Economics and Climate Change

By
Conor Barry[*], *Peter Clinch*[+] *and Frank Convery*[+],

Presented at the Climate Change Conference, Botanic Gardens, June 12, 2002.

Introduction
The field of economics has a number of insights to bring to the analysis of climate change. These include: forecasting greenhouse gas emissions, identifying the least cost strategy to meet a particular emission target; estimating the costs imposed by climate change and the benefits (in the form of reducing these costs) resulting from the reduction of emissions; the strategies that would maximise net benefits, the policy instruments likely to yield the desired abatement at least cost.

In this paper, we attempt to give you a flavour as to how these applications are relevant to the analysis of climate change policy in Ireland.

The Physical Production Function
For the application of economics to be fully effective, we need to know the relationship between inputs and outputs.

The physical relationships in the case of climate change are complex. In its efforts to develop environmental performance indicators, the European Environment Agency (EEA) has adopted a sort of linear life cycle approach, which and can be characterised as follows: Driver, Pressure, State, Impact, Response (DPSIR). Thus, in the case of climate change we might characterise some of the main actors as follows:

Table 1. Schematic Driver Pressure State Impact Response Framework for Greenhouse Gasses.

Driver	**Pressure**	**State (some likely effects)**	**Some Likely Impacts**	**Sample Responses**
Electricity Generation	Increased emission of CO_2	Increased concentrations of greenhouse gasses in the atmosphere and rising global temperatures, resulting in Increased flooding, migration north and south of 'tropical' diseases, more drought and more intense storms, change in cropping patterns and productivity	More storm and sea rise damage to property, more disease, illness and premature death, higher insurance premia	Do nothing, build sea walls, reduce fossil fuel based energy consumption, switch from coal to natural gas, carbon taxes, emissions trading etc
Cement Production	Increased emission of CO_2	ditto	ditto	ditto
Other Industry	Increased emission of industrial gasses, CO_2			
Transport	Increased emission of CO_2			
Farming	Increased emission of Methane and N_2O			
Households	Increased emission of CO_2			
Landfill sites	Increased emission of Methane			

[*] Department of Environment and Local Government
[+] Department of Environmental Studies, University College, Dublin

The physical relationships linking drivers and emissions – columns one and two above – are relatively well understood. In particular, where the source is the combustion of fossil fuels, if we know the quantity of each fuel type burned, we can determine the emissions of carbon dioxide with a high degree of accuracy. There is a wider margin of error possible in the case of agriculture and landfill.

There is much less certainty when it comes to determining the 'State' that these emissions induce. 'Uncertainty' as we use it here is the usual statistical convention that uncertainty exists when we cannot with any plausibility assign probabilities to the likelihood of estimated outcomes. There is reasonable agreement on the (rising) concentrations of greenhouse gasses in the atmosphere, but considerable scientific uncertainty about how these are influenced by emissions. Uncertainty increases when we attempt to link rising concentrations to effects such as rising sea levels, more intense storms, changing weather patterns, more drought etc. And history tells us (Alfsen, 2002) that climate change in the past – before *homo sapiens* existed - has been remarkably rapid, 'flipping' in a few decades from hot to cold and vice versa, but the timing of such radical changes in the future – if they occur - is impossible to predict. When we attempt to assess impacts, in terms of damage to infrastructure, loss of crops due to drought, positive effects on the productivity of crops due to rising carbon concentrations, more malaria etc. uncertainty increases further for many reasons, but an important one being uncertainty about the geography of these effects. The models indicate that the bulk of damage will be experienced in developing countries, who are least capable technically and financially to either take defensive action or to repair and recover later on. But the bulk of the damage could be concentrated in the North Atlantic or anywhere else. Given this widening arc of uncertainty as we move from 'driver' to 'impacts', where does economics fit in? Taking each of the economics related themes in turn

Forecasting greenhouse gas emissions

In most industrialised countries, emissions are related to economic growth, and specifically to the value of goods and services produced per unit time in an economy, what we call Gross Domestic Product. However, this is not a linear relationship, because, as economies grow, the energy intensity of the growth – the energy consumed per unit of GDP – tends to fall. If energy intensity falls by 6 per cent a year, and an economy is growing by 8 per cent a year, then energy consumption will grow by approximately 2 per cent per annum. The 'carbon intensity' of growth is a refinement which links greenhouse gas emissions to GDP. Energy consumption could be growing, but carbon emissions could be falling if there is a large-scale fuel switch from coal to natural gas or wind power.

A key 'driver' of greenhouse gas emissions in Ireland is the transport sector, which accounts for a rising share of the energy budget.

The macro economic model managed by John Fitz Gerald in ESRI is the main source in Ireland of emissions estimates linked to projections in overall economic and related sectoral performance. The emission forecasts depend for their robustness on the accuracy of the economic forecasts to which they are linked. The steps followed in estimating emissions projections for Ireland are outlined below (from Duffy et al, 2001).
Below we can see the recent past and benchmark or base line projections for the Irish economy: These are compiled on the basis that there will be a significant global slow down, but recovery will commence in late 2002 or early 2003.

Table 2. Recent and Projected Growth in Total GDP, Ireland

Year	Annual Average Real Growth (%)
1995-'00	8.4
2000-'05	4.8
2005-'10	4.3
2010-'15	2.8

Associated with this decline in the growth of GDP is a fall in the absolute growth in projected energy consumption. Final consumption rose by 3375 thousand tonnes of oil equivalent over the 1990 to 2000 period, but the increase over the 2000 to 2010 period is estimated to be 3007.

The sharp fall in GDP growth projected over the 2000-2005 period is a product of emerging local constraints on growth, and the global economic slowdown. The increasing dependence on oil is notable, with its share of total final consumption rising from 53 per cent in 1990 to 62 per cent in 2000 and a projected dependence of 63 per cent in 2010.

Table 3. **Final consumption of energy** (Thousand tonnes of oil equivalent)

Fuel	**1990**	**2000**	**2005**	**2010**
Coal	893	528	286	158
Oil	3874	6563	7594	8541
Peat	757	303	259	231
Electricity	1032	1726	2083	2442
Gas	576	1206	1657	1980
Renewables	109	129	131	128
Total	7241	10,616	12,158	13,623

Over the 1990 to 2000 period, growth has been driven by transport, which almost doubled, and commercial, which grew by more than 50 per cent; industry rose by 31 per cent. Over the 2000 to 2010 period, aggregate growth is expected to amount to 28 per cent, with absolute fall in agriculture of 9 per cent, and continuing large rises in transport (43 per cent) and commercial (35 per cent); final energy consumption in industry is expected to grow by 13 per cent over the 2000-2010 period.

Table 4. Final Energy Consumption, by Sector (Thousand Tonnes of Oil Equivalent)

Sector	**1990**	**2000**	**2005**	**2010**
Residential	2223	2576	2893	3109
Commercial	1,006	1,526	1763	2058
Agriculture	252	333	321	302
Transport	2,025	3913	4751	5590
Industry	1,735	2,268	2,430	2,564
Total	7241	10,616	12,158	13,623

Table 5. Change between 1990 and 2010 (%)

Sector	**% Change on 1990 in 2000**	**% Change on 2000 in 2010**
Residential	16	21
Commercial	52	35
Agriculture	32	(9)
Transport	93	43
Industry	31	13
Total	47	28

Growth in the economy and in energy consumption has resulted in rapid increase in greenhouse gas emissions, to the extent that the 13 per cent increase above the 1990 baseline has already been exceeded in 2000 amounting to a total quota of 61112 thousand tonnes. Under ‘business as usual’ the overshoot is expected to amount to 4459 thousand tonnes[i] by 2010, even with a contribution of over 3 million tonnes of CO_2 equivalent contributed by carbon sinks, attributable to afforestation.

Table 6. Greenhouse Gas Emissions (Thousand tonnes of CO_2 equivalent) 1990-2010

Gas	**1990**	**2000**	**2005**	**2010**
CO_2	32,159	43,359	47,130	48,914
Methane	12,836	11,666	11,590	11,081
Nitrous Oxide	9086	9629	9673	9719
Sinks	0	-893	-2013	-3008
Total	54,081	63,642	65,387	65,571
Change on ’90 (%)	0.0	17.7	20.9	21.2

Nearly all the growth is attributable to increases in carbon dioxide emissions, associated mainly with rising fossil fuel consumption, and to a lesser extent cement production. Methane and nitrous oxide are produced mainly by agriculture, and little growth is envisaged from this source.

Identifying the least cost strategy to meet a particular emission target

Where a compliance target has been set – as in the case of the Kyoto Protocol and the associated burden sharing arrangement in the European Union - then it is possible to estimate the least cost means of achieving the target. Most analyses of this sort identify a pyramid of opportunities of ascending cost, and one goes up the pyramid until the target has been reached; the sum of the costs of the measures identified provides the estimate of the total cost of complying with the scheme. In a study undertaken for the Department of Environment and Local Government and the Department of Enterprise, the costs of reducing CO_2 emissions by 11 million tonnes are estimated (Environmental Resources Management, 1998). It is estimated that in the order of 7 million tonnes of CO_2 could be eliminated at zero cost, mainly by converting from coal and peat fired plant to combined cycle gas turbines (CCGT), and undertaking energy conservation measures in households, including loft insulation, installation of lagging jackets, solid wall insulation.

There are limitations with such analyses, illustrated by the ERM study. First, the political/distributional dimension was not addressed. Specifically, maintaining peat-burning plants in the Midlands is a political imperative for all major political parties, and therefore the closure of the peat plants without replacing them with others, was most unlikely to happen. In such circumstances, a 'second best' - from a cost effectiveness point of view – should have been identified, which would highlight the costs of maintaining these plants, and also provide a wider range of (more expensive) options to the policy system.

Estimating the costs imposed by climate change and the benefits (in the form of reducing these costs) resulting from the reduction of emissions.

This is where the uncertainties in the production function linking human induced emissions to losses makes estimation very difficult. The preponderance of evidence indicates that human action is resulting in some warming of the planet, and this in turn is likely to imposes losses on some or all of the planet's inhabitants, but where, when and how it will occur, and the associated magnitude of the future damage is subject to wide variation.

Human civilisation – in the form of cultivated agriculture, the development of cities, and the subsequent evolution of knowledge, technologies, democratic institutions etc – is a product in part of the uniquely mild and benign weather the planet has enjoyed for the past 5 thousand years or so. But this very evolution has also for the first time in human history allowed the species to itself influence climate change. It is this paradoxical combination that make many nervous about playing dice with the future of the planet, and this generates what appears to be a willingness to pay – at least in parts of Europe – to reduce the human imprint as regards climate change.

Three broad categories of valuation approach can be identified. The first is not to try to estimate the benefits of reducing global warming in a single monetarily defined numeraire, but to provide a multicriteria framework for analysing the implications. The second is to use contingent valuation or other techniques to ask the inhabitants of the planet directly how much they would be willing to pay to avoid human induced climate change. The third is to estimate in market terms the losses that will result from global warming - crop losses due to more drought, property losses due to more flooding and increased storm damage, increased medical costs, loss of life and more illness, loss of value added in tourism due to biodiversity change – and then to net out the gains in terms of climate change induced increased output and productivity. The problems are intensified by the fact that the extent of damage, its significance and value is very influenced by where it occurs, and there is great uncertainty in this regard. However, most models indicate that the poorest on the planet will be most adversely affected, and they generally will be willing to pay less – because they have less to pay with, and have other priorities – than those in more affluent jurisdictions.

Strategies that would maximise net benefits – benefit cost analysis and the costs of time

If we estimate the abatement costs, and an associated reduction in emissions, and somehow estimate the willingness to pay for such abatement, we now have an estimate of costs and benefits and these can be compared to yield an estimate of net benefit. But the abatement occurs near the present, while the benefits are yielded 50 years or more in the future. To compare costs and benefits, we must adjust for time, on the basis that a benefit yielded soon is worth more than the same benefit yielded further in the future, and a cost deferred is less onerous than a cost incurred today. The interest rate mediates between present and future, and can be regarded in a sense as the price of time. Those who borrow €250,000 to buy a house pay about €500,000 once interest over the life of the loan is paid. This represents the premium the purchaser is willing to pay to have the house now rather than 25 years from now.

The higher the rate of interest, the heavier is the future discounted, and so the interest rate is characterised by economists as the 'rate of time preference'.

Environmental Policy Instruments

These include: information, negotiated agreements, regulation (command and control), research and development, infrastructural investment, subsidies, 'green' purchasing and budgeting, charges and taxes and emissions trading. Up to this point, these policy instruments have been applied almost exclusively at national level. In Europe, there is some small experience with transfrontier voluntary agreements, and an EU wide carbon energy tax was proposed, but these are exceptions. Emissions trading is proposed in the Kyoto Protocol as a trans frontier instrument, but substantive experience to date has been exclusively national. The Clean Development Mechanism (CDM) and Joint Implementation (JI) are also proposed in this Protocol as transfrontier mechanisms (project based, whereby the emission reductions achieved below a baseline by a project can attributed as a contribution to meeting the emissions target in a country that has accepted a cap on emissions).

Information is based on the idea that producers and consumers are not sufficiently aware of their energy and emissions performance, and if their knowledge was improved they would improve performance. Examples of the use of information as a policy instrument is a boiler testing service, whereby firms can have the performance of their boilers tested, and learn thereby what their performance is and if a change (e.g. a new boiler) is justified. Television and radio adds advocating that we turn down the thermostat, leave the car at home, turn off the lights etc are of this genre. More focused information is provided by the boiler testing service administered by the Sustainable Energy Ireland Authority, which gives firms very specific and customised information and advice on energy performance.

Negotiated agreements are where either an individual firm voluntarily agrees to meet a 'benchmark' performance standard (and may as a result benefit from reduction in tax or regulation), or a group of firms in a sector, e.g. the chemicals sector, agrees to meet an aggregate performance for the sector. An example of the individual firm type is found in Denmark and the Netherlands, where exemption from taxes and regulation respectively are granted to firms who meet a benchmark standard as regards energy consumption and conservation. Firms may also voluntarily agree to meet certain environmental or other standards, such as ISO 9000, or EMAS which typically have an energy efficiency dimension. A pilot project led by the Sustainable Energy Ireland Authority, involving a number of companies, whereby commitments to meet certain reductions in energy use are made, is at present (June 2002) under negotiation.

Regulation (Command and Control): This is where an individual or firm is required by law to meet certain standards. Examples would be minimum standards of insulation required in new houses, minimum energy performance standards before a firm qualifies to receives and integrated pollution prevention and control license. In the past, greenhouse gas reduction was not addressed in the licensing of industry by the EPA in Ireland. The EPA Act of 1992 requires that any emission from an activity that 'causes significant environmental pollution' be licensed, and the greenhouse gas emissions from an individual applicant are judged not to cause significant environmental pollution. However, under the Integrated Pollution Prevention and Control (IPPC) Directive all appropriate preventative measures are to be taken, through BAT, such that no significant pollution is caused, and energy is used efficiently (Article 3). BAT is defined as meaning the most effective and advanced stage in the development of activities and their methods of operation.

Research and Development R&D). R&D is the creation of new options that did not exist before. The research and development that produced the combined cycle gas turbine (CCGT) simultaneously made natural gas a key fuel for the generation of electricity, increased fuel efficiency in electricity generation dramatically, and reduced emissions.

Project based or Infrastructural Investment, whereby such investment changes and improves energy and environmental performance. An example would be the provision of an inter-connector that allowed more wind power to be connected to the grid, or a gas pipeline that allowed coal fired capacity to be replaced by gas. Where such investment is made in a developing country by a firm or country that has accepted a 'cap' under the Kyoto protocol, it may under certain circumstances qualify as a '**Clean Development Mechanism' (CDM)** project, and the ensuing reduction in emissions can be claimed as a contribution to meeting 'the cap.' **Joint Implementation** (JI) projects – also allowed under Kyoto - are identical in character, but take place in industrialised countries.

Subsidies, whereby carbon reducing activity is subsidised. Examples would be grants to householders to retrofit improved insulation on their houses, thereby increasing energy efficiency, and tax breaks that encourage householders to install solar cells in their houses.

'**Green' purchasing and green budgeting:** Where local, regional or national government through its purchase decisions favours environmentally positive goods and services, e.g. purchasing only 'green' electricity.

Resource and Environmental Charges and Taxes: If the cost to consumers of a good or service rises, then, other things being equal, they will use less. This is the underlying logic of this instrument. If the cost of using scarce natural resources such as water, or environmental endowments is increased, then consumers will use less than heretofore. By imposing a tax or charge that attempts to signify the value and scarcity of environmental endowments, these will be used more parsimoniously. It is called a 'market based instrument' because it operates directly through market signals. The imposition of a 15 Euro cent tax on plastic bags in certain uses is a good example of this instrument in action. Scott and Lawlor (1994, 1997) provide an interesting distillate of many of the opportunities to use this instrument in Ireland.

Emissions Trading: In the 'cap and trade' version of emissions trading, an aggregate ceiling is set on the amount of emissions allowed per unit time. This envelope is then allocated to the emitters, such that the sum of allocations does not exceed the overall cap on emissions. The holders of emissions permits can then buy and sell permits, so long as they hold sufficient permits to 'cover' their emissions. This allows those for whom compliance is very difficult and expensive to buy permits from those for whom it is very inexpensive to reduce emissions, thereby achieving the overall target, but at minimum cost to the economy. In the 'baseline and credit' version, emitters earn credits if they perform better than a pre specified baseline, and these can then be sold to those who do not meet the baseline. This is also called a 'market based instrument' because it operates directly through market signals.

The European Commission has proposed a cap and trade emissions trading scheme for the 15 Members of the Union, to be implemented initially as a pilot scheme, over the 2005-2008 period, before the Kyoto Protocol comes into effect. The salient features of the EU proposal are shown in Box 1.

Box 1. The European Union Greenhouse Gas Emission Trading Proposals – some key features

Obligatory or Voluntary: Scheme will be obligatory.

Scope: In the first phase, trading will be confined to carbon dioxide emissions from power station installations in excess of 20 MW (except incinerators), oil refineries, smelters, manufacture of cement (> 500 tonnes per day), ceramics including brick, glass, pulp, paper and board (>20 tonnes per day). These sources will comprise 4000 to 5000 installations. It is a 'downstream' proposal, i.e. those initially holding the quotas will be those using energy rather than importers and energy producers ('upstream'). The European Commission may make proposals by 31 December 2004 to include other activities and other greenhouse gasses, and to provide for inclusion of credits from project mechanisms, links to other policies such as taxation, and whether there should be a single registry.

Scope: It is estimated that the sources to which the draft Directive applies will account for 46 per cent of carbon dioxide emissions in 2010, and 38 per cent of total greenhouse gas emissions in that year. It is envisaged in subsequent periods that the range of activities included will be widened, and the other greenhouse gasses will be included. The extension to include other activities will require an amendment to the Directive.

Cap and Trade or Baseline and Credit: There are three types of emissions trading schemes, cap and trade, baseline and credit with absolute targets, and baseline and credit with relative targets.

The Commission proposal for a scheme for greenhouse gas emission allowance trading is cap and trade, but the EU cap is an aggregation of individual national caps, to be decided at Member State level, but with the approval of the Commission. In the UK national scheme, both baseline and credit and absolute cap schemes run in parallel, while the Netherlands is proposing the introduction of a baseline and credit scheme for acid precursors.

Allocation Mechanism: Member states must notify the Commission as to the total quantity of allowances it intends to allocate, and how it proposes to allocate them for the first 3 years. According to Annex III (Criteria for National Allocation Plans) the allocation of allowances must be consistent with the technological potential of installations to reduce emissions, and the projected and actual assessment and progress towards fulfilling the Community's commitments. Quotas are free for the first 3 year period. For the five year period beginning January 1 2008, each Member State shall decide upon the total quantity of allowances it will allocate and the allocation of those allowances to the operator of each installation.

Regulation (IPPC) and Emissions Trading: Strict regulation of every facility – as provided for in the Integrated Pollution Prevention and Control (IPPC) Directive - on the basis that 'best available techniques' must be installed and used undermines much of the power of emissions trading. The Commission recognises this problem, and Permits issued under this (IPPC) Directive shall not include an emission limit value for that (greenhouse) gas, unless it is necessary that no significant local pollution is caused.

Penalties: Where an operator does not have sufficient allowance to 'cover' his emissions, a penalty per tonne of CO_2 equivalent amounting to either €100 or twice the average market price between 1 January and 31 March of that year for allowances valid for emissions during the previous year, whichever is the higher. But the penalty will be lower for the first 3 years, beginning January 1 2005, with a penalty of €50 or twice the average market prices, whichever is the higher.

Banking and Borrowing: Banking, but not borrowing, will be allowed.

Source: 'Directive establishing a scheme for greenhouse gas emission allowance trading within the Community, and amending Council Directive 96/61/EC which was presented on 23 October 2001 [COM(2001) 581 Final]

An EU wide emissions trading scheme is facilitated by the fact that under a 'burden sharing' agreement in 1998, the total envelope agreed for the EU at Kyoto has been allocated across the Member States.

Table 7. Allocation of Emissions Quotas to Member States under the Burden Sharing Arrangements, European Union.

Country	% Reduction from 1990	Emissions 1990 (Million Tonnes of CO_2 equiv.)	Target or Quota, 2008-2012 (Million Tonnes of CO_2 Equiv.)	Difference (Million Tonnes of CO_2 equiv.)	Per capita emissions, 1990 Tonnes of CO2 equiv.
Austria	-13.0	78	68	-10	9.2
Belgium	-7.0	139	129	-10	13.7
Denmark	-21.0	72	57	-15	13.7
Finland	0	65	65	0	14.2
France	0	546	546	0	11.0
Germany	-21.0	1208	955	-253	14.7
Greece	25.0	99	124	+25	9.9
Ireland	13.0	57	64	+7	16.0
Italy	-6.5	543	507	-36	9.5
Luxembourg	-28.0	14	10	-4	34.7
Netherlands	-6.0	217	204	-13	13.5
Portugal	27.0	69	87	+18	7.0
Spain	15.0	302	348	+46	7.6
Sweden	4.0	66	68	+2	7.9
UK	-12.5	790	691	-99	13.3
EU Total	-8.0	4264	3922	-342	13.1

Source: European Environment Agency, 1999, p. 86.
CEC, 1999, Annex 1

It can be seen that Ireland 'did well' in the sense that we secured a 13 per cent increase about the 1990 baseline, in the context of an EU wide cut of 8 per cent, and a per capita emissions level exceeded only by Luxembourg.

However, the selection of 1990 as the base year was unfortunate, as it represented a sort of nadir in terms of Irish economic performance. After that, the economy took off, to the extent that output doubled over the following decade, and this had inevitable repercussions for greenhouse gas emissions.

The Commission proposal is at present being debated by the Member States, and the European Parliament. Key issues raised in this debate concern whether:

- Countries, and firms or sectors within countries, should be able to opt out in the first phase (2005-2008) – the UK, Finland, Ireland and perhaps Germany are of this view, but most economists favour compulsory schemes

- Emission quotas should be given away free as proposed by the Commission (most economists argue that allocation by auction would be more efficient economically, and would avoid issues of 'state Aid' etc., but this view is not supported by industry)

- Member States should have the right to decide, as proposed in the Draft Directive – but their decision must be approved by the Commission –on how many permits are allocated to each sector and firm within their jurisdiction. This gives rise to 'State Aid' issues, if, say, country X allocates far more quota to its steel industry than country Y.

- Equity will be served, and this specifically arises as regards giving away emissions permits free to electric utilities, who are likely to attempt to raise electricity prices to reduce demand and keep their emissions consistent with their permit holdings, which in turn will generate potentially large 'surpluses' which could accrue to private companies 'at the expense' of relatively poor householders. It is concern about this latter problem that drives the UK view that they should be able to exclude electricity generation from the eligible participants.

These and other issues are addressed at some length in Convery (2002). UCD is the co-ordinator of the European research Network – Concerted Action - on Tradable Emissions Permits (CATEP) which focuses on the research frontier in the mobilisation of this instrument. See web site: www.emissionstradingnetwork.com.

Conclusions

It is clear – at least to us! – that economists have an important role to play in enriching our understanding of the choices facing us as regards climate change policy, and how to react to challenges in ways that are simultaneously environmentally effective and economically efficient. It is also clear to us that there is far too little research on this potential undertaken in Ireland.

Key References

Alfsen, Knut, 2002. 'Climate Change and Sustainability in Europe,' in: *Achievement and Challenge – Ireland's Environmental Performance Assessed*, Edited by Frank J. Convery and John Feehan, Environmental Institute, University College, Dublin.

Concerted Action on Tradable Emissions Permits (CATEP)
www.emissionstradingnetwork.com

Convery, Frank J., 2002. *Emerging Trading Systems – Opening Statement* MIT Global Change Forum XIX - Managing Fragmented Climate Regimes 12-14 June 2002, L'Automobile Club de France, Place de la Concorde, Paris

Duffy, David, Fitz Gerald, John, Hore, Jonathan, Kearney, Ide, and MacCoille, Cormac, 2001.*Medium Term Review, 2001-2007*, No. 8. ESRI, Dublin, pp. ix, 85, 86, 88.

CEC, 1999. Preparing for Implementation of the Kyoto Protocol *Commission Communication to the Council and the Parliament* Com(1999) 230 final, 19 May 1999

Convery, Frank J., 1999. 'Insights for Climate Policy in Europe,' *Environmental Modelling and Assessment*.(EMA) (forthcoming).

Environmental Resources Management, 1998. *Limitations and Reduction of CO_2 and Other Greenhouse Gasses in Ireland*, Government Publications, Dublin

European Environment Agency, 1998. *Climate Change in Europe*, Copenhagen

Fitz Gerald, John, 1999. 'Implementing Kyoto,' Paper presented at the Energy Ireland Conference, Dublin, June 15, 1999, available from ESRI, Burlington Road, Dublin 4, Ireland

IPPC Second Assessment Report, 1995.
(a) Climate Change 1995 – 'The science of climate change', Report of the IPCC Working Group I, Cambridge University Press
(c) Climate Change 1995 – 'The economic and social dimensions of climate change', Report of IPCC working group III, Cambridge University Press

(d) 'The IPCC second assessment synthesis of scientific technical information relevant to interpreting Article 2 of the UN Framework Convention on Climate Change', IPCC Secretariat, World Meteorological Organisation, Geneva.

European Environment Agency, 1999. *Environment in the European Union at the turn of the Century*, Copenhagen.

Scott, S. and J. Lawlor, 1994. *Waste Water Services: Charging Industry the Capital Cost.* ESRI Policy Research Paper, no. 22

Scott, S. and J. Lawlor, 1997. "Environmental Services", chapter 5 in A. Barrett, J. Lawlor and S. Scott, *The fiscal system and the Polluter Pays Principle*, Ashgate, Aldershot.

Zhang, Zhong Xiang 1998. 'Greenhouse Gas Emissions Trading and the World Trading System.' *Journal of World Trade*, Vol 32, No. 5 October, 219-239

[i] 65571 minus 61112