ECONOMIC EVALUATION OF SECTORAL EMISSION REDUCTION OBJECTIVES FOR CLIMATE CHANGE: ECONOMIC EVALUATION OF EMISSION REDUCTION OF GREENHOUSE GASES IN THE ENERGY SUPPLY SECTOR IN THE EU

EXECUTIVE SUMMARY

The *Energy supply sector* comprises all centrally and decentrally produced steam and electricity, and refineries. Within the EU, the energy supply sector is an important source of carbon dioxide, accounting for almost 40% of total carbon dioxide emissions in 1990 and 31% of total greenhouse gas emissions. Including all emissions of greenhouse gases from this sector, 32% of the greenhouse gases are emitted by the energy supply sector.

Description of the sector

In 1995, in the EU15 about 2300 TWh of electricity has been produced and about 1066 TWh of steam. The steam and electricity are mainly supplied by conventional fossil fuel power plants, by nuclear plants, by combined heat and power plants (CHP), by steam boilers and by renewable energy sources, or by a combination of aforementioned types of plants. Emissions of CO_2 occur during the production of power with the use of fossil fuels.

Frozen technology reference level

The emission reduction potential for 2010 is calculated using an emission reference level based on frozen technology development. The reference level for 2010 is based on the projected total power and steam production from the Primes model [Primes, 1999]. It is assumed that in the frozen technology reference level no additional renewables and CHP units are installed in 2010 compared to 1995 and that for the ‘conventional fossil fuelled plant’ the emission factors are the same, i.e. assuming no fuel switch and efficiency improvements.

Emission reduction options

In this report options to reduce carbon dioxide emissions from the energy supply, option to reduce SF_6 from switch gears and options to reduce nitrous oxide emission from combustion from stationary combustion are discussed. There are various options to reduce CO_2 emissions in the energy supply sector. This can be done by increasing the share of lower or zero (CO_2) emission units like combined cycles, renewables, and combined heat and power plants (CHP). In principle extension of the share of nuclear energy leads also to a reduction of CO_2 emissions. In this study, however, it is assumed that there is no expansion of nuclear capacity in the EU towards 2010. A principal other way to reduce emissions is CO_2 removal; recovering of CO_2 from an (energy) conversion process and subsequently storage underground to avoid CO_2 entering the atmosphere.

In this study four ‘basic’ options are distinguished and discussed. In the first option all new capacity (to compensate for growth in production and to replace decommissioned capacity) will be efficient combined cycle power plants (NGCCs). The second option is implementation of renewables. In practice renewables may be an alternative for many other forms of power production. For computational reasons it is here defined as an option that is implemented instead of efficient combined cycle power plants (NGCCs). The third option is implementation of CHP. For this option the same remark as made for renewables is valid. Also in this case the option is defined as an

option that is implemented instead of NGCCs. When a CHP unit replaces a coal-fired steam boiler, it will be clear that in that case two options (options 1 and 3) are implemented at the same time, reducing in total CO_2 emissions of both options. The fourth distinguished option is the application of CO_2 removal.

Three options are described to reduce carbon dioxide emissions from refineries, i.e. reflux overhead vapour compression, recovery of power and use of improved catalysts. In addition, a set of options are categorized in the option miscellaneous.

Options to reduce nitrous oxide emissions from stationary combustion are limited to fluidized bed combustion. This type of combustion has a relatively high emission factor compared to other type of stationary combustion processes.

Finally, options to reduce SF_6 emissions from manufacture and use of gas insulated switch gears are identified.[1]

Table A and B give an overview of the investment costs, the yearly costs (sum of operation and maintenance costs and savings), average specific avoidance costs and potential for options applicable in the energy supply sector. The specific costs are calculated using a real interest rate of 4% and using the technical lifetime of the option, i.e. installation.

Table A. EU15-average costs and potential (Mt of CO_2) for emission reduction in the Energy supply sector (renewables only)

Pollutant	Measure Name	Emission reduction	Specific costs (euro/tCO2) at discount rate			
		Mt CO2 eq.	2%	4%	6%	Sector specific
CO2	Biomass 3b: heat only on solid biomass	25	-42	-42	-41	-41
	Biomass 1b: CHP on solid biomass	4	-38	-34	-30	-26
	Biomass 2: CHP anearobic digestion	4	-28	-23	-17	-11
	Subtotal: cost range < 0 euro / t CO2 eq.	**33**				
	Wind onshore	30	-6	3	13	24
	Small hydro	2	-5	10	27	46
	Large hydro	15	-4	11	29	48
	Biomass 3a: heat only on woody sources	64	15	15	16	17
	Subtotal: cost range 0 < 20 euro / t CO2 eq.	**111**				
	Biomass 1a: CHP on woody energy sources	29	17	20	24	28
	Subtotal: cost range 20 < 50 euro / t CO2 eq.	**29**				
	Geothermal electricity production	2	36	53	71	92
	Wind offshore	18	69	88	109	131
	Tidal	2	84	118	158	201
	Biomass 4a: ethanol	9	228	236	246	256
	Biomass 4b: biodiesel	24	287	299	312	326
	Solar photovoltaic	1	235	308	388	475
	Subtotal: cost range > 50 euro / t CO2 eq.	**56**				
	Total emission reduction options	**229**				

[1] These options are not described in this report but in the report "Economic Evaluation of Emission Reductions of HFCs, PFCs and SF_6 in Europe", J. Harnisch and C. Hendriks, Ecofys, March 2000.

Table B. EU15-average costs and potential (Mt of CO_2) for emission reduction in the Energy supply sector (except renewables see Table A)

Pollutant	Measure Name	Emission reduction	Specific costs (euro/tCO2) at discount rate			
		Mt CO2 eq.	2%	4%	6%	Sector specific
CO2	Refineries: Reflux overhead vapour recompression (distillation)	6	-66	-66	-65	-65
	Refineries: Power recovery (e.g. at fluid catalytic cracker)	1	-53	-51	-49	-42
	Refineries: Miscellaneous I (Low cost tranche)	6	-31	-29	-26	-17
	Replacement of capacity by natural gas-fired combined cycles	214	<0	<0	<0	<0
	New capacity by natural gas-fired combined cycles	286	<0	<0	<0	<0
	Subtotal: Cost range < 0 euro / t CO2 eq.	**513**				
	Refineries: Improved catalysts (catalytic reforming)	4	0	0	0	0
	CHP - Food, drink and tobacco	1	-3	12	28	46
	Subtotal: Cost range for 0 < 20 euro/t CO2 eq.	**5**				
	CHP - Refineries	6	6	25	44	65
	CHP - Residential - Small	5	5	27	49	74
	CHP - Non-ferrous metals	0.1	5	27	49	74
	CHP - Engineering goods	0.5	5	27	49	74
	CHP - Other industries	0.3	5	27	49	74
	CHP - Paper and pulp	3	5	27	49	74
	CHP - Tertiary - Large	1	5	27	49	74
	CHP - Textiles	0.1	5	27	49	74
	Subtotal: Cost range for 20 < 50 euro / t CO2 eq.	**17**				
	CO2 removal	50	46	50	54	59
	Refineries: Miscellaneous II (High cost tranche)	6	52	60	69	98
	CHP - Tertiary - Small	3	50	63	76	90
	CHP - Food, drink and tobacco (implemented in situation of overcapacity)	3	108	123	140	157
	CHP - Iron and Steel	1	113	131	150	171
	CHP - Chemicals	3	113	131	150	171
	CHP - Building materials	0.1	113	131	150	171
	CHP - Residential - Large	5	113	131	150	171
	CHP - Tertiary - Small (implemented in situation of overcapacity)	3	140	152	166	180
	CHP - Tertiary - Large (implemented in situation of overcapacity)	1	180	201	224	248
	CHP - Engineering goods (implemented in situation of overcapacity)	1	180	201	224	248
	CHP - Paper and pulp (implemented in situation of overcapacity)	3	180	201	224	248
	CHP - Textiles (implemented in situation of overcapacity)	1	180	201	224	248
	CHP - Residential - Small (implemented in situation of overcapacity)	5	180	201	224	248
	CHP - Non-ferrous metals (implemented in situation of overcapacity)	0.3	180	201	224	248
	CHP - Other industries (implemented in situation of overcapacity)	1	180	201	224	248
	CHP - Building materials (implemented in situation of overcapacity)	0.2	200	218	238	258
	CHP - Residential - Large (implemented in situation of overcapacity)	5	200	218	238	258
	CHP - Chemicals (implemented in situation of overcapacity)	7	200	218	238	258
	CHP - Iron and Steel (overcapacity)	2	200	218	238	258
	CHP - Tertiary - Medium	1	190	227	267	310
	CHP - Tertiary - Medium (implemented in situation of overcapacity)	1	361	398	438	481
	Subtotal: Cost range > 50 euro/t CO2 eq.	**101**				
Non CO2	Recovery of SF6 from gas insulated switchgears	1	3	3	3	3
	N2O Combustion processes Fluisidised bed after burner	1	2	3	3	4
	N2O Combustion processes Fluisidised bed reversed air staging	1	4	4	4	4
	Subtotal: Cost range 0 < 20 euro/t CO2 eq.	**3**				
	Cost range < 0 euro / t CO2 eq.	**513**				
	Cost range 0 < 20 euro / t CO2 eq.	**8**				
	Cost range 20 < 50 euro / t CO2 eq.	**17**				
	Cost range > 50 euro / t CO2 eq.	**101**				
	Total emission reduction potential	**639**				

In 2010 renewables may contribute with an emission reduction of about 229 Mt CO_2. In this figure it is assumed that renewables replace NGCCs. The potential is higher if renewables replace power production facilities with a higher CO_2 emission rate, e.g. coal-fired power plants.

Based on projected steam demand in 2010, the maximum technical potential of CHP units can cover about 90% of the required new capacity in the EU15, although this percentage may vary country by country. CHP and NGCCs may reduce about 564 Mt of CO_2. 500 Mt of CO_2 may be avoided by installing NGCCs thus replacing the 'average power plant' based on fossil-fuels. A further 64 Mt of CO_2 can be avoided by installing CHP units instead of NGCCs.

An adequate estimate of the potential of CO_2 removal is difficult to make. CO_2 removal is a technical feasible option, but still substantial research is required to understand better the impact, environmental consequences and risks of underground storage. In this study an EU-wide potential of 50 Mt of CO_2 is assumed, but the actual potential might be considerably higher.

The reduction potential for refineries is estimated at 23 Mt CO_2. The potential for emission reduction in stationary combustion is estimated at about 2 Mt CO_2.
The total technical emission reduction potential in the energy supply sector is estimated at about 869 Mt of CO_2.

Summary of the Energy supply sector

Table C summarises the frozen technology reference level (FTRL) in the energy supply sector and shows the position if all the measures in the table above were adopted.

Table C. Summary of emissions (Mt CO_2 equivalent)

	1990	**2010 FTRL**	**2010 with all measures**
Carbon dioxide	1268	1898	1032
Methane	12	12	12
Nitrous oxide	42	29	27
Fluorinated gases	4	4	3
Total	**1327**	**1943**	**1075**

Figure A shows the share in emission reduction in the energy supply sector categorised in four costs brackets.

Figure A. Energy supply sector: 1990 base year (left column, by gas) and 2010 frozen technology reference level (right column). Emission reduction potential is indicated for four costs brackets . The specific costs are calculated assuming a real interest rate of 4%.