Executive summary

1. Introduction

At the conference of the parties in Kyoto in December 1997, the EU agreed to reduce emissions of the six greenhouse gases (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) by 8% of 1990 levels by 2010[1]. The target applies to emissions weighted by their (100 year) global warming potential.

The overall objective of the study was to conduct an economic evaluation of EU's Kyoto target. More specifically, the study aimed at:

- identifying the least-cost packages of specific policies and measures for meeting the Community's quantitative reduction for greenhouse gases under the Kyoto Protocol. This evaluation included an analysis of the relative role of carbon dioxide, methane and nitrous oxide emissions, and of the different sectors of the economy (i.e. power production, industry, tertiary-domestic, transport, waste sector and agriculture). It combined two methodologies for the assessment of potentials and costs of reduction: ECOFYS cost curve methodology for methane and nitrous oxide, and the PRIMES partial equilibrium approach for CO2. The results of the evaluation are summarised in section 2, 3 and 4 below.

- analysing the costs and emission reductions of an emission trading system towards meeting the goals in a cost-effective way. In particular, the analysis included an assessment of the costs of a ceiling on CO_2 trading. The study results came from the POLES model (a sectoral model of the world energy system to 2030) and are summarised in section 5 below.

2. Emission reduction potential and costs for methane and nitrous oxide in the EU

A least-cost multi-gas strategy requires that differences in greenhouse gas warming potential between different gases are taken into account when deciding which policies and measures are the most cost-effective. Methane's GWP is 21 times CO_2 equivalent when calculated over 100-year period. Major sources of methane emissions are agriculture, waste and fuel production, distribution and combustion. The GWP of nitrous oxide is 310 times CO_2 equivalent when calculated over a 100-year period. Major sources of N_2O emission are agriculture, industrial processes and fuel combustion.

[1] More precisely, Member States have the choice of a 1990 or 1995 baseline for HFCs, PFCs and SF6, and a limited allowance can be made for sinks in calculating the 8% reduction.

Within each sector, specific emission reduction measures were defined together with their associated costs and reduction potentials. Costs are direct costs, i.e. they only include investment costs, operation and maintenance costs, and costs savings (e.g. fuel costs savings in the energy sector). At this stage, costs were assumed to be the same throughout Europe.

On the basis of the above data collected for each specific measure, sector specific discount rate figures and evolution of energy prices to 2010, specific emission reduction costs expressed in ECU per ton CO_2-eq. avoided, were determined for each Member State and for each reduction option. For the sake of consistency with the analysis conducted for CO_2 with the PRIMES model, the same sector specific discount rate figures and energy prices were used for the calculation of methane reduction costs.

Reduction potentials and costs were estimated in comparison with a baseline scenario for CH_4 and N_2O emissions up to 2010. Baseline energy related methane and nitrous oxide emissions were calculated on the basis of the pre-Kyoto energy scenario. Non-energy related emissions were determined from the analyses made by the AEAT (non-energy related agricultural projections) and analyses described in the *Expert Group's work on EU common and Coordinated Policies and Measures* (landfill emissions).

Total human induced 1990 methane emissions in the EU were estimated at 24 Mt CH4 (500 Mt CO2-eq). Projected baseline emissions in 2010 were estimated at 19 Mt CH4 (400 Mt CO2-eq). The emission reduction potential by the identified measures were estimated at an additional 8 Mt CH4 (170 Mt CO2-eq).

Main sources with high potential reduction possibilities are landfills, natural gas distribution pipelines and livestock. The potential of measures may reduce methane emissions in 2010 by 51% compared to 1990. Eighty percent of this potential can be obtained by measures with an average cost below 50 ECU/ton CO2-eq.

Total human induced 1990 nitrous oxide emissions in the EU were estimated at 0.9 Mt N2O (280 Mt CO2-eq). Projected baseline emissions in 2010 were estimated at 1.0 Mt N2O (320 Mt CO2-eq). The emission reduction potential by the identified measures were estimated at an additional 0.35 Mt N2O (110 Mt CO2-eq).

Main sources with high potential reduction possibilities are industrial production of nitric acid and adipic acid and by improving fertiliser use. The potential of measures may reduce the nitrous oxide emissions by 26% in 2010 compared to 1990. More than eighty percent of the reduction potential can be obtained by measures with an average cost below 1 ECU/ton CO2-eq. An additional emission reduction of 10% can be obtained by measures with an average cost below 50 ECU/ton CO2-eq.

3. Contribution of non-CO2 greenhouse gases to the EU Kyoto target: evaluation of the reduction potential and costs

Until recently, studies and strategies for addressing climate change mitigation have principally been focused on reducing emissions of carbon dioxide, but the importance of other greenhouse gases and opportunities for their abatement have been increasingly recognised in the last couple of years. In particular, DGXI of the European Commission has lauched three studies considering non-CO_2 greenhouse gases and examining their reduction potential and costs. These studies are:

(1) Economic evaluation of quantitative objectives for climate change, COHERENCE (ongoing); in the framework of this study ECOFYS produced a report in June 1998 on Emission reduction potential and costs for methane and nitrous oxide in the EU-15;
(2) Reductions of the emissions of HFC's, PFC's and SF6 in the European Union, ECOFYS, June 1998;
(3) Options to reduce methane emissions, AEA Technology Environment, September 1998, and
Options to reduce nitrous oxide emissions, AEA Technology Environment, September 1998.

This part of the project aimed at summarising the major findings from the above studies as to the reduction potential and costs of non-CO_2 greenhouse gases emissions in 2010. It also addressed the uncertainties in emissions and costs estimates for some sources and mitigation options. The reduction potential of each gas was estimated in comparison with a business-as-usual scenario to 2010. It was provided both in ktonne of gas considered and in ktonne of CO_2-equivalent using the global warming potential of the gases (100 years). Costs of reduction options or of packages of reduction options were provided in ECU (1995) per tonne of CO2-equivalent abated.

Emissions of non-CO_2 greenhouse gases under a business-as-usual scenario were projected to increase by 1% in 2010 compared to 1990/1995 levels. This is the result of the combination of a downward trend for methane emissions (-8%) and upward trends for nitrous oxide and the three halogenated gases emissions (+8% and +41% respectively).

The examination of measures to reduce non-CO_2 greenhouse gases emissions showed that such measures could make a substantial contribution to the achievement of the EU's Kyoto target.

The implementation of all measures identified would lead to a reduction of 380 Mt CO_2 equivalent in 2010. This would bring total non-CO_2 emissions to 43% (370 Mt CO_2 equivalent) below 1990 levels by 2010.

The EU six gas basket of emissions in 1990 was estimated to be about 4227 Mt CO_2 and a reduction of 600 Mt of CO_2 would be required to meet the EU's Kyoto target. The identified reduction in non-CO_2 emissions is equivalent to 63% of total reduction needed, and would bring emissions of the six gas basket to 2.5% below 1990 levels by 2010.

Table: Synthesis of reductions and costs of non-CO_2 mitigation options

Agricultural measures

	Em. reductions in 2010 (Mt CO2 equ)	Costs (ECU/t CO2 equ)
CH4	34	< 0
	20	0-50
	7	> 50
N2O	24	
Total non-CO2	**85**	

Non agricultural measures

	Em. reductions in 2010 (Mt CO2 equ)	Costs (ECU/t CO2 equ)
CH4	27	< 0
	71	0-50
	31	> 50
N2O	9	< 0
	86	0-50
HFC's	0	< 0
	48	0-50
	12	> 50
PFC's	4	0-50
SF6	7	0-50
Total non-CO2	**295**	
of which	36	< 0
	216	0-50
	43	> 50
Measures in place	146	
Additional measures	149	

Reductions from agricultural measures have been estimated at 85 Mt CO_2 (see Table above), these measures are potentially the most difficult to implement and estimates of their applicability and impact have still high level of uncertainty (this is particularly true for nitrous oxide and for methane from enteric fermentation).

Reductions from non-agricultural measures have been estimated at 295 Mt CO_2 (see Table above), of which half corresponds to reductions resulting from the implementation of existing and planned measures directed at landfilling of waste and adipic acid manufacturing plants. The cost-effectiveness analysis showed that 252 Mt CO_2 can be reduced at a cost below 50 ECU/tonne CO_2. With only non-agricultural measures implemented, emissions of the six gas basket were projected to stabilise at 1990 levels by 2010.

4. Energy system implications of reducing CO2 emissions

This part of the study was designed to quantify energy system changes that are necessary for the EU to reach a series of CO_2 emission reduction targets for 2010 and to evaluate the adjustment costs by sector and member-state. The analysis was based on the use of the PRIMES Ver. 2 energy system model. The results were confined to the energy system and considered that the macroeconomic and sectoral patterns of growth remain unchanged.

The methodology behind the calculations carried on and the assumptions behind the baseline scenario are described in chapter 5 of the report. The results of the baseline projection show a continuous increase of the use of fossil fuels in Europe and hence an increase of CO2 emissions from energy conversion and use. Compared to 1990 emissions, CO2 emitted in the EU is shown to increase by about 8% in 2010.

Some key findings of the study are summarised below.

- "Carbon value" and associated emission reduction targets

  A range of CO_2 emission reduction scenarios was defined for a spectrum of marginal abatement cost levels defined between 1 Euro per ton of carbon up to 900 Euro per ton of Carbon. A marginal abatement cost was defined as the cost that was necessary to pay to avoid the emission in 2010 of the last ton of carbon for a given emission reduction target. Given an emission reduction target, the “carbon-value” was defined as the associated marginal abatement cost measured in Euro per ton of carbon avoided.

  The Table below gives the carbon values and associated emission reduction targets as provided by the PRIMES model. The upper part of the table shows the level of the carbon value for a range of emission reduction scenarios referring to the year 2010 and the associated emissions of CO2 in 2010. Then for each level of carbon value, the table shows the associated quantity of CO2 the emission of which is avoided in 2010 (bottom part of the table) and the percent reduction of emissions in 2010 compared to the level in 1990 (middle part of the table).

Table: Carbon values and associated emission reduction targets

CO2 Emissions (Mtn CO2)

		Carbon Value : Marginal Abatement Cost in Eur per ton of Carbon avoided															
	1990	**0**	**1**	**2**	**5**	**10**	**20**	**40**	**70**	**110**	**160**	**220**	**290**	**370**	**460**	**560**	**700**	**900**
AU	55.0	58.1	58.0	58.0	57.8	57.2	56.1	54.3	52.5	49.8	47.6	45.9	44.3	41.9	40.7	37.9	34.2	30.9
BE	104.8	122.9	122.7	122.5	121.8	121.0	119.6	117.7	114.6	111.2	106.7	102.0	96.9	90.2	84.8	79.5	72.9	66.0
DK	52.7	54.9	54.8	54.8	54.6	54.3	53.0	50.9	47.8	45.0	41.7	39.1	37.0	34.3	32.3	28.9	25.8	23.5
FI	51.3	72.3	72.2	72.0	71.1	70.0	68.8	64.6	57.2	54.8	51.3	46.3	42.7	39.7	37.2	34.1	31.0	28.0
FR	352.4	393.3	392.8	391.6	390.9	388.7	384.2	372.6	360.4	347.6	341.4	323.3	306.1	286.3	270.8	249.6	219.8	192.5
GE	951.6	839.2	835.9	835.8	833.2	820.8	807.3	780.7	761.1	731.6	691.8	653.7	616.3	582.4	552.1	526.3	496.1	464.1
GR	70.9	109.4	108.4	108.4	108.3	107.9	107.4	96.7	95.0	92.6	90.0	87.1	83.7	80.0	77.6	75.8	73.0	70.6
IR	30.1	42.8	42.7	42.7	42.6	42.4	41.8	40.1	38.4	36.9	34.4	32.3	30.5	28.7	27.0	25.7	24.1	22.3
IT	388.0	429.9	429.2	429.1	428.6	426.2	421.1	409.3	387.9	373.2	361.2	347.6	333.7	319.4	305.2	287.1	261.9	234.9
NL	153.0	207.1	206.1	205.5	203.3	200.5	197.6	192.4	187.6	183.1	177.9	170.6	162.3	153.1	145.7	138.2	129.9	118.7
PO	39.1	64.6	64.5	64.5	64.1	63.6	62.7	61.9	59.7	56.6	50.1	47.5	45.3	42.7	39.6	37.3	34.3	31.2
SP	201.9	275.1	274.8	274.6	273.9	273.3	269.4	262.4	243.3	234.9	223.8	208.9	193.3	182.4	173.0	161.1	148.5	130.5
SV	50.0	69.2	68.9	69.0	68.9	67.7	66.8	64.4	62.1	57.4	54.4	50.4	47.7	44.9	41.7	37.7	32.7	29.0
UK	566.9	572.3	571.5	563.4	560.9	555.4	549.0	537.5	521.3	502.4	483.1	460.8	434.6	407.3	385.6	359.3	331.2	296.2
EU14	3067.5	3311.1	3302.7	3291.9	3280.2	3248.9	3205.1	3105.5	2988.9	2877.1	2755.3	2615.6	2474.5	2333.2	2213.3	2078.5	1915.4	1738.4

CO2 Change from 1990

	Emission Reduction Target : % Change of emissions in 2010 compared to 1990																
AU	5.7	5.6	5.5	5.2	4.1	2.1	-1.1	-4.5	-9.4	-13.4	-16.4	-19.3	-23.7	-25.9	-31.1	-37.9	-43.7
BE	17.4	17.2	17.0	16.3	15.5	14.2	12.3	9.4	6.2	1.9	-2.6	-7.5	-13.9	-19.1	-24.1	-30.4	-37.0
DK	4.3	4.1	4.1	3.6	3.1	0.6	-3.4	-9.3	-14.6	-20.8	-25.7	-29.7	-34.9	-38.7	-45.1	-51.0	-55.4
FI	40.8	40.6	40.2	38.5	36.4	34.1	25.8	11.5	6.7	-0.2	-9.9	-16.8	-22.7	-27.6	-33.7	-39.6	-45.4
FR	11.6	11.4	11.1	10.9	10.3	9.0	5.7	2.3	-1.4	-3.1	-8.3	-13.2	-18.8	-23.2	-29.2	-37.6	-45.4
GE	-11.8	-12.2	-12.2	-12.4	-13.7	-15.2	-18.0	-20.0	-23.1	-27.3	-31.3	-35.2	-38.8	-42.0	-44.7	-47.9	-51.2
GR	54.3	52.9	52.9	52.7	52.1	51.4	36.3	34.0	30.7	26.9	22.8	18.1	12.9	9.4	7.0	3.0	-0.4
IR	42.6	42.2	42.1	41.8	41.1	39.2	33.3	27.9	22.9	14.5	7.6	1.6	-4.4	-10.1	-14.6	-19.7	-25.9
IT	10.8	10.6	10.6	10.5	9.9	8.5	5.5	0.0	-3.8	-6.9	-10.4	-14.0	-17.7	-21.3	-26.0	-32.5	-39.5
NL	35.4	34.7	34.3	32.8	31.0	29.1	25.8	22.6	19.7	16.2	11.5	6.1	0.0	-4.7	-9.7	-15.1	-22.4
PO	65.4	65.2	65.1	64.2	62.7	60.7	58.5	52.9	45.0	28.2	21.5	16.0	9.2	1.4	-4.5	-12.3	-20.1
SP	36.3	36.1	36.0	35.7	35.4	33.5	30.0	20.5	16.4	10.9	3.5	-4.3	-9.7	-14.3	-20.2	-26.4	-35.3
SV	38.4	37.9	38.1	37.9	35.4	33.7	28.8	24.2	14.8	8.8	0.8	-4.6	-10.1	-16.5	-24.5	-34.5	-42.0
UK	0.9	0.8	-0.6	-1.1	-2.0	-3.2	-5.2	-8.0	-11.4	-14.8	-18.7	-23.3	-28.2	-32.0	-36.6	-41.6	-47.8
EU14	7.9	7.7	7.3	6.9	5.9	4.5	1.2	-2.6	-6.2	-10.2	-14.7	-19.3	-23.9	-27.8	-32.2	-37.6	-43.3

CO2 Emissions (Mtn CO2)

	CO2 emissions avoided in 2010																
AU	0.0	0.1	0.1	0.3	0.9	2.0	3.8	5.6	8.3	10.5	12.2	13.8	16.2	17.4	20.2	23.9	27.2
BE	0.0	0.2	0.4	1.1	2.0	3.3	5.3	8.4	11.7	16.2	20.9	26.0	32.7	38.2	43.4	50.0	56.9
DK	0.0	0.1	0.1	0.3	0.6	1.9	4.1	7.2	9.9	13.2	15.8	17.9	20.6	22.6	26.0	29.1	31.4
FI	0.0	0.1	0.3	1.2	2.2	3.4	7.7	15.1	17.5	21.0	26.0	29.6	32.6	35.1	38.2	41.3	44.3
FR	0.0	0.5	1.7	2.4	4.6	9.0	20.7	32.8	45.7	51.9	70.0	87.2	107.0	122.5	143.7	173.5	200.8
GE	0.0	3.3	3.4	6.0	18.4	31.9	58.5	78.1	107.7	147.4	185.5	222.9	256.8	287.1	312.9	343.1	375.1
GR	0.0	1.0	1.0	1.1	1.5	2.1	12.7	14.4	16.8	19.4	22.3	25.7	29.4	31.8	33.6	36.4	38.8
IR	0.0	0.1	0.1	0.2	0.4	1.0	2.8	4.4	5.9	8.4	10.5	12.3	14.1	15.8	17.2	18.7	20.6
IT	0.0	0.6	0.8	1.2	3.6	8.8	20.5	42.0	56.6	68.7	82.3	96.2	110.5	124.7	142.7	168.0	195.0
NL	0.0	1.0	1.6	3.8	6.7	9.5	14.7	19.6	24.0	29.2	36.5	44.8	54.0	61.4	68.9	77.2	88.4
PO	0.0	0.0	0.1	0.4	1.0	1.8	2.7	4.9	8.0	14.5	17.1	19.3	21.9	25.0	27.3	30.3	33.4
SP	0.0	0.3	0.5	1.2	1.9	5.7	12.7	31.8	40.2	51.3	66.2	81.9	92.7	102.1	114.0	126.6	144.6
SV	0.0	0.3	0.2	0.2	1.5	2.4	4.8	7.1	11.8	14.8	18.8	21.5	24.3	27.5	31.4	36.4	40.2
UK	0.0	0.8	8.9	11.3	16.9	23.2	34.7	51.0	69.9	89.2	111.4	137.7	165.0	186.7	212.9	241.1	276.1
EU14	0.0	8.4	19.2	30.9	62.2	106.0	205.6	322.2	434.0	555.8	695.5	836.5	977.8	1097.8	1232.6	1395.7	1572.7

The analysis with PRIMES permitted also the construction of marginal abatement cost curves for each Member State (referring to energy-related CO2 emissions only). Such a curve plots the tons of CO2 emissions avoided in 2010 against the carbon-value.

- Analysis of energy system changes

  Energy system changes induced by emission constraints were analysed by decomposing the effects into four general categories: structural and behavioural changes, technology changes, fuel-mix changes in direct combustion energy uses of fossil fuels and supply-side effects from power and steam generation. The results generally showed that the contribution of each of the above four categories of change were different, as the emission constraint becomes bigger:

  - In general, the contribution of structural and behavioural change becomes quite large, close to 20%, at relatively low levels of carbon values (20 Euro per ton of carbon, corresponding to about 4% increase of emissions in 2010 from 1990). As higher emission constraints are introduced the contribution of structural and behavioural changes stabilises between around 21%.

- The contribution of factors related to technology progress in the demand-side increases continuously with the level of the emission constraint. This contribution is of the same order of magnitude as that of the structural and behavioural change up to a carbon value of 110 Euro per ton of carbon, which corresponds to a decrease of emissions in 2010 from 1990 by 6.2%. As carbon values increase further the contribution of technology progress increases and at extremely high carbon values it accounts for nearly half of the overall emissions reduction.

- The role of changes in the fuel mix of fossil fuels directly used in end-use sectors is small for all values examined (of the order of 2 to 2.5%). It should be noticed that fuels used for steam generation are included in the power and steam sector, therefore fuel mix changes in this domain are included in the indirect effects from power and steam. The low contribution from changes in fossil fuel intensity of direct energy uses is due to the fact that natural gas is extensively used already in the baseline and high carbon-content fossil fuels are mostly used in specific processes.

- The role of supply-side effects is important. The power and steam generation system meters a large contribution to the emission reduction. At low levels of carbon-value, the effects from power and steam generation dominate, having a share ranging from 73 to 59%. However, the share of this sector in total emission reduction continuously decreases with successively increasing emission targets. In the range that is of interest for the Kyoto targets, the effects from power and steam system account for about 50% of the total. This share decreases up to 30% at high emission targets. Within that range, technology progress in the demand-side becomes significantly more important than the power and steam system.

• Sectoral costs of emission reductions

The imposition of emission reduction targets results in an increase in total energy system cost, partly due to the associated marginal abatement cost. The way the imposition of the carbon-value affects different energy consumers depends on their ability to adapt to emission reduction targets through investment in new, more efficient technologies, structural shifts and changes in their choice of fuel mix. Average system costs were computed at a sectoral level and summarised in the table below.

Table: Analysis of CO2 Emission reduction by Sector

ANALYSIS OF ENERGY SYSTEM CHANGES TO REDUCE CO2 EMISSIONS IN 2010 FOR EUROPE - 14

Level of Carbon Value (in Eur'90/ton of Carbon)	**1**	**2**	**5**	**10**	**20**	**40**	**70**	**110**	**160**	**220**	**290**	**370**	**460**	**560**	**700**	**900**
% Emission change in 2010 from 1990	**7.7**	**7.3**	**6.9**	**5.9**	**4.5**	**1.2**	**-2.6**	**-6.2**	**-10.2**	**-14.7**	**-19.3**	**-23.9**	**-27.8**	**-32.2**	**-37.6**	**-43.3**
DECOMPOSITION OF CO2 EMISSIONS REDUCTION (Mtn of CO2 avoided in 2010)																
In the table below the changes in Electricity and Steam are included in Demand Sectors																
Industrial Sectors - Metals	-1	-1	-2	-5	-8	-15	-24	-30	-36	-45	-59	-73	-83	-92	-101	-110
Industrial Sectors - Chemicals	0	-1	-2	-4	-7	-12	-19	-26	-32	-39	-45	-52	-56	-60	-64	-69
Industrial Sectors - Materials	0	-1	-2	-5	-7	-13	-20	-27	-34	-42	-50	-57	-62	-68	-76	-83
Industrial Sectors - Others	-1	-3	-4	-8	-12	-24	-37	-49	-61	-76	-89	-101	-110	-119	-127	-135
Industrial Sectors - Total	-3	-7	-10	-22	-34	-64	-100	-132	-163	-201	-243	-282	-312	-340	-368	-397
Services	-2	-6	-8	-17	-31	-60	-90	-116	-145	-179	-211	-238	-257	-274	-288	-304
Agriculture	0	0	-1	-1	-2	-4	-5	-7	-8	-10	-12	-14	-15	-16	-17	-18
Households	-2	-5	-8	-15	-24	-48	-79	-107	-137	-173	-206	-246	-280	-317	-361	-388
Passenger Transports	-1	-1	-2	-4	-8	-15	-27	-42	-61	-80	-98	-118	-139	-167	-219	-299
Goods Transports	0	0	-1	-2	-5	-9	-15	-22	-32	-41	-52	-62	-73	-94	-116	-130
TOTAL SYSTEM - FINAL DEMAND	-8	-19	-31	-62	-104	-201	-316	-426	-546	-684	-822	-960	-1,077	-1,208	-1,369	-1,537
In the table below the changes in Electricity and Steam in demand are included in Power and Steam Sectors																
Electricity production	-7	-15	-22	-41	-64	-127	-193	-242	-287	-349	-403	-447	-483	-519	-561	-593
Steam production	1	-1	0	-3	-5	-6	-9	-17	-23	-31	-38	-45	-48	-50	-52	-55
Other Supply Sectors production	0	0	0	0	-1	-2	-2	-3	-4	-5	-7	-9	-11	-12	-14	-16
Statistical Difference (second order effects)	-1	0	0	0	-1	-3	-3	-4	-6	-6	-7	-9	-11	-12	-13	-20
In the table below the changes in Electricity and Steam are included in Power and Steam sector																
Total CO2 emissions reduction	-8	-19	-31	-62	-106	-206	-322	-434	-556	-696	-837	-978	-1,098	-1,233	-1,396	-1,573
In Final Energy Demand	-1	-3	-9	-17	-36	-69	-117	-170	-239	-308	-387	-474	-553	-648	-765	-897
In Electricity and Steam Generation	-7	-16	-22	-45	-69	-135	-203	-261	-313	-382	-442	-495	-534	-573	-617	-660
In Other Energy Conversion Sectors	0	0	0	0	-1	-2	-2	-3	-4	-5	-7	-9	-11	-12	-14	-16

Combined with figures obtained in the analysis of reduction potentials and costs for non-CO2 greenhouse gases (see section 3), the above figures should provide useful information for the determination of sectoral targets for the EU as well as on the least-cost allocation of reduction effort between the different greenhouse gases.

5. Kyoto Protocol and emission trading: potential cost savings and emission reductions

In the context of the current debate on principles, rules and modalities for an international emission trading, the present study attempts to provide elements of answer as to the cost-effectiveness and supplementarity issue of an international trading system.

Its general objective was in fact to explore the potential costs and emission reductions impact of different designs of emission trading on the achievement of the Kyoto targets. Five different emission trading schemes or scenarios were designed that reflect different possible constraints on emission trading: in terms of participants (e.g. restrict the trading to Annex B countries), in terms of quantities (e.g. put a ceiling on emission trading), in terms of both participants and quantities.

It was not the aim of the study to address the economic theory of emission trading, nor to discuss the implementation issues of an international trading system (transaction costs estimates, monitoring, etc.).

The study results are based on the POLES model. POLES is a sectoral model of the world energy system to 2030, describing the international energy markets and national or regional subsystems. The methodology adopted consisted in using the POLES model to simulate the impact of the emission trading scenarios by comparing the results to a reference scenario without trading.

The analysis considered CO_2 emissions only due to lack of a consistent analysis framework for the other greenhouse gases and sinks. The Kyoto targets specified for the basket of six greenhouse gases were thus applied to CO_2 emissions only.

All scenarios take into account the Kyoto targets of Annex B countries. The trading of "hot air" was not excluded, so that Russia and Ukraine can sell emission permits equivalent to the difference between their Kyoto targets and the level of their emissions in a Business as Usual scenario.

The results suggest the following conclusions if trading is restricted to Annex B.

- Even without constraints on emission trading, trading is supplemental (more than 50% of the required reductions in 2010 would be done domestically) except in Japan where permit acquisition contributes to around 70% of the required reduction[2]. In the EU, domestic actions would represent 75% of the reduction in 2010. Party's acquisitions are up to 20% of their CO_2 emissions in 1990, depending on the country (6% for the EU, 15% for the USA, 20% for Japan).

- The permit price would be equal to 66.5 \$/tC (17 ECU/tCO_2). At Annex B level, the reduction effort is expected to decrease from around 0.2% of 2010 GDP without trading to around 0.09% of 2010 GDP with full trade.

- Reducing the traded volume to half would increase annual costs of total Annex B by 50% (or 10 billion \$/year). On the other hand, global emissions would be 1% lower since part of the "hot air" can not be sold.

- The main result of the analysis of emission trading among Annex B countries seems to be that no ceiling on flexibility mechanisms (ET and JI) is needed to ensure that these are supplemental to domestic action. Furthermore, restrictions on trade would result in significant cost increases.

If trading would take place world wide, the main findings are the following.

- Without restriction on the use of flexibility mechanisms (ET, JI and CDM), trading would not necessarily be supplemental (less than 50% of the required reductions in 2010 would be done domestically). Acquisitions could make up to 90% of the reduction in 2010 (70% in the EU, 76% in the USA, 87% in Japan).

[2] This result is in line with MITI's policy (The Ministry of International Trade and Industry of Japan) to reduce greenhouse gases emissions by 6% from 1990 levels by 2010: 2% reduction will come through national efforts while the remaining 4% reduction will come through emission trading with other nations.

Moreover, EU's acquisitions would represent 16% of its CO_2 emissions in 1990, compared to 6% if trading is restricted to Annex B. USA shows however the highest share with acquisitions representing 30% of their CO_2 emissions in 1990.

- The permit price would be equal to 24 $/tC (6 ECU/t$CO_2$), namely three times lower than if trading is restricted to Annex B.

- World wide, the total costs of reduction are expected to be six times lower than without trading (2 times for the EU, 3 times for the USA, 5 times for Japan and 4 times for Annex B as a whole). The emission reduction effort would decrease from around 0.1% of 2010 GDP without trading to around 0.02% of 2010 GDP with full trade. At Annex B level, the decrease would be from 0.2% to 0.06% of the GDP in 2010.

- Reducing the traded volume to half would make the world wide trading supplemental. However, the price to pay is a doubling of the annual reduction costs (12 billion $1990/year). Global emissions would be 1% lower since part of the "hot air" can not be sold.

- The analysis of a world wide emission trading system points to the conclusion that a ceiling on the use of flexibility mechanisms would be needed to ensure that these are supplemental to domestic action. However, a cap on trade is expensive and does not solve the "hot air" issue. Moreover, the resulting restriction on "hot air" that can be sold has only a very limited impact on global emissions (1 percentage point lower).

Finally, as caveat, it should be stressed that the present analysis did not consider the possibility of banking and assumed perfect market for emission permits. Furthermore, Parties were assumed to minimise costs and to ignore ancillary benefits of domestic action. In reality, domestic action might then be more important than the model results suggest.