

# Greenhouse Gases and their Implications for Agriculture

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In recent years public awareness about the environmental impact of pollutants in the atmosphere has increased. Two major categories of gaseous emissions may be identified in this regard:

**(a) The Greenhouse Gases (GHGs):** These are global in their effect upon the atmosphere. The primary ones are considered stock pollutants, i.e. substances which have a long lifetime and can therefore accumulate over time. Stock pollutants are also generally well mixed in the atmosphere and as a consequence their impact is mostly independent of where the gases were emitted. These characteristics imply that they should be addressed on a global, i.e. that is international scale.

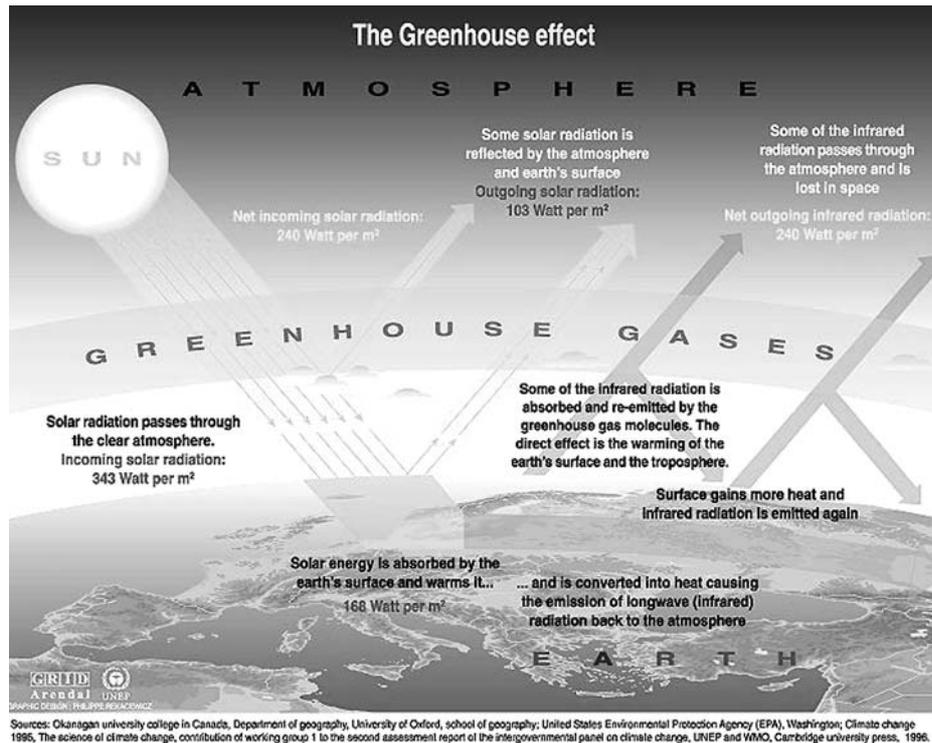
**(b) Transboundary Gases (TG):** These pollutants cause damage in the country of origin. However, they are also transported by winds and so may be spread over wide areas of both land and sea. As a result, their principal effects are commonly manifested far from the point of origin. Consequential damage is not global, affecting only limited areas. The gases can nevertheless only be addressed by international co-operation. The TG gases were addressed at the Fertiliser Association of Ireland meeting in 1999 and consequently they are not dealt with here.

## **Greenhouse Gases – The Greenhouse Effect**

The average temperature over the earth's surface is 15.5 degrees C. This is because a thin layer of certain atmospheric gases 25 km up behaves like glass panels in a greenhouse, letting heat through but stopping enough of the sun's energy from radiating back into space, so warming our world (Figure 1). Without this natural greenhouse effect the earth would be as cold as the airless moon which has an average surface temperature of minus 18 degrees C.

The energy from the sun, which has a surface temperature of 6,000 degrees C, is radiated to earth in short wavelengths. Most of this passes through the earth's atmosphere unabsorbed and warms the surfaces of land and sea. Due

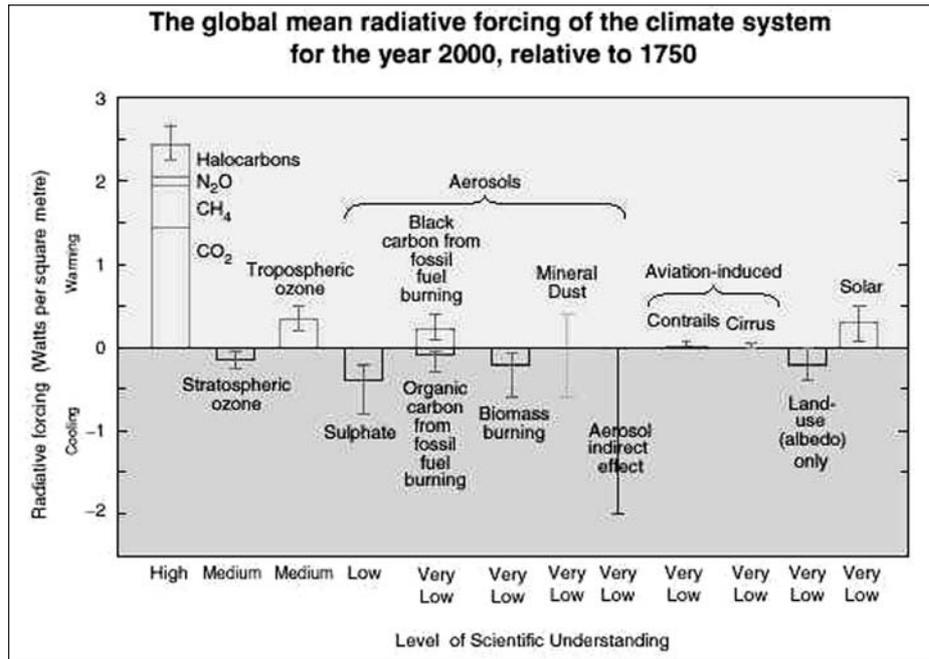
Figure 1



to the much lower earth temperatures, the energy is re-radiated back into space at much longer wavelengths. Some gases absorb energy of particular wavelengths, e.g. water vapour absorbs radiation between 4 and 7 micrometers, and CO<sub>2</sub> absorbs between 13 and 19. About 70% of the re-radiation from the earth's surface ultimately escapes into space through the "window" between 7 and 13, the remainder is absorbed by the water vapour and the CO<sub>2</sub> in the atmosphere, warming it up and being re-radiated yet again back to the ground until an equilibrium is reached between the energy received from the sun and the heat re-radiated into space. Other gases which selectively absorb radiation in the "window" between 7 and 13 micrometers are O<sub>3</sub>, CH<sub>4</sub>, N<sub>2</sub>O and the CFC's.

Any factor that alters the radiation received from the sun or lost to space or alters the redistribution of energy can affect climate change. A change in the net radiative energy available to the global earth-atmosphere system is termed a radiative forcing, (RF) with positive ones tending to warm the earth's surface and lower atmosphere, while negative ones tend to cool them.

Figure 2- Many external factors force climate change.



Increases in the concentrations of GHG's will reduce the efficiency with which the earth's surface radiates to space, tending to warm the earth and lower atmosphere.

Naturally-occurring GHG's in the atmosphere include water vapour, CO<sub>2</sub>, O<sub>3</sub>, CH<sub>4</sub> and N<sub>2</sub>O. Certain human activities, however, add to the levels of most of these. The amount of RF depends on the size of the increase in the concentration of each gas, the radiative properties of the gases involved and the concentration of other GHGs already present in the atmosphere (Figure 2). Further, many GHGs reside in the atmosphere for centuries after being emitted, thereby introducing a long-term commitment to positive forcing. The estimated RFs from the beginning of the Industrial Era (1750 to 2000) for the quantifiable natural and anthropogenic forcing agents are also given. The agents shown vary greatly in their form, magnitude and spatial distribution.

Some of the GHGs are emitted to the atmosphere directly while some are chemical products from other emissions. Some of the gases/factors are short-lived and have heterogenous regional concentrations. Forcing agents affect our climate in different ways, e.g. aerosols in the troposphere, such as those

derived from fossil fuel and biomass burning can reflect solar radiation, leading to a cooling tendency in the system. The aerosol black carbon (soot) absorbs solar radiation, thus tending to warm our system. However, in most cases, tropospheric aerosols tend to produce a negative RF and thus a cooler climate. The lifetimes of aerosols are short, only days to weeks generally, being removed from the atmosphere by precipitation.

These radiative forcings arise from changes in atmospheric composition, alteration of surface reflectance by land use and variation in the output of the sun. Except for solar variation, some form of human activity is linked to each. The rectangular bars represent estimates of the contributions of these forcings, some of which result in warming while others lead to a cooling effect. Forcing due to episodic volcanic activity, which has a negative effect and only lasts for a few years, is not shown. The indirect effect shown for aerosols is their influence on the size and number of cloud droplets. A second indirect effect of these substances is their impact on cloud lifetime, which would also lead to a negative forcing, is not shown. Effects of aviation on greenhouse gases are included in the individual bars. The vertical line through the rectangular bars indicates a range of estimates, guided by the spread in the published values of the forcings and physical understanding. Some of the forcings possess a much greater degree of certainty than others. A vertical line without a rectangular bar denotes a forcing for which no best estimate can be given owing to large uncertainties. The overall level of scientific understanding for each forcing varies considerably, as noted. Some of the radiative forcing agents, such as CO<sub>2</sub>, are well mixed over the globe, thereby perturbing the global heat balance. Others, such as aerosols, represent perturbations with stronger regional signatures because of their spatial distribution. For this and other reasons, a simple sum of the positive and negative bars cannot be expected to yield the net effect on the climate system. The simulations of the Third Assessment Report of Working Group 1 of the IPCC (Intergovernmental Panel on Climate Change) indicate that the estimated net effect of these perturbations is to have warmed the global climate since 1750.

### **Origins of the Gases / Factors that contribute to Climate Change**

These are additional to variations and changes in the earth's climate over the last 2 million years and are as outlined hereunder :

**CO<sub>2</sub>** It arises principally from the combustion of fossil fuels. The other anthropogenic sources are:

- aerobic decay of urban wastes (landfill) ;
- chemical processes such as brewing and mining operations ;
- cement manufacture. This is significant as almost all Irish cement is produced from limestone which releases primeval CO<sub>2</sub>.

**CH<sub>4</sub>** Natural sources of the gas come from coal mines, peatlands and wetlands. Human-influenced sources arise from enteric fermentation, manure management, landfills and fugitive emissions from fuels e.g. in the gas distribution network.

**N<sub>2</sub>O** This gas has natural and anthropogenic sources, arising principally from the agricultural sector. It comes from N processes in the soil, through nitrification and denitrification. Small amounts come from industrial processes, e.g. in the production of HNO<sub>3</sub> in the manufacture of fertiliser and in the combustion of fuels for energy. It is also produced by the transport sector as a result of the introduction of catalytic converters where N<sub>2</sub>O is formed as a by-product from NO<sub>x</sub> breakdown.

**Fluorinated Gases** These are very powerful GHGs that are not naturally occurring. They include HFCs, PFCs and SF<sub>6</sub> which are generated in a variety of industrial processes.

### **Other Important Gases — [Ozone] O<sub>3</sub>**

It is the 3<sup>rd</sup> most important GHG after CO<sub>2</sub> and CH<sub>4</sub>, being present in both the stratosphere and the troposphere. The gas is a secondary pollutant as it is not emitted directly. Instead, it is formed in the atmosphere from photochemical processes involving precursors.

### **Gases with only indirect GH radiative influences**

Many reactive gases, including NO<sub>x</sub>, CO and the VOCs, control the abundance of O<sub>3</sub>.

**Aerosols** They are not gases, but rather particles or droplets which are known to have significant climatic effects and these occur in two distinct ways :

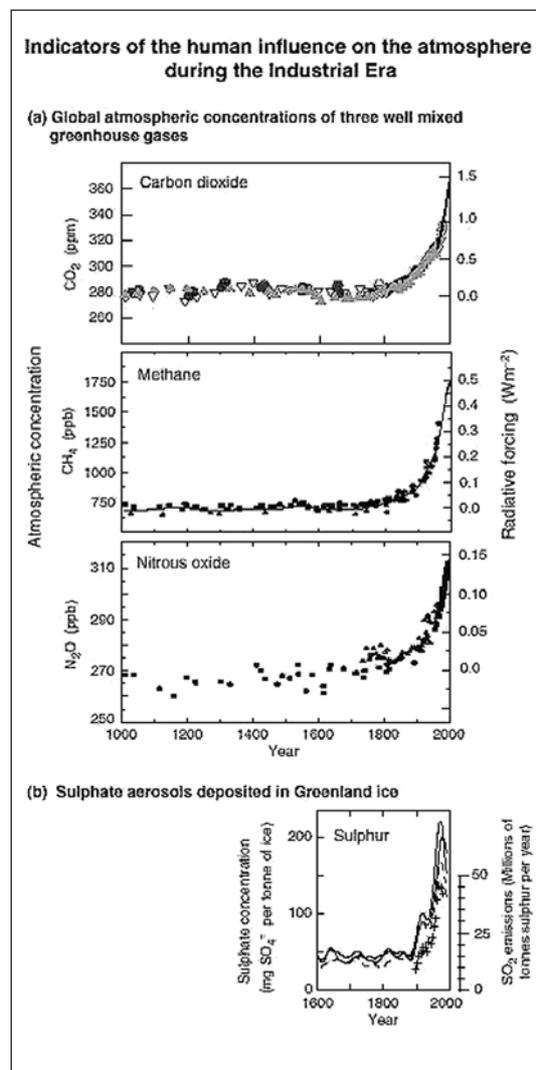
1. direct, by scatter and absorbance of solar radiation;
2. indirect, by modifying the radiative properties and amounts of clouds. They are produced from the combustion of fossil fuels, biomass burning, volcanic activity and dust storms.

### **Global Effects of these Gases/Factors**

At one time, almost all climatic changes occurred naturally. That was when human activity released very few gases or other climate-affecting factors into the atmosphere. However, during the Industrial Revolution, we began altering our climate and environment through changing agricultural and industrial practices. Observations over time have documented the changes that have occurred in both the quantities and concentrations of the above products in the atmosphere. Most notable among these are the effects of the large

increases in concentrations of the three principal GHGs over the past 1000 years, and  $\text{SO}_2$  a TG and a precursor of aerosols, over the past 400 years (Figure 3).

**Figure 3: Long records of past changes in atmospheric composition provide the context for the influence of anthropogenic emissions.**



(a) shows changes in the atmospheric concentrations of carbon dioxide ( $\text{CO}_2$ ), methane ( $\text{CH}_4$ ), and nitrous oxide ( $\text{N}_2\text{O}$ ) over the past 1000 years. The ice core and fern data for several sites in Antarctica and Greenland (shown by different symbols) are supplemented with the data from direct atmospheric samples over the past few decades (shown by the line for  $\text{CO}_2$  and incorporated in the curve representing the global average of  $\text{CH}_4$ ). The estimated positive radiative forcing of the climate system from these gases is indicated on the right-hand scale. Since these gases have atmospheric lifetimes of a decade or more, they are well mixed, and their concentrations reflect emissions from sources throughout the globe. All three records show effects of the large and increasing growth in anthropogenic emissions during the Industrial Era.

(b) illustrates the influence of industrial emissions on atmospheric sulphate concentrations which produce negative radiative forcing. Shown is the time history of the concentrations of sulphate, not in the atmosphere but in ice cores in Greenland (shown by lines; from which the episodic effects of volcanic eruptions have been removed). Such data indicate the local deposition of sulphate aerosols at the site, reflecting sulphur dioxide ( $\text{SO}_2$ ) emissions at mid-latitudes in the Northern Hemisphere. This record, albeit more regional than that of the globally-mixed greenhouse gases, demonstrates the large growth in anthropogenic  $\text{SO}_2$  emissions during the Industrial Era. The pluses denote the relevant regional estimated  $\text{SO}_2$  emissions (right-hand scale).

Volcanic activity can inject large volumes of sulphur-containing gases, principally SO<sub>2</sub>, into the stratosphere where they are transformed into SO<sub>4</sub> aerosols. Individual eruptions can produce large, but transitory, negative RFs, tending to cool the earth's surface and lower atmosphere. Examples of 6 GHGs and summaries of their 1750 and 1998 atmospheric concentrations are given in Table 1. This table also shows how rates of concentration changed over the period 1990 to 1998. The increase in concentrations of the principal gases have been calculated from an expanding set of paleo-atmospheric data from air trapped in ice (cores) over hundreds of millenia. Between 1750 and 1998 the concentrations of the gases CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O increased by 31%, 250% and 16% respectively and they continue to increase annually. During the 9 years, 1990 to 1998 their concentrations increased by 4.8%, 9.0% and 2.7%, respectively.

**Table 1: Examples of greenhouse gases that are affected by human activities.**

	CO <sub>2</sub> (Carbon Dioxide)	CH <sub>4</sub> (Methane)	N <sub>2</sub> O (Nitrous Oxide)	CFC-11 (Chloroflu oro-C-11)	HFC/23 (Hydroflu oro-C-23)	CF <sub>4</sub> (Perfluoro -methane)
Pre-industrial concentration	~ 280 ppm	~ 700 ppb	~ 270 ppb	zero	zero	40 ppt
Concentration in 1998	365 ppm	1745 ppb	314 ppb	268 ppt	14 ppt	80 ppt
Rate of concentration change <sup>b</sup>	1.5 ppm/ yr <sup>a</sup>	7 ppb/ yr <sup>a</sup>	0.8 ppb/ yr	-1.4 ppt/ yr	0.55 ppt/ yr	1 ppt/ yr
% Increase	31	250	16	-	-	200
Atmospheric lifetime	5 to 200 yr <sup>c</sup>	12 yr <sup>d</sup>	114 yr <sup>d</sup>	45 yr	260 yr	> 50,000 yr

<sup>a</sup> Rate has fluctuated between 0.9 ppm / yr and 2.8ppm / yr for CO<sub>2</sub> and between 0 and 13 ppb / yr for CH<sub>4</sub> over the period 1990 to 1999.

<sup>b</sup> Rate is calculated over the period 1990 to 1999.

<sup>c</sup> No single lifetime can be defined for CO<sub>2</sub> because of the different rates of uptake by different removal processes.

<sup>d</sup> This lifetime has been defined as an "adjustment time" that takes into account the indirect of the gas on its own residence time.

### Global Warming Potential (GWP)

Gases in the atmosphere can contribute to the greenhouse effect both directly and indirectly. The concept of a GWP has been developed to compare the ability of each GHG to trap heat in the atmosphere relative to another gas. To be consistent with IPCC (Intergovernmental Panel on Climate Change) Guidelines, CO<sub>2</sub> was chosen as the reference gas. GWPs are not provided for the pollutants CO, NO<sub>x</sub>, NMVOCs and SO<sub>2</sub> because there is no agreed upon method to estimate the contribution of gases that have only indirect effects on RF (IPCC 1996). The GWP of a GHG is the ratio of global warming or RF -both direct and indirect-from one unit mass of a GHG to that of one unit mass of CO<sub>2</sub> over a period of time. While any time period can be selected, the 100 year GWPs recommended by the IPCC is employed. GWP values for the main gases are listed in Table 2.

**Table 2: Global Warming Potentials. (100 Year Time Horizon)**

Gas	GWP
Carbon dioxide (CO <sub>2</sub> )	1
Methane (CH <sub>4</sub> )*	21
Nitrous oxide (N <sub>2</sub> O)	310
Hydrofluoro – carbon – 23	11,700
Hydrofluoro – carbon – 125	2,800
Hydrofluoro – carbon – 134a	1,300
Hydrofluoro – carbon – 143a	3,800
Hydrofluoro – carbon – 152a	140
Hydrofluoro – carbon – 227ea	2,900
Hydrofluoro – carbon – 236fa	6,300
Hydrofluoro – carbon – 4310mee	1,300
Perfluoro – methane (CF <sub>4</sub> )	6,500
C <sub>2</sub> F <sub>6</sub>	9,200
C <sub>4</sub> F <sub>10</sub>	7,000
C <sub>6</sub> F <sub>14</sub>	7,400
Sulphur Hexafluoride (SF <sub>6</sub> )	23,900

Source: (IPCC 1996)

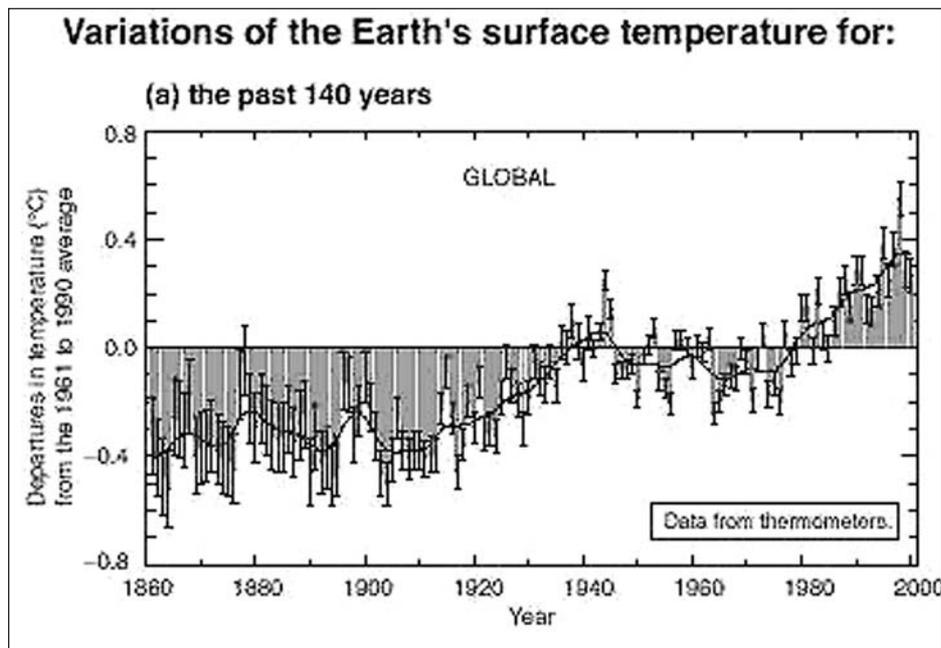
- The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapour. The indirect effect due to the production of CO<sub>2</sub> is not included.

### Climate Change Indicators

The main indicator is a global mean temperature rise. The potential consequences of this include rising sea levels, changes in rainfall patterns leading to floods and droughts, changes in biota and food productivity plus

increases in infectious diseases. It is very likely that the 1990's was the warmest decade and 1998 the warmest year in the instrumental record since 1860 (Figure 4). Observed changes have shown that annual precipitation has increased and continues to do so in the middle and high latitudes of the Northern Hemisphere, except over Eastern Asia. Over the sub-tropics, land surface rainfall has decreased on average.

Figure 4



### First International Action to Tackle Global Warming

This was taken by UNFCCC [United Nations Framework Convention on Climate Change] against the threat from gases, once considered harmless, impacting on our climate and exacerbating the greenhouse effect. The ultimate objective was to ensure the stabilization of GHGs in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The move required developed countries to put policies in place with the objective of returning GHGs to 1990 levels by 2000. All parties to the 1992 convention accepted as a basic principle that the rich industrialized countries should take the lead in combating climate change. This was only fair as their per capita emissions are between 10 and 20 times higher than those of

developing countries. This was one of the most important environmental agreements ever signed; it has been ratified by 186 countries. States that are signatories to the UNFCCC are committed to reporting their anthropogenic GHGs to the secretariat of the convention.

**Table 3: National greenhouse gas emission targets of EC member states.**

Member State	National CO <sub>2</sub> emission targets by 2000.	National GHG emission targets (incl. removals) by 2008 – 2012 under the EU burden sharing agreement.
Austria	Stabilisation at 1990 level	-13%
Belgium	5% reduction compared to 1990 levels (corrected for temp. variations)	-7.5%
Denmark	5% reduction compared to 1990 (corrected for temp. variations and calculated as if all electricity used in Denmark was produced in Denmark)	-21% <sup>(1)</sup>
Finland	Limitation of the increase in CO <sub>2</sub> emissions from energy production and consumption by the end of the 1990s	0%
France	Stabilisation of fossil fuel related CO <sub>2</sub> emissions at less than 2tC per capita per year by 2000	0%
Germany	No 2000 target	-21%
Greece	Limitation of the increase in CO <sub>2</sub> emissions to 15% during the period 1990 – 2000	+25%
Ireland	Limitation of the increase in CO <sub>2</sub> emissions to 20% during the period of 1990 – 2000 (or to 11% if carbon sinks are also included in calculation)	+13%
Italy	Stabilisation at 1990 level	-6.5%
Luxembourg	Stabilisation at 1990 level	-28%
Netherlands	3% reduction compared to 1990 levels (corrected for temp variations)	-6%
Portugal	No 2000 target	+27%
Spain	Limitation of the increase in CO <sub>2</sub> emissions to 11 – 13% during the period 1990 – 2000	+15%
Sweden	Stabilisation at 1990 level	+4%
United Kingdom	Stabilisation at 1990 level	-12.5%

(1) In connection with the agreement, Denmark made the following statement: "Denmark is able to reduce its emissions by 17% in the first commitment period compared to its 1990 level of about 80 million tonnes corrected CO<sub>2</sub> – equivalents through domestic policy and measures and present measures adopted by the Community. In making its legal commitment to a 21% reduction as set out in the agreement, Denmark has assumed the further elaboration and adoption of common and coordinated policies and measures (CCPMs) prior to the ratification of the Kyoto Protocol."

The stabilization of CO<sub>2</sub> at 1990 levels by 2000 was agreed by the EU as a whole, but MS (Member States) contribute in different ways to achieve this goal. Most, but not all of them, have set national CO<sub>2</sub> limitation targets (Table 3).

The adequacy of the commitments entered into was reviewed at COP1 [Conference of the Parties] in Berlin in 1995. The Parties decided that reducing GHG emissions by developed countries to 1990 levels by 2000 was inadequate to meet the Convention's long term objective of addressing the impact of these gases. This led to the adoption of the "Berlin Mandate", culminating in the production of a draft agreement which strengthened developed countries commitments. The text was forwarded to COP 3 for final negotiation.

### **Next Action to Tackle Global Warming (Kyoto Protocol)**

At COP 3 to the UNFCCC in Kyoto in December 1997 the Parties adopted the Protocol which sets different binding GHG emission targets for the Parties listed in Table 4. The Protocol aims at reducing aggregated emissions by these countries of 6 GHGs [CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs and SF<sub>6</sub>] by 5.2% from the 1990 levels during a first commitment period from 2008-2012. By September 2000 the agreement had been signed by 84 Parties. By signing the Protocol in April 1998, the EU as a whole as well as all of its MS individually agreed upon an 8% reduction of their anthropogenic GHG emissions by 2008-12 relative to 1990 levels. In June 1998 the Council of Ministers agreed upon the so-called EC Burden-Sharing Agreement. Within this, the MS politically agreed on an EU internal redistribution of the common 8% reduction target. This agreement resulted in setting emission targets for each MS according to its economic circumstances. Under this accord 8 states agreed to reduce, 2 to stabilise and 5, including Ireland, to limit their increases (Table 3). The targets set for 2012 are considered modest by any standard, however, the treaty is widely seen as an essential first step towards deeper cuts in the future. Developing countries will not have to make mandatory cuts until after 2012.

Table 4

Party	Quantified emission limitation or reduction commitment (% of base year or period)
Australia	108
Austria	92
Belgium	92
Bulgaria*	92
Canada	94
Croatia*	95
Czech Republic*	92
Denmark	92
Estonia*	92
European Community	92
Finland	92
France	92
Germany	92
Greece	92
Hungary*	94
Iceland	110
Ireland	92
Italy	92
Japan	94
Latvia*	92
Liechtenstein	92
Lithuania*	92
Luxembourg	92
Monaco	92
Netherlands	92
New Zealand	100
Norway	101
Poland*	94
Portugal	92
Romania*	92
Russian Federation*	100
Slovakia*	92
Slovenia*	92
Spain	92
Sweden	92
Switzerland	92
Ukraine*	100
United Kingdom (including NI)	92
USA	93

\*Countries that are undergoing the process of transition to a market economy.

## Ratification of the Protocol

The agreement will enter into force 90 days after it has been ratified by at least 55 Parties to the Convention, including developed countries accounting for at least 55% of the total CO<sub>2</sub> emissions during 1990 from this industrialised group. The treaty has currently been ratified by 42 countries but that does not include any major developed one. The EU states are hoping to ratify the accord in 2002.

## Overall Greenhouse Gas emission trends in the EU

In 1999, GHG emissions by the 15 EU countries were 4% below 1990 levels (Table 5). The reduction was comprised of : (a) a CO<sub>2</sub> decrease of 1.6%; (b) a CH<sub>4</sub> decrease of 17% and (c) an N<sub>2</sub>O decrease of 14% and (d) a fluorinated gas increase of 66%.

**TABLE 5 Greenhouse gas emissions in CO<sub>2</sub> equivalents (excluding land-use change and forestry) and Kyoto Protocol targets for 2008-12**

MEMBER STATE	1990		Change 1998-1999		Targets 2008-2012 under Kyoto Protocol and EU "burden sharing"		Evaluation of progress in 1999 <sup>(3)</sup>
	(million tonnes)	(million tonnes)	(%)	(%)	(%)	(index points)	
Austria	76.9	79.2	0.0	2.6	-13.0	8.5	☺
Belgium	136.7	140.4	-3.4	2.8	-7.5	6.1	☺
Denmark <sup>(2)</sup>	70.0	73.0	-4.6	4.0 (-4.6)	-21.0	13.5 (4.9)	☺ (☺)
Finland	77.1	76.2	-0.8	-1.1	0.0	-1.1	☺
France	545.7	544.5	-2.2	-0.2	0.0	-0.2	☺
Germany	1,206.6	982.4	-3.7	-18.7	-21.0	-9.3	☺
Greece	105.3	123.2	-0.7	16.9	25.0	5.7	☺
Ireland	53.5	65.3	2.5	22.1	13.0	16.3	☺
Italy	518.3	541.1	0.9	4.4	-6.5	7.3	☺
Luxembourg	10.8	6.1	4.6	-43.3	-28.0	-30.7	☺
Netherlands	215.8	230.1	-2.9	6.1	-8.0	8.8	☺
Portugal	84.6	79.3	2.9	22.4	27.0	10.2	☺
Spain	305.8	380.2	6.1	23.2	15.0	16.5	☺
Sweden	69.5	70.7	-2.6	1.5	4.0	-0.3	☺
United Kingdom	741.9	637.9	-6.5	-14.0	-12.5	-8.4	☺
<b>EU-15</b>	<b>4,198.7</b>	<b>4,029.6</b>	<b>-2.0</b>	<b>-4.0</b>	<b>-8.0</b>	<b>-0.4</b>	<b>☺</b>

(1) For the fluorinated gases most Member States have selected a base year other than 1990 (namely 1995), as allowed for under the protocol. However, for the analysis of EU emission trends in this report 1990 emissions data have been used as the base year for all gases, for consistency reasons.

(2) For Denmark, data that reflect adjustments for electricity trade (import and export) in 1990 are given in brackets. This methodology is used by Denmark to monitor progress towards its national target under the EC 'burden sharing' agreement. For the EU emissions, total non-adjusted Danish data have been used.

(3) The EEA evaluation of progress to 1999 awards 'smileys' according to the distance-to-target indicator in 1999. The following rating system is used:

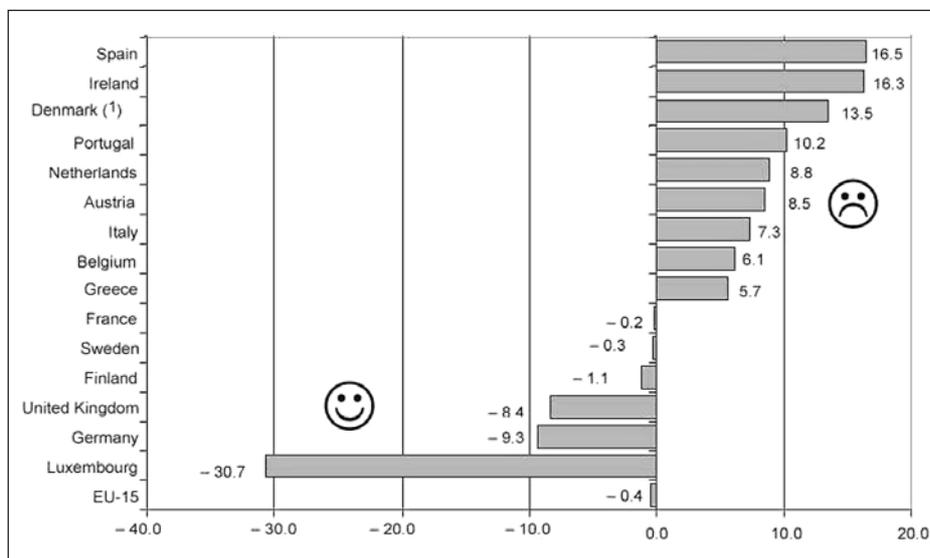
- ☺ distance-to-target indicator below minus 2 index points (positive contribution to EC trend)
- ☹ distance-to-target indicator above plus 2 index points (negative contribution to EC trend)
- ☺☹ distance-to-target indicator in a range of plus/minus 2 index points (limited positive or negative contribution to EC trend)

Source: Submissions by the EC Member States (CRF tables).

### Progress of the Member States

If GHG emissions of the 15 EU countries are compared with their linear target paths for 2000 and 2008-2012, progress of the different Parties appear as in Figure 5.

**Figure 5 Distance-to-target indicators (in index points) for the Kyoto Protocol and EC burden sharing targets of EC Member States**



(1) The Danish DTI is 4.9 index points, if Danish greenhouse gas emissions are adjusted for trade in electricity 1990.

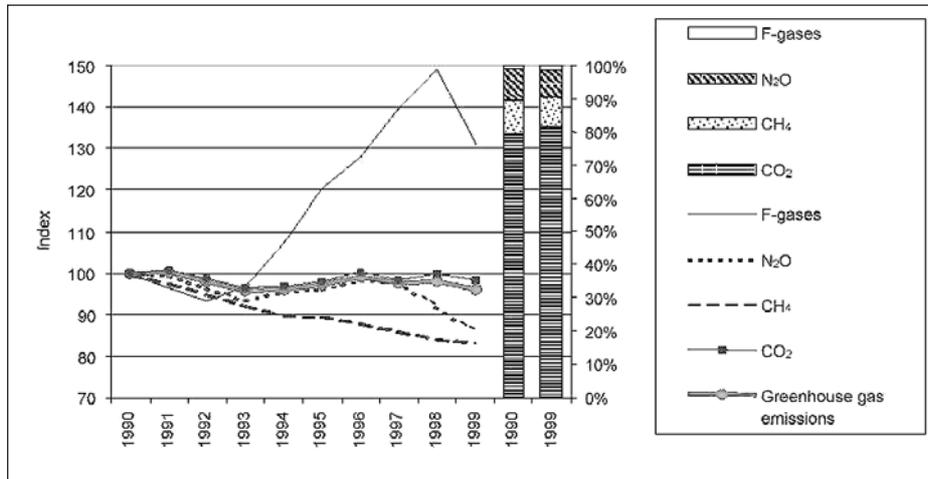
**Source:** Submissions by the EC Member States (CRF tables).

Emissions in 1999 were dominated by CO<sub>2</sub>, being 81% of the total (Figure 6); the corresponding contribution from the same gas in Ireland was lower than in all other MS (member states), being 64% in 1999. The contribution of non-CO<sub>2</sub> GHGs to our total emissions is unusually high relative to that in other developed countries. This is because of the importance of agriculture in the economy, where it contributes some 32-34% of the total GHG output.

Patterns of energy consumption and CO<sub>2</sub> emissions are similar. However, in respect of the EU 15 between 1990 and 1998, energy consumption increased by 8.2% but CO<sub>2</sub> losses only rose by 0.2%. The main reasons for this are efficiency improvements in the German industries, in particular in the economic restructuring of the 5 new lander, and the change from coal to natural gas in the UK power industry, plus a general switch from coal to gas. The largest relevant increases in CO<sub>2</sub> emissions occurred in the cohesion states of Ireland,

Portugal and Spain. Despite large reductions, Germany and the UK continued to be the 2 largest emitters within the EU 15, contributing 26.6 and 16.4% of the total respectively.

**Figure 6: EC greenhouse gas emissions by type (excluding LUCF)**



Source: Submissions by the EC Member States (CRF tables).

### Fluorinated Gases

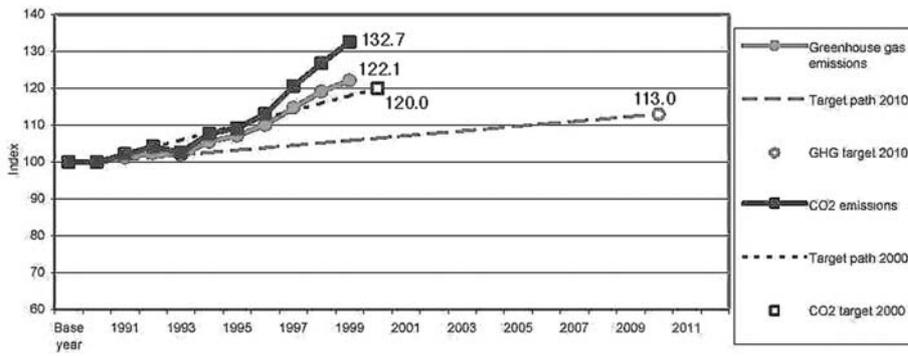
Emissions of these have increased by 66% between 1990 and 1999, and now account for 1.1% of total EU GH gases. This increase was the second largest of all EU key source emissions both in relative and in absolute terms.

### Greenhouse Gas emission trends in Ireland

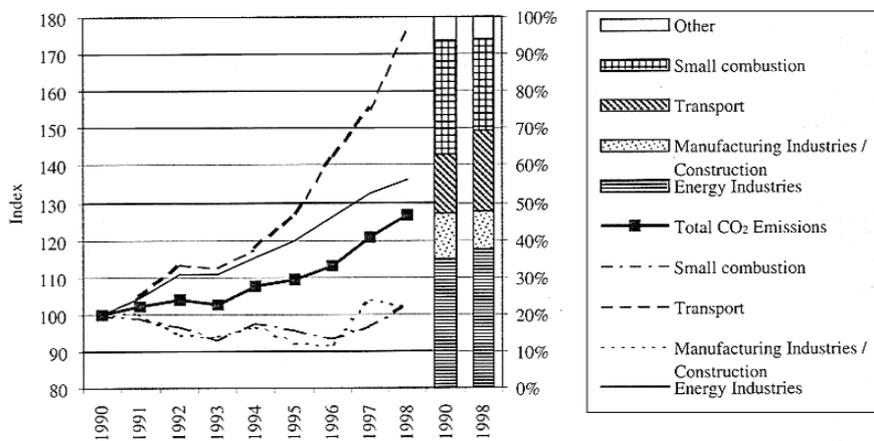
In 1999, Ireland's GHG emissions were 16.3 index points above the 2008-2012 target. The same applied to CO<sub>2</sub> which was 14.7 points above our limitation target for 2000 (Figure 7).

Ireland experienced a period of rapid economic growth during the 1990s, largely from the services sector and light manufacturing. Growth was driven by foreign investment, resulting in a real GDP increase of 80.4% between 1990 and 1998 compared with an average of 17.4% for the EU 15. The level of increase in GHG emissions is closely related to growth and activity, and during this time energy consumption and CO<sub>2</sub> emissions grew by 28.1% and 26.8% respectively. The main sources of gaseous output were from the transport sector and electricity demand (energy industry) and during this period emissions from both sources increased rapidly (Figure 8).

**Figure 7: Irish greenhouse gas emissions compared with targets for 2000 and 2008-12 (excluding LUCF)**



**FIGURE 8: Sectoral CO2 emissions of Ireland (excl. LUCF)**



### Energy Supply Measures

Electrical generation in Ireland is characterised by a high share of thermal power production; 95% of gross electricity was produced by combustion plants in 1997, 4.7% from hydro power and 0.3% from wind. The production of electricity from fossil fuels is inefficient (25-40%) unless an economical use can be found for the heat produced during the generation process. Besides, the costs of generation vary with the type of fuel used, being greatest for peat and renewable energy sources (Table 6). The quantities of CO<sub>2</sub> emitted during generation vary considerably, being highest for peat and lowest for natural gas used in a CCGT (Combined Cycle Gas Turbine) plant.

**Table 6 Price and Emissions from Different Generation Fuels**

Generation Source	Price / kWh		Emissions (kg CO <sub>2</sub> /kWh <sub>e</sub> )
	Pence	Cents	
Coal	2	2.54	0.912
Peat	6	7.62	1.607
Gas:			
Single Cycle	2.51	3.19	0.489
Combined Cycle Gas Turbine	2	2.54	0.346
Combined Heat & Power	2.51	3.19	0.238
Heat Energy	1.22	1.55	0.238
Oil	3	3.81	0.782
Renewables	>4	>5.08	0

### Measures to Control Greenhouse Gas Emissions

In November 2000 the Government published the National Climate Change Strategy. This was to ensure that Ireland reduced its current levels of GHGs to meet the Kyoto target of limiting the growth of emissions to 13% above 1990 levels by the commitment period 2008-2012. Without instigating such action, it was projected that the country's net annual emissions would increase by 37.3% over 1990 levels. The Strategy sets out a range of agreed policies and measures, including cross-sectoral measures and sector specific measures.

As provided in the Strategy, a cross-Departmental Climate Change Team has been established to ensure its early implementation. The Team is chaired by the Department of the Environment and Local Government (DOELG), and includes representatives of relevant Departments. The Team is required to report to the Environmental Network of Government Departments on a regular basis, and at least quarterly. Following review of its work by the Network, DOELG will also report to its Minister at least twice a year. The Minister will report to Government annually on progress under the Team's Terms of Reference. The Team recognises that a key element to ensure successful implementation of the Strategy will be to ensure that key sectoral interests are consulted on implementation. This will also ensure that key interests are informed of progress and can factor in climate change considerations and forthcoming policies and measures into the planning process.

### Implementation of Cross-Sectoral Measures

The Climate Change Team will undertake the initial work in regard to cross-sectoral measures, and making recommendations on the linkages between taxation and other cross-sectoral measures (such as emissions trading) and sector-specific measures and instruments (such as negotiate agreements).

### **Implementation of Sector-Specific Measures**

While the Minister for Environment and Local Government has overall responsibility for ensuring delivery of the Strategy, all Government Departments and Agencies are required to implement those parts of it for which they are responsible, undertaking the necessary consultation, analytical and other work to support this process. It is envisaged that Departments will integrate climate change considerations into the relevant policy areas, advancing review of policies where required to meet the implementation dates for the Strategy, and will establish their own internal management and external consultation arrangements for this purpose. Where cross-Departmental coordination is required for implementation of sector-specific measures, this will be established between the relevant Departments. Overall progress on the implementation of sector-specific measures will be facilitated and overseen by the Climate Change Team.

### **Emissions from the Agricultural Sector**

These are very significant in an Irish context, making agriculture the largest single source of GHGs, namely 34.6% of the national total in 1990. This figure is expected to fall to 25.6% by 2010 for two reasons: (1) because of the significant projected increases in CO<sub>2</sub> and industrial gases over the period and (2) because "business as usual" (BAU) projections predict that total agricultural emissions will only increase by some 3.3% over this two-decade span. The main sources of agricultural emissions, based on of GHGs 1990 data, are: (a) enteric fermentation (CH<sub>4</sub>), comprising 51.1%; (b) soils (N<sub>2</sub>O), 34.6% and (c) manure management (CH<sub>4</sub> and N<sub>2</sub>O), 10.4%. The principal source of CH<sub>4</sub> is from ruminant digestion by cattle, where gas production is directly linked to the size of the national herd.

### **Measures to Control Methane Emissions**

Due to the important position of cattle production enterprises in Irish agriculture, CH<sub>4</sub> emissions from ruminant animals constitute approximately one fifth of Ireland's total GHGs. Hence, reductions in this area could be significant in helping the country to meet its 2008-2012 Protocol target. The main contributors of CH<sub>4</sub> are cattle (86.8%) and sheep (12.6%).

The objective is to secure CH<sub>4</sub> reductions of 1.2 Mt CO<sub>2</sub> equivalent in emissions from livestock. This will be achieved by reducing stock numbers below BAU for 2010, on the basis that the required reduction is equivalent to a reduction of 10% in livestock numbers over the period. An appropriate balance will be maintained between direct reductions in stock numbers to be achieved based on current EU policies and coupled with extensification and other management measures in REPS, and intensification of the range of measures identified for the agriculture sector as well as any further appropriate

measures applied following dedicated research, and demonstrating equivalent GHG emissions reductions. Such measures will be applied on a least cost basis to contribute towards meeting the overall 1.2 Mt CO<sub>2</sub> equivalent target.

When developing CH<sub>4</sub> reduction programmes from livestock, certain criteria must be met; these include:-

- \* maintenance of the maximum number of family farms,
- \* identification of viable alternative enterprises to supplement farm income and alternative employment opportunities and
- \* measures to improve the sustainability of agricultural systems

The measures and programmes outlined above will be developed by the Department of Agriculture, Food and Rural Development (DAFRD) in partnership with the agriculture sector in the context of the overall need to coordinate measures through the Inter-Departmental Climate Change Team.

### **Reduction in Emissions per Animal**

A research programme will be undertaken to identify feeding regimes, appropriate to Irish conditions, that reduce CH<sub>4</sub> emissions from individual animals. The objective will be to reduce the level of emissions per animal, while maintaining productivity. While in some respects the technologies to achieve significant reductions are at an early stage of development, there are good grounds for expecting a reduction of 0.5 Mt of CO<sub>2</sub> equivalent, on the basis of this research work. The following list of measures with potential to reduce emissions per animal will be prioritised in research:-

- changes in the level of concentrate feeding;
- changes in the system of cattle production with a focus on finishing cattle at a younger age;
- use of feed additives;
- probiotics and engineering;
- improved feeding and management at farm level.

The ongoing review of this Strategy will incorporate appropriate measures identified by the research where the reductions potential is quantified and the measures involved are subsequently applied.

### **Measures to Reduce Nitrous Oxide (N<sub>2</sub>O) Emissions**

N<sub>2</sub>O emissions from nitrogenous fertiliser application will be reduced by 10% below BAU levels expected for 2010, with a consequential emissions reduction of 0.9 Mt CO<sub>2</sub> equivalent. This reduction in N<sub>2</sub>O emissions, based on reduced fertiliser use, will be supplemented by a number of measures, including:-

- \* adjustments to the requirements of support schemes;
- \* the use of slow release inhibitors;

- \* efficient recycling of slurry and dirty water;
- \* better management practices in the application of organic manures and effluents.
- \* growing of more forage maize and incorporation of slurry into the soil, and
- \* bandspreading of animal manures.

The full impact of all the measures outlined remains to be quantified by appropriate research and application. Combining the reduction of 10% fertiliser use with the additional measures identified, N<sub>2</sub>O emissions could be reduced by 0.9 Mt CO<sub>2</sub> equivalent below the BAU projections by 2010.

### **Forestry and Carbon Sequestration**

A change in land use arising from the conversion of agricultural land from animal production to forestry ensures a double dividend:- a reduction of CH<sub>4</sub> and N<sub>2</sub>O emissions and additional sequestration of carbon from the atmosphere. To the extent that this evolution of agriculture policy is driven by climate change considerations, enhanced sequestration of carbon will be a valuable part of the response of the agriculture sector.

The administration of REPS now places greater emphasis on forestry as an option. The Rural Development Plan 2000-2006, covering both REPS and Forestry, includes a proposal for the integration of the two measures to ensure coherence and to maximise environmental benefits including carbon sequestration. For all applications, it is proposed that the assessment at farm level by REPS planners will include identification of land suitable for productive afforestation. The current estimate is that on average 70,000 farmers will afforest about one hectare of land each by 2010 as part of a planned afforestation programme. The carbon sequestration to be achieved specifically within the agriculture sector, in addition to that to be produced and stored within the national forestry programme, is predicted to be 0.25 Mt CO<sub>2</sub> equivalent.

### **Animal Manures**

These represent the smallest source of agricultural emissions despite being identified by the EU as technologically the most promising area where CH<sub>4</sub> reductions could be made. Anaerobic digesters could be used to produce 'biogas', a renewable source of energy. To make maximum use of this energy source, optimise its potential in replacing fossil fuels and its economic potential, it should be utilised as efficiently as possible. Where produced in usable quantities, this will likely mean its combustion in a gas burner for domestic use. However, where production exceeds requirements, this will mean processing the gas in a CHP (combined heat and power) plant. Looking to the future, it is hoped that it will be possible to sell the electricity produced,

at a pre-negotiated price, to the national grid. The heat produced should ideally be used for a purpose that would otherwise have to be performed by a fossil fuel source. The National Climate Change Strategy aims to reduce CH<sub>4</sub> emissions by 0.06 Mt CO<sub>2</sub> equivalent from the processing of animal manures.

### Short-Rotation Biomass (Willow)

This fuel source is carbon neutral in the energy cycle. The crop grows throughout the Northern Hemisphere, mainly in cold, wet areas. It is harvested every 3 years and the wood is dried prior to combustion. Depending on size and efficiency of the plant/ enterprise used, between 1 and 1.6 kg of wood is required to generate 1kWh of power.

The potential for developing short-rotation biomass for energy generation as an alternative land use where livestock numbers are reduced will be developed in conjunction with the renewable energy programme.

### List of Abbreviations

BAU	Business as Usual
CFC	Chlorofluoro Carbon
CCGT	Combined Cycle Gas Turbine
CH <sub>4</sub>	Methane
CO	Carbon Monoxide
CO <sub>2</sub>	Carbon Dioxide
COP	Conference of Parties
DAFRD	Department of Agriculture, Food and Rural Development
DOELG	Department of Environment and Local Government
GHG	Greenhouse Gases
GWP	Global Warming Potential
HFC	Hydrofluoro Carbon
HNO <sub>3</sub>	Nitric Acid
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilowatt Hour
LUCF	Land Use Change and Forestry
MS	Member States
Mt	Million Tonnes
NMVOG	non-Methane Volatile Organic Carbon
NO <sub>x</sub>	Nitrogen Oxides
N <sub>2</sub> O	Nitrous Oxide
O <sub>3</sub>	Ozone
PFC	Perfluoro Carbon
REPS	Rural Environment Protection Scheme
RF	Radiative Forcing

SF <sub>6</sub>	Sulphur Hexafluoride
SRB	Short Rotation Biomass
SO <sub>2</sub>	Sulphur Dioxide
SO <sub>4</sub>	Sulphate
TG	Transboundary Gases
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile Organic Carbon

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