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ENERGY DEVELOPMENT AND POWER GENERATION COMMITTEE
International Practices Subcommittee

PANEL SESSION: DEVELOPMENTS IN TECHNOLOGY TO LIMIT GREENHOUSE GAS EMISSIONS IN EUROPE[#]

EXTENDED FULL LENGTH PAPERS

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Chair: Tom Hammons, University of Glasgow, Scotland, UK. T.Hammons@ieee.org

This Panel Session reviewed developments in technology to limit greenhouse gas emissions in Europe as seen by leading international authorities in power generation in the UK, Russia, Greece, Italy, and the Czech Republic.

Principal contributors included:

1) Boris G. Saneev, Deputy Director; Anatoli Laerev, Chief Researcher; Valentina N. Khanaeva, Senior Researcher; and Alexei V. Tcdhemezov, Engineer, Energy Systems Institute, Irkutsk, Russia
2) George C. Contaxis, Professor, and Costas.Delkis, National Technical University of Athens, Greece
3) Nick Otter, Director of Technology and External Affairs, ALSTOM Power Technology, UK
4) Ludovico Priori, Consultant, former Director, Edison Spa, Italy; and Luigi Salvaderi, Consultant, Italy
5) Jiří Tůma, Vice Dean for Science and Research, Czech Technical University of Prague, Czech Republic
6) Davor Vujatovic, London Electricity, UK, and Loi Lei Lai, City University, UK
7) Tom Hammons, Chair, International Practices for Energy Development and Power Generation, University of Glasgow, UK

Presented were the views of renowned international authorities on emerging technologies, alternative energy resources and renewable energy to limit greenhouse gas emissions in Europe.

Each Presenter spoke for approximately 20 minutes. Each presentation was discussed immediately following its respective presentation. There was a further opportunity for discussion of the presentations following the final presentation.

The Panel Session was organized by T. J. Hammons, Chair of International Practices for Energy Development and Power Generation (University of Glasgow, UK).

T. J. Hammons moderated the Panel Session.

The first presentation was on the outlook of power industry development in Russia in the 21st century and its impact on Russia's greenhouse gas emissions. It was prepared by Boris G. Saneev, Deputy Director; Anatoli Laerev, Chief Researcher; Valentina N. Khanaeva, Senior Researcher; and

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Alexei V. Tcdhemezov, Engineer, of the Energy Systems Institute, Irkutsk, Russia. Nikolai Voropai, Director of the Institute, presented it. Forecasts for developing Russia's economy and electric power industry in the first half of the 21st century were presented. Possible structural change in the electric power industry in Russia together with dynamic changes of CO2 emissions from fuel combustion in power plants were examined. CO2 emissions from fuel combustion at power plants in Russia may increase 2.7 fold in 50 years. Calculations depict that specific CO2 emissions in Asian Russia exceed greatly that of the European part, so there is considerable potential for reduction of greenhouse gas emissions in the Asian part. Russian implementation of the Kyoto protocol along with the direct benefits such as the introduction of new energy saving technologies and the attractions of financing may bring essential environmental and social results.

The second presentation was entitled: Measures to Limit Greenhouse Gas Emissions in Greece. George C. Contaxis, Professor, and Costas.Delkis, National Technical University of Athens prepared it. Sakis Meliopoulos from the Technical University made the presentation. Impact of the currently adopted measures and initiatives to reduce emissions in the Greek energy system for the period up to 2030 was discussed, with emphasis on the current decade. The measures are included in the baseline scenario which takes into consideration likely trends of the domestic and international energy market, as well as the commitments Greece undertook recently in the framework of the European Union to deregulate the energy market. Under the scenario for environmental policy, the additional commitments and measures to limit CO_2 emissions towards the Kyoto targets were presented. Simulation and study of the behavior of the economic system was performed using the model PRIMES. This is a partial equilibrium model for the European Union energy system developed and maintained at the National Technical University of Athens E3M-Laboratory led by Professor Capros. The most recent version of the model covers all EU member-states, and uses Eurostat as the main data source, updated with 1995 being the base year. PRIMES is a result of collaborative research under a series of projects supported by the programme Joule of directorate General for Research of the European Commission.

The third presentation was entitled: 'Clean Power Generation Technology for the 21st Century – a Perspective from the EU Power Plant Supply Industry'. Nick Otter, Director of Technology and External Affairs, ALSTOM Power, UK prepared it. Tom Hammons, Chair, International Practices for Energy Development and Power Generation, University of Glasgow; and Jim McConnach (who made comments on the viewgraphs), presented it. Here, a perspective from the Power Plant and Services Industry was presented with respect to impact of Global Climate Change on product development strategy. Such environmental drivers, typified by the increasing public and political desire to introduce measures that will reduce GHG (especially CO_2) world-wide have to be positioned against the other key market issues of wider globalization, increased liberalization, deregulation and privatization, all of which contribute to the substantial changes in the energy market world-wide. These were discussed. It was concluded that fossil fuel based power generation technologies will continue to play an important part of the energy mix in the foreseeable future and that different parts of the world will require different technologies to meet their local specific requirements. Consequently, in order to meet the environmental challenge arising from national and international efforts to reduce the effects of climate change, it will be necessary to continue to develop clean technologies and to promote their use world-wide.

The fourth presentation was entitled 'Limiting Greenhouse Gases: a possible Italian Strategy in the European Framework' It was prepared by Ludovico Priori, Consultant, former Director, Edison Spa, Italy; and Luigi Salvaderi, Consultant, Italy. Tom Hammons presented it. The presentation examined a possible Italian strategy for implementing Kyoto protocol mechanisms to meet commitments of the EU Emission Trading Draft Directive, the Italian strategy in the Ministerial documents, and final considerations.

The fifth presentation was on the ways of decreasing the impacts of power engineering on our environment. Professor. Jiří Tůma, Dean of Science and Research, Czech Technical University, Prague, Czech Republic prepared it. Tom Hammons presented it. It discussed impact of power engineering on our environment. Producing greenhouse gases can be considered to be a serious problem that is global. The decrease of these negative impacts is closely connected to sustainable development. It should be the duty of all countries to cooperate in this area. The presentation dealt with research and developmental theses under preparation, particularly those that are focused on the exploitation of the fossil fuels and renewable energy sources.

The penultimate presentation was on reduction of greenhouse gases in the UK. Davor Vujatovic, London Electricity Services, UK and Loi Lei Lai, Energy Systems Group, City University, London, UK prepared it. Tom Hammons presented it. It highlighted the extensive use of new and improved technology, by improvement in energy efficiency, change of fuels, introduction of new energy sources and abatement/sequestration of greenhouse gases, to achieve reductions in emissions without affecting the standard of living. Some of these technologies are widely available now; others are in their research stages. This presentation looked into the issues of greenhouse gases and proposed two potentially useful techniques to enhance environmental benefit through the use of renewable energy.

Finally, an in-depth review of the United Kingdom's achievements under the framework of the convention on climate change was summarized. Tom Hammons of the University of Glasgow made this prepared discussion. Here, the diverse and innovative spectrum of measures that are being taken to promote capacity building on climate change at all levels in the UK was evaluated. The most notable achievement has been a reduction in GHG emissions of 12.8 per cent between 1990 and 2000, thereby returning the UK's GHG emissions to their 1990 level. Notable decreases have been obtained for the three main GHGs, namely N_2O (35 per cent), CH_4 (33 per cent) and CO_2 (8 per cent). Important policies in meeting the reduction target include the Domestic Emissions Trading Scheme, the Climate Change Levy and the Renewables Obligation. This was reviewed.

Each presentation is summarized below:

1. OUTLOOKS OF RUSSIA'S POWER INDUSTRY DEVELOPMENT IN THE 21ST CENTURY AND GREENHOUSE GAS EMISSIONS

B.Saneev, A.Lagerev, V.Khanaeva, A.Tchemezov

Abstract

The paper presents the forecast for development of Russia's economy and electric power industry in the first haft of the 21st century and shows possible structural change in the electric power industry of the country and the dynamic in changes of CO_2 emissions from fuel combustion at the power plants.

Keywords: Fuel and energy complex, energy resources, greenhouse gas emission, electric power industry.

Human activity and, first of all, development of industry and fast reduction of forests on the planet enhances an anthropogenic factor of growing concentration of the so called "greenhouse" gases (carbon dioxide (CO_2), methane (CH_4) and nitrogen oxide (NO_2), etc.) in the atmosphere.

International Energy Agency[1] states that three fourths of the CO_2 volumes formed as a result of human activity are emitted when producing and using fossil fuels.

Fuel combustion is responsible for the most of anthropogenic greenhouse gas emissions and particularly large fraction is from fuel combustion at power plants. Currently their fraction in the total CO_2 emissions of the country is 35-36% [1].

The results of the studies presented in the paper contain the forecast for development of Russia's economy and electric power industry for the period up to 2050, the data on possible structural changes in electric power industry of the country in the considered time horizon and the dynamics in changes of CO_2 emissions from fuel combustion for large regions of Russia.

Estimation of CO_2 emissions in the electric power sector in the long-term prospect will allow a more substantial judgment on the potentialities for Russia to fulfill its obligations. In its turn a territorial analysis of greenhouse gas emissions will reveal the most unfavorable regions and will allow one to plan measures on emission reduction, to elaborate criteria of their selection and thus determine a potential for decreasing the total greenhouse emissions, both for individual territories and for Russia as a whole.

The factors that affect the volumes of CO_2 emissions and call for account in the studies include: dynamics in change of internal demand for electric power depending on the economy development scenarios and energy saving policy, development scales of nuclear power plants and renewable sources, scales and rates of technological progress in energy, structure and volumes of the fuel consumed (gas, coal, heavy oil), etc.

It is practically impossible to simultaneously estimate the influence of changes in these factors on the volumes of CO_2 emissions without a model tool. Therefore the optimization dynamic model of Russia's fuel and energy complex that was developed at Energy Systems Institute was used [2].

For estimation of electricity consumption level in the forthcoming 50-year period the authors considered an optimistic scenario of Russia's economy development. Dynamics in the change of per capita GDP and population size for the considered scenario are presented in Table 1.

[1] International Energy Agency statement on The Energy Dimension of Climate Change // http:/iea.org/new/clim/edcc_iea.pdf

Table 1. Forecast on development of economy and electric power consumption in Russia

Indices	Years				
	2000	2020	2030	2040	2050
GDP, billion USD	630	1600	2350	3400	4400
Average annual rates of GDP growth, %		4.77	3.92	3.76	2.61
Population, million people	145	143	142	141	140
GDP per capita, thousand USD/person	4.3	11.2	16.5	24.1	31.4
Electricity consumption, billion kWh	847	1445	1770	2080	2400
Average annual growth rates, %		2.71	2.05	1.63	1.44
Electricity-GDP ratio, MWh/1000USD	1.34	0.90	0.75	0.61	0.55
Per capita consumption, thousand kWh/person	5.8	10.1	12.5	14.8	17.1

Optimistic scenario supposes that GDP[2] level achieved by Russia in 1990 will be restored in no later than 2015 (with account for progressive structural changes) and by 2050 Russia's economy should near qualitatively and quantitatively (in per capita GDP) the current level of developed countries[3].

To attain these goals the average annual rates of GDP growth in 2000-2020 should be no less than 4.5-5%. In succeeding years GDP growth gets slower but its rates remain higher than those forecasted for the developed countries[3].

Figure 1 shows the forecasted dynamics in the change of electricity-GDP ratio depending on per capita GDP for some developed countries [3,4] and Russia. For Russia to have tendencies observed in developed countries its electricity-GDP ratio should decrease by 1.9-2.0% yearly in 2000-2020. Further, the rates of electricity-GDP ratio decline will get somewhat slower (1.6% yearly).

The obtained forecast of internal demand for electricity for the considered scenario of the economy development is presented in Table 1.

To reach the forecasted level of electricity consumption and supposed export supplies the electricity production in the country will have to increase 2.8 times in the 50-year period including 2.7 times at thermal power plants and 5 times at nuclear power plants (Table 2). Thus by 2050 the fraction of nuclear power plants in the electricity production structure of the country will rise to 26% against current 15%.

[2] 1990 - about USD 1000 billion (Russia's energy strategy for the period up to 2020)
[3] In 1997 per capita GDP in the USA made up USD 30.3 thousand, in Germany - USD 25.9 thousand [3,4].

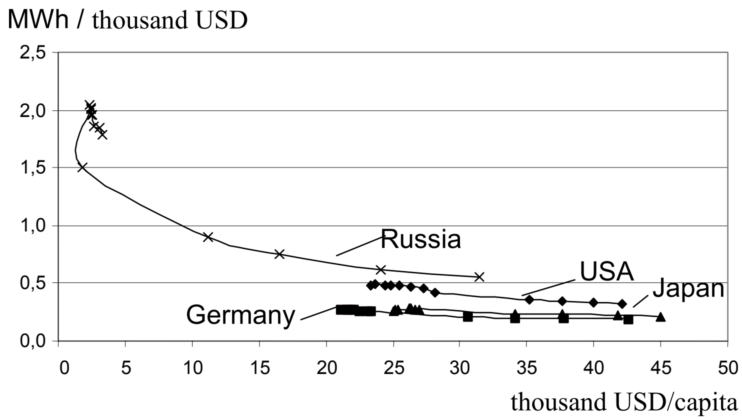

Figure 1. Electricity intensity of the economy versus GDP per capita (1980-2020, Russia 2000-2050)

The required growth of electricity production will necessitate commissioning of 525 GW of new capacities by 2050. Almost 60% or 315 GW of the capacities will replace those to be removed from service including 25-33 GW at nuclear, 50GW at hydro and 230 GW at thermal power plants.

Table 2. Basic indices of Russia's electric power industry development

Indices	Years				
	2000	2020	2030	2040	2050
Electricity production, TWh	876	1475	1790	2100	2450
Nuclear	131	300	390	500	640
Hydro	165	210	230	240	240
Thermal	580	965	1170	1360	1570
The same in %					
Nuclear	15	20	22	24	26
Hydro	19	14	13	11	10
Thermal	66	66	65	65	64
Commissioning of capacities*, GW		150	298	395	525
Nuclear		34	55	75	110
Hydro		8	29	44	65
Thermal		108	214	276	350
Dismantling*, GW		95	152	214	315
Installed capacity, GW	210	265	353	390	420
Nuclear	21	47	60	75	100
Hydro	44	53	58	60	60
Thermal	145	165	235	255	260

*Progressive total

The installed capacity of power plants in Russia by 2050 should increase almost twice as against 2000 and make up 420 GW.

At present fuel balance of power plants of the country consists of almost 63% of gas, 10% of heavy oil and 27% of coal and other fossils. The studies showed that by 2050 gas fraction might decrease up to 34% and coal fraction might increase up to 64% (Table 3). A 2.2-fold increase in fuel consumption at power plants may lead to a 5-fold rise in fossil fuel consumption.

Table 3. Forecast of fuel consumption by power plants in Russia, million tce

Indices	2000	Forecast			
		2020	2030	2040	2050
Russia, total	285	425	455	530	615
Gas	179	230	255	225	210
Heavy oil	29	20	20	15	15
Coal and others	77	175	180	290	390
The same in %	100	100	100	100	100
Gas	63	54	56	42	34
Heavy oil	10	5	4	3	2
Coal and others	27	41	40	65	64
Including:					
European part	195	270	280	310	350
Gas	146	175	200	185	170
Heavy oil	23	16	15	10	10
Coal and others	26	79	65	115	170
The same in %	100	100	100	100	100
Gas	75	65	72	60	49
Heavy oil	12	6	5	3	3
Coal and others	13	29	23	37	48
Asian part	90	155	175	220	265
Gas	33	55	55	40	40
Heavy oil	6	4	5	5	5
Coal and others	51	96	115	175	220
The same in %	100	100	100	100	100
Gas	37	35	31	17	13
Heavy oil	7	3	3	2	2
Coal and others	56	62	66	81	85

Essential changes are likely in coal consumption by power plants of European Russia: a 1.8-fold increase in fuel consumption will lead to a 6-7 rise in coal consumption and its fraction in fuel balance of power plants of this region will increase from 13% in 2000 to 48-49% by 2050.

Unlike European Russia the total fuel consumption by power plants in Asian Russia may increase 2.9 times mainly at the expense of coal in the 50 years. An estimated fraction of coal in the structure of fuel consumed by power plants of the region may reach 85% by 2050 against current 56%.

The supposed change in the fuel supply to thermal power plants (with gradual conversion to coal) and stricter environmental requirements cause essential changes in the technological structure of electricity production. Figure 2 presents the forecasted dynamics in the change of technological structure of thermal power plants in Russia.

Inertia in introduction of new technologies, longer service life of power plants owing to prolonged operation of physically worn equipment, shortage of investments will probably hinder a wide-scaled change in the technological structure of thermal power plants in the two forthcoming decades. Modernization of existing thermal power plants and construction of new ones have to be based on the new technologies and should become a priority in the succeeding decades. For the gas-fired power plants the new technologies include combined-cycle units, for power plants operating on fossil fuel - environmentally friendly steam-turbine plants (boiler plants with fluidized bed, ring furnace, etc.) and after 2020 combined-cycle plants with coal gasification. The new technologies will improve environmental indices of power plants and gradually increase their efficiency and thus, will essentially decrease the growing demand of thermal power plants for fuel.

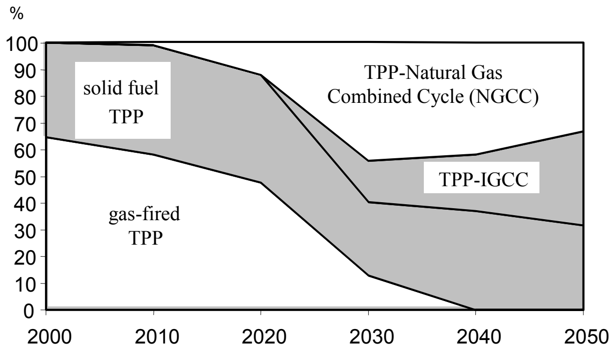

Figure 2. Dynamics in change of electricity production technology at TPP of Russia

The total investments required for development of electric and thermal power industries in the considered time horizon are estimated at more than USD 1.1 trillion. Dynamics in their distribution among the regions is presented in Table 4. It shows that about 67% of all the investments will fall on European part, 14% - on West Siberia, 13% on East Siberia and 6% on the Far East. Even in the first decade the average annual capital investments into this sector of energy have to be USD 4-5 billion and increase up to USD 13-14 billion in the next decade. Further the sizes of capital investments should be much larger.

Table 4. Forecast of capital investments into electric and thermal power industry of Russia, billion USD

Regions	2001-2010	2011-2020	2021-2030	2031-2040	2041-2050	Total 2001-2050
European part	27,7	93,5	177	213	233	744
West Siberia	5,7	16,5	35	47	49	154
East Siberia	6,6	18,5	26	39	52	142
The Far East	4,1	7,8	14	19	23	68
Russia, as a whole	44	136	252	318	357	1107
The same in %						
European part	63	69	70	67	65	67
West Siberia	13	12	14	15	14	14
East Siberia	15	14	10	12	15	13
The Far East	9	6	5	6	6	6
Russia, as a whole	100	100	100	100	100	100

The quantitative estimations obtained for the long-term development of Russia's power industry allowed one to determine the magnitude of greenhouse gas emission from fuel combustion at TPP (Table 5). The calculations show that the volume of CO_2 emissions at power plants may increase 1.7-1.8 times by 2030 and 2.6-2.7 times by 2050 as against 2000. The main source of increase in greenhouse gas emissions at power plants will be coal as its combustion may lead to a 5-fold increase in the emissions in the considered period and their fraction in the structure of emissions from TPP (from different types of fuel) may rise more than twice (from 36% in 2000 to 75% by 2050).

Table 5. Forecast of CO_2 emissions from fuel combustion at power plants of Russia, million t

Indices	Years					
	1990	**2000**	**2020**	**2030**	**2040**	**2050**
Thermal power plants of Russia, total	830	562	930	990	1235	1500
- gas	385	295	390	430	370	345
- heavy oil	110	65	45	45	35	35
- coal and others	335	202	495	515	830	1120
The same in %	100	100	100	100	100	100
- gas	46	52	42	43	30	23
- heavy oil	13	12	5	5	3	2
- coal and others	41	36	53	52	67	75
Including:						
Thermal power plants of European Russia	570	350	550	540	645	765
- gas	330	240	295	340	310	285
- heavy oil	98	50	35	35	25	25
- coal and others	142	60	220	165	310	455
Thermal power plants of Asian Russia	260	212	380	450	590	735
- gas	55	55	95	90	60	60
- heavy oil	12	15	10	10	10	10
- coal and others	193	142	275	350	520	665

Currently fuel combustion at power plants of Asian Russia causes 38% of CO_2 emissions of the country. In the future this fraction will gradually increase and may reach 48-49% by the end of the period.

Figure 3 shows that whilst in European Russia emissions from fuel combustion at TPP will exceed the 1990 level only after 2030 in Asian part this may take place in 2010 and by the end of the considered period there will be a 2.8-fold excess (against a 1.35-fold one for European part).

Thus, the calculations show that Asian Russia is the most unfavorable region in terms of increase in greenhouse gas emissions from power plants.

The calculations have also made it possible to determine dynamics in the changes of the indices of specific CO_2 emissions (CO_2 g/kWh) for different regions of the country (the so called "base lines"). Seemingly, they may be used in the first approximation when estimating environmentally preferable projects for different areas of Russia. The emissions are decreased by attracting projects with the indices of specific emissions below the base line.

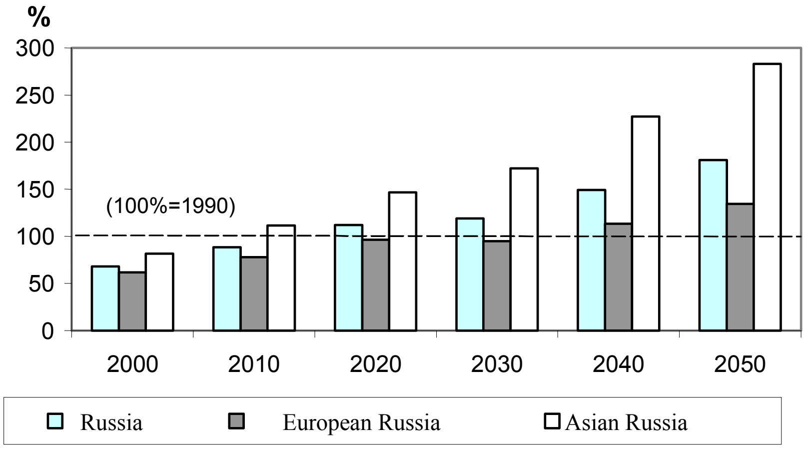

Figure 3. Fraction of CO_2 emissions (against 1990) at fuel combustion at power plants of Russia

The base lines of specific CO_2 emission indices at electric power production for European and Asian parts as well as for Russia as a whole are presented in Figure 4. It follows from the Figure that the indices for Asian Russia essentially exceed those for European part. Therefore Asian Russia has a considerable potential for reduction of greenhouse gas emissions, which can be achieved by structurally transforming the electric power industry (for instance, wider involvement of natural gas, traditional and non-traditional renewable energy sources) and by actively introducing new fuel combustion technologies. However, all this requires essential financial resources.

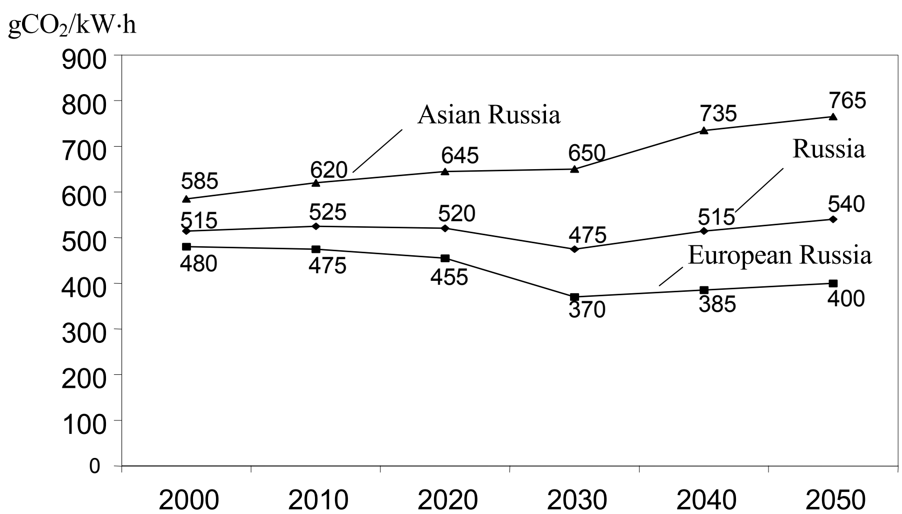

Figure 4. Base lines of specific CO_2 emissions at electricity production in Russia

It seems that attraction of funds gained when implementing the so-called Kyoto mechanisms - "joint implementation" projects and trade in emission quotas should become a priority line for Russia in the international cooperation in the environmental area.

Coming into effect of Kyoto protocol mechanisms and creation in Russia of an effective system for monitoring and management of greenhouse gas emissions, along with direct benefits such as fuel saving, introduction of energy and resource saving technologies, and attraction of additional funds into Russian economy may lead to considerable social and environmental results. Decrease in emissions of greenhouse gases is accompanied, as a rule, by reduced emissions of such pollutants as SO_2, NO_x, solid particles and heavy metals that decrease the threat to the population health.

Conclusions

1. Human activity increases the anthropogenic factor of growing greenhouse gas concentration.
2. Currently fuel combustion at power plants results in more than one third of total CO_2 emissions of the country and their fraction will increase in the forthcoming period.
3. The studies show that CO_2 emissions from fuel combustion at power plants in Russia may increase 2.7 times in 50 years. The main source of greenhouse gas emission growth at power plants will be coal. The fraction of emissions caused by coal combustion may increase more than twice in this period.
4. The supposed change in the fuel supply to thermal power plants (with gradual conversion to coal) and more strict environmental requirements cause the need to essentially change the technological structure of fossil-fired thermal power plants.
5. The studies performed determined dynamics in the changes of specific CO_2 emission indices at power production for different regions of the country (base lines). These indices are likely to be used in the first approximation when assessing environmentally preferable projects for different territories.
6. The calculations show that the specific CO_2 emissions (base lines) in Asian Russia exceed greatly the emissions of European part. Therefore, it is precisely this part of Russia that has a considerable potential for reduction of greenhouse gas emissions by attracting more expensive "joint implementation" projects with specific emission indices below the base line.
7. Russia's implementation of Kyoto protocol along with direct benefits (introduction of new energy saving technologies, attraction of finances) may bring essential environmental and social results.

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[1] Emission of greenhouse gases by energy complex of Russia for the period up to 2020. EUF of RAO "EES Rossii". INER RAS. -M., 2001, 53 p.

[2] Lagerev A.V., Saneev B.G., Khanaeva V.N. Dynamics model of Russia's fuel and energy complex // System studies of energy problems. Edited by N.I.Voropai. - Novosibirsk: Nauka. Siberian Publishing Company of RAS, 2000, pp..387-392.

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2. MEASURES TO LIMIT GREENHOUSE GAS EMISSIONS IN GREECE

G. C. Contaxis, *Senior Member IEEE,* C.Delkis, *Member IEEE*

Abstract. According to the undertakings in the Kyoto Protocol of December 1997, the EU is committed to reduce its greenhouse gas (GHGs) emissions in the 2008-12 period to a level that is 8% below that of 1990. Greece's commitment to the European Community is to restrict in 2010 the emissions to the +25% level in comparison to 1990. This paper reviews the potential of current measures and initiatives to limit Greenhouse Gas Emissions in Greece according to the Kyoto Protocol but also the additional required commitments towards the Kyoto's targets.

Index Terms-- Kyoto Protocol, greenhouse gas emissions, renewables, Greek energy balance.

Introduction

Over the last two decades, the greenhouse effect has been a topic of considerable concern among scientific and political circles. Despite the arguments as to the actual impact of the greenhouse phenomenon, everybody agrees that the greenhouse gas (GHGs) emissions have a severe damaging effect on the quality of the atmosphere and therefore upset the ecological balance. It is estimated that during the last century the average temperature of the Earth's surface has increased by 0.5-0.8 ^oC.

The GHGs covered are CO_2 (energy and non-energy related emissions), methane, nitrogen oxides, hydro-fluorocarbons, per fluorocarbons and sulphur hexafluoride. 80% of the above gases are result of the energy sector while the rest are due to industrial, agricultural and residential activities.

At the summit held in Rio in June 1992, 154 countries along with the European Union, signed the Framework-Convention on Climate Change (FCCC) in an effort to drastically reduce the CO_2 emissions and other greenhouse gases. In December 1997, more than 160 countries signed the Kyoto Protocol. According to the undertakings in the Kyoto Protocol of December 1997, the EU is committed to reduce its greenhouse gas emissions in the 2008-12 period to a level that is 8% below that of 1990. This is equivalent to a reduction of GHGs in 2010 by about 316 Mt CO_2 from their 3938 Mt CO_2-equivalent level in 1990. For the three synthetic gases the protocol gives countries the option of using 1995 as base year.

Although the European Union has globally adopted the Kyoto Protocol, it acknowledges the different levels of development of its Member States. Based on a fair distribution of responsibilities adopted by the Council of Ministers, Greece's commitment to the European Community is to restrict at 2010 the emissions to the +25% level in comparison to 1990. In order to achieve such reductions in greenhouse gas emissions major energy policy decisions need to be taken.

A number of serious uncertainties remain regarding the application of the Kyoto Protocol and the role that the energy system of the EU will be called upon to play in meeting the Kyoto obligations. The specific policies and measures have not yet been announced and are the subject of debate at present. A major potential area seen by the Commission is accelerating the penetration of renewable energy sources in the production of electricity. The countries that have agreed to the protocol are requested to promote, research, develop and increase the use of new and renewable forms of energy as one important instrument to limit greenhouse gas emissions.

In this paper the impact of the currently adopted measures and initiatives to reduce emissions in the Greek energy system is discussed for the period up to 2030, with emphasis on the current decade. The measures are included in the baseline scenario which takes into consideration also the likely trends of the domestic and international energy market, as well as the commitments Greece undertook recently in the framework of the European Union to deregulate the energy market. Next, under the scenario termed scenario for environmental policy, the additional commitments and measures to limit

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CO_2 emissions towards the Kyoto targets are presented. Simulation and study of the behavior of the economic system was performed using the model PRIMES. PRIMES is a partial equilibrium model for the European Union energy system developed and maintained at the National Technical University of Athens E3M-Laboratory led by Professor Capros. The most recent version of the model covers all EU member-states, uses Eurostat as main data source and is updated with 1995 being the base year. PRIMES is a result of collaborative research under a series of projects supported by the programme Joule of directorate General for Research of the European Commission.

Review of Current Situation In Greece (Baseline Scenario)

Following the ratification of the Rio Summit's resolution in April 1994 by the National Parliament of Greece, a plan for the reduction of CO_2 and other greenhouse gases was elaborated. In this plan the following major instruments to be applied towards the goal to reduce emissions were included:

- Increased use of natural gas in electricity generation
- Modification of existing power plants to include topping cycles and introduction of new clean coal technologies
- Energy conservation measures in the transport sector
- Increased energy conservation in the building sector
- Continuing emphasis on renewable energy sources utilization.

In particular, the greenhouse abatement measures included in this plan [1] are given in Table 1, which also includes the progress of implementation by 1997.

TABLE 1. GREENHOUSE GASES ABATEMENT MEASURES IN THE ENERGY SECTOR – PROGRESS OF IMPLEMENTATION (1997)

Measures	**Degree of implementation**	**Administrative planning**
PENETRATION OF NATURAL GAS		
Electricity generation	In progress	I
Industry	In progress	D
Residences – Commerce –Services	In progress	D
IMPROVEMENTS IN CONVENTIONAL POWER GENERATION SYSTEM		
Efficiency improvements Limitation of distribution losses	In progress	PD
Combined Heat and Power Systems	In progress	PD
RENEWABLE ENERGY SOURCES		
Wind energy (300 MW)	In progress	D
Small Hydro (34 MW)	In progress	I
Solar systems		
• Conventional systems	In progress	I
• New technology systems	Starting	D
Geothermal energy	In progress	D
Biomass		
• District heating	In progress	I
• Electricity generation	Starting	I
• Bio fuels	Under elaboration	PD
Research & Development	Starting	D
ENERGY EFFICIENCY IMPROVEMENTS IN INDUSTRY		
Cogeneration	In progress	D
Improvements in auxiliary operations	In progress	D
Interventions in energy intensive sectors	In progress	D
Environmental Energy Listings	Under elaboration	P
INTERVENTIONS IN DOMESTIC AND TERTIARY SECTORS		
Cogeneration	Starting	D
Lighting	Starting	I/D
Road-lighting	In progress	P
Central boiler maintenance	In progress	P
INTERVENTIONS IN THE TRANSPORTATION SECTOR		
Fuel-related interventions	In progress	PD
Vehicle-related interventions	In progress	PD
Interventions in the transport system	In progress	I/D
Interventions in Public Transports	In progress	I/D

I: Under implementation
D: Decided
PD: Planned / Pending Decision
P: Proposed

In the last years two major developments took place in the energy sector, which modified slightly the measures described in Table 1:

- Deregulation of the electricity market (Feb 2001)
- A considerable progress in the development of the electricity production from RES, especially from wind in order to achieve a target of 20.1% of renewable energy participation in total electrical energy production in Greece at 2010, indicated in the EU Directive 2001/77.

The above currently adopted measures and initiatives to reduce emissions in the Greek energy system are discussed as part of the baseline scenario. The baseline scenario takes into consideration the likely trends of the domestic and international energy market.

Basic Assumptions for the Baseline scenario

The baseline scenario is based on the following assumptions:

The population of Greece is expected to increase with an annual rate of 0.2% reaching 11.1 million habitants in 2010.

The Gross Domestic Product (GDP) will increase during the next decade with annual rate above 3% in the effort to converge the Greek economy to the European.

A fast increase in the per capita or household energy consumption is expected. According to 2001 statistics, the per capita annual electricity consumption in Greece was 4.2 MWh, considerably lower than the corresponding European average, 6.5 MWh.

It is expected that due to the anticipated convergence of the Greek economy to the average European an increase will take place in the average mobility of the households and the average car ownership, which are well below the European averages.

The turn of the Greek economy towards the tertiary sector will continue.

The currently adopted energy policy will continue without important changes or deviations. This policy includes complete deregulation of the electricity and gas markets and further improvement of the energy technologies, without however important achievements that could change the structure of the energy balance (for example fuel cells). Also this policy includes continuation in supporting renewable resources and co-generation, expansion of the natural gas infrastructure, the enforcement of agreements related to car emissions and fuel quality between EC and car manufacturers. It is assumed that no change in the current tax status for energy products will take place. Finally nuclear power for electricity generation is not foreseen for the period up to 2030.

Security and sufficiency in the supply of the Greek energy market is expected. It is estimated that the oil price will deviate between 18 and 28 $ per barrel (in 2000 prices) and that the coupling between the prices of oil and natural gas will continue resulting in the average price of imported natural gas being at the level of 80% of the corresponding price of oil in equivalent calorific base. Finally it is assumed that the coal import prices will remain constant.

Requirements for Primary Energy

The increase of GDP and the improvement of the living standards will result in continuous increase in the needs for primary energy in Greece during the next 30 years, as it can be seen in Table 2 [2]. Given the increase in needs for primary energy and the development of the energy sector, the country will face continuously increased needs for imports. The energy dependency will reach around 74% in 2020, in comparison to 69% today. More than 95% of the imports will consist of oil and natural gas.

From Table 2 it can be seen that the Greek energy system will continue to be dominated by the fossil fuels which are expected to cover more than 92% of the total needs of the country in primary energy.

TABLE 2. ENERGY BALANCE (IN KTOE)

	1995	2000	2005	2010	2020	2030
TOTAL PRIMARY ENERGY	27909	31928	36808	40523	44878	47337
Primary Production	9702	9946	11103	11924	11889	11325
• **Solids**	7911	8222	8947	9426	8878	7885
• **Oil**	459	280	0	0	0	0
• **Natural gas**	44	42	0	0	0	0
• **RES**	1289	1403	2156	2498	3011	3440
Net Imports	18207	21982	25706	28600	32989	36013
• **Solids**	925	768	798	694	702	2143
• **Oil**	17214	19527	20631	21727	23898	25129
• **Natural gas**	0	1689	4276	6170	8373	8723
• **Electricity**	69	-1	1	10	15	17
LOSSES / STORAGE	3772	3852	4121	4472	5135	5834
GROSS INLAND CONSUMPTION	24137	28076	32688	36051	39743	41503
• **Solids**	8783	9040	9745	10119	9581	10028
• **Oil**	13952	15929	16510	17255	18763	19295
• **Natural gas**	44	1705	4276	6170	8373	8723
• **Electricity**	69	-1	1	10	15	17
• **RES**	1289	1403	2156	2498	3011	3440
Import Dependency (%)	66	69	70	71	74	76

However a considerable differentiation in the structure of the country's energy balance will take place mainly due to the large penetration of natural gas, of which the contribution from 7.5% in 2000 will reach 17% in 2010 and 21% in 2020 covering together with the Renewable Energy Sources (RES) the largest part of the increase in the country's needs in primary energy.

The above development is the result of the very large penetration of natural gas in new electro-production units and in cogeneration as well as the considerable increase in the penetration of RES, as can be seen in Tables 3 and 4. The contribution of natural gas units and RES in electro-production from 8.3% in 2000 will reach 32% in 2010 and 40% in 2020.

During the '70s and '80s the exploitation of indigenous energy sources was the dominant argument towards energy independence. As a result, in the mid '90s generation from indigenous lignite represented more than 67% of the total produced electricity, while hydro production was around 10%.

Since the beginning of the '90s, mainly because of environmental reasons, the Public Power Corporation (PPC) of Greece scheduled new generation units (1560 MW) with natural gas. As a result, in the late '90s in the sector of electro-production a gradual substitution of oil by natural gas took place. Also, the lignite based expansion program continued by committing a new 300 MW unit having a supercritical boiler.

TABLE 3. PROGRESS OF INSTALLED CAPACITY (IN MW) FOR ELECTRICITY PRODUCTION

	1995	2000	2005	2010	2020	2030
Lignite	4533	4900	5250	5110	4577	3164
Other conventional thermal plants	2009	2269	2349	2349	1950	979
Natural gas	275	845	2022	4166	6482	6972
Gas turbines / Internal combustion	221	361	857	1054	1255	1726
Coal	0	0	0	22	1408	4940
Large hydro	2244	2397	2482	2658	2658	3040
Small hydro	0	10	150	150	216	225
Wind generators	30	189	741	958	2280	3126
Other RES	2	3	4	5	7	160
Total	9314	10974	13855	16472	20833	24332
Peak Demand	6060	8704	10612	13179	16974	21041
Reserve (%)	34.9	20.7	23.4	20.0	18.5	13.5

TABLE 4. CONTRIBUTION OF PLANTS IN ELECTRO-PRODUCTION (IN GWH)

	1995	2000	2005	2010	2020	2030
Lignite	28020	30685	33760	35686	27623	18603
Other conventional thermal plants	8134	12597	8191	7567	6742	4403
Natural gas	407	3977	14506	22020	30266	32194
Gas turbines / Internal combustion	1167	1738	2167	2420	2788	2775
Coal	0	0	0	170	10486	29108
Large hydro	3528	3690	5261	5651	5151	5865
Small hydro	0	2	299	299	428	445
Wind generators	34	451	1507	1899	4232	5812
Other RES	0	0	4	5	8	259
Total	41291	53159	65696	75717	87724	99464

In 2010 the installed capacity should be 50% larger than that of 2000, which was 11000 MW, while until 2020 it should be increased further by 26%. The technology of combined cycle units using natural gas prevails as the least cost solution to expand in the mid-term the generation system. The above conclusion assumes the competitiveness in price of natural gas, in conjunction with the competitive operation of the energy markets. Thus, natural gas units will represent during the current decade about 70% of the new capacity, while their total contribution will reach 25% in 2010 and 29% in 2020. However, in the long run the trend of increasing prices for hydrocarbons along with the improvement of clean coal technologies, could lead these technologies to be competitive for base load. Also, with the exception of isolated islands, no investments in oil units are foreseen.

The contribution of RES, including the capacity of large hydro plants, amounts to 25% of the total installed electro-production capacity for all the period examined. However, their contribution in the total energy produced is less, and in 2010 it will amount to 10%, considerably smaller than the national goal in the framework of European policy for the penetration of RES, which for the year 2010 is 20.1%. Additional measures to support RES will be required in order to reduce this difference. It should be noted that the penetration of RES in the electro-production system after the year 2010 would take place without support through subsidies. It is expected that by the end of 2030 a significant number of small RES units, mainly wind generators, will be installed, whose capacity will exceed 3500 MW, one third of which will be installed by 2010.

A smaller interest is observed for the construction of new water reservoirs for electricity generation due to economic and environmental reasons. Furthermore, a remarkable introduction of co-generation technologies is not anticipated, due to the limited use of steam by the industrial sector and because of the climatic conditions in Greece.

Final Energy Demand

The contribution of fuels in final energy demand is expected to vary considerably, due to the penetration of natural gas. The contribution of natural gas will increase significantly in all sectors, from 1.3% in 2000 to 10.2% in 2010 and over 12% in 2020. Oil products will remain as dominant fuels, however their rate of increase will be smaller than that of the total demand, due to their substitution by natural gas. Their contribution in the final consumption, from 67% in 2000, will be reduced to 57% in 2010 and to 55% in 2020. The use of oil products is expected to be gradually limited to transportation, generation of electricity in isolated islands, petrochemical industry and other specialized uses.

The electricity demand will increase with a rate that is greater that the increase rate of the total final energy demand.

The energy demand in the tertiary and the domestic sectors will increase most rapidly in the other sectors, reflecting the reorganization of the economy towards the sector of services as well as improvement of living standards.

Transportation is and will remain the sector with the largest energy consumption in Greece. The rate of increase for the consumption will decrease from 2.3% in the current decade to 1.2% in the next decade. Thus, the contribution of the transportation sector in the final energy demand will reduce from 40% in 1995 to 37.4% in 2010 and 36.7% in 2020, remaining however the most energy consuming sector of the economy.

Environmental consequences

CO_2 emissions in 2000 were increased by 25.4% in relation to 1990 and according to estimates an increase of 48.4 % is anticipated in 2010, if the current rate of emissions continue (baseline scenario). The increase in CO_2 emissions for the various sectors is shown in Table 5.

From Table 5 it can be seen that all sectors increase their emissions, but the tertiary and electro-production sectors increase their emissions more considerably because of their increased activity.

TABLE 5. CO_2 EMISSIONS PER SECTOR IN BASELINE SCENARIO

CO_2 emissions per sector (Mtn)	1990	Contribution %	2010	Contribution %	Increase (1990=100) %
Industry	9.45	13.3	11.89	11.3	25.8
Tertiary	2.86	4.0	4.64	4.4	62.3
Residential	5.11	7.2	6.76	6.4	32.2
Transportation	17.21	24.2	26.15	24.8	51.9
Electricity and steam production	34.34	48.3	52.61	49.8	53.2
Energy	2.14	3.0	3.50	3.3	63.3
Total	71.1	100.0	105.5	100.0	48.4

It should be noticed that the baseline scenario includes all current adopted policies. However, under this scenario, the deviation from the desired target (+25%) is considerable. The deviation would become even larger if new generation included coal or lignite power stations.

The introduction of natural gas in the energy balance of the country, as well as the penetration of RES in the electro-production in combination with the reduced contribution of conventional fuels lead to a small reduction of CO_2 emissions per energy consumption (tn CO_2 /toe) with an average annual rate of -0.8% for the period 2000-2010, -0.4% up to 2020 and -0.2% until 2030. Practically CO_2 emissions follow the evolution of the primary energy demand and increase with a rate of 1.7% for the period 2000-2010, 0.6% for the period 2010-2020 and 0.3% for the period 2020-2030.

As it can be seen in Table 6, the total CO_2 emissions increase, compared to the 1990 levels, until 2010 by 48.5%, in 2020 by 57.8% and in 2030 by 62.3%. However, the increase of emissions per sector differs. For 2010, the sector with the largest share in emissions is electro-production, with 49.8%; the transportation sector follows with 24.8% and then the industry sector with 11.3%.

The largest increase in emissions appears in the tertiary sector, 62.3% in 2010, due to considerable increase in its activity. The same can be seen for the sectors that follow, like electro-production with 53.2% and transportation with 51.9%.

In the sector of electro-production, the combination of using fuels with lower content in carbon and the increasing share of RES results in a significant improvement of the emissions per produced kWh (from 0.83 tn CO_2/ kWh in 1995 to 0.49 tn CO_2/ kWh in 2030). The CO_2 emissions that are avoided in 2010 amount to 14.65 million tons, due to the change of the mix of electro-production plants.

TABLE 6. CO2 EMISSIONS PER SECTOR IN BASELINE SCENARIO

Index (1990=100)	1995	2000	2005	2010	2020	2030
Industry	105.7	106.8	121.5	125.8	129.9	136.6
Tertiary	111.8	117.1	135.0	162.3	197.5	220.1
Residential	93.1	145.4	123.1	132.2	152.9	145.2
Transportation	110.5	123.4	142.4	151.9	170.2	173.5
Electricity and steam production	113.3	127.1	140.8	153.2	155.5	160.3
Energy	109.9	159.3	155.4	163.3	176.4	181.3
Total	110.0	125.4	137.5	148.5	157.8	162.3

The following Table summarizes the required, by 2010, reduction in CO_2 emissions in order to succeed from the baseline scenario (+48.5%) the commitment of +25% according to the national actions devised by the Athens National Observatory [3]:

TABLE 7. TARGET REDUCTION BY SECTOR

	Measure	ktn CO_2 reduction by 2010 Max - Min
a	**Residential and Tertiary Sector** (energy conservation in buildings, heating boilers, air-conditioners, solar collectors, electric appliances, lighting, larger penetration of natural gas, etc)	9303 - 7480
b	**Transportation** (increased use of means of mass transportation, biofuels, etc)	1369 - 1335
c	**Industry** (further penetration of natural gas, energy conservation, etc)	1684 - 1282
d	**Electro production** (further penetration of RES, conversion of fuel oil stations to natural gas stations)	9211 - 8081
	TOTAL	21567 - 18178

SCENARIO FOR ENVIRONMENTAL POLICY

Under this scenario the increase in CO_2 emissions is limited to the level of 25%, in comparison to 1990, for the period 2010 - 2025 while for the period 2025 - 2030 the increase is limited to the level of 32%. All other assumptions are similar as in the case of the baseline scenario.

The achievement of the above targets requires adjustments of the economic system. These adjustments due to the enforcement of the limiting constraints, under minimum cost, were determined by simulating, through the model PRIMES, the reaction of the energy system when fuel costs include environmental cost. This cost represents the minimum additional cost for the energy system to reduce one tn of CO_2. For the specific scenario the resulting cost was 67 Euro ´90/ tn CO_2.

Adjustment of the economic system consists mainly of energy conservation programs but also of fuel substitutions, which lead to reduction in carbon content of the energy fuel mix. The most important change in the structure of primary energy is the large reduction in the consumption of solid fuels not only because of the reduction in demand but also because of their substitution by other fuels having less content in carbon. Also, reduction of other forms of fossil fuels and considerable increase of RES is noticed. These changes in association with the baseline scenario form the environmental policy scenario. The impact of the adjustments on the emissions per sector, compared to the baseline scenario, is given in Table 8 for 2010.

As it can be seen from Table 8, the limitation of pollutants is due mainly to the large reduction of CO_2 emissions in the electro-production sector. For the specific sector, the reduction of emissions in 2010 is 12.52 million tons annually (from a total reduction of 16.72 million tons), that is a reduction of 23.8% compared to the baseline scenario. On the other hand, the contribution of the other sectors in emission reduction, compared to the baseline scenario, is smaller. The reduction in the sector of industry, the tertiary sector and the residential sector is around 10%. For the transportation and energy sectors, the reduction achieved is even smaller, 7% and 3.4% respectively, due to their inelasticity.

TABLE 8. 2010: CO_2 EMISSIONS PER SECTOR FOR BASELINE & ENVIRONMENTAL POLICY SCENARIO

CO_2 emissions per sector (Mtn)	2010 Baseline	Contribution %	2010 Environmental	Contribution %	Difference Mt	%
Industry	11.89	11.3	10.83	12.2	1.06	-8.9
Tertiary	4.64	4.4	4.13	4.6	0.51	-11.0
Residential	6.76	6.4	6.08	6.8	0.68	-10.1
Transportation	26.15	24.8	24.32	27.4	1.83	-7.0
Electricity and steam production	52.61	49.8	40.09	45.1	12.52	-23.8
Energy	3.50	3.3	3.38	3.8	0.12	-3.4
Total	105.55	100.0	88.83	100.0	16.72	-15.8

The reduction in CO_2 emissions per sector of economic activity is not the same. Detailed results for the study period are given in Table 9. Next, the changes in each sector are presented.

Changes in the industry sector: The reduction of emissions is a result of the reduction in demand (energy saving), as well as of the improvement of utilized technologies, which cause fuel substitutions in the industry sector and further energy savings. The largest percentage of reduction in emissions is due to the restructuring of the industrial processes (for example, more material recycling) and less because of the reduction in demand, where the industry sector does not present large flexibility. Also the improved electric technologies and the heat pumps contribute through respective substitutions in emission reduction.

TABLE 9. CO_2 EMISSIONS PER SECTOR IN ENVIRONMENTAL POLICY SCENARIO

Index (1990=100)	**1995**	**2000**	**2005**	**2010**	**2020**	**2030**
Industry	105.7	106.8	114.5	114.6	115.6	122.9
Tertiary Sector	111.8	117.1	123.0	144.5	173.7	197.3
Residential Sector	93.1	145.4	112.6	119.1	128.7	128.9
Transportation	110.5	123.4	137.3	141.3	149.4	158.8
Electricity Generation	113.3	127.1	127.8	116.7	103.9	114.1
Energy Sector	109.9	159.3	151.7	158.5	166.2	174.7
Total	110.0	125.4	127.8	125.0	123.0	132.4

Changes in the tertiary and the residential sectors: The tertiary sector seems to have significant margins to reduce emissions since the corresponding final energy demand reduces considerably in the order of 10%. The residential sector reduces the demand in smaller percentage, in the order of 7%. This reduction in the residential and tertiary sector is succeeded through the utilization of more efficient electric appliances but also through the reduction in their energy needs because of improved building installations. In addition, the residential sector offers significant margins to reduce emissions through substitutions in favor of natural gas and electricity. It is noticed that, because of efficiency, the direct utilization of natural gas in the residential sector is superior to the indirect utilization of electricity.

Changes in transportation sector: The reduction of emissions follows the reduction of demand, around 7%. The most important change in this sector involves trains and planes where the average efficiency increases and the market share reduces. With regard to road transportation, change in the market behavior of consumers but also in car utilization is observed, while no significant improvement in the vehicle's technology is expected. Only the enforcement of drastic constraints in emissions in the transportation sector can lead to significant technological changes.

Changes in the sector of electro-production: The sector of electro-production can adjust more than any other sector to a reduction of emissions with the least cost. This is achieved through the use of non-carbon primary energy sources (like hydro plants and RES) and by improving their total efficiency. The improvement of the total efficiency is achieved either by adopting new technologies or with alternative combinations of technologies and fuels (e.g. combined cycle units). Finally, the total efficiency can be improved through the increase of the degree of cogeneration heat and electricity. The changes related to the fuel consumption of power stations that the scenario for environmental policy brings to the baseline scenario are given in Tables 10 and 11.

TABLE 10. DIFFERENCES BETWEEN BASELINE AND ENVIRONMENTAL POLICY SCENARIOS IN THE ELECTRO-PRODUCTION SECTOR

GWH	1995	2000	2005	2010	2020	2030
Lignite	0	0	-2790	-11257	-22432	-18095
Natural Gas	0	0	-4054	-14	2852	9438
Supercritical Units	0	0	0	0	9146	2402
Clean Technologies	0	0	0	-170	-98	-84
Wind Generators	0	0	1042	1889	997	663
Large Hydro	0	0	0	562	682	0
Small Hydro	0	0	77	670	736	757
Other RES	0	0	0	0	71	26
Other Thermal	0	0	1007	2366	1624	-306
Total	**0**	**0**	**-4795**	**-6894**	**-7228**	**-5983**

TABLE 11. CHANGES BETWEEN ENVIRONMENTAL POLICY AND BASELINE SCENARIO IN FUEL ONSUMPTION (KTOE) FOR ELECTRO-PRODUCTION

	1995	2000	2005	2010	2020	2030
Lignite	0	0	-748	-3073	-4351	-4617
Coal	0	0	0	-32	-195	0
Oil Products	0	0	0	0	0	0
Natural Gas	0	0	-616	-29	353	1244
Total of Fossil Fuels	0	0	-1364	-3134	-4193	-3373
Biomass, Geothermal, New fuels	0	0	38	188	246	169
Total	**0**	**0**	**-1325**	**-2946**	**-3946**	**-3204**

From the above Tables it can be seen that there is significant reduction in the total produced energy as a result of the reduction in demand. Until 2010 it is noticed a substitution of energy produced by natural gas and lignite units by energy produced mainly by wind generators but also by the other conventional thermal stations (liquid fuels). From 2010 up to 2030 the situation changes. The reduction of the production by lignite units continues, the production by natural gas increases and there is considerable increase in production by hydro stations and units of supercritical coal.

Economic impacts: As it was mentioned before, the shadow price to succeed the target of 25% was calculated as 67 Euro ‘90/tn CO_2. The total cost for the adjustment of the energy system to the new conditions was estimated on annual basis in the order of 490 MEuro. This cost represents the increased investments in the various sectors. Of course these investments cannot be considered as net burden on the economy since a large portion of these investments recycle in the sectors of the economy.

Conclusions

The analysis of the scenarios mentioned above leads to the following conclusions [2], [4]:

- It is rather unlikely for Greece to satisfy the commitment towards the Kyoto protocol without significant policy changes. Instead of increasing CO_2 emissions in 2010 by 25% it is estimated that an increase in the order of 48.4% will take place. Depending also on the measures for the greenhouse emission gases not containing CO_2, such as CH4, a series of political initiatives is required for the reduction of the emissions associated with the energy system.
- Reductions in energy demand, the tendency of the fuel mix towards the natural gas and the changes in electro-production to the benefit of non fossil fuels, contribute considerably in the reduction of emissions. All the above reduce also the pollutants causing acid rain, which can be considered as an additional benefit.
- The timely application of policy measures, which will lead to the reduction of emissions, is very important, since the delayed enforcement of restrictions to the emissions will increase considerably the implementation cost, making the compliance of the energy system to the Kyoto protocol in the future unfeasible.
- The utilization of natural gas in the electro-production and the substitution by the natural gas of other fuels in the industry, tertiary and residential sector presents multiple benefits, since it not only leads to the reduction of CO_2 emissions but also allows the application of edge cutting technologies in the above sectors, improving considerably the efficiency of the energy system.
- The long-term supply of the Greek energy market with natural gas in sufficient quantities and competitive prices is a permanent goal of the energy policy.
- The promotion and support of renewables in Greece is also important. It is expected that during this decade the impact of wind farms and small hydro stations in the reduction of emissions will be essential.
- The policy regarding energy savings should continue and intensify in the near future. The improvement of building facilities, the utilization of more efficient technologies and the actions that will lead to the adjustment of the consumers to the new needs of the energy system, will contribute considerably to the total effort in achieving the goals of energy policy. There is great uncertainty regarding the ability of realizing the measures for the domestic and tertiary sector because they mainly refer to interventions in existing buildings and houses.
- It is pointed out that a realistic evaluation of an achievable level of emissions for 2010 is +35% in comparison to 1990 (opposed to 48.4% that would occur in the baseline scenario).
- The policy measures, which will lead to the reduction of energy consumption in the transportation sector, should encourage mass transportation and the enforcement of limiting measures on emissions. The last assumes the enforcement in Greece also of the agreements at European level with the car manufacturers. Finally the renewal of vehicle fleet is of paramount importance.
- Although the assumptions concerning technological advances are conservative, the energy sector is open to cut edge technologies.

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3. CLEAN POWER GENERATION TECHNOLOGY FOR THE 21STCENTURY - A PERSPECTIVE FROM THE EU POWER PLANT SUPPLY INDUSTRY

Nick Otter, Director of Technology and External Affairs, ALSTOM Power, UK

A perspective from the Power Plant and Services Industry is presented with respect to the impact of Global Climate Change on product development strategy. Such environmental drivers, typified by the increasing public and political desire to introduce measures that will reduce GHG (especially CO_2) world-wide, have to be positioned against the other key market issues of wider globalization, increased liberalization, deregulation and privatization - all of which contribute to the substantial changes in the energy market world-wide.

Although there is substantial interest in the development of energy from renewable sources, it is clear that fossil fuel based power generation technologies will continue to play an important part of the energy mix in the foreseeable future and that different parts of the world will require different technologies to meet their local specific requirements. It is predicted that primary energy growth will continue at an average global rate of approximately 1.7% per annum over the next 30 years (IEA World Energy Outlook 2002), with electricity demand being projected to double by 2030 growing at an annual rate of roughly 2.4%. Also electricity demand is likely to be strongest in the developing countries, where demand could climb to around 4% per annum and tripling by 2030. Many of these developing countries will use large indigenous supplies of fossil fuel to meet this demand, especially coal and gas.

Consequently, in order to meet the environmental challenge arising from national and international efforts to reduce the effects of climate change, it will be necessary to continue to develop clean technologies and to promote their use world-wide. Cost effectiveness will remain a critical issue. For fossil fuels this will mean continuing to improve efficiencies, developing and introducing competitive new systems, and ultimately achieving near zero emission through CO_2 capture and sequestration.

European industry – typified by ALSTOM Power, one of the large international players in world energy markets, and representative of the equipment and service sector in Europe - is addressing these issues. The strategy being adopted covers the important aspects of (i) increased efficiency, thereby reducing the ratio of CO_2 produced per unit of fuel used (ii) switching to low carbon fuels, for example from coal to gas including retrofit and re-powering options (iii) renewable energy, including hybrid technologies and co-firing with biomass, and (iv) the development of cost effective CO_2 capture technologies and systems that include a future link to hydrogen production.

The presentation also covers the aims and content of Global Climate Change related work, how environmental matters in a rapidly changing market are monitored, and the consequent impact on technology acquisition strategy. Within the European Union, with the launch of the European Commission Research Framework Programme FP6 (due to run from 2003 to 2006) and associated national Member State programmes, there is an increasing desire to collaborate on longer term energy issues that are critical to Europe, for environmental reasons but also increasingly for security of supply and competitiveness of European industry reasons. The capture and storage of CO_2, especially associated with clean fossil fuel power generation plant, has been identified as a specific high priority theme and is becoming increasingly regarded as one of the critical transitional technologies in the move towards a sustainable future. How European industry is responding is assessed.

In conclusion, the concerns of industry will have to be considered in the context of future energy policy. Of critical concern are the mechanisms and measures required to successfully meet the challenge of introducing new technology into the market place.

1. THUMBNAIL OF ALSTOM

First, a thumbnail of ALSTOM is made. ALSTOM Power is one of the largest Energy and Infrastructure Suppliers in the world. Total ALSTOM revenue in 2001/2 was 24 billion euro and the organization employed 118,000 people. The Power Sector revenue in 2001/2 was 13 billion euro with 43,000 people, 70% of which are resident in Western Europe, mainly in UK, Germany, France, Sweden, and Switzerland. The organization has a strong global operating base of power plant with over 1100 GW installed. It has a wide product range of conventional and advanced power generation products and technologies.

ALSTOM is one of the lead representatives for the `sector` in Europe and worldwide. It is active in a wide number of governmental activities in the countries in which it has a major presence. For example, in UK it has been involved in Energy Foresight since its inception and is now chairing the APGTF and ZEPG Group, both dealing with advanced power generation systems; in Europe it has advised the EC on Energy RTD on Non Nuclear Energy, and chaired the EC Energy WG on Energy RTD Strategy for Europe.

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1.1 Working with Governments to Set Future Energy Research Agenda

One of the main tasks is to work with Governments to set future Energy Research agenda. The activities in the UK are representative of the activities performed and these are described in more detail in the three following sections under the headings of:

- The Current Baseline: The Sector and the Changing Market Scene
- The Industry Response: an Energy Equipment, System and Service Providers Viewpoint, as illustrated by ALSTOM Power Programmes, and
- The Future: What is next

2 THE CURRENT BASELINE

As a major equipment, systems and services provider, ALSTOM has a wide product range of conventional and advanced power generation products and technologies. The aim is to satisfy the growing need for energy and electricity throughout the world, operating in a global way and in competition with other global players.

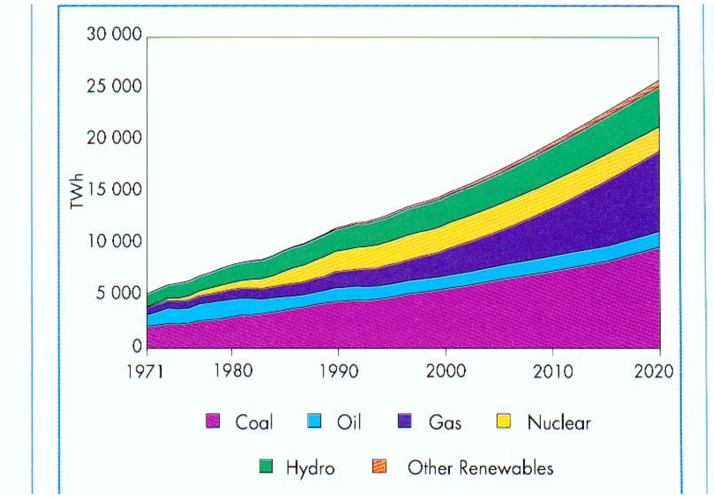

Figure 1. Energy Growth Curve

It is recognized that there will be a continuing reliance on fossil fuels in the energy mix, especially for countries like China and India. There will be a continuing need for more efficient, cleaner and more reliable power plant within a portfolio approach. Also it is recognized that installed capacity is ageing and within the next decade or so many plant will reach the end of their lives.

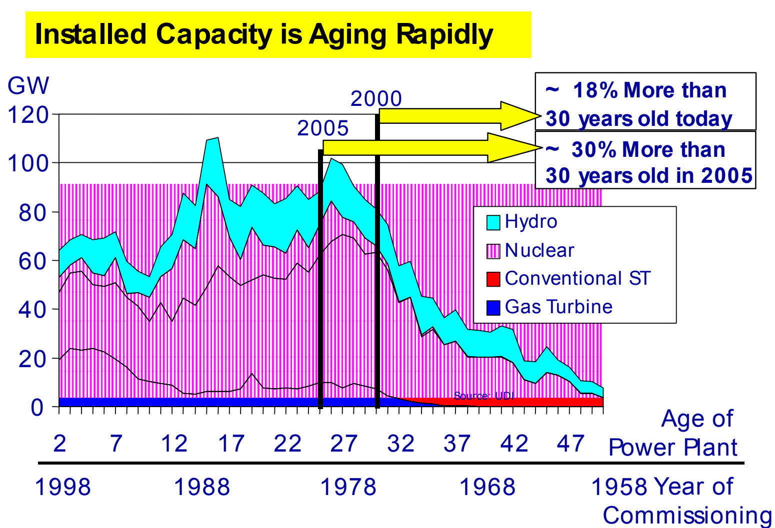

Figure 2. Ageing Plant

2.1 Global Position

The global market continues to be cyclic in nature, typified by the two major booms within the last decade.

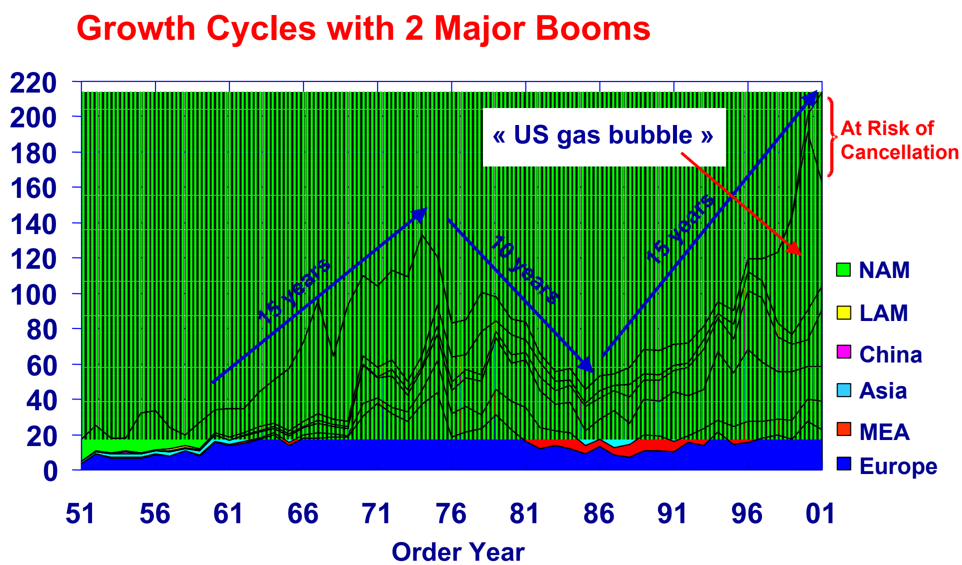

Figure 3. Sales Chart from 1990 to 2000

Against this background there is a significant impact of increased liberalization/re- and de-regulation/privatization in the market place. Electricity is becoming a `commodity` to trade with more open markets, driving down the cost of electricity. There are new operators, new trading rules and a real change in products/services. This makes future investment difficult and it is problematic to get advanced technologies accepted in what is an increasingly risk minded market. As a result markets continue to fluctuate and are difficult to predict.

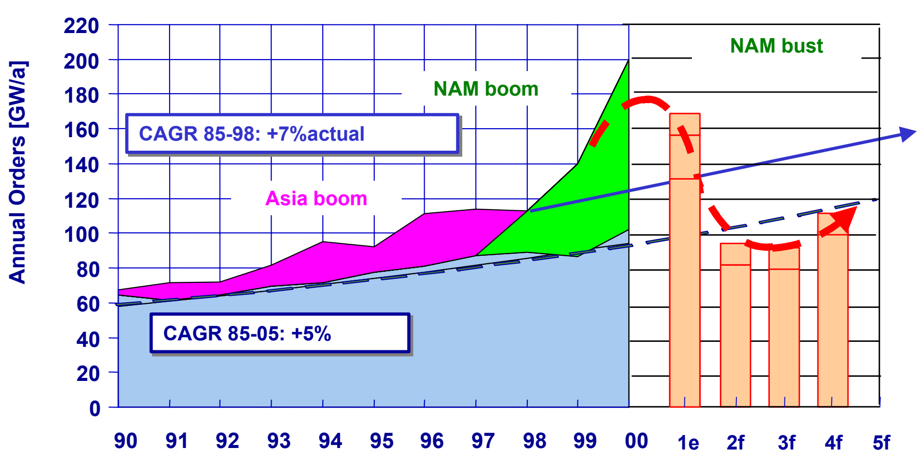

Figure 4. Down Turn and Uncertainty

There is a highly competitive market:

- Risk adverse culture with more focus on financial return
- Cyclic nature of business
- Cost effectiveness (euro/kW and euro/kWhr continues to be the key).

2.2 Energy Market Increasingly Hard to Understand and Predict

There is increasing importance of the environment as a market driver, with emphasis on CO_2:

- Global Climate Change implications (UK RCEP quoting need for 60% reductions by 2050)
- Tighter emission directives (e.g., EC LCPD)
- National and international Emissions Trading Schemes starting up.

Drive for more REN and Energy Efficiency, especially in Europe

- REN Targets being set - UK for instance, 10% by 2010 and a desire for 20% by 2020
- Promotion of CHP at national and European level
- Awareness of Environment Implications on Energy.

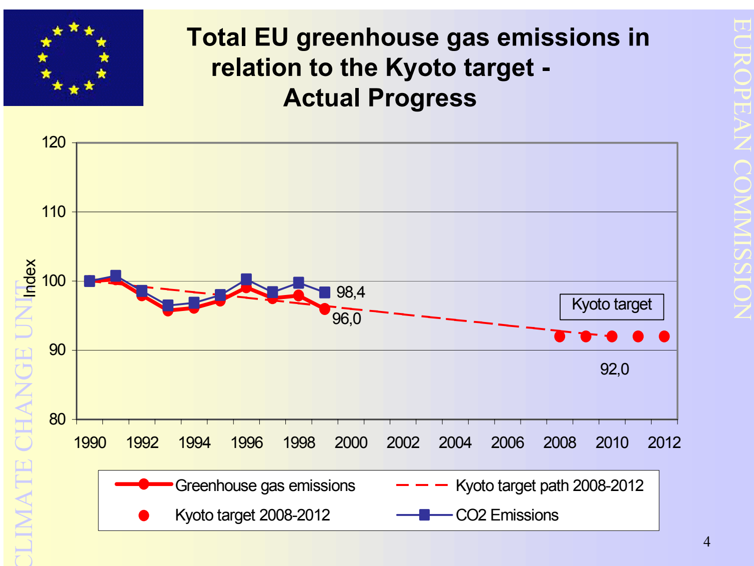

Figure 5. GHG Trend

The environment is a key driver that needs to be addressed in the full context

3. THE INDUSTRY RESPONSE

This is illustrated by some of ALSTOM Power activities in relationship to awareness of environment implications on energy.

Activities:
- Political Developments
- Legislation Issues
- Emission Trading
- Economic Assessments
- Emerging Technologies
- Collaborative Programmes.

Involvements:
- IEA GHG/CCT and ZET initiative
- MIT global climate change programme
- Advisory Boards of important networks: EC CO2NET/POWER CLEAN/CAME-GT Networks; European Climate Forum; UK Tyndall Centre on Climate Change.

3.1 Constant Observation/Analysis--Prepare for the Future

Matters arising are:

Global Climate Change (up to and post 2050) targets will need full range of solutions:
- Acceptability of nuclear?
- Developing countries (e.g. China) have to be engaged if GCC is really to be tackled.

Security of Supply Implications:
- REN will become significant in the energy mix only in time (post 2020)?
- Economics
- Continuing reliance on fossil fuels for decades to come.

Mitigation of CO_2 requires clean use of fossil:
- Improved efficiency/fuel switch/co-firing/retrofit/CO_2 capture/sequestration.
- A major transitional issue will be clean use of fossil fuels.

3.2 CO2 Capture Options

These include:
- Tail end CO_2 capture: adsorption/stripping process using MEA, physical absorbents, etc.
- Oxygen combustion: internal (membrane) or external (ASU) oxygen supply
- Other options: oxidation/reduction cycles; carbonate capture; chemical looping.

  These options should be aimed towards zero emissions at the right price.

3.3 Key Basic Technology Modules

These include:

- Process design and economic evaluation, including 'virtual demonstration'
- Combustion in alternative oxidants ($O_2/CO_2/H_2O$) and with alternative fuels (syngas, bio-gas, H_2)
- Integration of air separation technologies (cryogenic, membrane based) into power plants
- CO_2 conditioning, expansion/compression and sequestration
- Ceramic technologies (production, design, joining).

4. THE FUTURE: WHAT IS NEXT

Some Industry concerns are:

Uncertainty and Change:

- Difficult to forecast future; no one single winning technology; broad balanced portfolio approach - fossil, REN and nuclear (?)
- Impact of a real value for CO_2 - Emission Trading/Tax implications; market could change dramatically
- Industry trying to position itself developing strategy towards ZEPG with fossil fuels: efficiency improvement, fuel switch/co-firing/retrofit, CO_2, capture and storage.

Basis for Opportunity:

- Consistent policy to give sufficient confidence to underpin private sector investment and RTD
- Really tough to get new advanced technologies into the market place
- Correctly targeted market based measures/incentives for technology take-up commensurate with RTD Programmes.

4.1 <u>Need for Balanced Broad Based Consistent Approach to Energy Policy to set the Right Framework</u>

Government Initiatives include:

European Countries:

- UK: Government White Paper on Energy Policy with Environment at the heart of policy - March 2003
- Germany: new CORETEC Programme addressing clean fossil alongside REN
- Denmark: KLIMATEK Programme.

European Commission/EU:

- EC Framework 6 (2003-2006) theme of 'CO_2 Capture and Storage associated with clean power and fossil fuels'

- Building on basis established under FP5 (projects AZEP/GRACE/CO2STORE GESTCO/NASCENT plus networks of CO2NET/POWERCLEAN/CAME-GT)
- Seeking large 'integrated projects' of critical mass with an international dimension and 'networks of excellence'.

4.2 Increasing Government Recognition of Zero Emission Issue for Fossil Fuels

Some final thoughts are:

CO2 Capture and Storage:
- Need for early experience associated with PG technologies at large scale
- Use EOR as an early way to introduce the technology (e.g., North Sea Window of Opportunity)
- Continue active international co-operation and collaboration.

Setting the Future Agenda:
- Important to bring together different Industrial Sectors with government and research: Power Generation; Oil and Gas; Chemical and Industrial
- must be some early benefits to engage industry
- innovation will be at the heart of the ability to meet a reconciliation of the future complex global energy and environmental issues.

In conclusion, there is need for incentives and policy measures to engage the industry with real commitment/support from Governments.

Nick Otter is currently Director of Technology and External Affairs - a senior technology role within ALSTOM Power, a company formed in 1999 by the merger of the power generation activities of ABB and ALSTOM and resulting in one of the largest power generation equipment and service providers in the world with a turnover of over 11 billion euro.

Prior to the formation of ALSTOM Power, he held the position of Director of Technology within the Core Technology Group of ALSTOM Energy. This followed being the Director of Engineering Research Centre at Whetstone, Leicester (1988 - 1992) that was formerly part of GEC Research Ltd. Prior to this, he held various engineering positions with GEC Power Systems, with particular emphasis on high temperature structural performance in nuclear and conventional plant. He was educated at Manchester University 1966-69 and Sheffield University 1970-72 and has Degrees in Applied Mathematics and Engineering.

Current responsibilities include the external acquisition and provision of technologies necessary to underpin the future development of the Company's products, including direction of the corporate university programme for ALSTOM Power. This involves the understanding of future market needs, including the impact of global environmental and energy issues, and the alignment of a technology strategy to be consistent with those of Europe and the national countries in which the Company has a presence.

4. LIMITING THE GREENHOUSES GASES: A POSSIBLE ITALIAN STRATEGY IN THE EUROPEAN FRAMEWORK

L. Priori, Consultant, Edison Spa, Italy; L. Salvaderi, Consultant, Rome, Italy, IEEE Fellow

1. THE COMMITMENTS OF THE KYOTO PROTOCOL

The Kyoto Protocol (KP) is an addendum to the United Nations Framework on Climate Change (UNFCC), signed in December 1997 and represents a treaty, potentially binding to reduce six greenhouse gases (GHGs) [carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), sulphur hexafluoride (SF6), hydro fluorocarbons (HFCs), per fluorocarbons (PFCs)], to combat global climate change.

Limits are assigned in terms of "carbons equivalence", since the above mentioned GHGs differ in term of how much a given quantity of each traps solar energy, for trading purposes they must be standardized: for instance 1 kg of Methane (CH4) is equivalent to 21 kg of CO2.

The most industrialized countries **have committed to reduce their emissions of GHGs by an average of 5.2*%* in respect the level of 1990 *by the 2008-2010 ("first commitment period")*.**

The *developing countries are not* subject to caps.

The Kyoto Protocol shall enter in force when a minimum of 55 Countries (Parties to the United Nations Framework Convention on Climate Change (UNFCCC)) that account for at least 55% of the CO2 emission in 1990 have ratified. Thus far the ratifying countries are 116, which accounts for some 44%; a decision of Russia, which could increase the percentage up to 61.6%, is expected.

Under the KP*, the European Union* has agreed a reduction target *of 8%* during the first commitment period; its 15 Members made on 4/3/2002 an internal agreement to distribute the total target in various "burden sharing". With decision dated 25/4/2003 the EU and its entire MS ratified the KP.

Italy, who ratified the agreement with the bill N^0 120/2002 on 1/6/2002, has committee itself to a burden sharing of *–6.5%* of the 1990 emission level (521 Mton), with a corresponding target of 487 Mton by 2010.

In the Kyoto Protocol no clear penalty regime for non-compliance exists. Each individual signatory nation is liable for the implementation of its responsibility; parties may form regional blocks, as the EU did, which may fix emission reductions commitments. However, in the event of regional non-compliance, the signatories will be held responsible separately.

2. MECHANISMS TO MEET COMMITMENTS

The Kyoto protocol established three mechanisms to allow countries flexibilities in meeting their commitments: the first two are "project-based"; the third one is international Emission Trading.

The project-based mechanisms, under the rationale that GHGs reduction is a *global* issue and therefore the place where the reduction take place does not matter, enable the various Countries to meet *only part* of their commitments by reducing GHGs emissions in other countries *at lower cost* than "at home" gaining credits. Nonetheless, the industrialized countries keep the responsibility to reduce domestic GHGs. The two-project based mechanisms are:

- *Joint Implementation (JI):* can be implemented jointly between two or more *developed countries* or countries with *economies in transition.* JI applies only to nations that have quantitative emission caps under KP. The related emission reductions against a baseline are called Emission Reduction Units (ERUs), issued by the host Country. The *total emissions allowed* in the concerned countries *remains the same*: correspondingly JI is a "*zero sum operation*".

JI can also be implemented between two Member States of the EU: naturally also in the case the "zero sum" provision is valid within the EU.

It is expected that JI will take place particularly in Russia, showing a great potential for transfer of advanced technologies.

- *Clean Development Mechanism (CDM):* Investors of the developed countries make projects in *developing nations,* which have no quantitative targets, and receive *Certified* Emission Reduction (CERs) units for the *additional* amount of GHG reduction achieved against a baseline. A UNFCCC body supervises the CDM, which is responsible for issuing of the CERs. The CDM is expected to transfer advanced technologies to developing countries, a vehicle for assisting them in the efforts for poverty alleviation and economic reforms.

The draft Directive provides for application of the mechanisms to begin as of 2008, subject to the KP entering into force.

The third mechanism is the Emission *Trading (ET):* a "cap & trade " mechanism, with an ex-ante allocation of allowances, applied only to countries with targets. After long debate and various institutional passages, the EU Council adopted a common position on March 2003 and an Emission Trading Directive is expected by 2003. It will *not* officially start until the Kyoto protocol enters into force

Since difficulties and risks for the investments were perceived due to the lack of definitions in force internationally and of standard procedures for the nations assumed to participate to the JI and CMD projects, the Commission issued at the end of July 2003 a further Draft Proposal, namely an amendment to the ET Directive, where the JM and CDM are recognized as equivalent – within certain limits- to the ET allowances for their use within the Community to fulfill their obligation. The key elements of such proposal will be described in a following paragraph.

3. THE EUROPEAN EMISSION TRADING DRAFT DIRECTIVE

3.1 The main institutional steps

The European Directive for Emission Trading (ET): -i) was launched by the Commission in October 2001; -ii) The Draft was approved by the European Parliament in a "first reading" on October, 10, 2002; -iii) A *common political position* was obtained by the EU Environment Ministers Council on 9 December 2002 and adopted on 18 March 2003; - iv) Amendments were tabled by MEPs in April 2003 and a "second reading" by the EU Environmental Committee took place on June, 11, 2003; - v) the final vote of the EU Parliament took place on July, 2nd, 2003. – vi) the Directive is expected to enter in force this year (2003).

The proposed EU Directive, as agreed in the *common position*, in a first step would be applied only to CO_2 emissions for a set of activities. For the energy activities it will be applied to the combustion plants with capacity > 20 MWt.

3.2 The political agreement ("common position")

The main point of the political agreement of December 2002, *the "common position*", were:

- The ET system will start in 2005, and will be implemented in two phases: 2005-2007 and 2008-2012
- The sectors included are: heath & power production, steel, cement, glass, tile, paper & cardboard. The Directive can be extended at a later stage to include others sectors (chemical & aluminum)
- Even if the mechanism is compulsory by 2005, Member States can apply to the Commission to allow enterprises or sectors to be excluded only during the first phase ("opt-out option"), provided that an enterprise in accordance with national regulation (e.g. CO2 taxes) achieves equivalent reductions in emission of CO2
- Each Member State must develop a National Plan, with ceilings consistent with the obligations of the EU burden sharing, stating the total amount of allowances it intends to allocate in each period and how it proposes to allocate it. The Commission to draw up emission-allocation guidance rules by 31 December 2003
- During the first phase (2005-2007) the allowances will be allocated to the enterprises free of charge, while in the second the free allocation should at least cover 90% of the total
- Penalties for non compliance: the enterprises exceeding their CO2 allowances would be charged 40 Euro/tonne during the first phase and 100 E/tonne during the second phase (and delivery of the due allowances: no "buy out option")
- Member States can allow "pooling", on a voluntary basis, of enterprises, allowing them flexibility in compliance
- From 2008 Member States may apply to extend emission trading to other GHGs.

3.3 The second reading and the final vote by the European Parliament

MEPs have tabled on the above-mentioned Draft a total of 68 amendments, covering various economical and political issues are.

In particular the Union of Electricity Industry (EURELECTRIC) sent to the Environmental Committee on 28 April 2003 a position paper covering various issues of concerns and recommendations. Among such issues:

Cap/trend line: since there are in draft Directive safeguards which state that the national allocation plan shall not discriminate between companies or sectors, over or under-allocation to the trading sector is inhibited. Therefore Eurelectric did not support the concept of a cap/trend line proposed by the European Parliament. A trend line based on 1990 would not reflect economic development and structural changes in industry, particularly in the electric sector, since then.
Allocation: partial (10% or 5%) or full auctioning as allocation mechanism was expected to cause economically and politically unacceptable costs. A smooth transition, in term of cost both to industry and consumers, from the present situation was required. *A free allocation* to installations provides the greatest certainties and will improve the chances for the successful introduction of the ET scheme and a more stable framework for the transition. Allocation should be made at Company or Sector level and not directly to sources.
Banking: Unrestricted banking between the periods 2005-2007 and 2008-2012 should be permitted: this will reward early actions and would provide certainty for companies in planning investments.
Penalties: Both penalties levels of 40 Euro/tCO2 in the period 2005-2007 and 100 E/tCO2 in the subsequent years appear too high, by taking into account that exists an emission reduction potential much higher than the EU Kyoto target at costs lower than 20 Euro/tCO2. This figure therefore should be dissuasive enough.

Force majeure: Since the period 2005-2007 is a "pilot" phase learning exercise and the new market will take time to adequately develop, Eurelectric strongly supported the possibility of allocating additional allowances to plants in presence of "force majeure" as a means to provide flexibility to the companies to cope with unforeseen events (market failure, extreme weather conditions).
JI & CDM Credits: should have been admitted unrestrictedly and should be fully fungible with the EU allowances.
Inclusion of other sectors: provided that other GHGs are also included, was supported because this would increase liquidity of the market.

The European Parliament's Environmental Committee took the second reading vote on 11 June 2003; the debate and vote in a plenary session took place on July 2, 2003.

The following decisions were taken:

- **free allocation of allowances**: the free allocation in the second period was not passed: auctioning of 5% was adopted
- **credits from JI & CDM**. The Commission was asked to present the Draft Directive for the link JI & CDM with ET. As mentioned, such proposal was issued on July 23, 2003
- **Cap on the allowances**: even if a general consensus existed on the need of avoiding the over allocation, undue penalization for some countries should also be avoided. A compromise between the Institutions (EP, Council, Commission) to be investigated
- **New entrants**: they will receive a suitable amount of allowances; the same in case of restructuring of existing plants
- **Penalties for not compliance**: were confirmed at 40 E/tonne CO2 during the first phase; 100 Euro/tonne CO2 during the second phase. No "buy out" option
- **Early actions**: such actions by the industry will be adequately recognized
- **Inclusion of other gases**: allowed, provided that the Commission implements uniform methods for calculation and control
- **Inclusion of other activities & sectors ("Opt in"):** the extension from 2005 is supported, with particular reference to the chemical & aluminum sectors
- **Exclusion ("0pt out"):** the temporary exclusion will be limited to the plants and not to the activities
- **Banking:** unrestricted allowances banking will be permitted between the periods 2005-2007 and 2008-2012 and between years in the second period
- **Pooling:** Accepted, also for plants of Companies pertaining to different sectors (e.g.: refinery and thermal production)
- **Force majeure:** allocation of additional allowances in presence of FM accepted; the Commission to lay drawn guidelines to define the related circumstances.

3.4 The amendment for linking the ET with the "project-based" JI and CDM.

The *"common position*" of the Commission on the Directive for Emission Trading did not provide for the inclusion of recognition of the JI & CDM; the issue of the "equivalence" of JI and CDM credits to the allowances was a hot issue before the final vote of the European Parliament. To comply with the recommendations, on July 23 the Commission presented to the Council a Proposal for a Directive, just amending the ET Directive for the JI and CDM treatment.

The Environment Division of the Commission has examined the impact on the total compliance cost of the various EU Countries during the period 2008-2012, of various percentage of utilization of the credits arising from JI and CDM on the ET mechanism. On one side it was recognized that it is necessary to establish a bridge between the ET scheme and the JI & CDM; on the other side, the Commission stated that providing unlimited access to JI & CDM credits may undermine the EU ET scheme, discouraging too much the reduction of the emissions within the EU; pushing down the market price of the compliance cost could also retard the development of new advanced emission reduction techs with the EU.

As a balance, based also on the concept of "supplementary" of the two types of mechanisms, the Commission proposes not to constrain the quantity of credits converted in the time being but to monitor the level of CDM and JI credits converted for use by the EU and *automatically review* the issue when the number of credits coming from CDM (CERs) and JI (ERUs) reaches 6% of the total allowances allocated by each Member State. In this case, the Commission will consider whether a maximum level of say 8% of the total quantity allocated by Member States should be introduced for the remainder of the period.

According to the figures produced in the Draft Proposal, the JI and CDM credits used in the Community could be estimated at 7% of the initially allocated allowances for the period 2008-2012. The mandated level of 6% is estimated to correspond to some 2% of the EU baseline; the maximum limits that the Commission would consider when the 6% threshold had been reached should correspond- so the proposal - to 2.7% of the EU baseline emissions or almost 1/3 of the 8% target of the EU as a whole.

This proposal will now be forwarded to the EP and Council of Ministers for scrutiny, under the EU "co decision procedure".

4. THE ITALIAN STRATEGY IN THE MINISTERIAL DOCUMENTS

4.1 The scenarios considered

The basic official document of the Italian Government enacting the Law 120/2002, which ratified the Kyoto Protocol, is the ruling of CIPE N^{o}.123/2002 "Revision of guidelines for national policies & measures for GHGs reduction", Issued in the Italian "Gazzetta Ufficiale" (Official Journal) on 22/3/2003.

The key parameters describing the Italian situation are the following:

Baseline (all 6 GHGs)	1990:	521 Mton CO2equiv
Target (-6.5%)	2010:	487 Mton CO2equiv

Correspondingly, by applying "burden sharing" ruled by the EU for Italy of 6.5%, the total reduction from the BAU evolution should be 93 MtonCO2equiv.

The Interministerial document presents two scenarios for 2010: i) *Business as Usual (BAU*) and – ii*) Reference scenario.* The following Table presents the details of the, "Baseline" 1990 and of these two situations:

	Baseline **1990**	BAU **2010**	Reference **2010**
Energy sources	*42.9*	*484.1*	*444.5*
- Energy industries	147.4	170.4	144.4
o Thermal production	124.9	150.1	124.1
o Refineries (direct consump)	18.0	19.2	19.2
o Other	4.5	1.1	1.1
- Manufacturing industry & construction	85.5	80.2	80.2
- Transport	103.5	142.2	134.7
- Civil	70.2	74.1	68.0
- Agriculture	9.0	9.6	9.6
- Other	9.3	7.6	7.6
Other sources	*96.1*	*95.6*	*95.6*
- Industrial processes (mining, chemical)	35.9	30.4	30.4
- Agriculture	43.4	41.0	41.0
- Waste	13.7	7.5	7.5
- Others	3.1	16.7	16.7
2.1 Subtotal	521.0	579.7	540.1
2.2 Credits from JI & CDM			-12.0
2.3 Total	521.0	579.7	528.1
2.4 Target			487.0

Source: Agenzia per la Protezione Ambientale e Servizi Tecnici (APAT) & MATT

The ***"Business as Usual"*** scenario takes into account all the measures already triggered according to the present legislation. As can be seen from the Table, the total related emission level of 580 Mton CO2equiv, would imply -- instead of the mandated reduction of 6.5%-- an increase of some 11.3% in respect to the 1990 baseline.

In this scenario, for the *electric sector* a relatively moderate 2%/yr rate of increase of the demand is considered, which should entail for the year 2010 a total demand of 364 TWh, some 65 TWh higher than the 299 TWh for the year 2000 (gross production= 277 TWh, net production for load= 255 TWh; import 44 TWh). It is worthwhile to mention that more recent projections are targeting a demand around 395- 400 TWh.

The measures envisaged are:

- the completion of all the plants by private producers triggered by the ministerial decree investigating in 1992 the renewables and assimilated sources (the so called CIP 6/92 provision)
- the obligation for the producers to inject into the network since 2003 a 2%/year (presently planned to be increased 0.3%/year) of *new* renewable energy, enacted with a mechanism of tradable green certificates. This provision should increase the renewable production, hydro excluded, mainly wind source and waste, from the present 7 TWh up to 12 TWh, with an increase of 5 TWh and a capacity addition from 1700 MW to 3700 MW. In addition, a further expansion of hydro production is taken into account, from the present 45 TWh up to 49 TWh
- the plans to transform existing 10 GW of oil fired plants, out of the total 15 GW sold by ENEL to 3 GenCos according to the new electric law introducing liberalization in Italy (the so called "Bersani Decree"), in CCGT. In this scenario the total amount of CCGT at 2010

should be: - GenCos = 10 GW; Transformation of ENEL: 4 GW, New entrants = 4 GW, for a total of 20 GW

- the conversion of two ENEL large oil fired power plants, each rated at 2640 MW, Torrevaldaliga Nord and Porto Tolle, respectively, to coal and Orimulsion. This move, suggested by the need for Italy to decrease the costly oil dependence and therefore the wholesale price, should entail only a modest increase of 4.5 Mton. Incidently, this project presently now seems probable, after opposition of local municipalities have recently been overcome
- Decrees to increase energy efficiency.

The ***"Reference scenario***", with measures already approved but not necessarily implemented, a first amount of JI+CDM for 12 Mton CO2equiv included, entails emissions of *528 Mton* al 2010, corresponding to a reduction of approximately 52 Mton CO2equiv in respect to BAU.

The contributors should be:

- Electric sector: - 26.0 Mton
- Civil Sector: - 6.1 Mton
- Transport: - 7.5 Mton
- ***Subtotal:*** ***- 39.6 Mton***
- JI & CDM credits: - 12 Mton
- **Total** **~ - 52 Mton**

For the electric sector, in the "Reference scenario", the demand of 364 TWh the electric sector should generate through a gross production of 330 TWh which --netted by the internal and pumping consumptions for 26 TWh-- should result in a net production for the load of 304 TWh, and by import assumed to increase to some 60 TWh.

As seen, the contribution asked by the electric sector in the *reference scenario* in respect to the *BAU scenario* is huge: 124.1 Mt in respect to the BAU level of 150.1 Mt, with a reduction of 17% and a total contribution equal to the 66% of the total (by excluding the JI & CDM credits) with a related huge economic burden.

The main variations in the electric sector contribution should be obtained by:

- a further increase, in respect of the BAU scenario, of CCGT of some 3.2 GW, up to 23.2 GW (some 10 GW from the generation of units sold by ENEL to the GenCos, 4 GW of ENEL generation and some 8.7 GW of new entrants). and by greater efficiency.

This scenario will be characterized by a huge recourse to natural gas. The related production is assumed to be some 171 TWh, corresponding to 52% of total gross production, with an increase in efficiency from the present 44% up to of the order of 54%, a total consumption gas of 33 Gcm and total emissions of 63.1 MtCO2 out of the total 124 MtonCO2.

It should be noted that the above figures are considerably lower than connection requests of new CCGT capacity (some 50-55 GW). At the moment (September 2003), the capacity of new plants having the final Ministerial Decree is some 12 GW; their main problem is their financing. Another consideration to be kept in mind is that too much CCGT capacity will not be allowed to run for the 6000 hours conventionally assumed in the financial evaluations.:

- **Increase of renewables, mainly wind**. The renewal (hydro excluded) should rise to 25.7 TWh; this figure, added to the hydro 53.4 TWh (including some 4 TWh of pumping), gives a total of 79

TWh, corresponding to 24% of the total gross production. In the year 1990, the corresponding percentage was some 17%, while in 2000 it was roughly 20%. In particular, as far as the capacity of renewables is concerned, the total increase from 2000 should therefore be 4220 MW, out of which 2137 MW is wind and 1282 MW biomasses. This last target entails the introduction new simplified authorization procedures to speed up the process, as well as incentives to make the investment attractive, and in some areas of the country considerable work is required on the transmission and distribution 132-150 kV network.

- **Increase Import up to some 60 TWh.** This is possible but it is still limited by interconnection capacity, even if in the North the Net Transport Capacity (NTC), due to better coordination of the various TSOs, is already increased from the past 5600 MW to 6300 MW; a reasonable value in 2010 could be around 8000 MW by taking into account new lines with Switzerland and an HVDC link with Greece.

From the above, the target imposed on the electric sector in 20 years is a reduction of the specific emission of some 35%, with a reduction of 12% in the first decade and a *further considerable reduction of 26% to be obtained in the second phase.*

Naturally the situation is in evolution and the assumptions contained in the "reference scenario" could change.

In addition to that stated in the above scenarios, it is also worthwhile to remember that in the new "Energy Restructuring Bill", presently to be discussed by the Senate after being passed by the Lower Chamber on July 16, 2003, there is a provision (Art 22) according to which the Ministries of the Productive Activities and of the Environment are expected to issue various operational decrees in which decreasing limits, in the period 2003-2010, on the CO2 emissions in p.u. of the produced energy should be respected, with progressive penalties applied to the variation in relation to the mandated limits. This provision, naturally, is another burden on the electric sector.

In the Ministerial projections in the "Reference scenario" t*he total CO2 emissions of the Italian electric sector" at 2010, should be 124 Mton, corresponding to a total gross thermal production of 251 TWh* (out of a total gross production of 330 TWh*)***.**

One parameter that could be assumed for reference is the "specific emission/kWh". The evolution of such parameter from the "baseline year" 1990 up to the year 2010 should be:

Year	**Gross Production TWh**	**Emission MtCO2**	**Specific emission kg/kWh gross**
1990	216.9	124.9	0.576
2000	276.6	140.0	0.506
2010	330	124.0	0.376

It is hoped that an overall organic review of all the aspects will be made. In particular it seems suitable a revision will be made of the so called "carbon tax", introduced in 1998 and in principle aimed to a "correct internalization" of CO2 emissions obtained by various fuels, but in reality strongly penalizing the production by coal and orimulsion, since one Kg CO2 *emitted* by coal & orimulsion is taxed 5 times the one emitted by gas. The corresponding resulting burden is of 1 Euro/MWh for coal production and 0.1 Euro/MWh for gas production.

Finally, it is worthwhile to mention that the *planned total reduction of 51.8 Mton* should be obtained with the contribution of the *JM & CDM credits* for a total of *12 Mton* in Italy and abroad. As discussed, the utilization of such mechanisms, even if hoped, is now still poor.

4.2 Further Initiatives needed to obtain the overall reduction target

The target of total abatement of 93 MtonCO2equiv requires – in addition to the measures already envisaged by the Ministry of Environment, corresponding to a reduction of 52 *MtonCO2equiv* - a *reduction of further, 41 MtonCO2equiv*, to be obtained with other measures.

Such figure increases to some 53 *MtonCO2equiv* if the "first contribution" 12 JI & CMD is *not taken* into account.

In the ministerial document, various possibilities have been examined, both national and international.

The *national initiatives* cover a range of potential reductions between 32.5 and 47.8 Mton CO2, out of which 6.9 to 13 Mton CO2 is obtainable in the electric sector.

Further potential abatements could be obtained through *international measures* thanks to the JI and CDM mechanisms. Electric production has a potential primary affect on such projects, particularly in the developing countries, where the rate of increase in demand is expected to be higher that in the developed countries.

The solutions examined are in a range of 20.5- 48.0 Mton CO2 (10.20 of which is related to JI and CDM projects of gas flaring and gas venting in oil drilling).

As a result of *national* and *international* initiative a possible range of *53.0 to 95.8 Mton CO2* has been singled out.

Naturally, the said further accomplishment of 41 Mton CO2 reductions should be obtained by proper selection of the more efficient possibilities.

The strategy for CO2 abatement as envisaged by the Environment Ministry should follow the following steps:

- check degree of accomplishment of the measures already inserted in the BAU scenario and its complete implementation
- identification of further measures national and international
- evaluation of needed costs and investments
- proper selection of more efficient initiatives.

A considerable portion of the measures included in the BAU scenario and all the further measures identified to obtain the needed further 41 Mton reduction are not yet financed.

It is expected that the majority of the investments required will be made by the private sector.

4.3 Recourse to Emission Trading

A portion of the emission reduction of 93 Mton from the BAU level (580 Mton) to the target level (487) could be obtained by recourse to the Emission Trading mechanism. According to what is described above, this recourse could range from a maximum of 53 MtonCO2 if level foreseen in the Reference scenario (540 Mton) will be obtained and no other measures (JI+CDM or other) will be implemented, to lower values as soon as the various initiatives envisaged in the Ministerial documents could be implemented.

5. FINAL CONSIDERATIONS

5.1 The key figures representing the Italian situation in relation with burden sharing accepted for the Kyoto emission control are the following:

- Baseline 1990: 521 Mton CO2 equiv
- Italian Target 487 Mton CO2 equiv = - 93 = -6.5% baseline.

The emissions produced with the scenarios presently envisageable are:

- BAU: 580 Mton CO2 equiv
- Reference scenario without JI&CDM: 540 Mton CO2 equiv = - 40 in respect BAU
- Reference scenario with JI+CDM: 528 Mton CO2 equiv = - 52 in respect BAU.

Correspondingly, given for implemented the “reference scenario”, the further measures needed *without JI&CDM* are some *53 Mton* CO2 equiv.

5.2 To cover the gap three mechanisms are available:

i) Emission Trading
ii) Joint Implementation
iii) Clean Development Mechanisms.

Even if the purchase of allowance through the Emission Trading mechanisms seems in any case probable, the Ministry of Environment has reaffirmed the willingness of Italy, within the EU, of having well presented that the GHGs is a “global issue” and, as such, its strong support to the application of the JI & CDM, to comply with lower costs than those anticipated for ET. The Italian Government is against an interpretation of the Kyoto protocol in a local regional view. The “pure” recourse to Emission Trading, especially in case of prices of the allowances being higher than the possible range, could have a huge impact on the industry and on the economy.

5.3 The requirements for the electric sector for reducing emissions from the Business as Usual scenario to the more “environmental friendly” Reference Scenario are large. The electric sector should face the burden of some 66% of the total reduction envisaged. The reduction is linked to evolution of the generation system (generation mix, development of import and renewables), which so far presents incertitude**.**

5.4 Concerning impact of ET, a key issue is the method that will be used to finance purchase of the allowances, general taxation or energy taxation? More generally, taxation of electricity is an open issue. In fact, it is worthwhile to mention that, in addition to the high production cost connected to the fuel mix (due to lack of primary energy sources and to the need of importing coal, oil and gas), the final price of electricity in Italy is heavily affected by various taxations, which makes more dramatic competition of the Italian industry in the new global environment. The “carbon tax” presently in force is not balanced for all the types of production and strongly disadvantages coal (and orimulsion) production. In occasion of the measures that will be taken for financing emission trading a more general organic review of the all taxation system for the electric sector should be undertaken.

5.5 At the moment (September 2003), the Government has not yet officially disclosed its compliance strategy. Various possibilities are discussed, among which are:

- Voluntary Climate Change Agreements with the Companies
- Sector Framework Agreements

- Benchmark on specific emissions (kg CO_2/kWh).

Various technicalities are still to be defined by the Ministries of Productive Activities (MAP) and the Environment (MAMB), such as the emission allocation of self-production, exhaust gases, gasification of coal or TAR, Combined Heat Power production (CHP) with considerable heat.

5.6 A new "Energy restructuring" bill passed by the Lower Chamber in July 2003 and now being examined by the Senate deals with related questions such as clean coal technologies, and CO_2 specific emissions. It anticipates decreasing limits on the emission in p.u. of production, with related penalties for non-compliant producers.

5.7 An Agreement Protocol is under study between the Ministries of Environment & Productive Activities and the Industry Associations. A joint WG to trigger proposals for the framework of possible Climate change Agreements, the National Plan for allowances allocation, and promotion & coordination of the JI & CDM activities has been established.

Ludovico Priori was born in Bologna, Italy, in March 1925. He received his PhD. Degree in Electrotecnic Engineering from the University of Bologna, summa cum laude, in November 1947.

He began his career with Montedison in 1948 and was appointed manager in April 1956. Since 1976 to 1984 he was Deputy General Director of the Utilities Division of Montedison Spa, with responsibilities for the following energy-related activities:

- Self production of electric energy
- Production and distribution of gas for the city of Milan and its neighboring municipalities, up to 1981
- Research in development of hydrocarbons.

In addition, Dr. Priori was Vice President of the Electric Sector of the Montedison daughter Company SELM. He was also a Member of the Board of many Companies of the Montedison conglomerate and President of SGM**,** a Company for transmission and distribution of natural gas in the South of Italy.

Dr Priori, in his long activity in the energy sector, had many responsibilities in National and International Industrial Organizations. He was a member of the board of the Confindustria, the general Italian Association of Industry, as well as President of the Association of the Electric Producers UNAPACE (now Assoelettrica) in the period 1982-1995 and of the Energy Committee of Confindustria and of Federchimica, the industrial chemical association. He was also President of the Commission "Electric Tariff" of Confindustria and Deputy President of the gas industrial association ANIG.

Dr Priori is Author of various papers covering the issues of power system regulation and transmission. Presently Dr. Priori has the following activities and responsibilities:

- Energy Consultant
- Honorary President of UNAPACE-Assoelettrica
- Member of the Board of the Italian Committee of the World Energy Council (WEC)
- Member of the Energy Committee of the Confindustria
- Member of the Board of IFIEC-EUROPE (International Federation of Industrial Energy Consumers)
- Member of the Swiss Company Kraftwerke Hinterrheim (hydro generation).

Luigi Salvaderi was born in Ancona, Italy, in June 1938. He received his PhD. Degree in Electrotecnic Engineering from the University of Genoa, Italy in March 1962.

After an initial experience in the automatic control field, he joined ENEL in 1965, the Italian Electricity Board, where he held the following positions and responsibilities:

- *Design & Construction Department:* Design of 220-380 kV stations and commissioning of the SACOI HVDC link
- *Research & Development Department:* Development of techniques for generation & transmission system reliability evaluation
- *Planning and Strategies Department (1997-1996):* Responsible for Generation planning of the Italian system and Manager of the Strategies & Technologies Sector
- Relations with the Energy Authority Department (1996-1999): *Responsible for Tariff Studies, Coordination of the Grid Code for the new Italian Independent System Operator.*

On behalf of ENEL Spa he has been acting as a Senior Consultant Engineer in various countries. Since 1968 Dr. Salvaderi has been a very active member of various International Bodie.These include:

:

- Eurelectric- Bruxelles: Member of the WG on "Transmission Tariff"
- CIGRE-Paris: Italian Member of the Study Committee SC 37 "Power System Planning" 1992-2000 and member of the WGs: "Transmission Pricing", "Adequacy evaluation in the new liberalized environment", "Impact of regulation structure on power system planning"
- Chairman of the WG "Transmission Cost Benchmarking"
- Presently is Member of WGs in the two CIGRE SC: C1: "System Development and Economics; C6 "Distribution Systems and Dispersed Generation"
- Institute of Electrical and Electronics Engineers (IEEE)-New York: Member of WGs "Reliability, Risk, Probability Applications" and " International Practices for Energy Development and Power Generation"
- World Energy Council-WEC- London: Member of the Committee "Performance of Thermal Plants".

Dr. Salvaderi has co-authored more than 120 technical papers published in international reviews on power system planning, reliability evaluation, and energy issues. He has given lectures and tutorials in Institutions, Associations and Universities in various countries of Europe and North America.

He is co-editor of the IEEE book on "Applied Reliability Assessment in Electric Power Systems" used by Consultants, Utilities, and Universities.

He was Panelist and Special Reporter at many IEEE and CIGRE sessions on various issues related to planning and new unbundled structure of the electric utilities.

Dr. Salvaderi received in 1996 the "CIGRE Technical Committee Award", in recognition of his outstanding contribution to the work of the Study Committee "Power System Planning and Development". He was elected a Fellow of IEEE in 1996. He has received twice the Award of the Italian Electro technical Association. Dr. Salvaderi, since January 1 2000, has been acting as International Consultant for Power System Issues, Market Organization, and for a major Italian Wind Source Developer.

5. THE WAYS OF DECREASING THE IMPACTS OF POWER ENGINEERING ON OUR ENVIRONMENT

Prof. Ing. Jiří Tůma, DrSc., CTU Prague, Czech Republic

Summary

The impact of power engineering on our environment and, particularly, its substantial influence on producing greenhouse gases can be considered as a serious problem, which is global. The decrease of these negative impacts is closely connected to sustainable development, and it should be the duty of all countries to cooperate in this field.

It can be demonstrated by the approach of the Czech Republic, where exist models which aim at reaching these postulates not only within the energy sources (like fossil, nuclear and renewable sources), but also within the ways of their ecological exploitation.

This article deals with research and developmental theses under preparation, particularly those that are focused on the exploitation of fossil fuels and renewable energy sources.

Introduction

Speaking about power engineering, a positive scenario of the world's development is based on the following presumptions:

- population growth in the developing countries
- growth of standard of living in the developing countries
- relevant increase of the primary sources consumption resulting in the growth of fossil fuel prices
- increase of primary energy sources leading to the necessity of an intensive search for the solution of the problems with climate changes
- potential danger of the situation, when energy sources could become a tool for political instability in the case that power engineering is included into strategic policy.

The role of nuclear engineering, clean coal technologies and renewable sources exploitation will increase worldwide. Renewable sources will play only a supplementary role and they will be used only in places with suitable natural conditions.

European Approach

Studying energy strategies of member states of the European Energy Chart, it is evident that all the states have their own national approach to the solution of their energy needs. The approach is influenced by the requirement for the minimal dependence of the country on external sources, i.e., energy safety of the state.

Generally speaking, the goal is to ensure the long-term stability in supplying the country with electric energy and n

At the end of the year 2000 The European Economic Commission for Sustainable Development took up the program focused on:

- standard-making activity in power engineering concentrated on the classification of the fossil supplies and its corresponding legislation
- liberation of the energy market, price policy and safety of energy supplies
- development of regional energy strategy for the 21st century
- effective energy exploitation, energy savings

- energy infrastructure, network linking for electric energy and gas transport
- energy production in steam power plants considering the principles of sustainable development.

Trends in the Czech Republic

State energy policy starting in the year 2000 is based on the same principles as European policy. It is closely connected to economic and raw material exploitation strategy with respect to the state environmental policy.

The core problems in the power-engineering sector lie in the high-energy demands of the Gross National Product, when compared to the European Union countries. The consumption of primary energy sources per GNP unit is 2.3 times higher than in the EU. On the other hand, the comparison of energy demands with the countries in Central and Eastern Europe comes out more positive.

The main cause of the high-energy demand is, besides a lower level of GNP, the structure both of primary energy sources and final consumption with higher rate of fossil fuels. Next factor is a historically existing structure of the industrial production, where high rate of energy-demanding industrial branches prevails.

It is necessary then to concentrate first on the sources of energy and second on the ways of its exploitation. Thus the trends in energy sourcing are going to be discussed now.

See Figure 1 where the present state on the level for the year 2002 is illustrated.

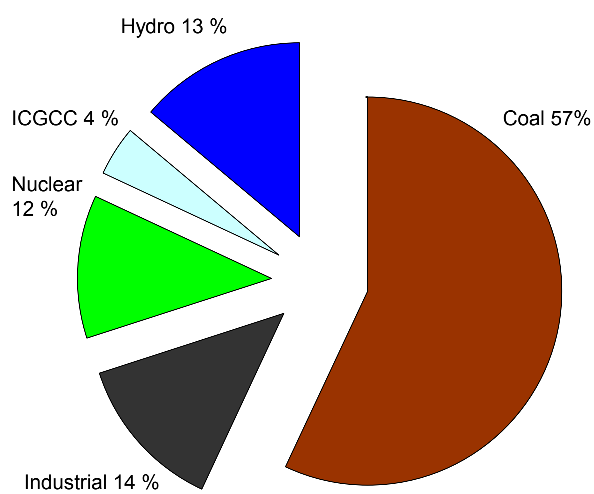

Figure 1 Present State of Energy Production in Czech Republic

The structure of energy sources shows that the power engineering in the Czech Republic is based on coal and nuclear energy sources.

Coal Exploitation

Brown coal, whose exploitable supplies are qualified to approximately. 5 billion tons, is a backbone of the Czech energy system. The technological chain, starting with fuel for electric energy production and ending with its distribution to the consumer, has its historical traditions, and in spite of containing a high percentage of ballast components like ash or water, it is still considered to exploit in a suitable clean form in the future.

The trends in exploiting coal depend e.g. on the rate of exploitation of coal supplies, ecological demands and a competitive ability of coal in electric energy and heat production, as well as in non-energy usage. It is highly demanding to form suitable conditions for the gradual increase of the rate of coal usage in CCT (clear coal technologies), particularly by its gasification into man-made natural and synthetic gases. The usage of CCT enables specific emissions of carbon and nitrogen oxides to be minimized, and to increase the total efficiency of the production processes minimally by 10 per cent. The solution of problems in fossil fuel exploitation is influenced by the following factors:

- supplies of domestic raw materials
- present state and modernization of the plants in operation
- prognoses of the growth of electric energy and heat
- state of domestic technological and production bases.

There are basic trends in research and development:

- increase of efficiency, stability and reliability of energy systems
- possibility of minimizing specific insurants in fuel burning
- exploitation of brown coal for electric energy production at peak periods
- CCT
- development of devices and equipment for modeling, diagnostics and optimization of thermo chemical burning processes
- exploitation of mixed-fuel sources
- exploitation of fossil residues and side products of burning
- methods of the rescue of laid-up source localities.

The development and establishing of the combined production of electric energy and heat are also significant. It is a more effective way of energy conversion and it participates a great deal in minimizing the influence of power engineering on the environment. Establishing small technological units into the economy of industrial and communal organizations plays a substantial role as well.

Nuclear Energy

The exploitation of coal and nuclear energy in the Czech Republic has promising perspectives. Presented data show that nuclear energy is able to compete with power plants and equipment burning fossil fuels, particularly natural gas and crude oil. It is substantially cheaper than energy from renewable sources.

The production of electric energy from nuclear fuels considerably minimizes the production of greenhouse gases. The drawback of presently exploited nuclear reactors is their low exploitation of fissile materials (3 per cent). Therefore, future exploitation of nuclear energy will be more promising in the higher exploitation of fissile materials, in case that the higher safety of nuclear power stations is ensured, which will be more acceptable for the public.

Renewable Energy Sources

Renewable sources cannot remain a substantial source of energy up to the year 2020, but they can become an important benefit to local and regional places of energy consumption. Particularly the biomass can be used wherever transport costs will be acceptable.

Small water power stations and wind power stations will be more and more important in the future. Wind power stations can be built in regions with the wind speed of more than 5 m/s. Solar systems are limited in our conditions by a relatively short time of sunshine. Energy state policy supposes that the rate of renewable sources will increase from 1.5 percent to 6 percent in the year 2010.

Renewable source increase rate in energy balance is closely linked to the principles of sustainable development of the society.

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Biography

Jiří Tůma was born in 1934 and is Professor of Power Engineering, Faculty of Electrical Engineering, Czech Technical University, Prague. He graduated in 1958.

Professional experience: Construction of Thermal Power Station, 14 years with the National Dispatch Centre, 1975 – 1986 Power Research Institute, deputy director for research and science, 1986 – Czech Technical University, 8 years Head of Department of Power Engineering, 6 years Vice Dean for Research and PhD Studies.

Scientific activities: Development of Power Systems, Control of Power Systems in normal and emergency states, and conservation of electric energy. He has published numerous papers in these areas. He managed 7 research projects founded by both the National Grant Foundation and the local utility company in the last 10 years.

International cooperation has essentially been with: University of Tennessee, Tennessee, USA; RWTH Aachen, Germany; and the Nippon Institute of Technology, Japan.

6. REDUCTION IN GREENHOUSE GASES

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Abstract

It needs extensive use of new and improved technology, by improvement in energy efficiency, change of fuels, introduction of new energy sources and abatement/sequestration of Greenhouse gases in order to achieve reductions in emissions without affecting standards of living. Some of these technologies are widely available now; others are in their research stages. This panel paper looks into the issues of Greenhouse gases and proposes two potentially useful techniques to enhance environmental benefit through the use of renewable energy.

Introduction

As a starting point, it will be asked what are the appropriate targets to use in developing new technology for control of Greenhouse gas emissions. Technology will enable reduction in emissions of Greenhouse gases, whilst minimizing impact on human aspirations. The 1997 United Nations conference in Kyoto agreed some targets for emission reduction. Key features of the Kyoto protocol included the agreement to reduce emissions by 5.2% by 2008-2012 compared to baseline levels, the inclusion of a basket of gases, recognition of the concept of sinks and land-use changes, introduction of the Clean Development Mechanism and progress on Joint Implementation [1].

It would be prudent to be able to have access to technologies that could achieve deep reductions in emissions. Such research is a sensible precaution against the more severe outcomes of climate change.

Greenhouse Gases

The most significant Greenhouse gas is carbon dioxide (CO_2), accounting for over 50% ofthe Greenhouse effect. The three other main gases are Methane (27 times as bad as CO_2), Nitrous Oxide (165 times) and chlorofluorocarbons (CFCs), which are 15-25,000 times as bad. It is fortunate that the CFCs, which are mainly used in aerosols, refrigerators and plastic foam, are present in relatively small quantities. Ozone is also a Greenhouse gas.

Until recently, nature controlled the level of Greenhouse gases, maintaining a balance between emissions from natural sources (mainly of CO_2 and methane) and their destruction or removal from the atmosphere by natural processes. Damages from Greenhouse gases could be huge. A rise of 3 - 4^{o}C ended the last ice age; predictions suggest global warming could raise the Earth's temperature by 2.5 - 3.5^{o}C in next 50 years.

Measurements taken around the world show that CO_2 has increased from a level of about 275 parts per million (ppm) in pre-industrial times to about 350 ppm now [1]. Increases have also been observed in the levels of methane and the CFCs. The increases have resulted from human activities; CO_2 from energy generation, such as the burning of fossil fuels: coal, oil and gas, and methane from farming. Oil and gas emit less CO_2 than coal, 85% and 50% per unit of electricity respectively. The equivalent figures for nuclear and the renewables are both zero.

Reduction of Emissions

One obvious way to reduce emissions is to reduce the Earth's consumption of energy. By improving energy efficiency in the home, in transport and in industry. This means better insulated buildings, more efficient lighting and electrical appliances, more efficient vehicles, improved energy control and the use of waste heat from energy production in combined heat and power schemes [2].

Most experts agree that even with a drive to improve energy efficiency, by 2020 the world will be using at least 50 % more energy than it is now. This will come from rising standards in the developing world and an increase in population. There are some views that by 2020 energy demand could be kept to around that of today by using high efficiency techniques with less emphasis on voluntary savings.

Change of Fuel

There is an effort to move away from fossil fuels. Renewables, especially hydro, can make a contribution but not on the scale required to replace fossil fuels. Nuclear energy can, however, play a major part and already does so. France, which produces over two-thirds of its electricity from nuclear, has reduced its CO_2 emissions by 60% in less than ten years. It is calculated that if the world nuclear share of energy production continues to rise at its current rate, by 2020 it will account for about 20% of electricity generation and will be saving around 4 billion tonnes per annum, representing 12% of the CO_2, which would otherwise be emitted. At a higher rate of building nuclear stations to achieve 50% by 2020, the savings would be 30%, reducing global warming by 15%.

Electricity Supply Industry

The electricity supply industry is the major consumer of fossil fuels, and hence the major source of carbon dioxide emissions in the UK. There have been significant changes in the generating mix between 1980 and 1997. The level of CO_2 emissions is determined by both the fuel mix and the generating technology used. During the 1970s the electricity supply industry was dominated by coal and fuel oil fired thermal power stations, and coal and oil consumption increased to meet the rising demand for electricity. The use of coal for generation peaked in 1980 at 89.6 Mt and has subsequently declined. The fall has not been steady showing minima in 1982 and 1984 due to recession in the early 1980s and the miner's strike. During the late 1980s and early 1990s, the closure of inefficient plant led to an overall increase in the thermal efficiency of the conventional thermal power plants, and the contribution of nuclear power generation increased with the greater utilization of existing nuclear plants and the commissioning of Sizewell B in 1991. The use of oil generation peaked in 1972 and apart from increased consumption during the miners strike of 1984 has been in decline ever since. More recently, the privatization of the power industry has resulted in a move away from coal and oil generation towards combined cycle gas turbines (CCGT). The use of gas in power generation has increased by a factor of 29 since 1991.

The effect of these changes in the power sector is clearly reflected in the carbon dioxide emissions. Since 1970 there has been an increase in the electricity generated of around 40% but a large decrease in emissions of around 30%. More significantly, emissions have decreased by 27% between 1990 and 1997. This is due specifically to:

- The greater efficiency of the CCGT stations compared with conventional stations - around 50% as opposed to 34%
- The calorific value of natural gas per unit mass carbon being higher than that of coal and oil
- The proportion of nuclear generated electricity increases from 17% to 25%.

Technologies for Reducing Emissions

Technologies which can contribute to reducing emissions range from improvement in energy efficiency, change of fuels, introduction of new energy sources to abatement/sequestration of Greenhouse gases; they all have a role to play. In most cases, the motivation for commercial development will be small, since the technology will offer little or no competitive advantage to the user. In these circumstances, it is necessary for governments and industry to work together, to share resources and co-operate on early stage research and development, especially to learn about new technologies. This is especially important in examining the performance of full-scale prototype plant, since there may be very few such opportunities.

Technical Innovation

The most important impacts are caused by gaseous emissions from fossil fuel combustion.

The environmental benefits of innovative technologies are generally not reflected in their market prices. In general, the main factor driving the uptake of environmental technologies is legislation and regulation. The UK government, the European Commission and other international organizations such as the United Nations set limits on atmospheric emissions. In addition, many new developments are subject to a local or national planning processes or public enquiries, which can strongly influence the uptake of certain technologies. These restrictions will become increasingly important in future.

The main constraint on uptake of many environmental technologies is their high capital cost, and, for novel technologies, the perceived risk involved in such an investment.

In addition to purely economic competitiveness, factors influencing the uptake and development of new and existing technologies in the energy sector include:

- environmental concern
- security and diversity of supply
- environmental regulation
- investment constraints and attitudes
- government support for new technologies
- potential for exports.

Phase Balancing for a Self-excited Induction Generator

In regions where renewable energy resources are abundant but usually situated in remote locations, connection to the central power grid is expensive and in many cases difficult to provide. Small-scale, autonomous generation schemes, on the other hand, are both economical and practicable. They utilize the energy resources available and supply the consumers in the local regions. The system cost can be reduced by using cage-type, self-excited induction generators (SEIGs) [3] since these machines are cheap and readily available.

Autonomous power systems often employ single-phase generation and distribution schemes for reasons of low cost, ease of maintenance and simplicity in protection. When a three-phase SEIG is used to supply single-phase loads, however, the stator currents are seriously unbalanced, causing degradation in generator performance such as over current, over voltage, poor efficiency and machine vibration. These undesirable effects can be alleviated to a certain extent by the use of the Steinmetz connection in which the excitation capacitance and load are connected across different phases. For isolated operation, however, perfect phase balance cannot be achieved when the load is purely resistive.

The objective of this case study is to introduce a modified Steinmetz connection that enables perfect phase balance to be achieved in a three-phase SEIG, which supplies single-phase loads.

Controlling a Solar Plant with Fuzzy-Genetic Techniques

Whilst thermal heating technology may generally be accepted as being well developed, cost reduction is still expected to continue owing to larger scale production and advanced control techniques. This is evident from research effort devoted to improving the efficiency of solar thermal power plants operating with distributed collectors, by means of various advanced control-methods. These control methods, developed and tested at the solar power plant Plataforma Solar de Almería in Spain bear a varying degree of both complexity and success. The key characteristic of a solar power plant is that its primary energy source, solar radiation cannot be manipulated, and varies throughout the day and exhibits seasonal cycles. This results in significant variations in the dynamic characteristics of the collector field and the plant as a whole. Thus, conventional controllers such as the proportional-integral (PI) schemes, which use a fixed set of system parameters optimized for a prescribed range of operations, have proved to be inadequate. Recently, fuzzy logic control (FLC) schemes, which encompass the human-like approach of processing and handling of information, have been applied to the control of non-linear plants with promising results. However, early studies show that in such FLC schemes the optimization of the 'if-then' rule base is often a cumbersome and laborious process involving 'trial and error'. Genetic algorithms based on the natural law of evolution lend themselves as an ideal optimization tool to be used in conjunction with FLC systems [4]. This study is one of the first of its kind to show the development of a GA-FLC scheme aimed at optimizing the response time of a solar power plant to input power and temperature demand.

Conclusions

It is essential to have innovative methods to promote renewables in order to make them a good source of energy in the future to reduce Greenhouse gas emission. Two novel techniques have been proposed to promote the use of renewables, which can reduce the emission of Greenhouse gases.

For distributed generation, a modified Steinmetz connection for the phase balance of a three-phase SEIG, which supplies single-phase loads, has been proposed. The feasibility of the Steinmetz connection is verified by experiments on a practical induction machine, and high generation efficiency has been obtained [3]. Since only passive circuit elements are involved, the Steinmetz connection is an economical and effective phase-balancing scheme for a three-phase SEIG used in an autonomous single-phase power system.

A new GA-based FLC scheme for the control of a solar power plant has also been proposed. The scheme optimizes the strength of individual 'if-then' rules in the rule base of an FLC algorithm. Simulation results performed on a proven simulator of the plant show that the proposed scheme provides extra robustness for the plant under turbulent external conditions when compared with conventional PI control schemes [4].

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7. INDEPTH REVIEW OF UNITED KINGDOM ACHIEVEMENTS UNDER FRAMEWORK CONVENTION ON CLIMATE CHANGE

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ABSTRACT

This paper summarizes the diverse and innovative spectrum of measures that are being taken to promote capacity building on climate change at all levels in the UK. It makes an in-depth review of the achievements in the United Kingdom (UK) under the United Nations (UN) framework convention on climate change. The objective has been achieved and exceeded mainly as a result of the policies and measures that were put in place for liberalizing the electricity market. It discusses national circumstances together with relevant general, energy, and environmental policies; greenhouse inventory information (inventory preparation, and overall emission trends); policies and measures (cross sect oral policies and measures, energy production and transportation, residential and commercial sectors, transport, industry, agriculture and waste); and total projections and total effect of policies and measures (scenario definitions and key assumptions, projected emission trends, effects of policies and measures, and overall evaluation of projections). Also considered are vulnerability assessment, climate change impacts and adaptation measures; research and systematic observation; and education, training and public awareness.

The most notable achievement has been a reduction in GHG emissions of 12.8 per cent between 1990 and 2000, thereby returning its GHG emissions to their 1990 level. Notable decreases have been obtained for the three main GHGs, namely N_2O (35 per cent), CH_4 (33 per cent) and CO_2 (8 per cent). Important policies in meeting the reduction target include the Domestic Emissions Trading Scheme, the Climate Change Levy and the Renewables Obligation.

***KEYWORDS*:** Climate change measures in UK, greenhouse gas (GHG) emissions and removals, GHG inventory for UK, policies and measures on GHG emissions in UK, projections for GHG emissions in UK, vulnerability assessment and climate change impacts, research and observations on GHG emissions in UK.

1. INTRODUCTION

This paper summarizes in a form not presented in the literature in a convenient form heretofore the diverse and innovative spectrum of measures that are being taken and implemented to promote capacity building on climate change at all levels in the United Kingdom of Great Britain and Northern Ireland (UK). The most notable achievement has been a reduction in GHG emissions of 12.8 per cent between 1990 and 2000, thereby returning the UK's GHG emissions to their 1990 level. This objective was achieved and exceeded mainly as a result of the policies and measures that were put in place for liberalizing the electricity market, and also by a shift in economic structure from heavy industries to light manufacturing and services; as well as an aggressive effort in reducing non-CO_2 GHGs in industry.

The UK has successfully been able to decouple its economic growth from energy intensity and emissions intensity. Notable decreases have been obtained for the three main GHGs, namely N_2O (35 per cent), CH_4 (33 per cent) and CO_2 (8 per cent). Important policies in meeting the reduction target include the Domestic Emissions Trading Scheme, the Climate Change Levy and the Renewables Obligation. The third National Communication of the UK (NC3) projections indicates that the UK is likely to meet its Kyoto target. However, to ensure that GHG reductions are sustained, the UK government needs to vigorously pursue the measures outlined in the 'with additional measures' scenario.

[4] Contributors include Anthony Adegbulugbe (Nigeria), Miroslav Maly (Czech Republic), Martin Walsh, (Australia), Shardul Agrawala (OECD), Xin Ren (UNFCCC Secretariat) and June Budhooram (UNFCCC Secretariat Coordinator), together with various UK Government Departments and Organizations.

2. INTRODUCTION AND NATIONAL CIRCUMSTANCES RELEVANT TO GREENHOUSE GAS EMISSIONS AND REMOVALS

The UK ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 8 December 1993. It signed the Kyoto Protocol to the Convention on 31 May 2002 and ratified it with the other members of the European Community (EC) on the same day. The first national communication (NC1) of the UK was received by the UNFCCC secretariat in 1995, the second (NC2) in 1997, and the third (NC3) on 30 October 2001.

The in-depth review of the NC3 [1] was conducted from September 2002 to April 2003 and included a visit by a review team to London from 14 to 18 October 2002. During the visit, the team met experts who participated in the preparation of the NC3 and representatives of business and environmental non-governmental organizations (NGOs).

2.1 National Circumstances

After a recession in the early 1990s, when growth in gross domestic product (GDP) fell from 5 per cent in 1990 to -1 per cent in 1993, the economy regained momentum and has since experienced steady growth of around 2.3 per cent annually, exceeding both OECD and EC averages. Over the past decade, per capita GDP has grown by 20 per cent and economic growth by 25 per cent in constant terms, while per capita GHG emissions have declined by 9.5 per cent. This growth in GDP was driven primarily by rapid growth in transport, communications, and financial and business services, which together accounted for about 70 per cent of total output in 2000. This important shift in economic structure from traditional heavy manufacturing industry to light manufacturing and services, along with changes in sources for energy supply as a result of a liberalized electricity market, enabled the UK to reduce GHG emissions from 761.8 to 664.1 Tg CO_2 equivalent between 1990 and 2000, a sizeable reduction of 12.8 per cent. In returning GHG emissions to their 1990 level by the end of the 1990s, the UK has been able to decouple its economic growth from energy intensity and emissions intensity, as shown in Table 1.

Table 1. Main Macro-economic Indicators and GHG Emissions for the UK

	1990	2000	Change **(%)**[a]
Population (millions)	57.6	58.8	2.1
Gross domestic product - GDP (billions of US$ of 1995)	1 008.0	1 263.4	25.3
Total primary energy supply - TPES (Mtoe[b])	213.7	233.4	9.2
Electricity consumption (TWh)	309.4	371.6	20.1
GHG emissions[c] (Tg[d] CO_2 equivalent)	761.8	664.1	-12.8
GHG emissions per capita (Mg $C0_2$ equivalent)	13.2	11.1	-15.9
GHG emissions per GDP unit (kg $C0_2$ equivalent per US$ of 1995)	0.76	0.53	-30.3

Source: The population data are from the NC3 and data provided during the review. Data for GDP are from "Energy Balances from OECD countries, 1998--1999" OECD. Electricity and TPES data are from "UK Energy in Brief - July 2000", Department of Trade and Industry (DTI). GHG emission data are from NC3.

[a]The change is calculated as: [(2000 - 1990)/1990] x 100.

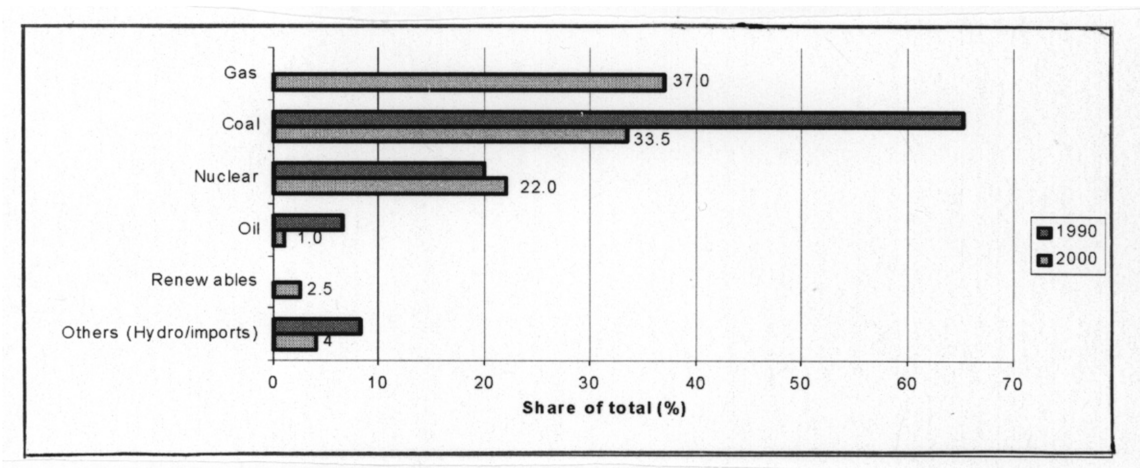
[b]Millions of tonnes of oil equivalent.

[c]Without accounting for land-use change and forestry (LUCF).

[d]One teragram (Tg) is equal to 1,000 gigagrams (Gg) or one million tonnes.

The UK has diverse primary energy sources. It is a major producer of natural gas and oil, and a net exporter of oil. In the 1990s, gas became the main fuel of choice for generating power and its share in the industrial, commercial and residential sectors increased. The increasing share of gas and the decreasing share of coal in electricity production over the decade (see Figure 1) helped reduce GHG emissions. The large share of nuclear energy (around 22 per cent) in electricity generation in 2000 also contributed to keeping emissions in check. However, as existing nuclear power generating stations retire over the next 20 years, the UK will face the challenge of replacing this energy source with non-GHG emitting alternatives.[5]

The Department for Environment, Food and Rural Affairs (DEFRA) is responsible for overall climate change policies and for coordinating appropriate actions in the UK. The Environment Agency for England and Wales, the Scottish Environment Protection Agency and the Environment and Heritage Service of Northern Ireland enforce environmental regulations, including relevant directives issued by the EC. Climate policy is developed following national consultations among devolved administrations, ministries, agencies and government departments,[6] regional assemblies and stakeholders affected, including NGOs. Some policies or aspects of certain policies require primary or secondary legislation, for example, penalties for emissions trading and the Renewables Obligation of the Climate Change Programme. All relevant ministries agreed to the Climate Change Programme before it was published.



Source: "UK Energy in Brief - July 2002". Department of' Trade and Industry (DTI).
Note. The sum of shares may not be exactly 100 per cent because of rounding.

Figure 1. Structure of Electricity Supply in the UK

The UK is outstanding in its rigorous verification and evaluation scheme for determining the effectiveness of climate change policies and measures in different areas ranging from the inventories to polices and measures and work undertaken in the scientific and research fields, all of which are well documented in the NC3. Plans are also under way to continue the internal monitoring and ex-post analysis in 2004 by independent consultants for policies and measures, prior to the preparation of the NC4.

[5] The Energy White Paper, which sets out the UK's energy strategy, was published on 24 February 2003 and is available together with supporting documents on the following web sites:
http://www.dti.gov.uk/energy/whitepaper/index.shtml
http://www.defra.gov.uk/environment/climatechange/ewpscience/index.htm

[6] These include the Department for Transport (formerly the Department for Transport, Local Government and the Regions), the Department of 'Trade and Industry, HM Treasury', the Foreign and Commonwealth Office, the Forestry Commission and the Department for International Development.

2.2 Relevant General, Energy, and Environmental Policies

Within the EU 'bubble agreement under the Kyoto Protocol, the UK has a target of reducing six GHG emissions to 12.5 per cent below the 1990 level in the first commitment period (2008-2012). In November 2000, the UK's Climate Change Programme was published. The programme contains a broad package of policies and measures across all sectors of the economy from transport to agriculture. The programme estimates that these measures could reduce GHG emissions by 23 per cent below 1990 levels by 2010. On this basis, and in fulfilling its desire to lead early action, the government has gone even further in its GHG reduction policies by adopting a domestic goal of reducing CO_2 emissions by 20 per cent below 1990 levels by 2010.[7] The domestic goal is based on using policies that have a range of benefits and builds on the partnership between the UK Government and the devolved administrations. Specific reduction targets have not been set for any of the devolved administrations or for any sector, but they can set up their own programmes and targets if they so desire.

The UK's Climate Change Programme formulated in 2000 comprises policies such as the Climate Change Levy package, including Climate Change Agreements (CCA), a new Carbon Trust to accelerate the take-up of cost-effective, low-carbon technologies; support of £30 million per annum for the five-year domestic emissions trading scheme; targets to deliver 10 per cent of electricity from renewable energy sources; the Ten Year Plan for transport; and increased budget for impacts and adaptation efforts.

As part of the European Union (EU), the UK is obliged to implement measures contained in the EC Directives on the environment. Some recent initiatives include voluntary agreements between the EC and car manufacturers to improve fuel efficiency of new cars, the European Best Practices Initiative, regulations such as the Integrated Pollution Prevention and Control (IPPC) and Landfill Directives, and measures to increase energy efficiencies of appliances and equipment.

A sustainable development strategy is in place. There are also a series of new policy strategies, which are in the pipeline but not yet adopted, for meeting general development objectives that have GHG mitigation benefits. Some of these include the Energy White Paper, published in February 2003, which will address, among other issues, the long-term strategy for energy and its compatibility with the objectives of the Climate Change Programme; and a conservation strategy.

3. GREENHOUSE GAS INVENTORY INFORMATION

3.1 Inventory Preparation[8]

DEFRA is responsible for planning, overall coordination and submission of the UK greenhouse gas inventory[9] to the UNFCCC and to the EC. DEFRA contracts out the compilation and updating of the National Atmospheric Emissions Inventory (NAEI) to a private consulting company - the National Environmental Technology Centre (NETCEN), a division of AEA Technology plc, a consultancy company. As the NAEI does not cover all the emission sources, NETCEN obtains estimates for emissions and removals from land-use change and forestry (LUCF) from the Centre for Ecology and Hydrology (CEH) and estimates for agricultural emissions from the Institute of Grassland and Environmental Research (IGER). The Department of Trade and Industry (DTI), the Department for

[7] A recent report by the Royal Commission on Environmental Pollution, "Energy - The Changing Climate" recommended that the UK Government should adopt a strategy for the long-term goal of reducing GHG emissions by 60 per cent by 2050.

[8] The UK's GHG inventory includes emissions from the Channel Islands and the Isle of Man. Emissions from Gibraltar will be included in the near future.

[9] The inventory is disaggregated each year to the devolved country level.

Transport (DfT) and the Forestry Commission are also pivotal in providing data and assisting in developing the methodologies for their respective areas.

NETCEN obtains energy and fuel statistics from the Digest of UK Energy Statistics (DUKES) compiled and published by the DTI. Information on industrial processes is provided either directly to NETCEN by individual sectors and/or through the Environment Agency (EA) Pollution Inventory. Large companies are required to report emissions of key pollutants to the EA. Some data are also obtained from reports of DEFRA-funded research contracts. For example, emissions estimates for methane in landfill sites are obtained from commissioned research contracts. Similarly, Enviros March, a consulting company, prepares estimates of emissions of HFCs, PCFs and SF_6 in consultation with industry.

The inventories presented in the NC3 were prepared using the *Revised 1996 Guidelines for National Greenhouse Gas Inventories* (hereinafter referred to as IPCC Guidelines). The methodologies employed for the estimates correspond mostly to the detailed Tier 2/3 methods of the IPCC Guidelines. Inventories are presented for the period 1990 to 1999 and include estimates for CO_2, CH_4, N_2O, PFCs, HFCs, SF_6; and GHG sinks. Emissions from biomass and international bunker fuels are also presented. The GHG emission trends in the NC3 are very well presented.

Emission factors used in the inventories were mainly from national sources, supplemented with some IPCC default values. For the energy sector, these factors were obtained from industry sources such as British Coal and the UK Petroleum Industries Association. All emission factors, with the exception of that of coke oven gas (which seems very high) are reasonably close to IPCC values. Most of the factors applied for this sector are dated 1989. All non-CO_2 emission factors for transport are estimated using experimental measurement. Emission factors for N_2O from the production of adipic acid are obtained from actual measurements. In the case of CH_4 and N_20 in the agriculture sector, IPCC default values were applied.

Although uncertainties of the emission estimates were not discussed in the Section dealing with the inventory in the NO3, they were presented in detail in the inventory report. The uncertainties were estimated using both the Tier 1 and Tier 2 approaches in the IPCC Guidelines. The result of the simpler Tier 1 approach showed an uncertainty of 18 per cent in the overall GHG emissions in 2000 and an uncertainty of 2 per cent in the trend between 1990 and 2000. In the Tier 2 approach, a Monte Carlo simulation technique was employed and uncertainty distributions were assigned to emission factors and activity data for CO_2. CH_4 and N_2O.

The Tier 2 uncertainty estimate for the total of GHG in 2000 was 15 per cent compared to 14 per cent in 1990. This indicates that there is little change in estimates of uncertainty from 1990 to 2000. Agricultural soils contribute most to the overall uncertainties. It should be noted that there is high uncertainty associated with activity data on aviation fuel. Inventory experts have indicated that there is no system of data collection currently in place to distinguish aviation fuel used for domestic and international flights, so the split is calculated by subtracting fuel consumption by domestic civil aircraft from the total aviation spirit delivered in the UK. However, NETCEN is currently upgrading this approach to make it compatible with the CORINAIR 'Detailed' (Tier 3) methodology for both domestic and international contributions. This will greatly improve both domestic and international estimates.

3.2 Overall Emission Trends

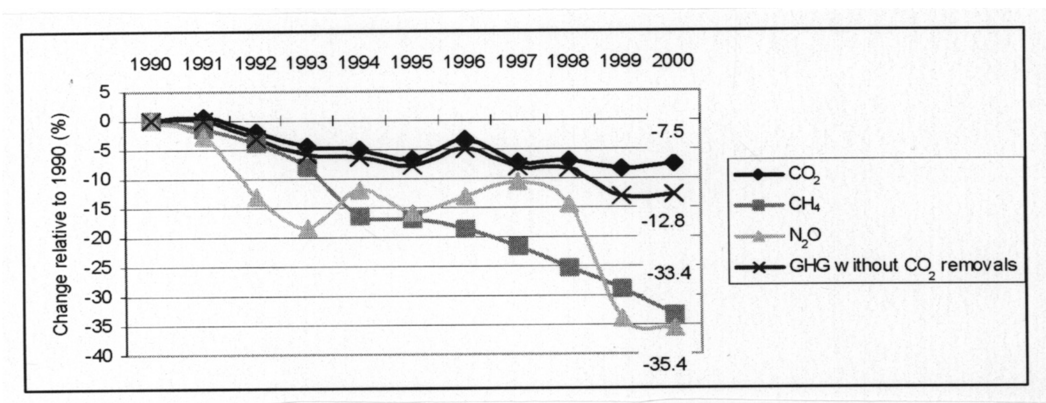
The total GHG emissions without CO_2 removals by sinks declined by 12.8 per cent between 1990 and 2000. An examination of the individual gases (see Table 2 and Figure 2) indicates that emissions of five of the six gases declined in that period. $C0_2$ fell by 7.5 per cent. CH_4 by 33.4 per cent, N_20 by 35.4 per cent. Total emissions of the fluorinated compounds (HFCs, PCFs and SF_6,) fell by 24.2 per cent. In the same period, the share of CO_2 emissions in the GHG total increased slightly from 79.1 per cent to 84 per cent, while the share of CH_4 emissions declined from 10.0 per cent to 7.7 per cent and N_20 from 8.9 per cent to 6.6 per cent. The fluorinated compounds have remained more or less constant (change from 1.8 per cent to 1.7 per cent).

Although removals of CO_2 by the LUCF sector have increased between 1990 and 2000 by 10.4 per cent, the sector has been a net source of CO_2 emissions (see Table 3).

Table 2. GHG Emissions by Gas

	Tg Equivalent											Change
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**(%)[a]**
$C0_2$	603.1	606.8	592.1	576.6	572.6	563.6	583.5	559.0	561.6	552.9	557.7	- 7.5
CH_4	76.5	75.4	73.6	70.4	63.9	63.6	62.2	59.9	57.2	54.4	51.0	-33.4
N_20	67.9	66.0	59.1	55.4	59.8	57.1	59.1	60.8	58.0	44.9	43.8	-35.4
HFCs	11.4	11.9	12.3	12.9	13.8	15.2	16.3	18.4	20.2	8.6	9.3	-18.1
PFCS	2.3	1.8	1.0	0.8	1.0	1.1	0.9	0.7	0.7	0.7	0.7	-70.7
SF_6	0.7	0.8	0.8	0.9	1.1	1.1	1.3	1.3	1.5	1.5	1.5	113
HFCs+PFCs+SF_6	14.4	14.4	14.1	14.6	15.9	17.4	18.5	20.4	22.4	10.8	11.5	-24.2
GHG without $C0_2$ removals:	761.8	762.6	738.9	717.1	712.2	701.7	723.3	700.1	699.1	662.9	664.1	-12.8
$C0_2$ removals	-10.6	-10.7	-10.8	-11.1	-11.3	-11.5	-11.6	-11.6	-11.5	-11.5	-11.7	-10.4
GHG with $C0_2$ removals	751.3	751.9	728.1	706.0	700.9	690.2	711.7	688.5	687.6	651.3	652.4	-13.2

Source: This table uses the data from the 2002 inventors' submission to the UNFCCC.
[a]The change is calculated as: [(2000 - 1990)/1990] x 100. Values in thus table are rounded, so the calculation may not be exactly as shown in this column.



Source: Report on the In-depth Review of the Third National Communication of the United Kingdom of Great Britain and Northern Ireland, United Nations Framework Convention on Climate Change (UNFCCC) [1].

Figure 2. Trends in the Main GHG Emissions of the UK

3.3 Key Emission Sources and Sect oral Trends

Table 3 presents GHG emissions by major sectors for the period 1990-2000. The energy category[10] remains the key contributor to the GHG total (about 85 per cent in 2000) but its emissions decreased by almost 9 per cent over the decade. All sectors within this category, except transport, experienced overall reductions in emissions. The largest reductions between 1990 and 2000 were achieved in industrial processes, fugitive emissions and waste. It should be noted that there are four important trends: a notable decrease in energy-

[10] Includes fuel combustion in the energy industry, manufacturing industry, and transport sectors.

related CO_2 emissions (about 8 per cent); a substantial decrease in CH_4 emissions (about 33 per cent); and in N_2O emissions (35 per cent); and mixed changes in emissions of the fluorinated gases, with an overall decrease.

Notable decrease in energy-related CO_2 emissions. The decline is due mainly to a reduction in CO_2 emissions from power plants, which fell by about 29 per cent in spite of an increase of 16 per cent in electricity consumption in the same period. The major reason that emissions did not increase proportionately to generation was fuel substitution from coal to gas. For example, coal accounted for 70 per cent of fuel used for electricity generation in 1990 but only 33 per cent in 2000. On the other hand, gas utilization for electricity generation increased from less than 1 per cent to 38 per cent between 1990 and 2000. Other reasons for the decrease in CO_2 emission are the increases in the use of renewable energy and cogeneration (combined heat and power), and higher efficiency of the combined cycle gas power plants.

Other trends in CO_2 emissions are the declining emissions from the manufacturing and construction sector and an increase in emissions from transport. Emissions from the manufacturing sector decreased by 7.62 Tg CO_2 or by 8 per cent between 1990 and 2000. Improved energy efficiency and fuel substitution of coal by gas are among the reasons for this trend. Emissions from transport have increased by 8 per cent between 1990 and 2000. The emissions from this sector are dominated by the contribution from road transport, which rose by about 6 per cent over the period. Road transportation, measured in passenger-km, has continued to increase, although petrol usage decreased by around 12 per cent since 1990. However, this decrease was offset by increased diesel fuel utilization owing to an increase in the stock of diesel cars and trucks. There had been a reduction of 7.3 per cent in CO_2_emissions per km driven between 1990 and 2000.[11]

Table 3. GHG Emissions by Sector and Sub sector

	Tg CO_2 Equivalent											Change
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	
1. Energy	604.8	610.9	596.3	580.4	570.8	563.2	581.7	557.8	559.2	548.5	553.6	-8.5
A1. Energy industries	230.5	228.5	218.4	201.6	199.0	200.3	200.3	186.2	192.0	184.0	194.2	-
A2. Manufacturing industries	95.6	96.3	95.3	93.9	95.3	93.1	94.0	94.6	91.7	91.0	87.7	-8.3
A3. Transport	118.6	118.1	119.6	121.0	121.7	120.9	126.0	127.3	126.8	127.8	127.6	7.6
A4-5. Others	120.0	130.3	126.3	129.5	123.9	119.1	132.4	122.3	123.3	122.2	122.4	2.0
B. Fugitive emissions	40.2	37.7	36.8	34.4	31.0	29.8	29.1	27.3	25.3	23.5	21.7	-46.1
2. Industrial processes	58.0	53.8	47.7	45.0	50.7	49.1	52.3	53.9	53.2	29.7	30.9	-46.7
3. Solvents	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
4. Agriculture	53.6	53.1	51.5	50.8	51.7	51.7	52.0	52.7	51.9	51.2	48.6	-9.3
5. LUCF	8.8	8.9	8.3	6.6	5.4	4.7	5.0	4.8	5.0	4.8	3.4	-61.8
6. Waste	26.0	25.2	24.2	23.2	22.3	21.5	20.7	19.4	18.4	17.1	16.0	-38.5
Total (without	**742.5**	**743.0**	**719.8**	**699.4**	**695.5**	**685.5**	**706.7**	**683.8**	**682.6**	**646.5**	**649.1**	**-12.6**
Total (with LUCF)	**751.3**	**751.9**	**728.1**	**706.0**	**700.9**	**690.2**	**711.7**	**688.5**	**687.6**	**651.3**	**652.5**	**-13.2**

Source: Report on the In-depth Review of the Third National Communication of the United Kingdom of Great Britain and Northern Ireland, United Nations Framework Convention on Climate Change (UNFCCC) [1].
[a] **The change is calculated as: [(2000 - 1990)/1990] x 100.**

Substantial decrease in CH_4 emissions. The large reduction in CH_4 emissions is mostly due to decreasing emissions from coalmines and landfill sites. CH_4 emissions from deep mined coal production have fallen by 68 per cent from 17.2 to 5.56 Tg CO_2 equivalent between 1990 and 2000. This is due to the general decline in deep coal mining

[11] Natural Atmospheric Emissions Inventory 2002 (NAEI).

production, which fell from 72.9 to 17.2 Mt in the same period. Similarly, CH_4 emissions from landfill sites have declined by 41 per cent since 1990, because of an improvement in gas collection for energy- production and environmental control. This trend is likely to continue because new landfill sites are expected to have CH_4 recovery systems.

Substantial decrease in N_2O emissions. The most notable contributor to the decline in N_2O emissions is the large decline in emissions from industrial processes, particularly in the production of adipic and nitric acid, which fell by 79 per cent from 29.27 Tg CO_2 equivalent in 1990 to 6.18 Tg CO_2 equivalent in 2000. N_2O emissions from adipic acid fell sharply in 1998 and 1999 as a result of the retrofitting of an emissions abatement system in those industries: N_2O emissions decreased by 92 per cent in its first year of operation.

Overall reduction in the emissions of fluorinated gases[12] but doubling of SF_6. HFCs emissions almost doubled between 1990 and 1998. But in 1999, with the installation of an HFC destruction system fitted to the largest HCFC production plant operating in the UK (accounting for 43 per cent of total emissions of HFCs in 2000), total HFC emissions fell by 43 per cent compared to the previous year, they fell by 18 per cent between 1990 and 2000. The decline in the PFCs was even more remarkable, with emissions falling by 71 per cent between 1990 and 2000 owing to process improvements and increased recycling in the aluminum industry, as well as process improvements in the electronics sector.

4. POLICIES AND MEASURES

The NC3 is in full compliance with the reporting guidelines in presentation and organization of the information. The report is organized by sector and by gas, with discussion and data presented within each sector by gas.

4.1 Cross-Sectoral Policies and Measures

A key cross-sectoral measure of the Climate Change Programme is the Climate Change Levy (CCL), introduced on I April 2001. It is a tax instrument[13] that applies to energy consumption in industry, commerce and the public sector (excluding the residential sector), with no increase in the tax burden on industry as a whole and no net gain for the public finances. Combined heat and power and renewable sources of electricity are exempt from the CCL. Rates of levy are 0.15 pence/kWh for gas, 1.17 pence/kWh for coal, 0.07pence/kWh for liquefied petroleum gas (LPG) and 0.43 pence/kWh for electricity. The levy is expected to raise £ 1 billion in a full year and reduce $C0_2$ emissions by 2.0 Mt C/year by 2010.

The levy package also establishes Climate Change Agreements (CCAs), which provide an 80 per cent discount in levy rates for those energy intensive sectors of industry that have agreed to improve energy efficiency or reduce GHG emissions. Carbon savings from CCAs have been estimated at 2.5 million tonnes of carbon annually by 2010. CCAs have already been completed with almost all eligible sectors. There are 10 major energy-intensive sectors namely aluminum, cement, ceramics, chemicals, food and drink, foundries, glass, non-ferrous metals, paper and steel.

Another key cross-sectoral measure is the UK voluntary domestic emissions trading scheme, the world's first economy-wide GHG permit trading scheme. Government support of £ 215 million between 2002 and 2006 is available to 34 companies that, at an auction in March 2002, successfully bid to take on binding emission reduction targets. The scheme has only recently been established so there is little

[12] The UK uses 1995 as the base year for the fluorinated gases. Experts believe that 1995 data for these compounds are more reliable and that the EU will use 1995 data as the common base year.

[13] The government will return revenues from the CCL to the non-domestic sector, principally through a cut of 0.3 per cent in the rate of employers' National Insurance Contributions. Businesses will benefit from the schemes aimed at promoting energy efficiency and take-up of renewable energy sources. The government will also provide £120 million of additional support for energy saving measures.

information available on the indicative price of permits, or trends, although it is understood that early trades have taken place in the range of £ 11- £ 44/tonne of carbon.

The scheme has been designed to limit fungibility. Carbon reductions under the Renewables Obligation Certificates (ROCs) scheme can be traded into the emissions trading scheme, although this cannot happen in reverse (i.e., permits from the emissions trading scheme cannot be used to meet obligations under the Renewables Obligation). There is a limited interface with Energy Efficiency Commitments. In general, electricity, generators were excluded from the scheme, but there is a possibility for generators, or generators in conjunction with a project developer, to cam out domestic projects generating credits once the Energy Efficiency Commitment has already been met.

4.2 Energy Production and Transformation

The energy category[14] accounts for the lion's share (about 85 per cent in 2000) of the UK's total GHG emissions. Emissions from the industries have declined in the past decade, despite healthy economic growth over most of the period. A key objective of the government is to sustain the ongoing real reductions in GHG emissions from the energy sector while at the same time maintaining low-cost energy supply to consumers and diversity and security of supply.

The main policy instrument for determining the appropriate policies and measures to balance and achieve these objectives is the Energy White Paper[15] and it will also address the longer-tern viability and GHG reduction potential of electricity generation from coal and nuclear energy.

Emissions reduction over the past decade has come mostly from the rapid increase in the use of gas, which was driven by a range of factors including deregulation of the electricity sector and the availability of cheap gas. Although coal-fired electricity generation still makes a major contribution to GHG emissions, the UK is in a position to tap the future potential of clean coal technologies such as coal gasification and geological sequestration, which are still some years away from economic deployment.

In this regard, the Climate Change Programme makes provision for developing cleaner conventional fuels technology. Nuclear generation is constrained primarily by concerns about the disposal of nuclear waste. However, as it is a carbon-free source of large-scale generation, the government has signaled its interest in keeping the nuclear option open for the longer term, in the event that other options to reduce GHG emissions from the energy supply sector are not effective.

There is a continued focus on liberalization of the gas and electricity markets, which are now fully open to competition. This was achieved through (a) the Utilities Act 2000, which aims to reform regulation of the gas and electricity sector through the use of a single regulator with a new principal objective of protecting the interests of consumers: and (b) the New Electricity Trading Arrangements (NETA), which aims to remove market distortions to ensure security and diversity of supply. The new market arrangements have been successful in achieving the government's primary objective of reducing the price of energy to the consumer. Prices over the first year of the NETA (March 2001 - March 2002) fell by 20 per cent.

Important initiatives for reducing GHG emissions from the energy sector include reducing consumer demand for power through the Energy Efficiency Commitment, and increasing renewable sources through the Renewables Obligation[16] and renewables support programme. The Energy Efficiency Commitment and Renewables Obligation measures are both market-based instruments that place an obligation on energy suppliers to meet targets, but at the same time allow them to choose the means by which the targets are met, including trading of the property rights to the achievement of individual targets. The Energy Efficiency Commitment is designed to encourage or assist consumers to take up energy saving opportunities over the period 2002-2005. The total obligation on all suppliers is 62 TWh, which is equivalent to about 1 per cent of domestic consumption.

[14] Includes fuel combustion in the energy industry, manufacturing, industry and transport sectors.
[15] The Energy White Paper is not discussed in this report, as it was still under discussion.
[16] A separate Renewables Obligation exists in Scotland.

In keeping with the objectives of the Climate Change Programme, the Renewables Obligation requires licensed electricity suppliers to supply an increasing proportion of electricity, rising to at least 10.4 percent by 2010, from renewable sources. Suppliers liable under the measure use a system of certificates to demonstrate compliance. The certificates are tradable, which encourages the market to find the most economically efficient means of achieving the target. The Renewables Obligation initiative has a buyout price of £30/MWh, yet it is understood that some forward trades have occurred at well above the buyout price, at around £45/MWh.

The Renewables Obligation contains no special arrangements to encourage small generators (e.g., at the residential or small-business scale) to participate.[17] All small generators under the Renewables Obligation must separately meter their output.

Early strong signs that the NETA is discouraging small generation, including renewables and combined heat and power, appear to have weakened somewhat with the Office of Gas and Electricity Regulation (OfGEM) reporting in July 2002 that smaller generators were producing about the same amount of electricity as before the NETA. Prices for smaller generators were reported to have fallen in line with prices in the market as a whole. The government has attempted to address ongoing concern about smaller generators of renewable electricity by providing financial support from the Renewables Obligation and other programmes.

A target for new combined heat and power of at least 10,000 MWh by 2010, representing a doubling of present capacity, has also been adopted. The UK currently has around 4,700 MWh of combined heat and power in operation, estimated to save around £800 million and 4 Mt C annually. Combined heat and power provides one of the most cost-effective approaches for reducing CO_2 emissions, and with further savings by 2010 it is expected to play a crucial role in the Climate Change Programme.

It is expected that the renewable energy target will be extended to 20 per cent by 2020, but, like the call for an increased energy efficiency target, this will depend on the government's consideration of these issues in the context of the Energy White Paper.

Table 4 compares costs and impacts of selected emissions reduction measures in the energy sector. Although the figures incorporate a fair degree of uncertainty, owing to the early stage of implementation of the schemes, it seems reasonable to assert that targeting emissions reductions from increasing the uptake of renewables is likely to come at a much higher cost than the other measures, which tend to draw out lower cost emissions savings in energy efficiency.

Table 4. GHG Reduction Potential by 2010 of Key Measures in the Energy Sector

Measure	Cost (£/tonne of Carbon	GHG Reduction Potential (Mt C)
Renewables Obligation	210-380	2.5
Energy Efficiency Commitment	-270-60[a]	0.4
Climate Change Levy (excluding CCAs)	17-40	2.0
Climate Change Agreements (CCA)		2.5
UK Domestic Emissions Trading Scheme	11-44	0.8

Source: OfGEM submission to Energy Policy Review, August 2002.
[a]Note that there is a minus sign before 270, given that the energy efficiency commitment is expected to create financial savings. Oily in some instances may there be a cost; hence the large range -270 to +60.

4.3 Residential and Commercial Sectors

[17] For example, one possibility can be making the renewable electricity output mandatory, as is the case in the Australian Mandatory Renewable Energy Target.

GHG emissions in the residential and commercial sectors come from combustion of fuels for space and water heating. Mitigation measures in these sectors focus mainly on measures to improve and promote energy efficiency in homes and buildings and through a number of policy instruments, including building regulations, energy conservation, incentives for using energy-efficient equipment, education and public awareness. The Carbon Trust includes an integrated programme to accelerate the take-up of energy saving measures.

The Energy Efficiency Commitment is being supported by the revision of building regulations in up to three stages, including adequate performance of heating and hot water systems, higher standards of insulation and use of energy efficient lights in new buildings. The NC3 forecasts possible sayings of 1.4 Mt C by 2010, from implementation of all three stages of the full programme.

4.4 Transport

The transport sector accounted for about 20 per cent of the UK's total GHG emissions in 2000. There is a close correlation between growth in the economy and growth in transport use, and emissions are forecast to grow in line with the expected growth in road traffic. Road transport is the dominant mode of transport for both passengers and freight.

The institutional arrangements for managing terrestrial modes of travel are quite complicated as there are varying responsibilities between the UK Government, devolved administrations and local authority administrations. The network of `strategic roads' is run by a national agency for England. These roads are only 4 per cent of total length of road, but carry the largest share of transport volume. Local authorities undertake the rest of transport management.

. The most important policy development in the sector since the NC2 is the 10 Year Transport Plan, effective to 2010. This plan was prepared in partnership with industry to address key transport challenges, including growing traffic congestion on the roads; overcrowding and declining performance on the railways; poor quality public transport; and environmental impacts, including GHG emissions reduction. The plan is supported by a commitment to increase investment in transport infrastructure by 75 per cent in real terms, with £ 180 billion of public funding over 10 years. This would be more than twice the annual investment in transport in the 1990s. The plan is expected to reduce GHG emissions by 1.6 Mt C per year by 2010.

With the plan, the government expects to achieve a 50 per cent increase in rail passenger use; eliminate road maintenance backlog; increase bus use by 10 per cent; treble cycling trips; reduce air pollution; reduce congestion on inter-urban networks in urban areas; and double light rail use.

There is a range of other measures in place to reduce emissions from road transport, and a range of taxation instruments. The Vehicle Excise Duty, an annual vehicle tax charge in existence for decades, was reformed in 2001 to encourage the use of less polluting vehicles. Previously differentiated for two classes by engine size, it is now differentiated for five classes by CO_2 emission level.

Looking to the future, a government strategy, *Powering Future Vehicles,* completed in July 2002, sets a range of emission targets for new cars and buses by 2012. A target for selling ultra low carbon cars by 2020 is being developed.

Alternative fuels, such as natural gas and LPG, are being encouraged through fuel duty incentives. For example, biodiesel (sourced mostly from recycled vegetable oil, incorporating waste reduction benefits) has a 20-pence/litre lower fuel duty than diesel.

Domestic passenger air travel is currently growing at about 3.5 per cent per year. Total passenger numbers on national and international flights rose from 32 million in 1970 to 180 million in 2000 and is expected to reach 500 million by 2030. This growth is expected to have an effect on the growth in GHG emissions from air transport. Airfreight is also steadily increasing, by about 7 per cent annually.

4.5 Industry

Industry (excluding energy production) accounted for about 5 per cent of GHG emissions in 2000. A decline in CO_2 emissions experienced over the 1990-2000 period was attributed to process changes and fuel shifts in many of the energy-intensive industries such as cement, aluminum, glass, and pulp and paper. Emissions of non-$C0_2$ gases from industrial processes have dropped, as a result primarily of regulatory controls on larger industrial sites but also of the closure of some plants. Overall N_2O emissions from industrial sources have decreased considerably (by 79 per cent) since 1990. This was due to voluntary and commercially driven reductions in the manufacture of adipic and nitric acids.

Emissions of HFCs make a relatively low contribution to the UK's overall emissions (about 1.8 per cent in 2000). The installation of abatement technology has reduced these emissions, but there is an upward trend in the use of HFCs for refrigeration, reflecting the mandated move away from ozone-depleting gases under the Montreal Protocol, and the government has committed itself to longer tern action on this front.

4.6 Agriculture

The agriculture sector accounted for about 8 per cent of total GHG emissions in 2000. Agricultural policy in the UK is primarily directed from the European level, through the Common Agricultural Policy (CAP). Emission reductions in the sector are being obtained through increased productivity, mainly in the dairy industry, and in efficient use of fertilizer, primarily driven by CAP limits. The UK is leading the world in electricity generation from burning poultry litter, with three power plants.

4.7 Land-use Change and Forestry

In 2000. CO_2 removals by sinks amounted to 11.7 Tg CO_2 equivalent. According to the inventory data, sink capacity increased by about 11 per cent between 1990 and 2000. However, the sector as a whole was a net source of CO_2 between 1990 and 2000. Forestry policy in the UK is implemented by the devolved administrations.

4.8 Waste

Emissions from waste contributed about 3 per cent to total GHG emissions in 2000. By far the largest single source of emissions in the waste category is CH_4 from landfill, which has declined by 41 per cent since 1990 because of the implementation of economic CH_4 recovery systems, largely through the stimulation provided by the Non-Fossil Fuel Obligation (NFFO). The main measure on the sector is a landfill tax, in place since 1996, which will escalate to £15 per tonne in 2004, after which it will be reviewed. The main policy driver that promotes GHG emission reductions from the sector is the EC Landfill Directive, which imposes, inter alias, legally binding limits on the amount of biodegradable municipal solid waste (MSW) that is land filled (with stepped targets to 35 per cent of the 1995 level by 2020). Some 83 per cent of municipal solid waste is sent to landfill sites in the UK, and about 9 per cent is recycled or composted; this is among the lowest rates in Europe. The government has addressed this and other priorities in its Waste Strategy 2000, which is comprehensive in its coverage, proposing actions covering waste from all sectors of government, industry and the community.

5. PROJECTIONS AND THE TOTAL EFFECT OF POLICIES AND MEASURES

The NC3 contains a complete set of projections for all GHGs to 2020. The general responsibility for development of GHG emission projection is with DEFRA which shares the work with some other specialized government departments and agencies and also involves, to a large extent, universities and private companies to deliver projections for specific sectors or activities. The structure of emission sources and the GHGs covered in the projections are consistent with those covered in the inventory, and projections have been prepared for each gas, namely CO_2, CH_4, N_2O, HFCs, PFCs and SF_6. Emissions of individual GHGs are presented in Mt C. GHG projections are presented for 2000, 2005, 2010, 2015 and 2020, and a comprehensive data set, in tabular format, is included for each sector and gas. Projections are consistent with the 2000 inventor, submission except for the LUCF projection, which had been revised to reflect a change in inventor, methodology between the 2000 and 2001 submissions that resulted in a large difference in LUCF data.

The DTI is responsible for preparing projections for CO_2 emissions, and these are derived from the DTI's energy model, which comprises a set of sub-models of final user energy sectors and the electricity supply sector. It is a combination of a `top down' model, based on econometrically estimated relationships between energy demand, economic activity (income) and energy prices, and a linear optimization model for the electricity industry (this model uses a 'bottom-up' approach). The models provide possible future levels and composition of energy demand, based on a set of different assumptions for economic growth and world energy prices, rather than one single forecast.

5.1 Scenario Definitions and Key Assumptions

The NC3 presents two GHG emission projections: the 'with measures' projection and the 'with additional measures' projection. The `without measures' projection is not presented. The 'with measures' projection also serves as a 'baseline' scenario. The scenarios are derived from the Climate Change Programme. The baseline scenario originated from the work published by DTI in its Energy Paper 68 [18] in 2000, which identified six core scenarios based on three GDP growth rate assumptions and two energy price assumptions. The baseline scenario is an average of two central scenarios with the same GDP growth rate assumption but each with a different energy price. The scenario `with additional measures' was not obtained from modeling; instead, it was prepared by deducting the estimated emission reductions due to the additional measures from the `with measures' projections.

The key assumptions for the baseline scenario are: GDP growth of 2.55 per cent annually between 2001 and 2005 and 2.25 per cent a year between 2006 and 2020; population growth of 5 per cent by 2021; oil price at US $10 and US $20 a barrel in 1999 prices; a tax structure assumed to be maintained in real terms; and a continuing upward trend in temperature.

The base year for emission projections is 1999, as this was the latest year for which inventory data were available at the time of preparation of the NC3. Projections are presented for the years 2000, 2005, 2010, 201 and 2020. Data on energy use relating to the 'with measures' projection and 'with additional measures' projections are not presented in the NC3.

5.2 Projected Emission Trends

Figure 3 shows the latest inventory data at the time of the review[19] and the GHG projections for the period 1990-2020. The 'with measures' projection includes a wide range of currently implemented and adopted policies, such as, the price effect of the Climate Change Levy; the Renewables Obligation based on the 10 per cent renewable target; Fuel Duty Escalator to 1999; and the Waste Strategy and EU Landfill Directive. These policies and measures have all been implemented since the Kyoto Protocol was adopted in 1997, except for the Fuel Duty Escalator, which was introduced in 1993. The UK's Kyoto target is a GHG reduction of 12.5 per cent. Based on the `with measures' projection (baseline), the UK's emissions of GHGs are expected to be about 13 per cent below the 1990 level in 2010, and CO_2, emissions about 8 per cent below.

The `with additional measures' projection includes the following planned policies and measures: Climate Change Agreement and the IPPC energy efficiency measures under the Climate Change Levy package; emission trading scheme; amendment of building regulations; appliance standards and labels;

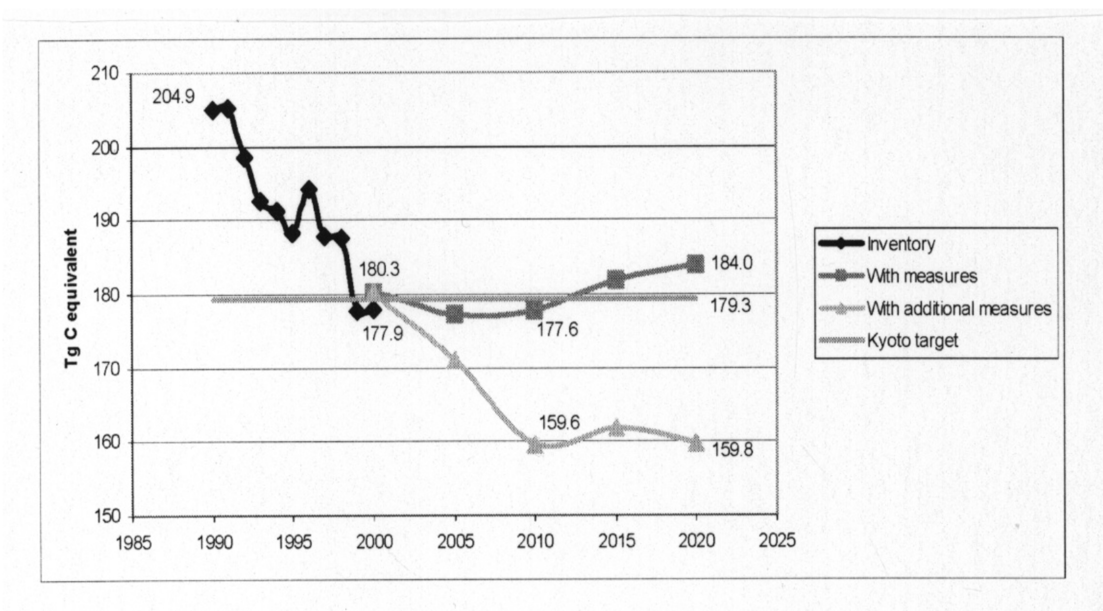
[18] Energy Projections for the UK - Energy Use and Energy-Related Emissions of Carbon Dioxide in the UK, 2000) to 2020. Energy Paper 68, DTI.

[19] UK Greenhouse Gas Inventory, 1990-2000. NETCEN, March 2002.

improving the quality of local authority housing stock and community heating; public sector targets: 10 Year Transport Plan; voluntary carbon offset schemes; and afforestation.

Based on the `with additional measures' projection, the national GHG emissions are expected to decline by an additional 8 per cent in 2010 compared to the 1990 level, with CO_2 emissions about 11 per cent below. In total, the UK's emissions of GHGs are expected to be about 22 per cent below the 1990 level in 2010, with CO_2 emissions about 19 per cent below. The `with additional measures' projection contains a very wide range of policies and measures and thus low performance of one policy or measure would not have a critical impact on meeting the Kyoto target.

In 2002, GHG emissions increased compared to 1999, the most recent year taken account of in the CO_2 projections, and thus inventory data for the year 2000 are slightly above projected data for 2000 in the NC3 (by about 1 Tg CO_2 equivalent). The difference in projected data for the year 2000 between the `with measures' projection and the `with additional measures' projection is about 2.5 Tg CO_2 equivalent. In 2010 the difference in GHG emissions between scenarios is 18 Tg CO_2 equivalent and in 2020, 24 Tg CO_2 equivalent. This increase in emissions between 1999 and 2002 was due mainly to an increase in the use of coal for electricity supply. Although this fuel shift may influence meeting the Kyoto target without the additional measures quantified in the NC3, the target should be met by a significant margin with these additional measures, as indicated in Figure 3.



Source: Report on the In-depth Review of the Third National Communication of the United Kingdom of Great Britain and Northern Ireland, United Nations Framework Convention on Climate Change (UNFCCC) [1].

Figure 3. Comparison of Projections of the Total GHG Emissions by Scenario

The NC3 presents a sensitivity analysis. The following sources of uncertainty in projections are assessed: combination of GDP and fuel prices (the estimated effect is ±4 Mt C per year in 2010); economic modeling process for energy-related $C0_2$ (±9 Mt C per year); area and parameter assumptions driving land-use change emission projection (±2 Mt C per year); and the non-$C0_2$ GHG range (±1 Mt C per year). The resulting total uncertainty is estimated as ±10 Mt C in 2010, which is much less than the difference between the 'with additional measures' scenario and the Kyoto target.

5.3 Effects of Policies and Measures

In accordance with the reporting guidelines, the NC3 contains a 'with measures' projection and a 'with additional measures' projection. However, it does not contain any `without measures' projection. Nevertheless, the effects of the already implemented measures are estimated in the NC3. Table 5 presents a breakdown of emissions reductions by major policies for the 'with measures' projections. The two measures that contribute the most to reducing emissions are the Renewables Obligation and the Fuel Duty Escalator to 1999. Together, they account for more than 50 per cent of the mitigation effect in the baseline ('with measures') projection. The projected contribution of the Climate Change Levy to the emission reductions grows between 2010 and 2020.

Table 5. Mitigation Effect[a] of Implemented Measures for the 'With Measures' Scenario

	Tg C Equivalent [b]		
Measure	**2000**	**2010**	**2020**
	0.7	1.5	1.5
Renewables Obligation	0.0	2.5	2.5
Climate Change Levy	0.0	1.0	2.0
Fuel Duty Escalator to 1999	n.q.	1-2.5	1.8
Waste Strategy and EU Landfill Directive	0.0	0.1-0.5	n.q.
Total	**0.7**	**8.0**	**7.8**

Source: Report on the In-depth Review of the Third National Communication of the United Kingdom of Great Britain and Northern Ireland, United Nations Framework Convention on Climate Change (UNFCCC) [1].

n.q. - Not quantified

[a] The mitigation effect is the contribution of measures in the 'with measures' projection.

[b] Estimates are based on data presented in the annex B of the NC3.

The NC3 contains a comprehensive set of additional measures that are included in the 'with additional measures' projection. These measures are identified for all sectors. Table 6 presents a breakdown of the contribution of individual policies and measures aggregated by sector.

TABLE 6. MITIGATION EFFECT[a] OF ADDITIONAL MEASURES FOR THE `WITH ADDITIONAL MEASURES' PROJECTION

Sector	Mt C Equivalent[b] 2010	2020
BUSINESS, PUBLIC AND COMMERCIAL SERVICES	7.0	8.3
Residential	4.7	5.4
Transport	5.7	9.2
Forest	0.6	1.2
Total effect	**18.0**	**24.1**

Source: Report on the In-depth Review of the Third National Communication of the United Kingdom of Great Britain and Northern Ireland, United Nations Framework Convention on Climate Change (UNFCCC) [1].

[a]The mitigation effect is the difference in annual GHG emissions between the 'with measures' projection and the 'with additional measures' projection.
[b]Estimates are based on data presented in the annex B of the NC3.

In 2000, the achieved reduction relates mostly to the business sector, public and commercial services, and the residential sector. For the future, the reduction of GHG emissions becomes nearly equally distributed among major sectors: business, public and commercial services, residential and transport.

5.4 Overall Evaluation of the Projections

In reporting on the projections, the NC3 follows, in general, the UNFCCC guidelines. The definition of scenarios and the modeling assumptions are presented comprehensively. This can be attributed to the early and continuous involvement of various parties in the development of GHG emission projections, a process that seems to have given excellent results.

Projections are regularly checked and verified by comparing trends in actual historical emissions with future emission estimates. If there is a significant variation, project methodologies and assumptions are revised accordingly.

The NC3 meets all requirements of the reporting guidelines on projections, including the incorporation of the total effect of policies and measures.[20] Many policies and measures in the `with additional measures' scenario are innovative and thus could be recommended for use in other countries.

The scope of policies and measures is very impressive. The modeling tool being developed by the Department for Transport could be valuable for modeling sect oral GHG projections; however, this is currently not possible as these models have different objectives.

CO_2 emissions from flue-gas desulphurization (FGD) with limestone at power plants are not included in either the emission inventory or projections. Due to an expected increase in the number of power plants equipped with FGD technology, emissions released from this technology should be included in an updated inventory and also in the projections.

Energy demand and emission projections are sensitive to changes in energy prices, as shown by the increase of GHG emissions between 1999 and 2002 when more coal was used for energy production.

The NC3 describes in detail the key assumptions used for developing the projections (GDP, energy prices, tax structure, population, vehicles, industrial production, etc.). However, the main assumptions for the non-CO_2 GHGs were not always clear and could also be presented in tabular form, e.g. projected development of livestock, land use, waste management, in the future.

GHG emissions in the 'with measures' projection are slightly below the Kyoto target but in the ‘with additional measures' projection emissions they are well below the Kyoto target. **Therefore, it appears likely that the UK will meet its Kyoto target.** The low-carbon-economy strategy would make the trends presented in the GHG emission projections sustainable and consistent with broader national objectives. Coordination is an important component in preparing GHG emissions projections. It has been exemplary, and should be supported even more in future efforts.

6. VULNERABILITY ASSESSMENT, CLIMATE CHANGE IMPACTS AND ADAPTATION MEASURES

The NC3 complies adequately with the reporting guidelines on vulnerability assessment, climate change impacts and adaptation measures. Climate change is projected to have major impacts on the UK. The risk of flooding is expected to increase in many lowland areas due to more frequent river flooding and more severe storm surges. Increased water demands and more droughts could aggravate the water situation in many areas, particularly in the South East. Rare flora and fauna currently at the edge of their natural geographic ranges might be lost due to their inability to migrate with a shifting climate. Increased weather variability and flooding could affect UK businesses through impacts such as disruption in supply of goods. In health and agriculture, the effects of climate change are expected to be mixed. Growing seasons might lengthen due to warmer winters, but pest populations might increase due to more conducive climates. In health, summer heart-related deaths are expected to increase.

The UK is a leader in climate modeling through the Hadley Centre and its role in the IPCC Working Group 1 between 1990 and 2001. Over the past decade, considerable progress has also been made on impacts and adaptation work. On climate modeling, the spatial scale of climate model projections has been improved through downscaling techniques to make model outputs more useful for impacts research. The UK Climate Impacts Programme (UKCIP) was set up by the government in 1997 to provide a coordinated framework for assessing impacts and adaptation strategies. A Science Advisory Panel oversees the scientific integrity of the work. To date, several sect oral (such as biodiversity. health, water, marine environment) and regional (such as Scotland, Wales, West Midlands, South East England) studies have been initiated as part of the UKCIP. A key feature of these studies is that they are led by the stakeholders, with the UKCIP providing common frameworks and tools, as well as access to the relevant experts.

The NC3 does not discuss economic impacts of climate change but such studies are currently under way. A methodology document for costing of impacts and adaptation options had recently been produced. The NC3 does not discuss implications for the insurance sector.

[20] Policies such as the Renewables Obligation, emissions trading and the Climate Change Levy are considered innovative.

At an international level, work under the Fast-track programme is ongoing to develop quantitative estimates of climate change impacts worldwide. The UK is also engaged in more in-depth collaborative studies on climate change impacts in India and China.

On adaptation, good progress has been made since the NC2. The government and the devolved administrations aim to ensure a strategic response to adapt to climate change, while actively involving the public and private sectors. Sectors that involve planning decisions of several decades for infrastructure have been identified as current priority areas for adaptation (water resources, flood and coastal defenses and buildings).

The NC3 outlines efforts to educate farmers on potential climate change impacts, but it is not clear how- that might be achieved because farming decisions are more likely to be influenced by seasonal variability. On conservation policies, there is an apparent conflict between site protection policies that are geographically specific and climate change adaptation that would need to respond to large-scale impacts on the distribution of species and habitats as climate changes.

7. FINANCIAL RESOURCES AND TRANSFER OF TECHNOLOGY

The NC3 reports UK contributions to the Global Environmnent Facility and multilateral institutions (including the World Bank, the International Finance Corporation, the Asian Development Bank, the African Development Bank, the United Nations Development Programmme, the United Nations Environment Programme, UNFCCC and the World Meteorological Organization).

With regard to technology transfer, the UK participates mainly through its involvement in multilateral activities, particularly through the EC, and the Climate Technology Initiative of IEA/OECD. Domestic programmes include the UK Technology Partnership Initiative that provides know-how to developing countries on a commercial basis, and the Climate Change Projects Office (CCPO) established in 2001 to facilitate the UK's participation in JI/CDM projects. Details of policies to encourage the role of the private sector, as required by the reporting guidelines, are not provided in the NC3. It does not mention successes or failures, or give specific instances of technology transfer, as recommended by the reporting guidelines. Such information is provided as part of the electronic version of the NC3.[21]

8. RESEARCHES AND SYSTEMATIC OBSERVATION

The NC3 has complied with the reporting guidelines on research and systematic observation activities. The UK has a strong domestic programme on climate modeling and impacts research, and also contributes to several international research, assessment and monitoring efforts. Climate research and systematic observation are highly devolved activities in the UK and there are therefore no "national plans" for climate research and observations. However, such activities are coordinated nationally through the Global Environmental Change Committee chaired by DEFRA, which provides about £ 12 million for climate research, observations and policy formulation. Other funding agencies include DTI. DFID, FCO, the Forestry Commission and national research councils.

The Hadley Centre of the UK Met Office has been a centre of excellence in climate modeling since its establishment more than a decade ago. In particular, its modeling effort has been a major contributor to IPCC Working Group 1. Highlights of important Hadley Centre work since NC2 include climate model runs without the need for "flux adjustments" that had earlier cast some doubt on the credibility of General Circulation Model’s projections.

A more recent development has been the establishment, in October 2000, of an interdisciplinary centre for climate change research - the Tyndall Centre - by three of the research councils of the UK (the Natural Environment Research Council, the Economic and Social Research Council. and the Engineering and Physical Sciences Research Council). Established with a core funding support of £ 10 million over five

[21] www.defra.gov.uk/environment/climatechange/3nc

years by the three research councils, the Tyndall Centre seeks to break new ground in innovative research on several themes connected with policy responses, including mitigation and adaptation.

The UK also makes large contributions to several international research, assessment and monitoring efforts, including the World Climate Research Programme, the International Geosphere-Biosphere Programme, the International Human Dimension Programme and the Global Climate Observing System (GCOS). The UK GCOS report was submitted to the UNFCCC secretariat in 2001. One area where the NC3 does not completely follow the reporting guidelines is that opportunities for and barriers to the free and open international exchange of data and information are not discussed.

9. EDUCATION, TRAINING AND PUBLIC AWARENESS

The government and devolved administrations place great emphasis on public awareness campaigns as a means of changing consumer behavior. These include the Energy Efficiency Campaign conducted by the Energy Savings Trust that aims to create a long-term shift in consumers' attitude to energy efficiency. The approach is multi-pronged, and includes direct mail, advertising, hotline, energy labeling, and national campaigns. A December 2001 evaluation found that two-thirds of consumers recognize the Energy Efficiency Recommended label, reflecting the success of this campaign.

10. CONCLUSIONS

The NC3 of the UK is comprehensive and consistent, covering all major sectors and GHG emissions for the six gases. Key climate change policies and measures are reflected sufficiently and concisely. Presentation of the information follows, for the most part, the reporting guidelines. Since the NC2, the UK has made commendable progress in achieving a number of its stated objectives in the NC2.

The most notable achievement was the sizeable reduction in GHG emissions of 12.8 per cent between 1990 and 2000. In this regard, the UK has succeeded remarkably in returning its GHG emissions to their 1990 level. This objective was achieved and exceeded mainly as a result of the policies and measures that were put in place for liberalizing the electricity market and also a shift in economic structure from heavy industries to light manufacturing and services as well as an aggressive effort in reducing non-CO_2 GHGs in industry. In meeting this objective, the UK has successively been able to decouple its economic growth from energy intensity and emissions intensity. Notable decreases were obtained for the three main GHGs, namely N_2O (35 percent), CH_4 (33 percent) and CO_2 (8 percent).

In 2000, the government approved the comprehensive UK Climate Change Programme. This programme identifies a series of strengthened measures to reduce, through domestic action, GHG emissions in accordance with UK's commitments under the Kyoto Protocol and the EC burden sharing agreement (a 12.5 per cent reduction in 2008-2012 compared to 1990). The programme signifies a more focused approach to GHG mitigation and an increase in the use of economic and fiscal instruments for pursuing environmental objectives. Important policies in meeting the reduction target include the Domestic Emissions Trading Scheme, the Climate Change Law and the Renewables Obligation.

The NC3 projections indicate that the UK is likely to meet its Kyoto target. However, to ensure that GHG reductions are sustained, the government needs to vigorously pursue the measures outlined in the 'with additional measures' scenario. Ensuring compatibility between the Climate Change Programme and the Energy White Paper is of particular importance for meeting the Kyoto target. The low-carbon economy strategy currently being discussed in the UK would make the trends in GHG emission projections sustainable and consistent with broader national objectives. Should the Climate Change Programme be implemented to its fullest potential, GHG mitigation under the programme may go significantly beyond the Kyoto Protocol target in the direction of its domestic goal to reduce $C0_2$ by 20 per cent.

The UK has put in place a diverse and innovative spectrum of measures to promote capacity building on climate change at all levels.

11. ACKNOWLEDGEMENT

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12. REFERENCES

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