.05	0.02	0.02	0.23	0.17
Sweden	0.77	0.91	0.30	0.30	0.14	0.12	1.21	1.33
UK	9.22	10.68	0.35	0.33	1.14	0.70	10.71	11.71
EU-27	57.31	58.62	5.74	5.13	9.30	8.56	72.35	72.31

Table 6-4: Reasons for major discrepancies in the estimates of total F-gas emissions for 2005

Country	GAINS estimate (kt CO_2eq)	Emissions reported to UNFCCC as of Nov 30, 2007	Difference	Reasons for major discrepancies
Austria	2050	1316	56%	GAINS SF_6 estimates are more than 800 kt CO_2eq higher due to higher estimates for gas insulated switchgears (GIS) and sound proof windows.
Belgium	1430	1638	-13%	
Bulgaria	170	391	-57%	GAINS HFC emissions are lower because the growth of Bulgarian HFC-stock between 2000 and 2005 has been underestimated
Cyprus	80	54	48%	
Czech Rep.	540	690	-22%	The main difference relates to SF_6 emissions. However, as these emissions are not specified on a sector level in the CRF table, the reasons for the discrepancy are unclear.
Denmark	920	841	9%	
Estonia	160	14	1064%	Reported F-gas emissions are generally low, reasons for differences unidentified.
Finland	860	893	-4%	
France	12800	14113	-9%	
Germany	14510	14822	-2%	
Greece	5480	5786	-8%	
Hungary	510	928	-45%	GAINS estimates for PFC and SF_6 are lower by about 250 kt CO_2eq; the reasons are not known.
Ireland	850	701	21%	HFC estimates differ by 180 kt, SF_6 emissions by 90 kt in an unidentified sector
Italy	6570	6089	8%	
Latvia	100	27	275%	Reported F-gas emissions are generally low, reasons for differences are not known.
Lithuania	150	20	638%	Reported F-gas emissions are generally low, reasons for differences are not known.
Luxembourg	160	86	85%	
Malta	50	30	69%	
Netherlands	2720	1956	39%	The main difference comes from several HFC sectors, leading in total to a discrepancy of 1500 kt. Reported HFC emissions from refrigeration and air conditioning are low compared to other countries. CRF tables do not provide details on individual refrigerant sectors, and do not provide corresponding emission factors.
Poland	1840	3034	-39%	The difference originates from several HFC-sectors, mainly from foam industry.
Portugal	910	401	127%	Reported F-gas emissions are generally low, reasons for differences are unidentified.

Table 6-4, contd.: Reasons for major discrepancies in the estimates of total F-gas emissions for 2005

Country	GAINS estimate (kt CO_2eq)	Emissions reported to UNFCCC as of Nov 30, 2007	Difference	Reasons for major discrepancies
Romania	340	574	-41%	GAINS estimates lower HFC emissions because growth of Romanian FC-stock has been underestimated for 2005.
Slovakia	150	212	-29%	Reported F-gas emissions are generally low, reasons for differences unidentified.
Slovenia	170	237	-28%	Reported F-gas emissions are generally low, reasons for differences unidentified.
Spain	5740	5527	4%	
Sweden	1340	1215	10%	
UK	11740	10715	10%	
Total EU-27	72340	72310	0%	

Table 6-5: Major factors that lead to discrepancies between the GAINS F-gas emission estimates and the inventories reported in the UNFCCC 2007 database for the year 2005

Emission source	**Comments**
Domestic refrigeration	• Belgium, Bulgaria, Czech Republic, Ireland and Italy report emissions from all refrigeration (except mobile air conditioning) under domestic refrigeration. Three of these countries do not provide historic data. • Denmark, Estonia, Finland and Hungary report emissions from all refrigeration under domestic refrigeration. No historic data are provided. • Lithuania, Luxembourg and Netherlands report emissions from all refrigeration (except mobile air conditioning) under industrial refrigeration. No historic data are provided. • 19 out of 25 countries (excluding Cyprus and Malta) provide incomplete activity data for domestic refrigerators. • Emission factors would typically assume an annual leakage of approximately one percent. However, some countries imply higher losses (e.g., over 60% in Hungary). High numbers could indicate a misunderstanding of the nature of the emission factor (i.e., a product life factor does not mean a factor over a lifetime, but is an average annual factor). • Portugal reports activity levels that would correspond to an equivalent of about 500 million refrigerators. Also Slovakia, Slovenia and Spain report unreasonably high activity levels. • Reports for the UK seem to mix up kilograms and tons for all refrigeration sectors.
Commercial refrigeration	• The same aggregation problems as described under domestic refrigeration apply. • 15 of 25 countries provide incomplete data on commercial refrigerators. • Emission factors typically indicate annual leakages between 5 and 10%, and some countries use lower levels. The typical range corresponds to GAINS emission factors.

Table 6-5, contd.: Major factors that lead to discrepancies between the GAINS F-gas emission estimates and the inventories reported in the UNFCCC 2007 database for the year 2005

Emission source	**Comments**
Transport refrigeration	• The same aggregation problems as described under domestic refrigeration apply. • 17 of 25 countries provide incomplete data for transport refrigerators. • Emission factors for transport refrigeration indicate annual leakage rates between 7 and 30%. Only few countries report their emission factors. In GAINS, the emission factor without measures assumes 20% annual leakage. The reported use of refrigerants is close to the average use in GAINS.
Industrial refrigeration	• The same aggregation problems as described under domestic refrigeration apply. • 21 of 25 countries delivered incomplete data for industrial refrigeration. • Emission factors for industrial refrigeration indicate annual leakage rates between 8 and 12%, which is in line with the GAINS assumptions. The accuracy of data on refrigerant types is difficult to verify as sectors and applications are very heterogeneous.
Stationary air conditioning	• The same aggregation problems as described under domestic refrigeration apply. • Emission factors indicate annual leakage rates between 3 and 10%, which is in line with GAINS assumptions.
Mobile air conditioning	• The same aggregation problems as described under domestic refrigeration apply. • Emission factors in the UNFCCC database indicate annual leakage rates from 0.1% (Ireland) to 77.5% (Portugal). In GAINS, an emission factor close to 10% is used for the major emitters. • HFC-134a is reported as the only refrigerant for mobile air condition in almost all EU countries.
Foam blowing	• For Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Spain, Sweden, and UK, emission have been reported only for hard foams. • Italy has reported emissions only for soft foam. • Emission factors indicate annual leakage rates between 25 and 85%. • Gases used in hard foam blowing were HFC-134a and HFC-152a. The latter gas has a significantly lower GWP and is treated as a mitigation option in GAINS. • Some countries define emissions as end-of-life emissions, while others define them as lifetime emissions.
Aerosols	• Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Romania, Slovakia, and the UK report only emissions from metered dose inhalers (for medical purposes). For Austria, reported activity data for metered dose inhalers are very high. • 18 of 25 countries delivered incomplete data for aerosols. • Most countries use an emission factor for aerosols of 100%, except the Netherlands which uses 0%.
HCFC-22 production	• Activity numbers for HCFC-22 production are often missing in the UNFCCC database, probably due to confidentiality.
Semiconductor manufacturing	• 19 of 25 countries reported incomplete data for semiconductor manufacturing.
Electr. equipment	• 14 of 25 countries reported incomplete data for electrical equipment.
Other sectors	• F-gas activities in industry are often directly linked to production volumes. As these are often confidential, also information on f-gas activities may be difficult to obtain. • Two smaller sectors are not included in GAINS (fire extinguishers and PFC manufacturing).

Annex 2: National cost curves for greenhouse gases

This annex compares national cost curves for CH_4, N_2O, F-gases and total non-CO_2 emissions for all Member States. The curves refer to the national activity projections for 2020. The x-axis shows emissions relative to the year 2005, while marginal costs are displayed on the y-axis. For convenience, the x-axes range from 40 to 140 percent of 2005 emissions for all countries, even if some data lay outside this range. The scale of the y-axes is limited to a carbon price below € 100/t CO_2eq, although the calculation has been performed up to € 300/t CO_2eq.

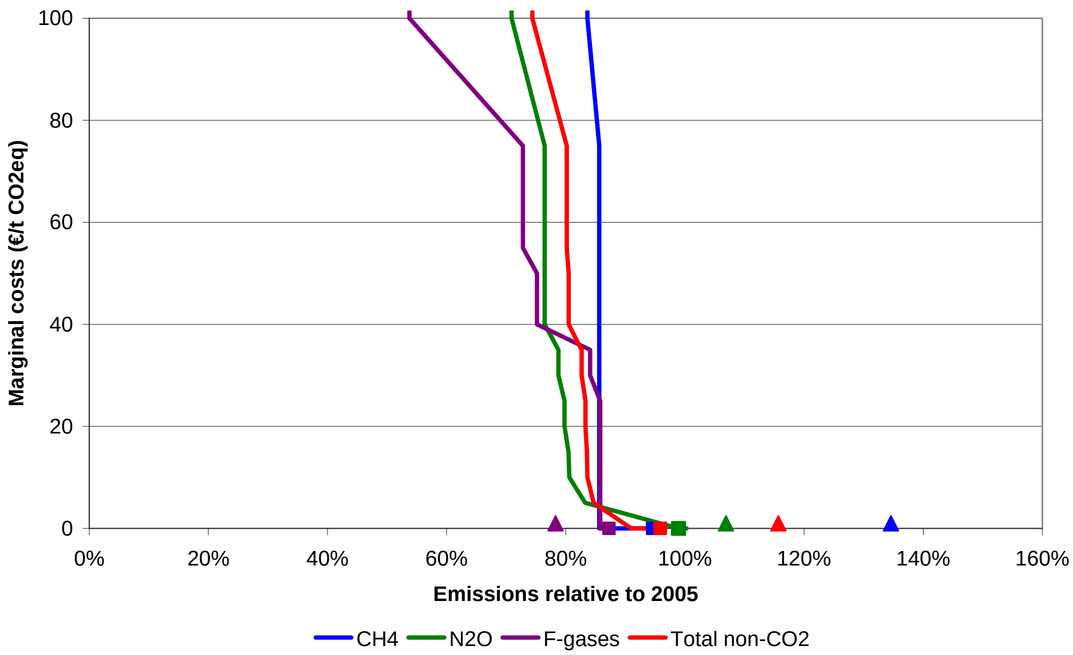

Figure 6-1: National cost curves for non-CO_2 greenhouse gases for Austria. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

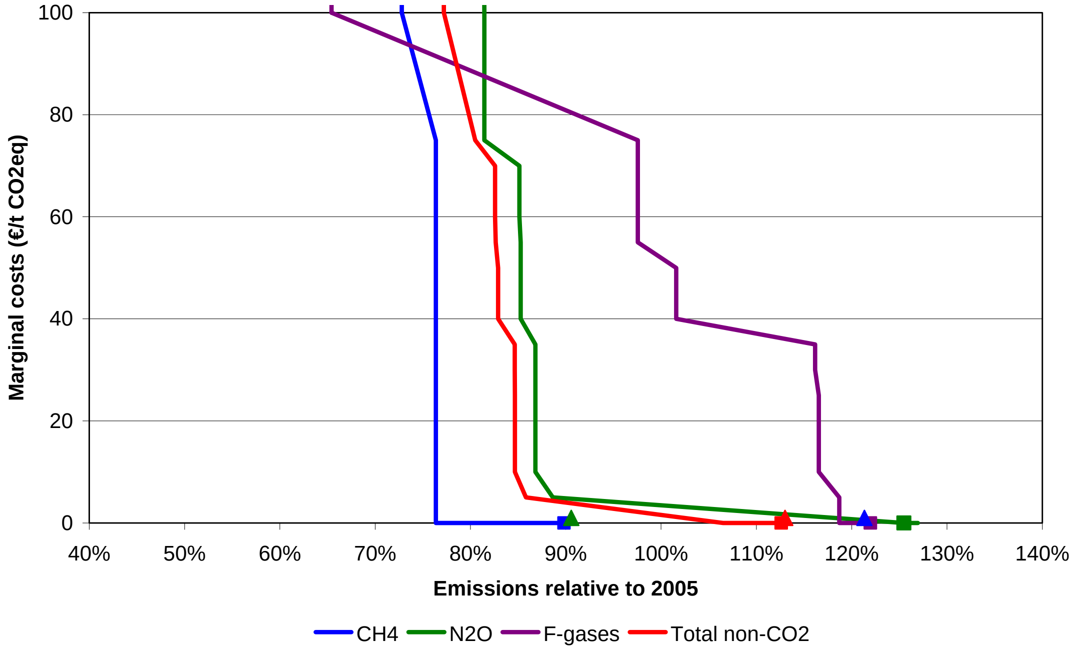

Figure 6-2: National cost curves for non-CO_2 greenhouse gases for Belgium. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

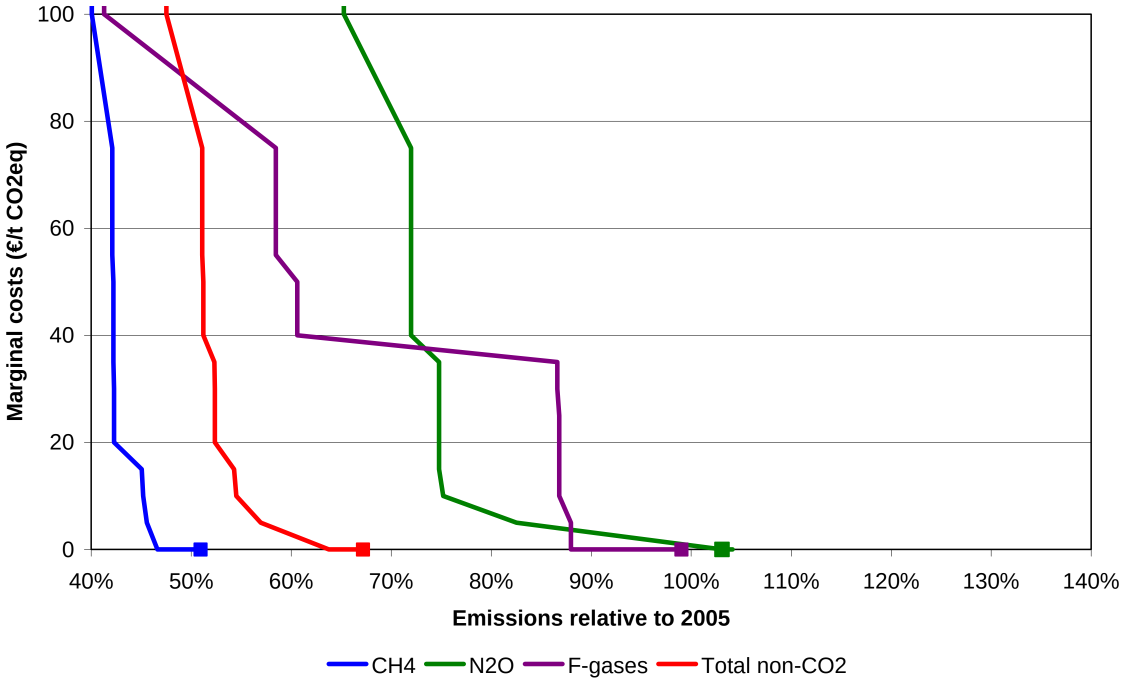

Figure 6-3: National cost curves for non-CO_2 greenhouse gases for Bulgaria. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

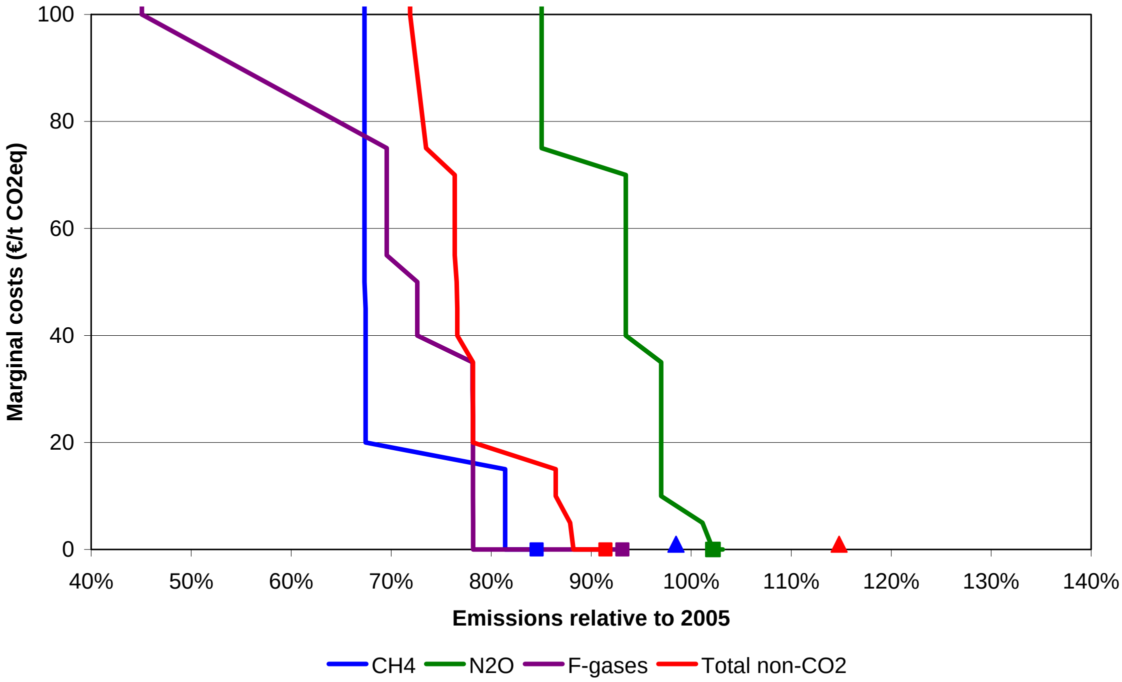

Figure 6-4: National cost curves for non-CO_2 greenhouse gases for Cyprus. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

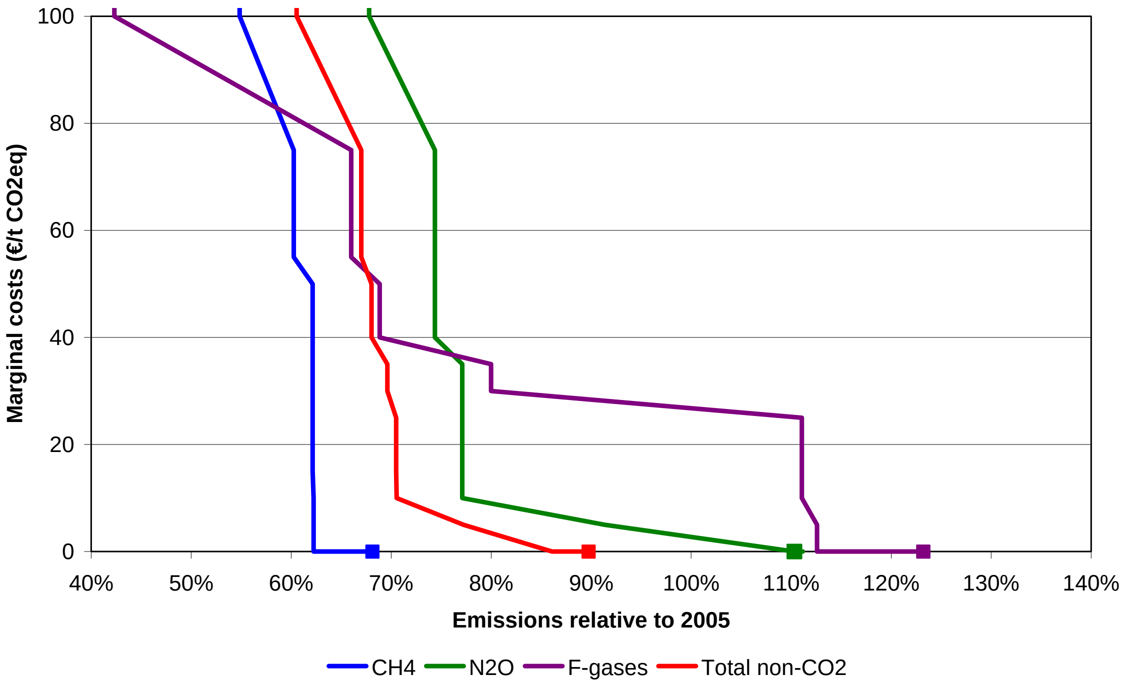

Figure 6-5: National cost curves for non-CO_2 greenhouse gases for the Cezch Republic. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

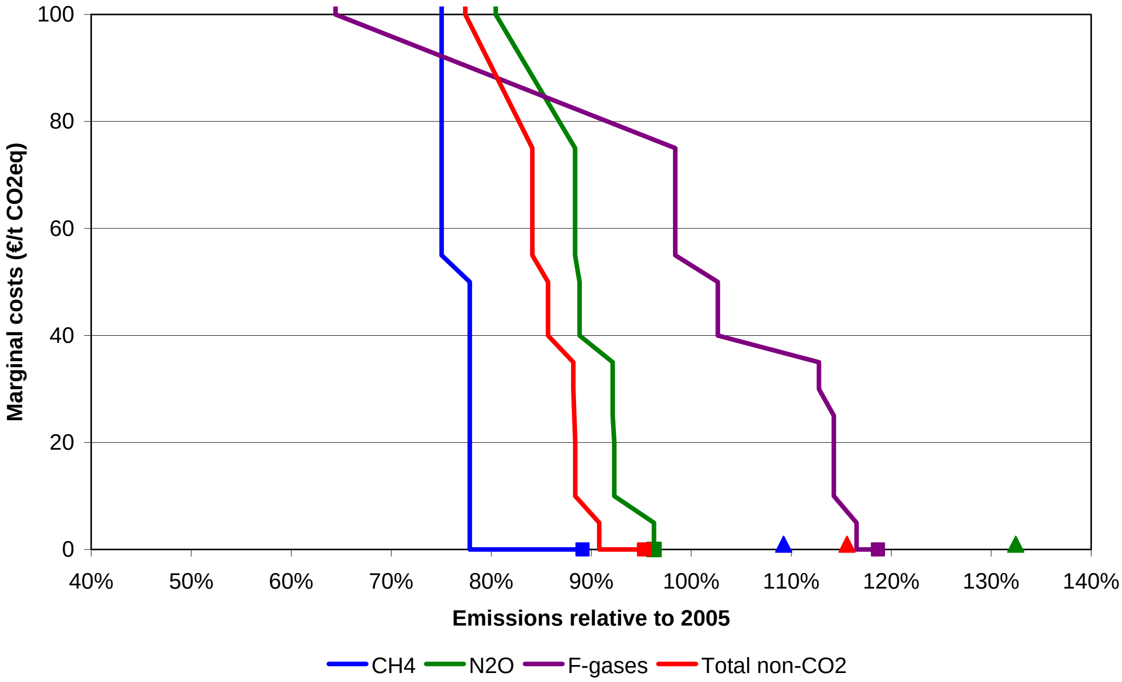

Figure 6-6: National cost curves for non-CO_2 greenhouse gases for Denmark. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

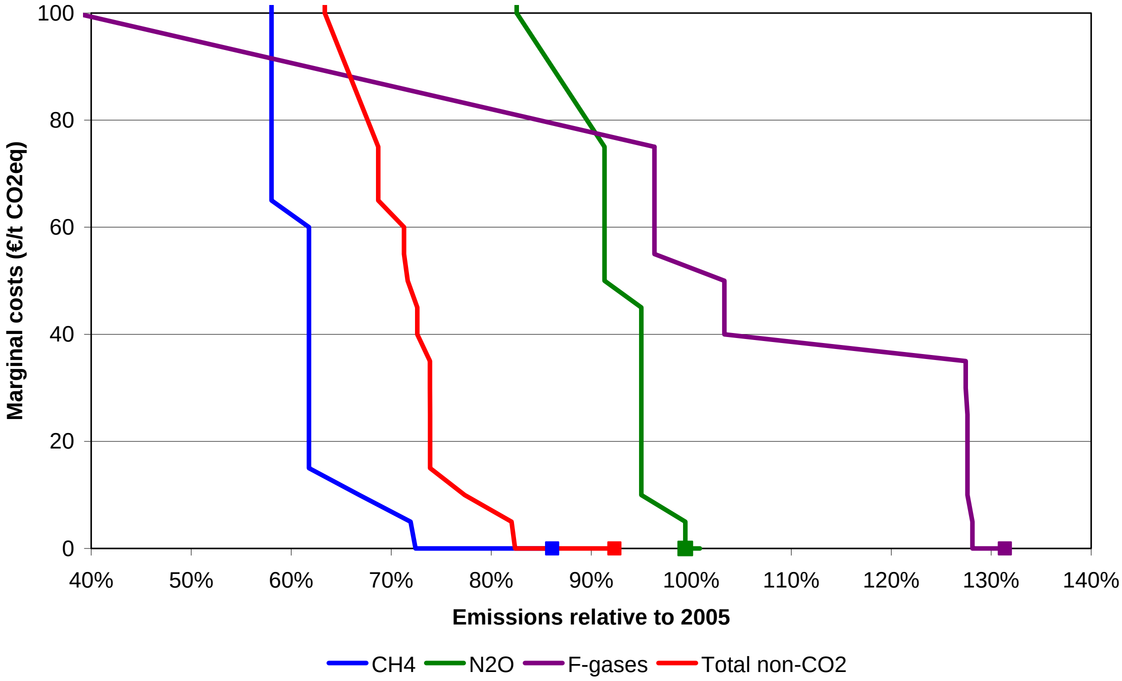

Figure 6-7: National cost curves for non-CO_2 greenhouse gases for Estonia. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

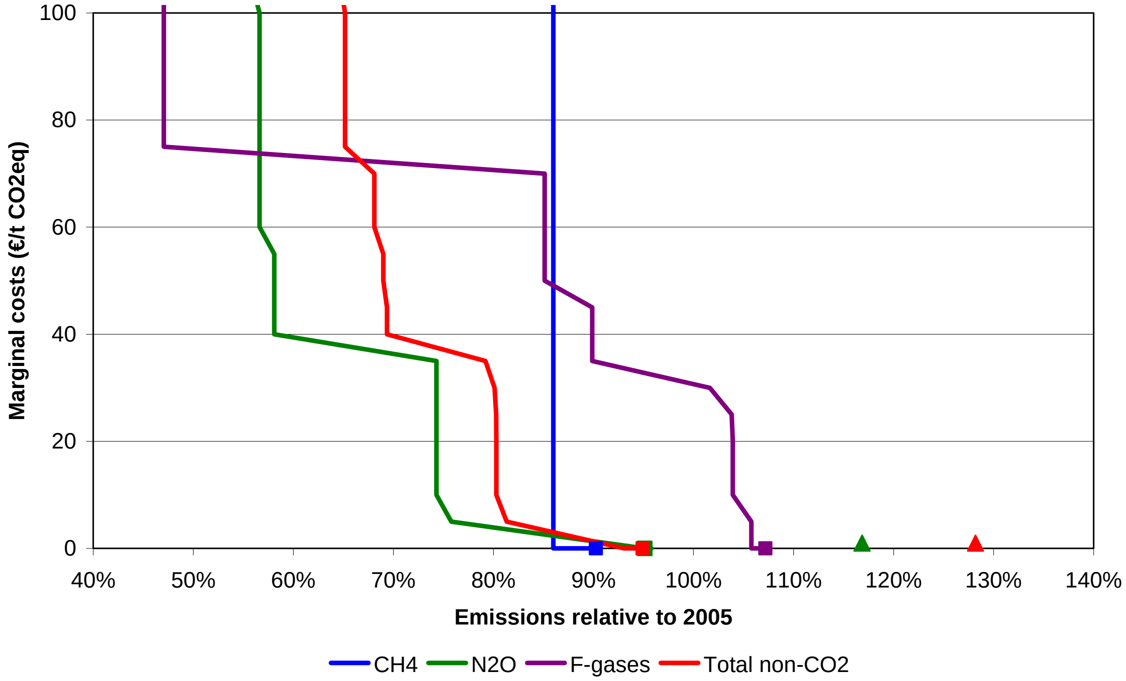

Figure 6-8: National cost curves for non-CO_2 greenhouse gases for Finland. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

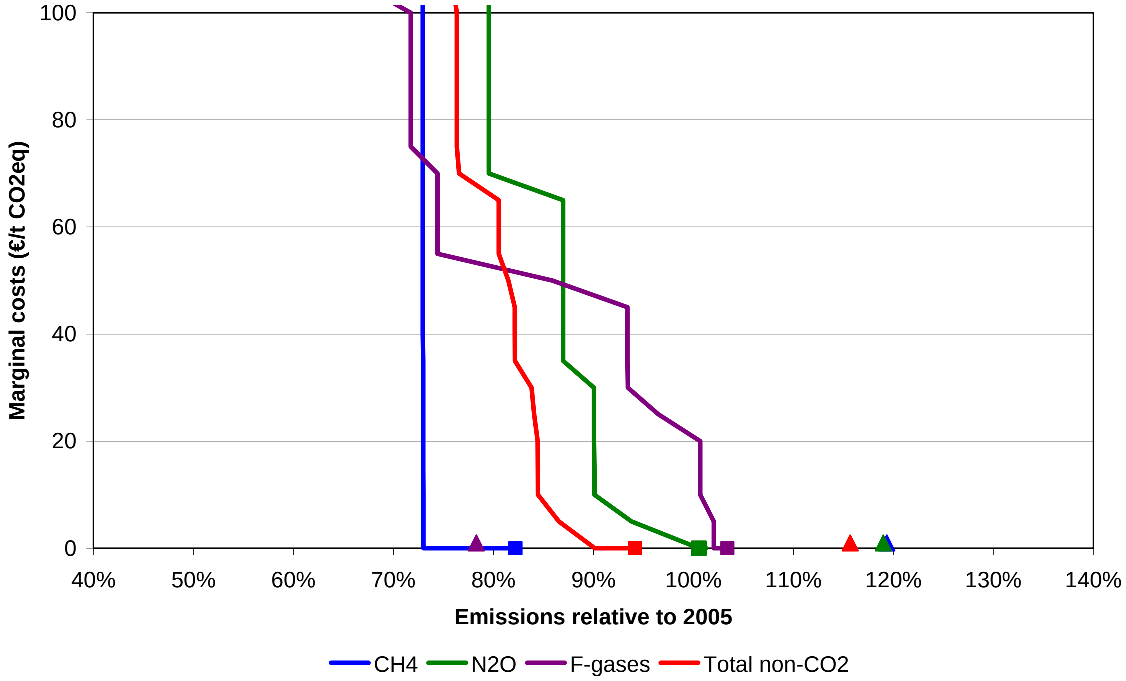

Figure 6-9: National cost curves for non-CO_2 greenhouse gases for France. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

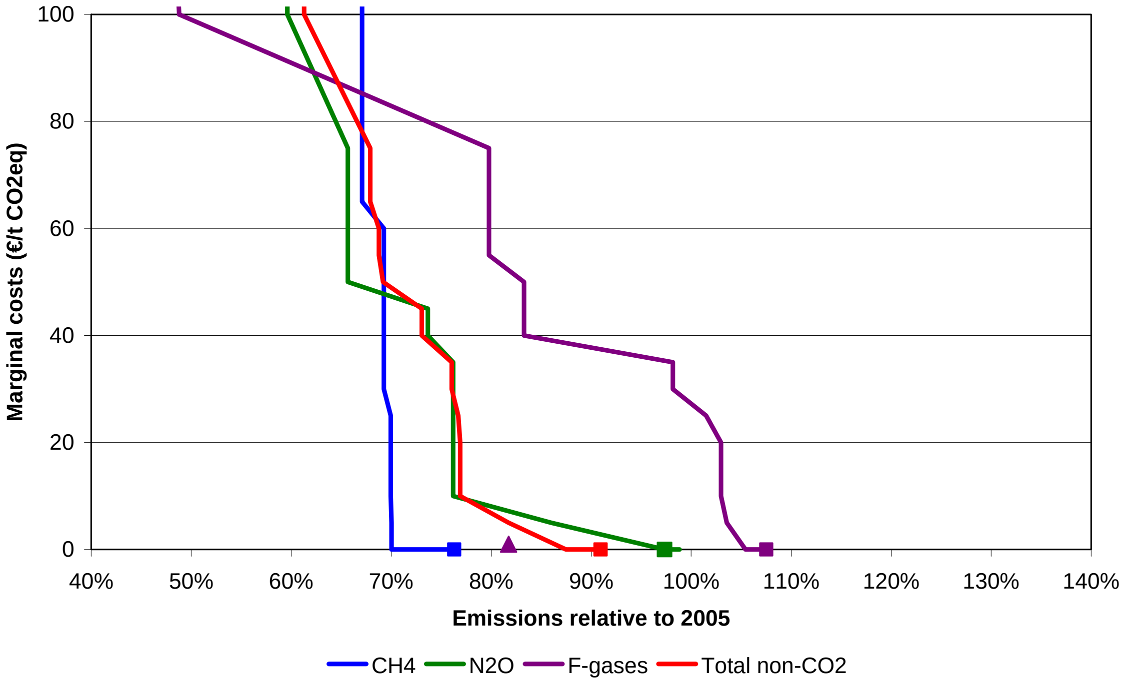

Figure 6-10: National cost curves for non-CO_2 greenhouse gases for Germany. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

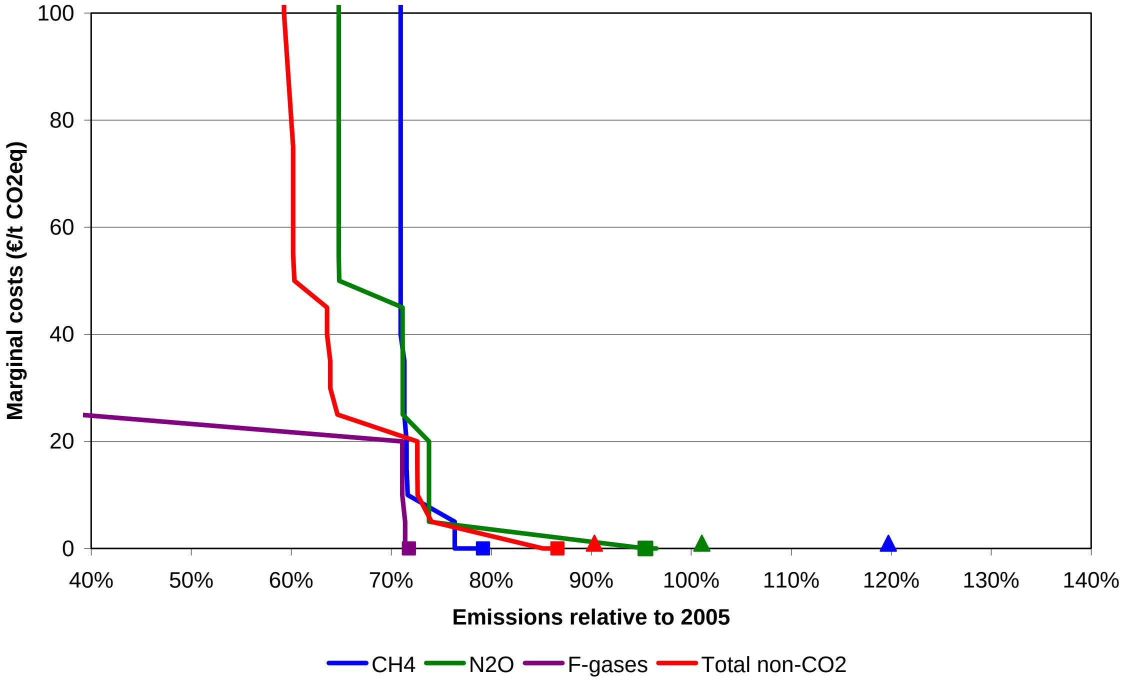

Figure 6-11: National cost curves for non-CO_2 greenhouse gases for Greece. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

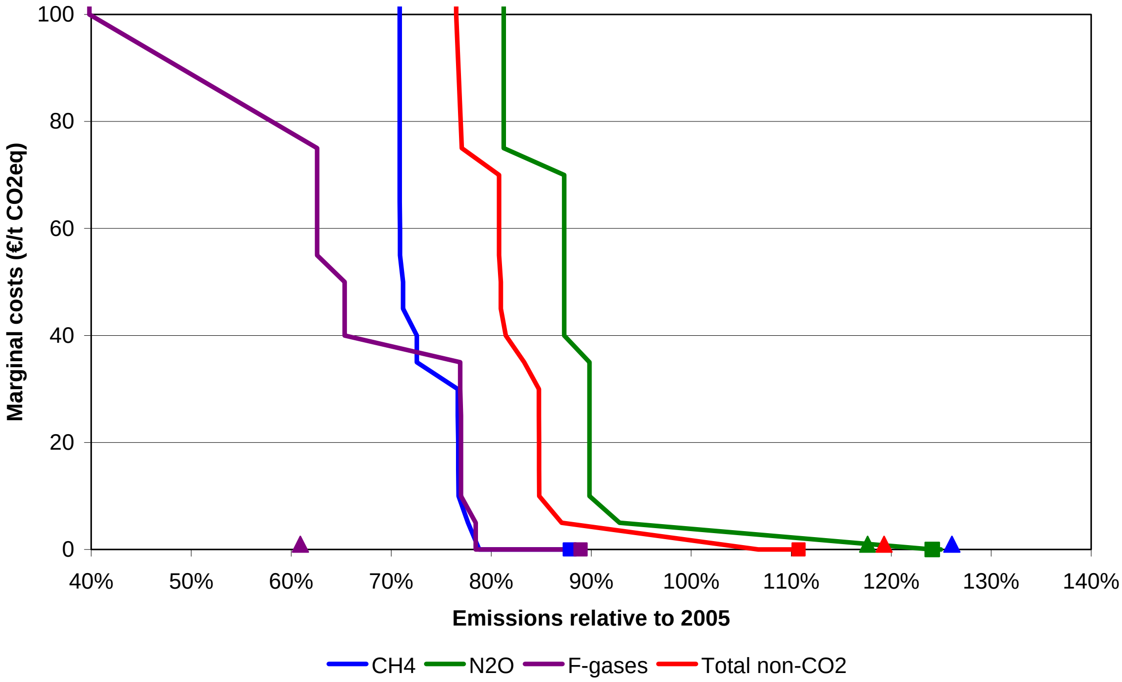

Figure 6-12: National cost curves for non-CO_2 greenhouse gases for Hungary. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

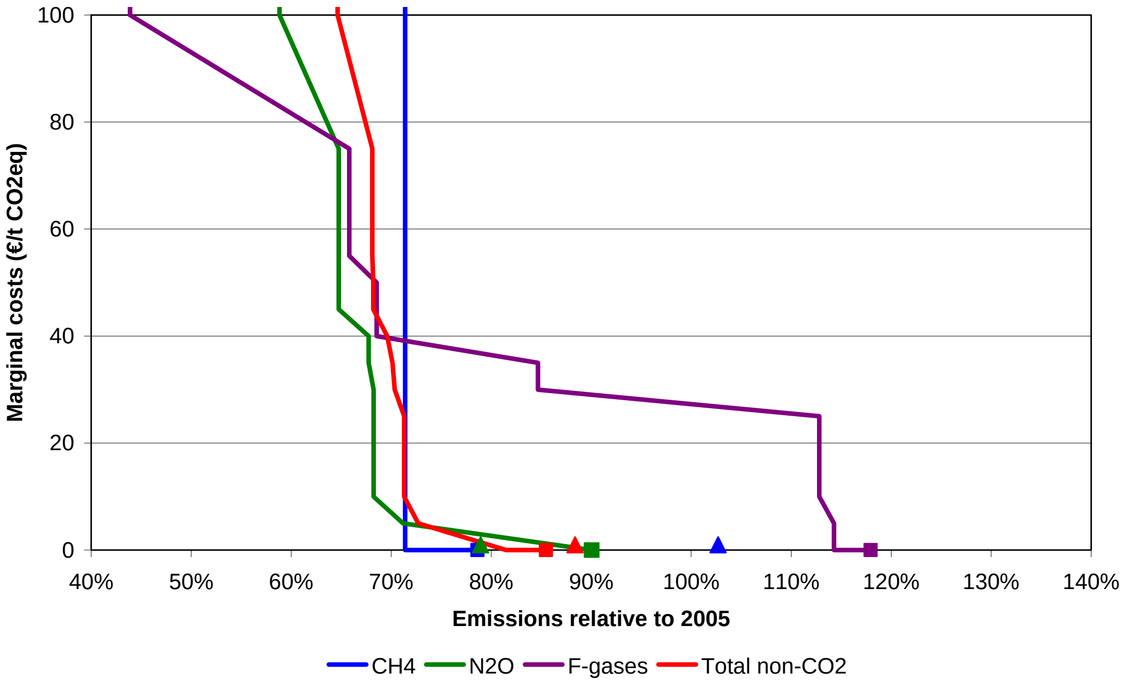

Figure 6-13: National cost curves for non-CO_2 greenhouse gases for Ireland. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

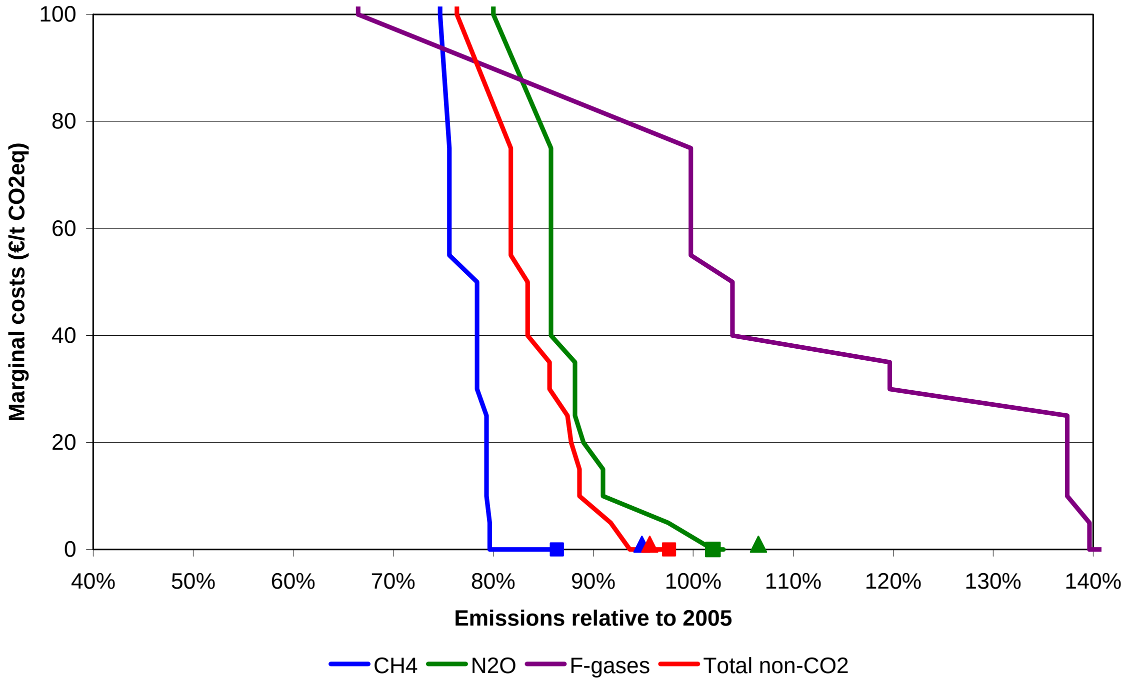

Figure 6-14: National cost curves for non-CO_2 greenhouse gases for Italy. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

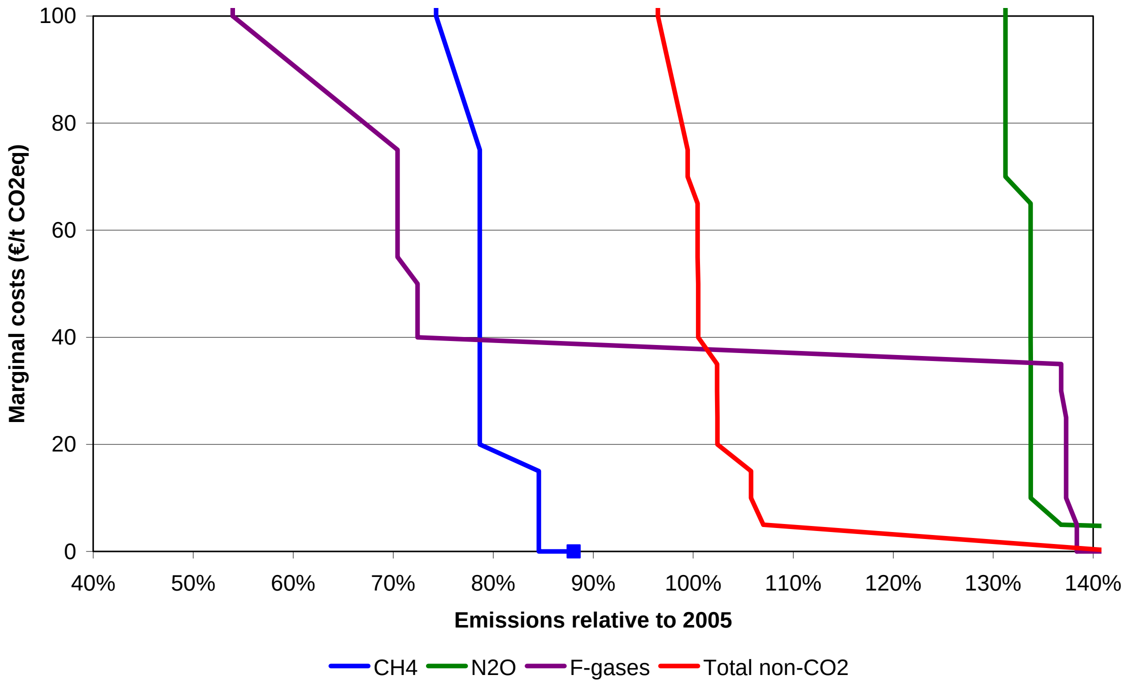

Figure 6-15: National cost curves for non-CO_2 greenhouse gases for Latvia. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

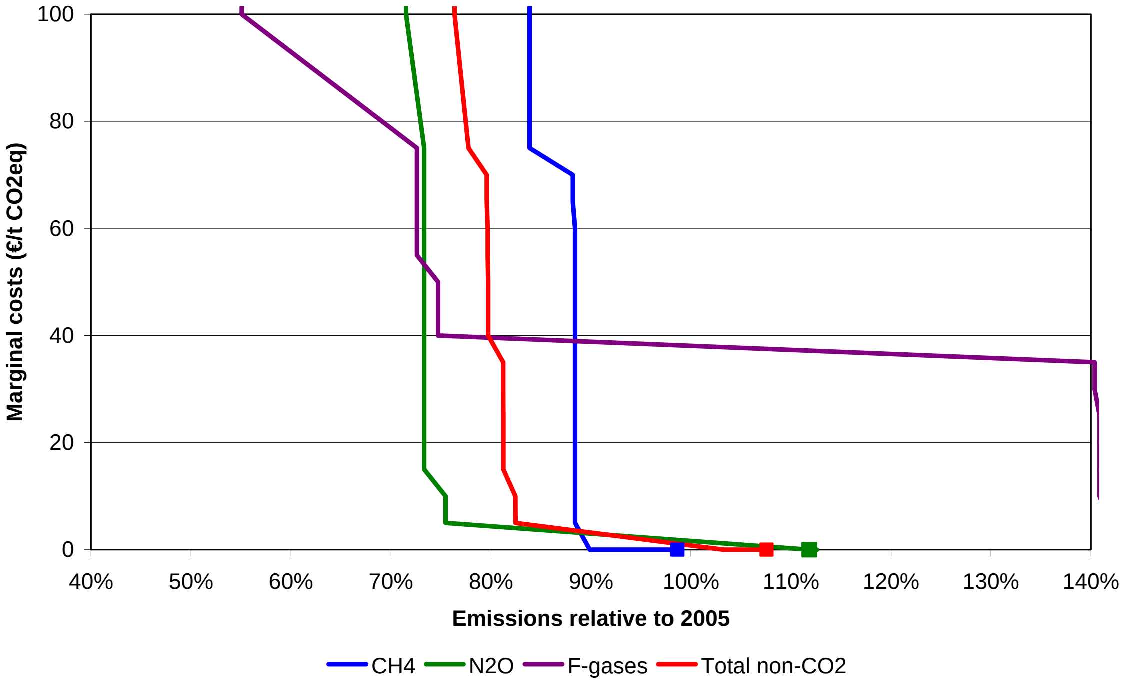

Figure 6-16: National cost curves for non-CO_2 greenhouse gases for Lithuania. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

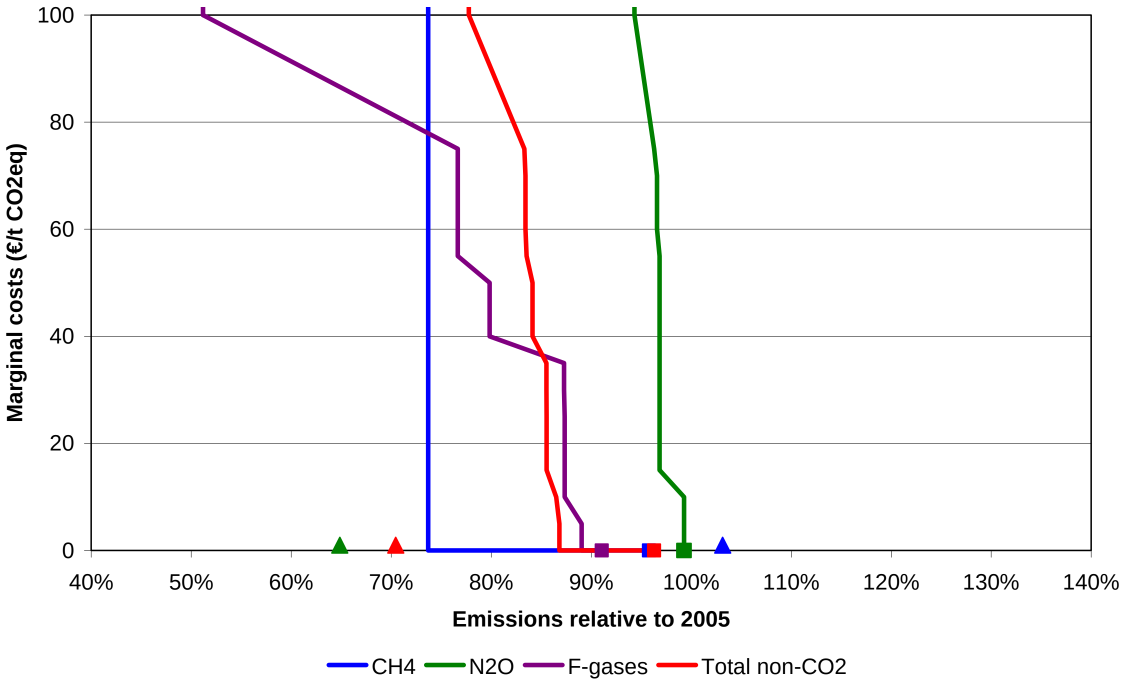

Figure 6-17: National cost curves for non-CO_2 greenhouse gases for Luxembourg. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

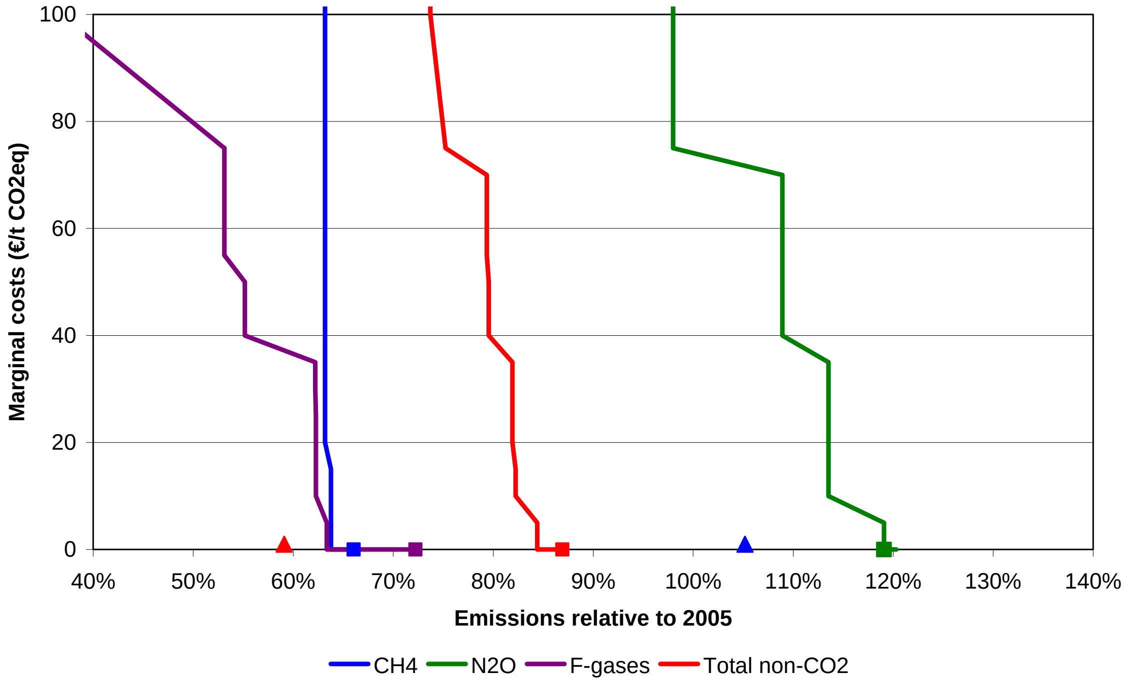

Figure 6-18: National cost curves for non-CO_2 greenhouse gases for Malta. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

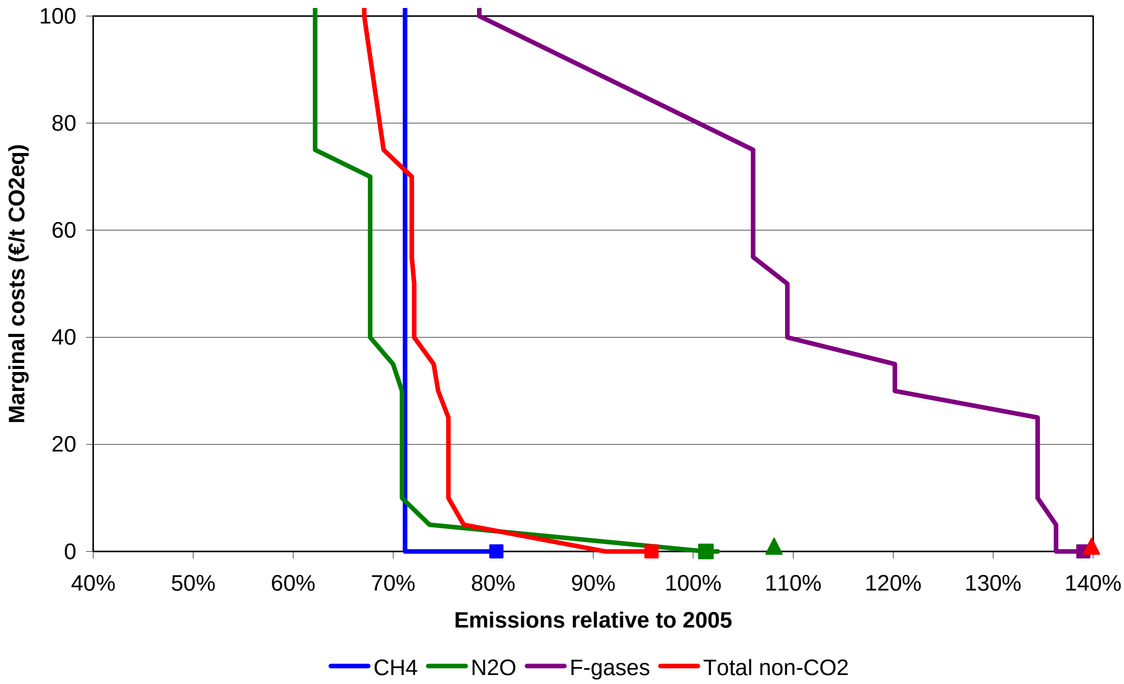

Figure 6-19: National cost curves for non-CO_2 greenhouse gases for the Netherlands. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

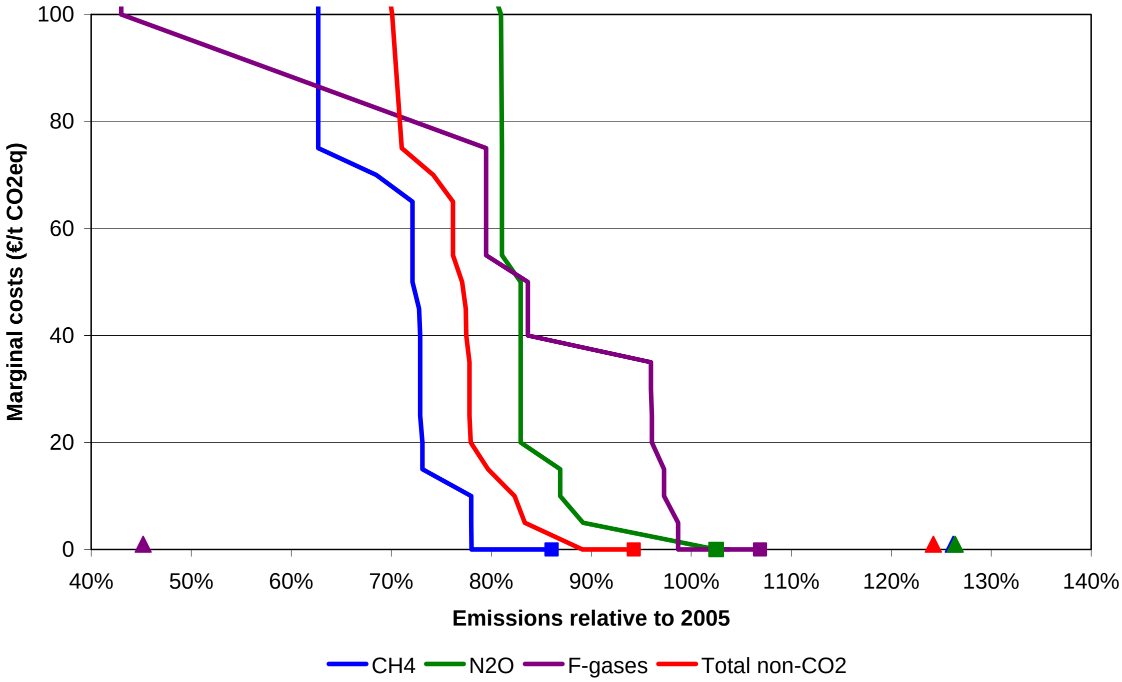

Figure 6-20: National cost curves for non-CO_2 greenhouse gases for Poland. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

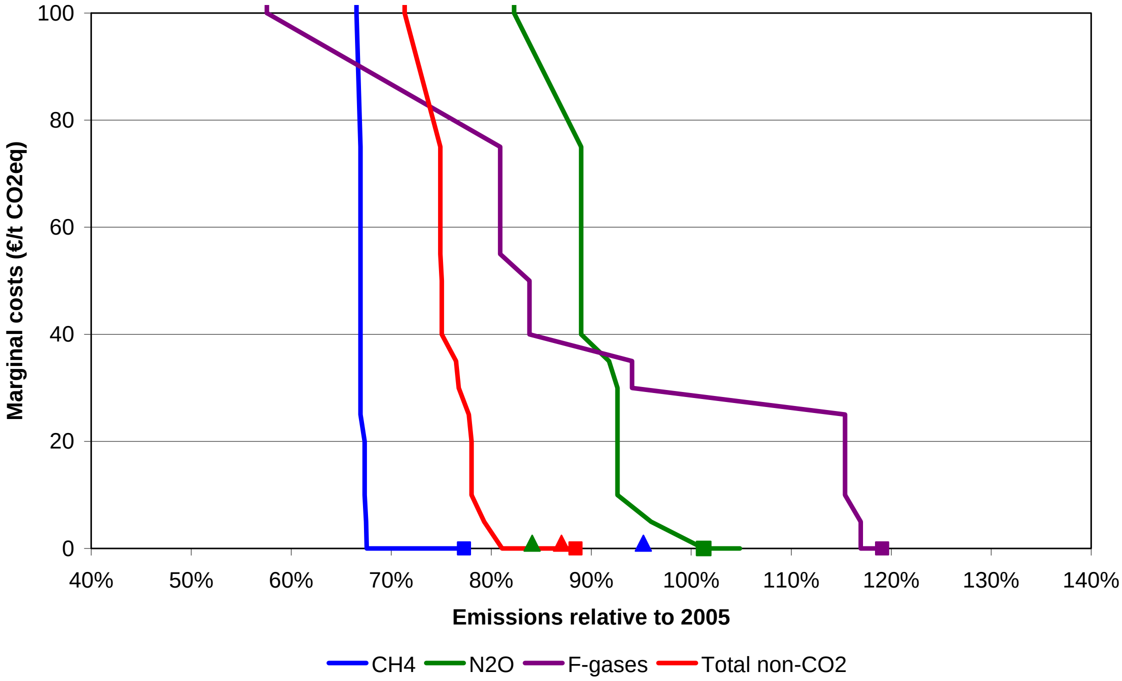

Figure 6-21: National cost curves for non-CO_2 greenhouse gases for Portugal. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

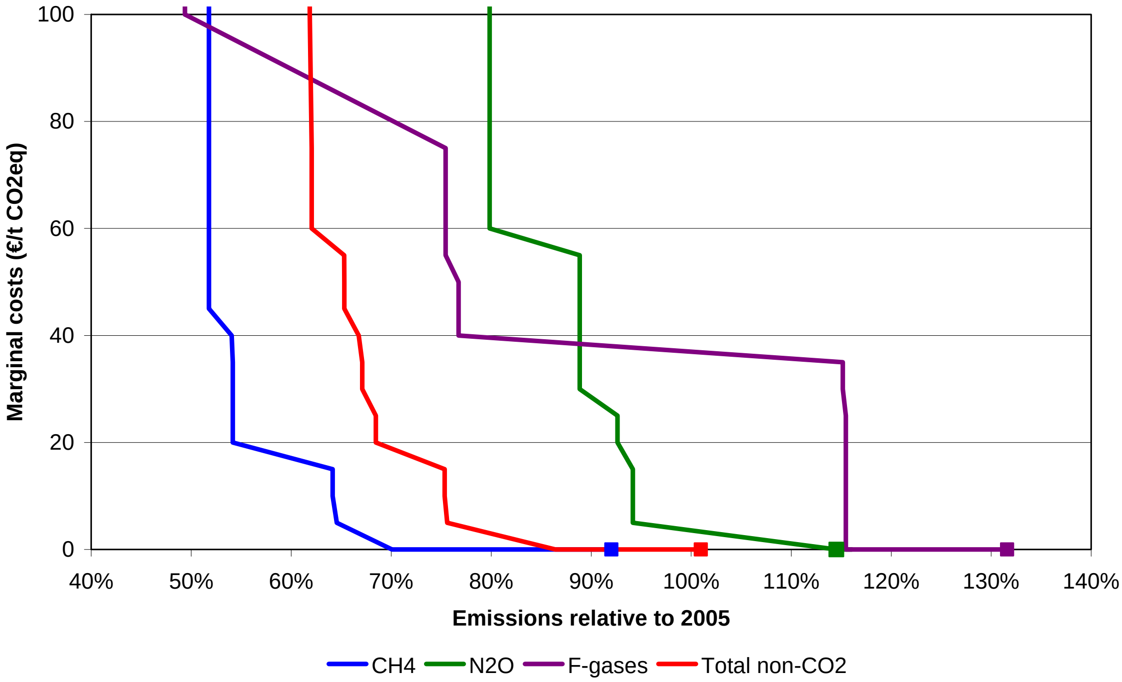

Figure 6-22: National cost curves for non-CO_2 greenhouse gases for Romania. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

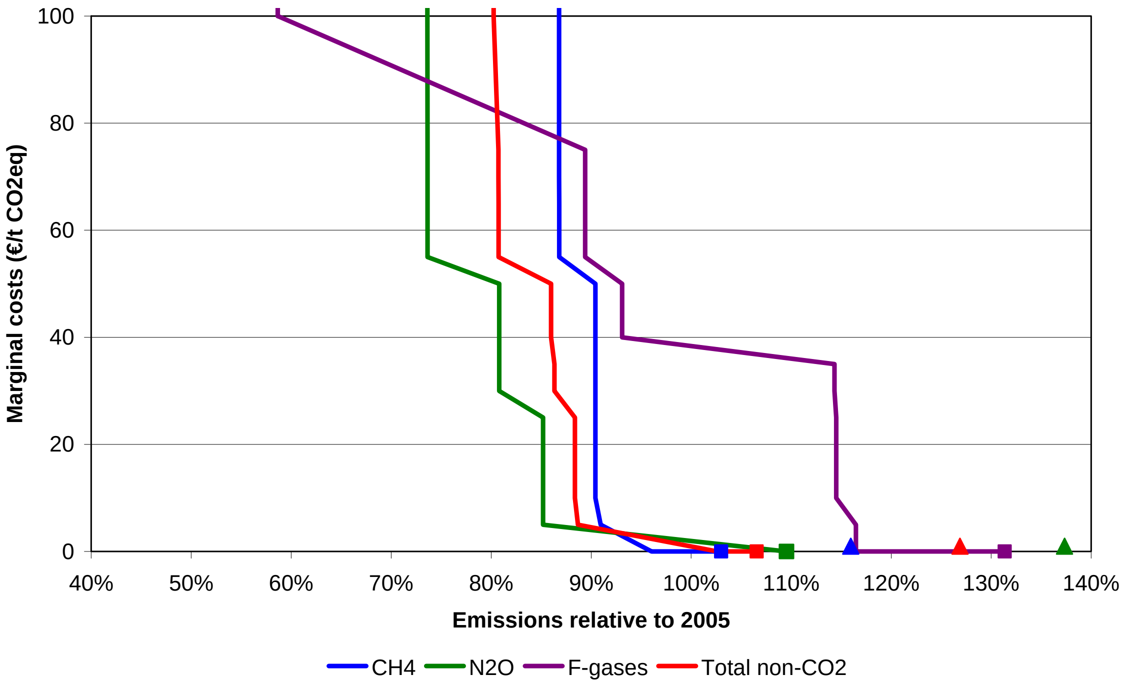

Figure 6-23: National cost curves for non-CO_2 greenhouse gases for Slovakia. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

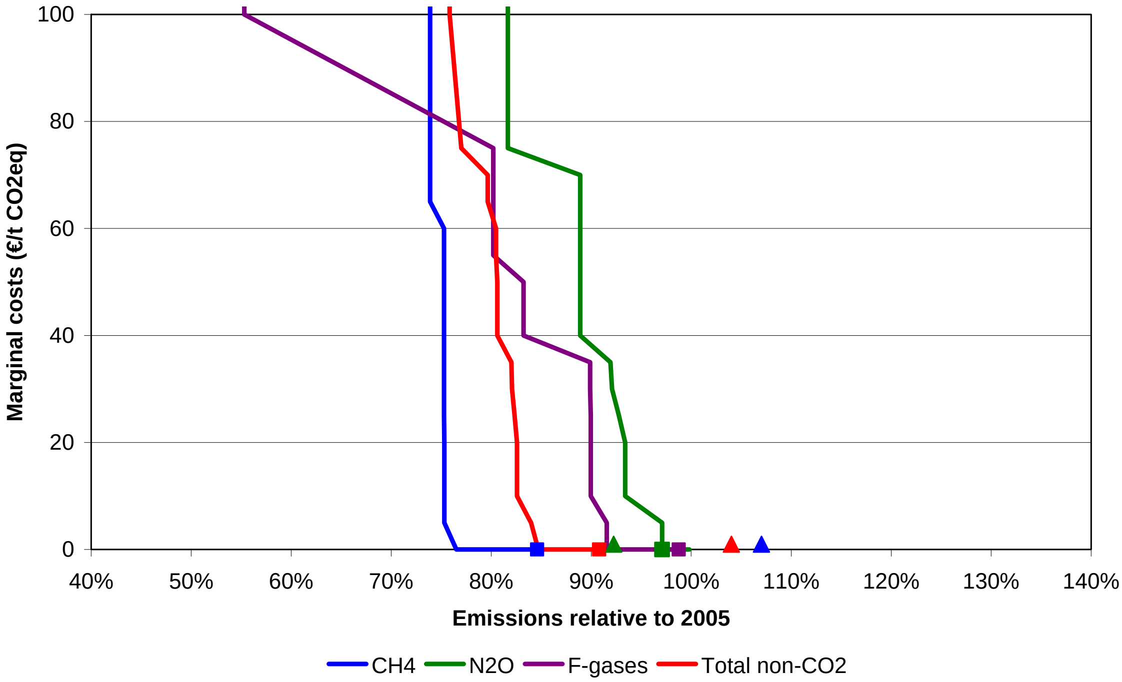

Figure 6-24: National cost curves for non-CO_2 greenhouse gases for Slovenia. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

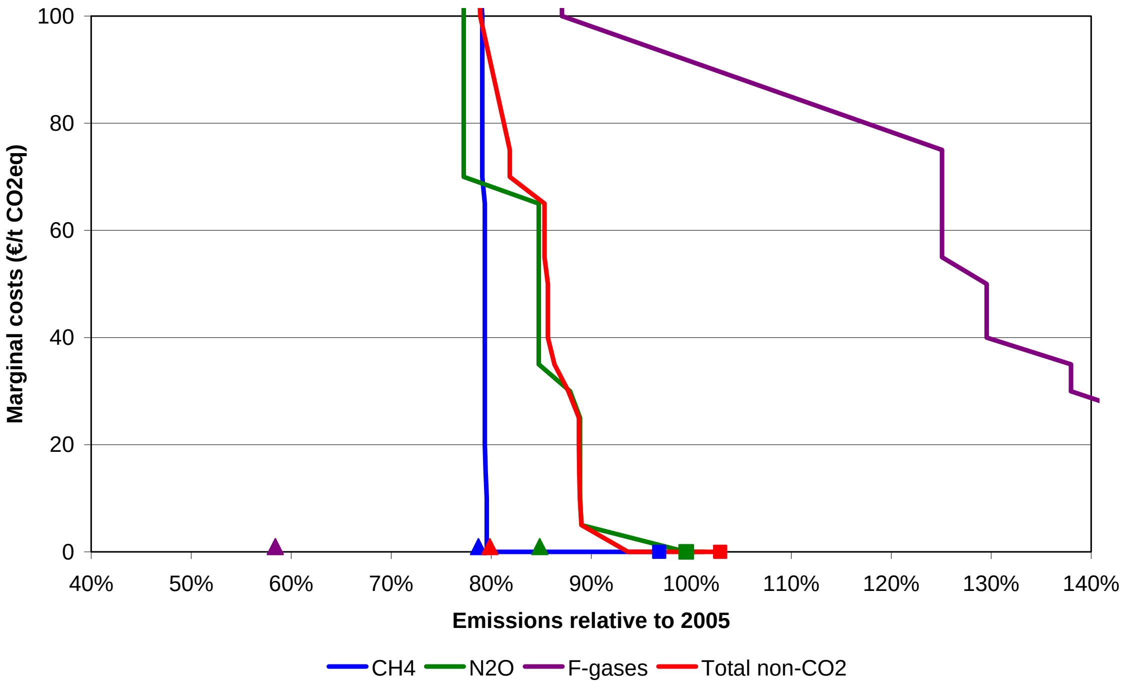

Figure 6-25: National cost curves for non-CO_2 greenhouse gases for Spain. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

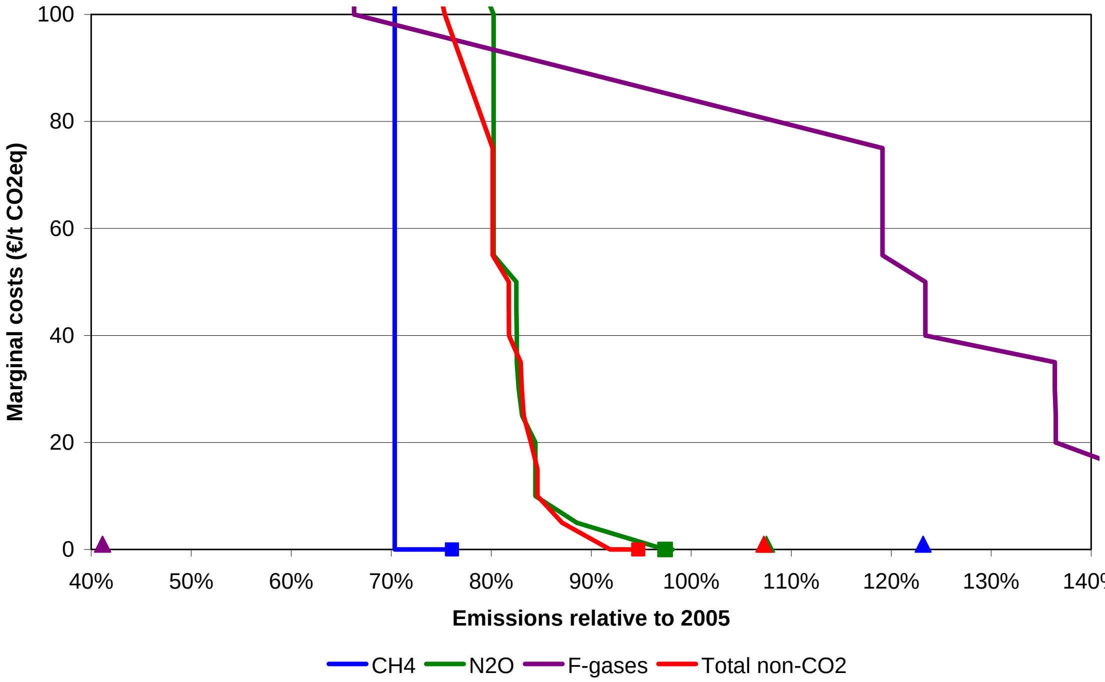

Figure 6-26: National cost curves for non-CO_2 greenhouse gases for Sweden. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

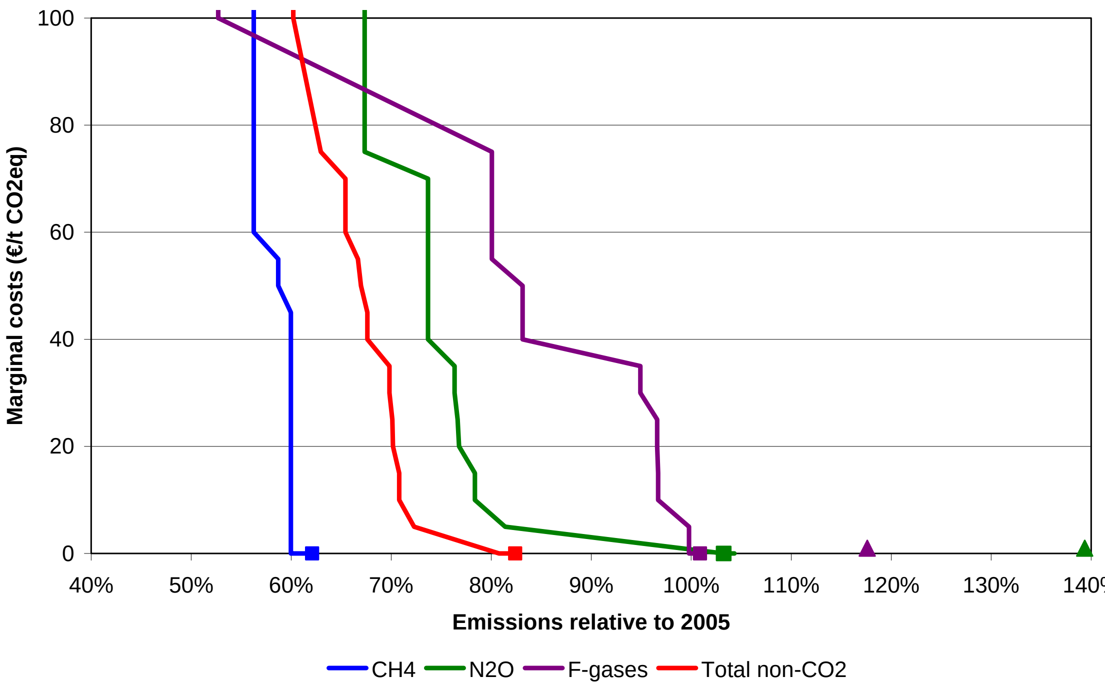

Figure 6-27: National cost curves for non-CO_2 greenhouse gases for the United Kingdom. The squares indicate the baseline current legislation case; 1990 emission levels (in relation to 2005) are marked by triangles.

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