Surrey Energy Economics Centre

ENERGY, ENVIRONMENT AND THE MARKET

by

S.T. Boyle, I. Brown, P.M.S. Jones,
M.J. Parker and P.J.G. Pearson

SEEDS 47

September 1989

Discussion Paper Series

Editors: David Hawdon, Peter Pearson and Paul Stevens
Department of Economics, University of Surrey,
Guildford, Surrey GU2 5XH

Erratum

Two lines are missing from the bottom of page 7 of SEEDS 47. The last four lines of the page should read as follows:

> (b) Secondly, because of their relatively low levels of per capita income and energy consumption, the issue of equity in international environmental policy-making cannnot be sidestepped, as the Third World delegates to the Ozone Layer and other conferences have themselves pointed out.

ENERGY, ENVIRONMENT AND THE MARKET

by

S.T. Boyle, I. Brown, P.M.S. Jones,
M.J. Parker and P.J.G. Pearson

SEEDS 47 September 1989

The first four papers arose out of a Seminar on Energy, Environment and the Market, held at the University of Surrey in June 1989.

ISBN 1852370491

CONTENTS

ENERGY, ENVIRONMENT AND THE MARKET: MARKET FAILURE AND GLOBAL ISSUES

PJG Pearson
Surrey Energy Economics Centre, University of Surrey

First, a few recent headlines - in chronological order:

For the UK:

Ridley claims lead in greenhouse fight

Ridley proposes tax on coal-fired homes

Ridley backs away from tax on coal

Patten takes gamble with green economy blueprint

For the USA:

White House blunders in action on global warming

'Green' Bush to pledge ecology package

Bush locks horns with Congress on pollution

These headlines indicate two points: first, that energy-related environmental issues have made a major entry into the political arena; and second, that much remains to be resolved in terms of both the nature and content of policy.

That the issues have entered the political arena can only be a good thing - without this no effective action will be taken, especially on transnational or global issues like acid rain, the greenhouse effect and damage to the ozone layer. And that the issues have gone beyond the 'more research is needed before we can discuss policy' line is also important, since we have to learn to take decisions in a world of uncertainty. Actually this is exactly the sort of thing that politicians are supposed to be good at; it's just that they are not yet used to doing it in the face of scientific and climatic as opposed to political uncertainty.

Areas of Concern

What are the main areas of concern? A short-list must include the following:

The greenhouse effect
Damage to the ozone layer
Acid rain
Other forms of atmospheric pollution
Oil pollution
Toxic waste dumping
Destruction of tropical forests

Why are these areas of concern? Not because of their purely physical effects but because of their actual or potential impacts on the welfare of current and future generations. It is important to stress this since what we have to choose between is not a pollution-free versus a polluted environment but rather which pattern of pollution is likely to contribute most to (or detract least from) welfare.

Aims of the Paper

The main aim is to reflect on some aspects of the seminar's title, 'energy, environment and the market' - on what the market can and can't be expected to do; and I want then to consider the global nature of the problems, particularly as they affect Third World countries, whose development both threatens and is threatened by energy-related environmental damage. I do this for two reasons: firstly, development in the Third World is fundamental to the wellbeing of the majority of the world's population; and secondly, projected Third World economic and therefore energy growth has also been widely touted as a key determinant of future global emissions of greenhouse gases and of diminishing biodiversity.

What the Market Does Not do Well

I begin with what the market does not do well - the claim here is that there are some scarce environmental resources that markets tend not to allocate effectively - and that these include the atmosphere, the oceans and sometimes forests. The essence of the argument is that the services of the environment tend to be underpriced, so people overuse - indeed, abuse them.

Let us just run through the argument: the key feature of the market as a decentralised resource allocator is that prices convey signals about the relative scarcity and value of resources. If the right kind of market operates then its prices will reflect the social opportunity costs and benefits of resource use. So - when people use a resource they bear and hence are aware of the social costs of doing so and adjust their behaviour accordingly; this, of course, is what lies behind the 'polluter pays principle'.

But - as A.C. Pigou pointed out decades ago - where there are differences between the private and the social costs of resource use - where the price that individuals or groups have to pay to use a resource is less than what it costs society - where, to use the jargon, there are harmful 'externalities', then from society's point of view, too much of the resource will be used (Cornes & Sandler, 1986). The market has failed to convey appropriate price signals - and where environmental services are underpriced, people, firms and governments will tend to overuse them.

In what circumstances do such effects occur? One of them is where people have uncontrolled access to a resource - what are often called 'open-access' or 'common-pool' resources. People tend to overuse such resources because access is not rationed and they do not have to pay the full social costs involved (for example, the few extra drivers whose arrival on the M25 slows the entire traffic stream to a crawl, or the emitters of greenhouse gases and toxic waste who use the atmosphere, land and oceans as a free waste sink). The problems tend to result because of the difficulties of limiting access - in some cases, such as the atmosphere, it is hard to assign and enforce ownership and control - or they arise because of a lack of awareness of the need to limit access.

In these circumstances the market 'fails' to allocate resources appropriately, and it does so in two ways: first, there is an incentive to overuse; and secondly, there are no means of generating the revenues that may be necessary for environmental maintenance to prevent the depreciation of the stock of environmental capital.

The next stage in the argument of course is to suggest that where there is market failure in the allocation of environmental resources, some form of regulatory activity on the part of society may be desirable in order to improve welfare.

I want to move on to regulation later but at this point it is important to be clear about what we can take from the theory here: it is important to know that while in principle we might identify an efficient resource allocation - one where no opportunities to make people better off are unnecessarily wasted - in practice we do not have the information to do this (Baumol & Oates, 1988). What we tend to settle for in practice are decisions where a change can be said to be an improvement on the status quo for society.

And here is the added complexity. When we talk of social costs, which society do we mean? And how external are external costs? The original formulators of the theory tended to use examples like a farmer's crops being set alight by the sparks from a passing train. But when we talk of acid rain or fallout from Chernobyl, the externalities are transnational, while for greenhouse gases they are global. So we have to define what we mean by 'society' in order to delineate social costs - and it is clear that we can no longer formulate our environmental policies on the basis of damage caused only within territorial boundaries.

This adds great complexity to the task of devising, implementing and monitoring environmental control strategies - it implies the need for international agreements and monitoring. And it makes it very difficult to estimate social costs if we wish to adjust prices.

Just to add an extra spanner to a works already festooned with them, there is a temporal as well as a spatial dimension to defining social costs. Social costs are not only transnational, they are also transgenerational. This used to be cited as no more than the sort of theoretical nicety that economists like to play with - it is now recognised as a fundamental issue (Spash & D'Arge, 1989). If our decision-making time-horizon is limited to our own lifetime, we are likely to take very different decisions from those we might take if we had become a grandmother. This time-dimension brings problems in particular in the application of cost-benefit analysis.

Counter-Arguments

Not everybody would agree that we need to regulate because the market misallocates some environmental resources. Let us look at the counter-argument that says that even if the market signals are not appropriate now, they will be in the future - i.e. when the problems of environmental degradation are serious enough, successful adaptation will occur. At that time, it is argued, prices will signal appropriate reallocations of resources, including technological innovation, and political processes will also ensure the taking of necessary steps, so we do not need to worry now.

The problem with this argument is that by that time there may be significant irreversible damage - and even though there may also have been (conventionally recorded) economic growth, we will not necessarily be able to undo the damage. The adaptations aren't guaranteed to maintain and improve on our existing standard of living - for example, new technology might find a way round climate change but it might not be comfortable - how would you like to live indoors all the time, munching only on new-style forest-friendly eco-burgers?

A further point: even if the price signals are promoting adaptation in the right direction, they may not be able to ensure that it is at the right speed or that different types of adaptation will interact benignly. For example, the physical processes of adaptation may not be able to respond quickly enough - how rapidly can agriculture adapt to rapid climate change and species adapt to changed habitats?

Moreover, this approach is essentially reactive rather than proactive, so that although there is adaptation to new environmental situations (climate change, sea level rise, for example) this does not mean that action is being taken to slow the continued accumulation of greenhouse gases. We would be continually trying to adapt ex post to a dynamically worsening situation.

This is about choices, in the sense that if what we do now causes irreversible changes on a significant scale, then we are restricting the set of opportunities open to us in the future, no matter how ingenious we are.

Global warming could alter the whole framework within which we operate - and although it is conceivable that for some people it will alter it for the better, the prognostications are that it may alter it for the worse - for example, one of the latest scenarios from one of the American Global Climate Models suggests that regions that do not suffer from increased droughts seem likely to suffer from too much rain, frequently in the form of devastating storms and floods.

Now I am not arguing that the end of the world is nigh - nor am I naive enough to think that government intervention is a panacea: it could conceivably make things worse. But there is in my view no guarantee that the market will find satisfactory solutions to all of the major energy-related environmental problems, especially if it seems not to be giving the right signals to slow down the causes of the problems. If we want an example of technology unfolding in response to market incentives then we have only to think of Thomas Midgley, the inventor of leaded petrol, who also conceived the use of CFCs in refrigerators. He would - quite reasonably - have viewed himself as responding creatively to the market signals of his day.

What Can be Done?

Suppose you accept that the market unaided gives inappropriate or badly-timed signals, then what can be done? Clearly, there is a range of possible policy responses, none of them costless to implement. Here is a list of some of the most widely canvassed policy responses, followed by a list of some of the policy instruments that can be used in order to promote them:

Policy Responses

Form international groups - to examine evidence & consider policy responses
Adaptation - coastal defences, modified farming, etc.
Reduce emissions - direct abatement
- reduction of use of fossil fuels
  - reduce demand
  - use alternative energy sources

Re-afforestation

Some Policy Instruments

Emission charges/taxes
Marketable pollution permits
Regulation
Subsidies
Direct public investment
Zoning
Education/propaganda
Self-regulation through public pressure & the power of the purse

When we consider policy instruments, it is here that economists have been saying for years, 'use the market to 'internalise' the externalities'. In other words, implement the polluter pays principle: set appropriate prices which allow for social costs. The market may not set the right prices of its own accord - but you can use the market to encourage people to make their own adaptive choices at the prices you set. In this way they may have more choice than if you regulate, and the costs of abating pollution emissions may in some circumstances be minimised.

It is in the area of greenhouse gases, particularly carbon dioxide, that proposals for charges - the so-called carbon tax - deserve to be considered much more seriously. It is of course exceedingly difficult to know how much the externality premium should be, although some iterative experimentation might permit the market's responsiveness to be gauged.

However, it must be said that pricing is neither the only nor necessarily the best way of dealing with all forms of pollution in all circumstances. It can have major drawbacks. For example, pollution taxes raise revenues which could be but often might not be used to remedy environmental damage. And it is not clear that such taxes could effectively be implemented in all countries.

Moreover, the fact is that governments have in practice shown much reluctance to use pollution charges, preferrring regulations, zoning and often subsidies. Although there are obvious reasons why polluters would prefer not to face a regime of taxes, there are other reasons why governments tend not to implement them. One of these is the issue of equity or fairness - a reluctance to subject certain groups to the explicit, visible impact of taxes in the pursuit of efficiency. And on the international scene, the isuue of equity is clearly of major significance.

Environmental Control and the Third World

What can we say about the role of the Third World in all this? The Third World matters for at least three reasons:

(1) Because their populations are so so numerous and so poor, and consequently their development and energy consumption so important;

(2) Because although their per capita energy use is very low, their growth rates tend to be higher than those of industrialised countries - hence it is likely that this is where relatively fast increases in energy use and environmental damage will come from; and

(3) Because their populations are highly vulnerable - both to the disruption of food suplies through climatic change, and, as Sir Crispin Tickell has been suggesting recently, they are vulnerable to the flooding of low-lying land areas in which many people live - the Nile Delta, Bangla Desh, the Maldives, for example.

International discussion and negotiation over CFCs and other greenhouse gases have already begun. Why might we think that some of the major difficulties over reaching and implementing agreements are likely to arise between the Third World and the other country groupings? Anderson (1989) suggests that there are two important reasons here:

(a) Because within the Third World the effective institutional arrangements for environmental maintenance and pollution control are not in place: '...the weaknesses of institutions, laws and administration in many LDCs are bound to impede the implementation of environmental policy, whether the issue is local or global. The fate of the rainforests illustrates the dilemma perfectly' (p 7).

(b) Secondly, because of their relatively low levels of per capita income and energy consumption, the issue of equity in international environmental policy-

Thus the Third World is likely to cooperate with the industrialised world only at a price - if the countries are, in various ways, compensated for this. As Anderson notes, the fact that subsidies to agriculture in Europe, Japan and the US cost these countries $75 billion per year, more than twice the level of official development assistance, has not been lost in the discussions.

International agreements are,therefore, likely to be dependent on major financial (and probably technological) transfers from the industrialised countries to the Third World - through aid programmes or other means. And if it is through aid programmes, it has been pointed out that current aid programmes are based on principles of project-based capital finance, whereas what will be needed is a system of international public finance to implement and monitor arrangements for regulating the global commons. A number of alternative schemes have already been mooted but it is clear that developing appropriate, workable institutions will be far from easy.

What about using the market and the prospects for a carbon tax here? Well Third World countries understandably ask why in equity they should pay high prices for their current use of the atmosphere, when the reason why there's a problem now is that the industrialised countries added so rapidly to the stock of pollutants while their economies were maturing. But I would argue that in principle it would still make sense to apply the carbon tax while also finding ways of compensating Third World countries on the grounds of equity. Whether in practice a carbon tax would be implemented is another matter - the wide variations in the passing on of changes in oil prices since 1973-74 in Third World suggest that implementation might be very patchy, quite apart from any administrative problems.

It is noticeable that in some of their more recent public pronouncements commentators for the industrialised countries have begun to stress the need for population control in the Third World, presumably partly because this might be one way of limiting the growth of energy demand. However, not only are Third World countries unlikely to welcome outside admonitions to limit their populations, they are also unlikely to be able to do so in the absence of that most effective of birth control devices - the rapidly rising income level.

Conclusion

I would like to conclude with a quote from an article written by the late Professor Alan Coddington in 1972, entitled 'The Cheermongers - or How to Stop Worrying and Love Economic Growth':

> Samuel Butler hit on a great insight when he wrote: "All progress is based upon a universal innate desire on the part of every organism to live beyond its income." Since the industrial revolution industrialised societies have been able to fulfill this desire by consuming their natural wealth at unprecedented rates. Is this cause for celebration or disquiet?

In my view it is cause for both celebration **and** disquiet.

REFERENCES

Anderson, D (1989) 'Environmental Maintenance and Investment', in Pearson, P (ed) **Energy and the Environment in the Third World**, Surrey Energy Economics Discussion Paper No. 46, University of Surrey, Guildford.

Baumol, WJ and Oates, WE (1988) **The Theory of Environmental Policy**, Cambridge University Press, Cambridge.

Coddington, A (1972) 'The Cheermongers or How to Stop Worrying and Love Economic Growth', **Your Environment**, Autumn.

Cornes, R and Sandler, T (1986) **The Theory of Externalities, Public Goods, and Club Goods**, Cambridge University Press, Cambridge.

Spash, CL and D'Arge, RC (1989) 'The Greenhouse Effect and Intergenerational Transfers', **Energy Policy**, 17(2), 88-96.

THE ECONOMICS OF ENVIRONMENTAL CONTROL OF ENERGY

M J Parker
Director of Economics, British Coal

1. The economics of the environmental control of energy is by no means a straightforward subject, and it is worthwhile beginning with a discussion of general principles:

a) This is not a matter that can be resolved by conventional 'market forces' since, although the costs of emission controls may be fairly readily qualified, the benefits cannot; so that a 'cost/benefit' approach is often very difficult, if not impossible.

b) The 'demand' for environmental protection, including emission controls, may develop without regard to the costs involved, on the basis that the need to avoid some of the worst aspects of potential environmental damage is judged to be so great that large insurance premiums should be paid.

c) Regulations to control emissions or other environmental effects are essentially political acts, and will reflect political pressures 'to do something' rather than precise 'cost/benefit' calculations; so that often 'the politics will be ahead of the science'.

d) The increasingly international (or transboundary) character of environmental concerns places a further dimension of difficulty in reaching agreement on the form of regulation, since there are much greater potential conflicts of interest and fewer policy instruments to resolve such conflicts. Further, rich countries will generally be more willing than poor countries to accept the costs of environmental protection, since they will have a different view of the balance between costs and benefits. 'Market forces' are even more out of place here than in a national context.

e) However, even though environmental regulations may be introduced in a way bearing little relation to economics in the conventional sense, such regulations, once in place, may have significant implications on the economics of energy production and use.

f) More particularly, the speed with which regulations may be introduced or amended may often be in conflict with the investment lead-times, or lives of assets, of the energy industries or energy users.

2. It is interesting to note that, in the setting of EEC regulations to reduce SO_2 emissions in power stations, the whole decision-making process was more political than economic, and that:

i) There was no attempt to use the pricing mechanism by applying taxes or other imposts on high sulphur fuels.

ii) There was no economic assessment of the costs as against the benefits.

Although the process of arriving at effective sulphur dioxide abatement regulations in the EEC and elsewhere has been 'political' rather than by 'market forces' or a scientifically precise cost/benefit calculation, the resultant regulations are effective and result in only modest economic costs, and very little distortion of the markets for power generation fuels.

3. The greenhouse effect is a very different matter. This is not the place to go over the scientific evidence, or to speculate on the causal links between rising CO_2 emissions and changes in global climate. It is sufficient to say that, given the present state of knowledge and lack of reliable world climate models, there appears to be no possibility of doing any kind of sensible cost/benefit calculation. On the other hand, the political awareness of the potential problems arising from the greenhouse effect has risen very rapidly over the last year - even though over the same period there has been no appreciable increase in hard scientific knowledge or measurable adverse effects. Once again the 'politics are ahead of the science', and something must be seen to be done.

The Toronto conference in June 1988 produced a 'Conference Statement' which has not been adopted by any country that is a major contributor to the greenhouse effect. But this 'statement' has received such attention that it is worth looking at in some detail. It called for a 20% reduction in CO_2 emissions by 2005, with half of the reduction coming from 'energy efficiency' and half from 'fuel-switching'. However, in proposing these targets, the conference does not appear to have faced up to the global energy arithmetic and the associated economic consequences.

5. If we look at the last 20 years, we can see that world energy consumption has risen from 6.35 to 11.16 billion tonnes of coal equivalent (tce), with the following changes by fuel:

(Billion tce)	1967	1987
Coal and other solid fuel	2.35	3.41
Oil	2.53	4.20
Natural gas	1.08	2.22
Nuclear & Renewables	0.39	1.33
Total world	6.35	11.16

6. These are large numbers, both in percentage and absolute terms. But if we look behind them, we see that OECD increases have been modest, CPE large, and Third World very rapid increases from a low base.

	Increase in billion tce	% Increase
OECD	1.58	40%
CPE	2.23	130%
Other	1.00	135%

7. These trends will not stop. World population is likely to rise by a third by 2005, and the less-developed countries will continue to press for more energy per capita as they seek to increase living standards. Past average annual growth rates continued to 2005 would result in the following energy demand and carbon output:

Energy demand (billion tce)	1987	2005
OECD	5.51	7.48
CPEs	3.91	8.35
LDCs	1.74	3.74
Total world	11.16	19.57
World carbon emissions (billion tonnes)	5.78	10.27

In other words, if the world energy economy were left to itself, CO_2 might increase by 75% rather than reduce by 20%. But, if we are looking at the practicability of reductions, we have to take something like the above figures, not today's levels, as the theoretical bench mark.

8. It may be objected that such a large increase in world energy demand (and hence in carbon output) is inherently implausible, as such demands could not be met without very large rises in energy prices around the world. There is something in this argument. On the other hand, the difficulties of inducing 'energy efficiency' are well known. In the UK we have seen how ineffective mere exhortation can be, even when there appears to be great scope for savings which give a very rapid payback: the institutional and behavioural barriers are notorious.

9. However, let us consider the 'Toronto' recommendations as follows:

	billion tonnes
Carbon emissions in 1987	5.78
20% target reduction	-1.16
Target carbon emission in 2005	4.62
Projected carbon emissions in 2005, using trends of past 20 years	10.27
Thus total saving required to meet target	5.65
Half each from:	
Energy efficiency/conservation	2.82
'Fuel switching'	2.82

10. Given the present mix of fuels, the total world energy demand could be no more than some 14.2 billion tonnes of coal equivalent. In other words, the absolute increase in world energy demand by 2005 would have to be less than the absolute increase of the past equivalent period, despite all the demographic trends, and pressure for higher living standards in the Third World. But even if we accept this heroic premise, we are still a long-way from meeting the 'Toronto' targets', and all we have left is fuel switching.

11. So far as fuel switching is concerned, there needs to be some basic understanding of the limitations of this approach. In particular:

a) The ratios of carbon emission are:

Coal	100
Oil	83
Natural gas	58
Nuclear/Hydro	-

Thus, switching between coal and oil will give little benefit, and is not worth serious consideration. Two theoretical routes are worth considering:

Coal to nuclear
Coal to natural gas

b) However, nuclear is almost exclusively used for electricity generation, and coalfired power stations contribute less than 8% of all the greenhouse gases. Thus, even if all coalfired generation were replaced by nuclear, the effect in mitigating the greenhouse effect would be modest.

12. Finally, the question of feasibility. Using the above analysis we calculate that, if the 'Toronto targets' were to be met:

a) By switching from coal to nuclear:
   i) World nuclear output would have to be increased 8-fold, with about 1,500 stations of the size of Sizewell B started by the mid 1990s.
   ii) World coal output would have to be reduced by 80%, requiring the complete elimination of coalfired power generation as well as substantial cutbacks in other coal use.
b) By switching from coal to natural gas:
   Even if world natural gas output were trebled, and world coal use completely eliminated, this would, still be insufficient to meet the 'Toronto targets'.

13. Clearly these hypotheses are absurd, and show the total infeasibility, even on a global basis, of meeting the 'Toronto targets' of CO_2 reduction by fuel switching, even after taking account of very large hypothetical savings due to 'energy efficiency' and conservation.

14. But the problem becomes even more intractable if we consider problems of distribution within the global totals:

a) Over 80% of all coal used in the world is in 10 countries. Some countries have economies dominated by coal production and use - notably China, India, Poland and South Africa, and the very large coal industries of USA and USSR make a vital contribution to their economies. There is no way these countries could manage without coal for the foreseeable future - and the same is true for the UK.
b) Two-thirds of all natural gas reserves are in the USSR and the Middle East.
   How is this to be transported to replace coal in the coal-dependent economies? What would happen to the price if world output had to be hugely increased?

c) Huge increases in the nuclear contribution required to solve the greenhouse problem could not all be absorbed in OECD countries, so that large numbers of nuclear stations would also be needed in less developed countries. If this was a practicable possibility (which it is not), this would raise serious problems of nuclear proliferation, waste management and higher risks of nuclear accidents.

15. A graduated carbon tax has been suggested as a means of discouraging those fossil fuels (particularly coal) with a high carbon content. But in the light of the above considerations, the tax would have to be very high to produce even part of the desired effect and, furthermore, would enhance the value (and therefore the price) of natural gas. There would be the fundamental anomaly that the most abundant fossil fuel (coal) would have to have the highest price in order to discourage its use. Moreover, how would the level of such a tax be evaluated in the absence of any quantified knowledge of the environmental cost? And what would be the effects on economic activity?

16. This analysis leads one to almost neo-Malthusian conclusions - always assuming that it is necessary to do something to avert the greenhouse effect. But it is very clear that the differences of interest between countries on this issue are potentially so great, particularly between rich countries and poor countries, that it is difficult to see how effective international agreements can be reached. The corollary to that is that there is a gross imbalance for many countries between the potential penalties of unilateral action, and the global benefit. For example, if the European Community were to impose a penal carbon tax in order to completely phase out coalfired power stations in favour of nuclear, then the economic penalty would be very large, but the global reduction in greenhouse gases would be only $1^{1}/2$ per cent. Are we to expect carbon taxes in China?

17. We can therefore recapitulate on the contrasts between the acid rain problem and the greenhouse effect

	SO_2 abatement	Greenhouse
Environmental cause/effect	Partially understood	Not understood
Regulatory framework	OECD - mostly in place	Non-existent
Certainty of abatement	Very high	Non-existent
Effects on energy costs	Modest	Enormous
Effects on interfuel competition	Minimal	Enormous
Effects on world economy	Minimal	Enormous
Conflict of interest between countries	Minimal	Enormous

18. There may be very serious global environmental problems arising from the greenhouse effect, but there would also be very serious global economic problems arising from attempts to find solutions. These must not be forgotten. At the present point of time, the sensible approach would appear to be:

a) Find out more about the possible effects of global warming by substantially increased research effort.

b) In the meantime, take such measures that can alleviate the problem, but which have no significant economic penalty, in particular:

i) Increases in the efficiency of energy production and use.

ii) Phasing out of CFCs.

iii) Reduction in deforesation/increase in afforestation.

19. What is essential, therefore, is that when discussing measures to introduce greater environment protection, particularly in relation to the greenhouse effect,

we constantly consider the economic consequences of the measures which are proposed. Otherwise there could be widespread disruption of the world economy and international conflict which might prejudice the ultimate achievement of protecting the global environment.

[Note: The views expressed in this paper are those of the author and not necessarily those of the British Coal Corportion]

ENERGY, ENVIRONMENT AND THE MARKET: THE INTERNALISATION OF EXTERNALITIES

by Peter M S Jones, UKAEA and University of Surrey

INTRODUCTION

Environmental impact is the classic example of an 'externality' that is unlikely to be reflected in product prices in a free market economy, although it may be reflected in the market shares of competing products if the impacts are recognised and purchasers adapt their behaviour for reasons of self-interest or for the common good.

Government responses to recognised deleterious impacts have generally been to introduce regulations and controls which are designed to reduce the impacts to 'acceptable' levels on aesthetic, safety or public health grounds, or to 'internalise' costs via taxes or levies set at levels designed to achieve the same end result through the operation of the market.

In the specific case of energy most taxes and duties introduced by governments in the past have been for the purpose of revenue raising or other policy purposes, such as decreasing national dependence on specific fuels for security of supply or balance of payments reasons: notably oil in the aftermath of the Yom Kippur war. A recent exception in the UK has been the relative reduction in taxation on lead-free petrol to encourage its more widespread use.

However, several recent taxation proposals have had overtly environmental objectives and this may mark the beginning of a new trend. Sweden, for example, plans to impose a value added tax and fees related to the emissions of carbon dioxide, sulphur dioxide and nitrogen oxides, including those from vehicles (1). The Dutch Government recently resigned after opposition to similar plans to tax vehicle users to discourage pollution and raise revenue to fund environmental improvement proposals (2). The 1988 Toronto conference, in addition to calling for reductions in the production of ozone-depleting chlorofluorocarbons, proposed that greenhouse gas emissions should be reduced by 20% by 2005 and speculated on the introduction of a carbon tax (3). The latter has received some support within the Commission of the EEC (2) and in a paper by Nicholas Ridley (13) which has generated political controversy in the UK.

Outside the energy field taxation or the introduction of compulsory returnable deposits are being tried as means of reducing the production and use of non-biodegradable packaging which adds to unsightly litter and can in some cases be harmful if incinerated with domestic refuse. Denmark, Italy and the Federal Republic of Germany have already introduced measures (4, 5).

In the remainder of this paper some of the problems involved in the process of internalisation of environmental costs are discussed, and some specific aspects of the economics and effects of fuel substitution are examined with particular reference to the greenhouse effect.

PROBLEMS OF INTERNALISATION

In an ideal world with perfect information it would be possible to adopt policies that brought about an optimum balance between the costs to society arising from the deleterious effects of a process or product and the benefits arising from its use. The balance between costs and benefits would be brought about by market forces if prices fully reflected the social costs.

A tax on noxious emissions related to their damage, for example, would impose extra costs on their producer (Curve A, Figure 1) which he would seek to reduce by introducing physical controls with their own set of costs (Curve B, Figure 1). The total cost Curve C will have a minimum Z which will, if the optimum level of controls are introduced, minimise the product unit cost (and price) and allow the volume of sales to be determined by market forces. Some iteration would be necessary to reach a true optimum in situations where the control/damage balance is scale dependent.

The first problem in the real world is the lack of good quantitative data on damage levels. This is not surprising when one examines specific cases. It is extremely difficult to measure meaningfully the impact on forests, human health, wildlife, or even buildings that can be attributed to pollution: not least because the impact relates to both the numbers affected and the degree of the effect.

The next problem is the relationship between pollution emissions and their impacts. Take, for example, the emission of acid gases from fossil fuel combustion in power stations, industry, commerce, the home and transport. It is well known that these gases (sulphur and nitrogen oxides) can be injurious to human health; can damage stonework, metals, paint, paper and fabrics; can acidify soils and harm vegetation and wildlife. Nevertheless the relationship between biological or physical damage and an exposure to the relevant chemical species is poorly understood. Additionally the actual exposures due to individual pollution sources depend on their proximity to subjects at risk, on geographical and climatic factors that lead to dilution or concentration of the pollutants, and on the manner and times at which pollutants are released.

Even if precise links between a given source and its physical and biological impacts could be established the attribution of monetary values to the impacts is fraught with difficulties. In this latter connection it is hard enough trying to put a value to physical damage to buildings, but ecological and human health impacts, including morbidity and mortality, are not susceptible to

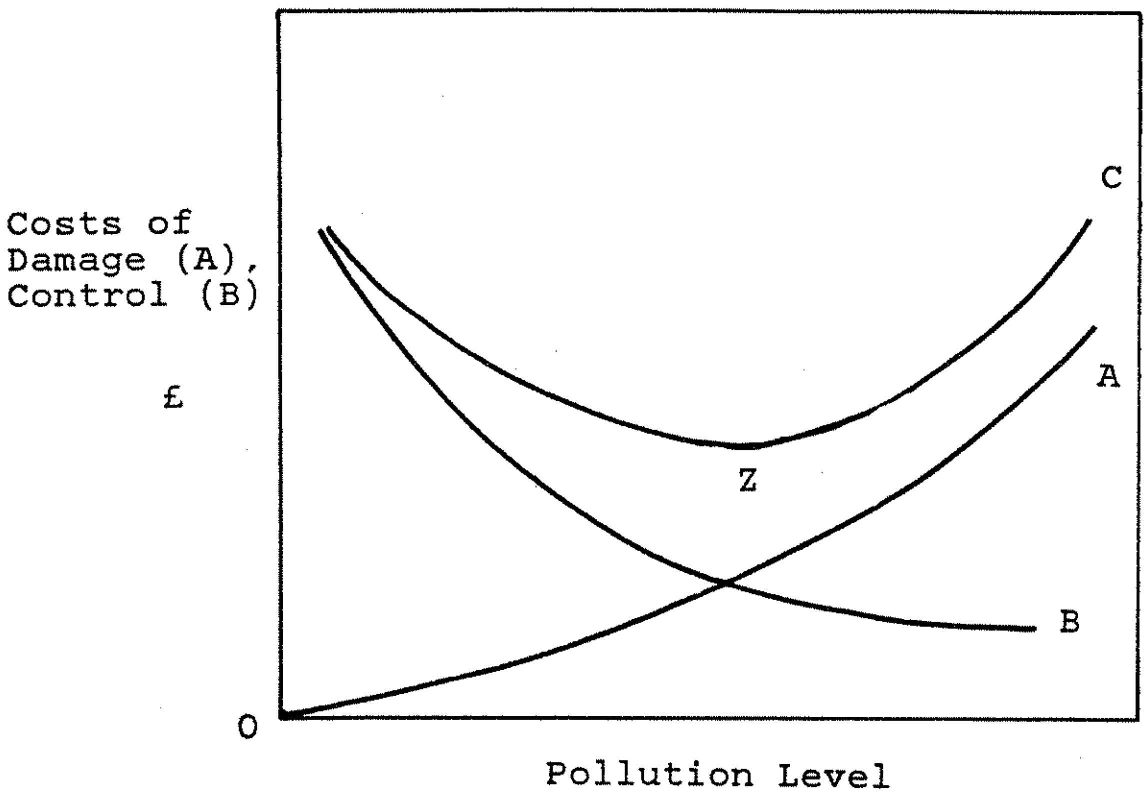


Fig. 1 Costs v. Pollution Level

anything but broad approximations based upon current economic perceptions (see later discussion under radiological protection optimisation).

If it were possible to evaluate all the above at a particular point in time and to optimise costs and prices for each activity, differing national perceptions would lead to different detriment costs in different countries and in different locations within countries. Market forces should, over time, lead to the movement of noxious processes to those locations where they were considered least detrimental. However, both knowledge and perceptions change over time so that there could be no once and for all 'solution'. A continuous process of adaptation would be needed, paralleling the tightening of standards we have witnessed over recent decades as the significance of some damaging effects has come to be recognised and as society has shown willingness to divert resources to environmental improvement.

This raises a further question of valuation - namely whose values should be used? Those based on current perceptions or those projected to apply in the future when the full impacts of environmental damage may be felt. The question of the balance between short term gains and long term losses also raises the ethical question of intergenerational equity and how this should be accommodated in any attempts at optimisation of social welfare.

Pollutants also differ in the geographical distribution of their effects. Solid wastes can be localised; liquid effluents mostly travel along reasonably defined paths; but gaseous effluents may disperse and produce impacts on a continental or global scale - the CFCs, the Chernobyl radionuclides, acid gases and greenhouse gases from fossil fuel burning are all examples of the latter. It may be relatively straightforward in principle, though contentious in practice, to match controls and perceived damage costs when those affected live in close proximity to the pollution source. Gaseous emissions, however, may impose their costs so far from their point of origin that the costs and benefits of control fall to totally different populations with no effective trade-off. Indeed, those affected may in many instances be unaware that they are, particularly if the incremental damage is small compared with what is perceived as natural incidence. For example changed incidence in bronchitis or emphysema from acid gas exposures or cancer resulting from radiation emissions may be statistically undetectable.

This poses major political and educational problems, and raises the issues of compensation and property rights. Do, or should, all people have an absolute right to clean air, water and land? If so those despoiling it should compensate those suffering the damage - the polluter pays principle. However, is it reasonable to expect the poorer nations to abstain from utilising their natural resources to improve their living standards because the rest of us (who for centuries have done the same thing) may suffer? Should they be compensated for showing restraint, for example in destruction of the rain forests of the Amazon? Should a group believing that the greenhouse effect would improve their climate and economic well-being, despite adverse impacts elsewhere, be expected to participate in schemes aimed at its reduction without compensation?

The arbitrary allocation of property rights has been argued to lead to the same eventual balance between pollution and control (6). However, ability and willingness to pay may lead to significant differences depending upon how the property rights are initially allocated, and their initial allocation has a considerable redistributional effect between sectors of society. These latter matters, which are moral and political rather than economic, are only now beginning to receive serious attention at the international level.

RADIATION PROTECTION

One area in which a serious attempt has been made to introduce economic optimisation into policy decisions is that of radiological protection. In designing and operating nuclear reactors, nuclear fuel plant or other nuclear R&D facilities, decisions have to be taken about the level of protection built-in to protect both the workforce and the general public from the effects of radiation.

The International Commission on Radiological Protection has laid down the general principle that radiation exposures should be as low as readily practicable (ALARP), and this has been interpreted by them as involving a balance between the costs of protection and the potential impacts on those exposed to radiation. The principle effect of low level radiation on people is a small increase in the risk that they will develop cancers some ten or twenty years later. There is also believed to be a small risk that there could be genetic effects on subsequent generations, although such effects have not been demonstrated in populations that have received significant doses of radiation in the past.

The United Kingdom National Radiological Protection Board has translated the ICRP advice into detriment costs per unit of radiation exposure to the public or the workforce (7). To do this they have estimated the value to be attached to premature deaths from radiation exposure and related it to the risk factor linking the additional chances of incurring cancers or genetic defects to the radiation dose received based on linear, zero threshold, relationships.

Their economic methodology for valuing life has consisted of an estimation of the direct medical costs and lost income (gross) for individuals dying prematurely. These pecuniary costs have been estimated both including and excluding allowances for housewives and at discount rates of 0% and 3%, which they originally adopted as social time preference rates when the government required rate of return for low risk public sector investment was 5% (it has recently been increased to 8%). The choice of discount rate has a major effect on the pecuniary valuations as shown in Table 1.

Table 1 - Revised NRPB Pecuniary Costs for the Man Sv

Estimated Cost £ (1989)				
Discount Rate %	Output Losses from labour force +H	-H	Output losses from the total population +H	-H
0	4800-5100	4500-4800	8300-10000	7800-9400
3	1100-1200	1000-1100	2000-2300	1800-2100

Note: H with (+) or without (-) housewives
On the basis of these figures the NRPB recommend a baseline value of £5000 for the man Sv.

It will be evident that this is at best a very approximate figure which may significantly overstate the true welfare cost if higher rates of discount are considered appropriate. However the NRPB also introduce an arbitrary scaling factor which increases the baseline detriment cost associated with premature death for higher individual doses where the risk is proportionately greater. The reason they have adopted this practice is stated to be to take account of risk aversion towards increasing radiation exposure. Taking account of typical exposures the NRPB suggest that figures of £10,000/Man Sv for the public and £30,000/Man Sv for radiation workers would accommodate most circumstances (7).

The NRPB's basic values correspond to £200,000 per statistical death avoided which is broadly consistent with values used in transport studies and by the UK Health and Safety Executive. However, NRPB's risk aversion factor gives upper values of around £2.5 million whilst HSE at Sizewell argued that ALARP requires safety measures to be adopted unless the costs are grossly disproportionate which was interpreted as a factor of
10 corresponding to values per death avoided of £1.5 million (8).

The expenditure of sums significantly higher than the pecuniary costs associated with the risks was favoured by the Inquiry inspector, Sir Frank Layfield (8) and the nuclear industry (9) have long adopted this practice.

Whilst such a course may be seen by management in specific industries to be good for public relations and a means of winning acceptance it is a major deviation from the concept of maximising social welfare where, if an optimum balance is to be reached, the sums expended on avoidance of premature death in different sectors of the economy should be such as to produce equal benefits at the margin.

The general shape of safety level (measured as lives saved) versus expenditure curves would normally be as shown in Figure 2. Each plant, facility or sector of the economy will have a differently shaped curve depending on the particular circumstances applying. Curves for specific facilities may lie wholly above or below those others (curves A and B) or they may cross (curves B and C). In the real world curves may exhibit abrupt discontinuities where there are stepwise differences in the costs of alternative protective measures.

The relationship between expenditure per life saved versus the number of lives saved has the form shown in Figure 3, and if, for the purposes of argument, we accept that all lives have equal value, £M, then this 'value' would justify the expenditure of up to this sum to save a life. It can be seen from Figures 3 and 4 that this will imply that larger expenditures producing greater life-saving would be justified for some industries than for others. If the total sum available for expenditure were fixed at the optimum level and one industry decided to increase its share of the total at the expense of others, then the shape of the curves is such that there will be a penalty in terms of total lives lost.

From this it follows that if any industry over-invests in safety, there will be a misallocation of national resources which could possibly lead to increased total premature death.
Misallocation and a net increase of social detriment can also arise from the use of 'low' discount rates. If detriment costs are discounted at rates below the achievable rate of return on investment, then it can readily be shown that decisions will be favoured which could reduce the overall benefit. An immediate investment of £200,000 might be equally acceptable at 0% discount rate for saving a life now by an expensive operation or averting a 10 year deferred death from cancer resulting from an exposure to radiation. Yet if we invested the £200,000 at 10% pa we could save more than two lives in 10 years' time from equivalent operations.

There is also a logical constraint on society's ability to pay for enhanced safety. The overall risk of premature death from occupational, domestic, traffic accidents plus environmental and lifestyle hazards is certainly above 0.1% per person per year, so that expenditure justified on a pecuniary basis, following the NRPB, Department of Transport and HSE method would amount to some 2% to 4% GDP. This is a consequence of the use of discounted summation of future earnings foregone. If higher 'risk aversion' or 'not greatly disproportionate' evaluations of life were adopted, following the NRPB and HSE pattern, this figure would increase ten-fold and would represent a very considerable fraction of GDP. This would imply that significant reductions in other forms of consumption would be needed if the 'optimum' investment in safety were to be made. It is far from clear that society as a whole would be prepared to make such sacrifices, even if some individuals were prepared to so for their own personal benefit.

There are other issues on which the NRPB's approach is open to question. In determining the values to be attached to premature death they have not fully taken account of the lengthy

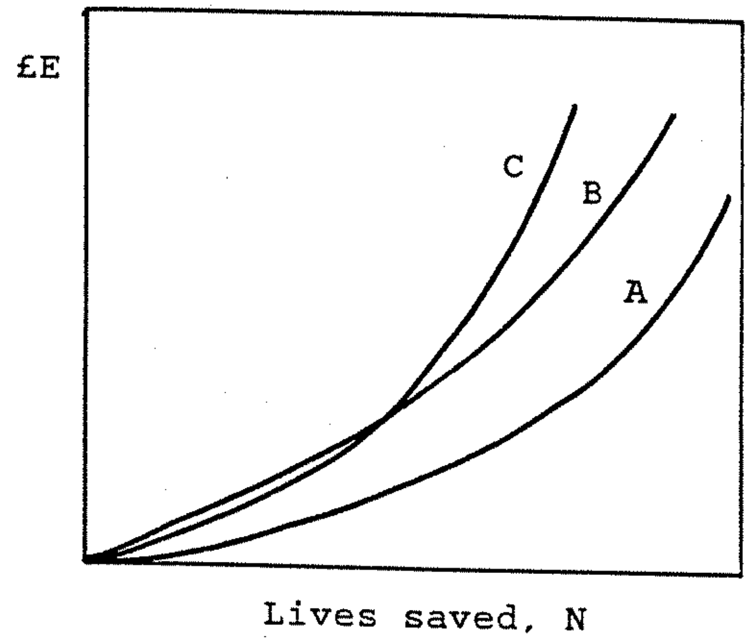


Fig. 2 Lives Saved Against Expenditure

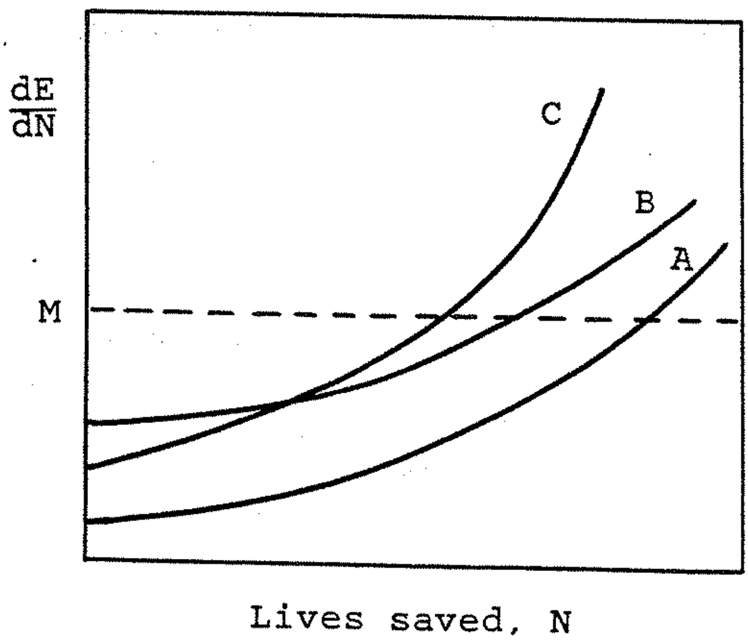


Fig. 3 Marginal Cost v. Lives Saved

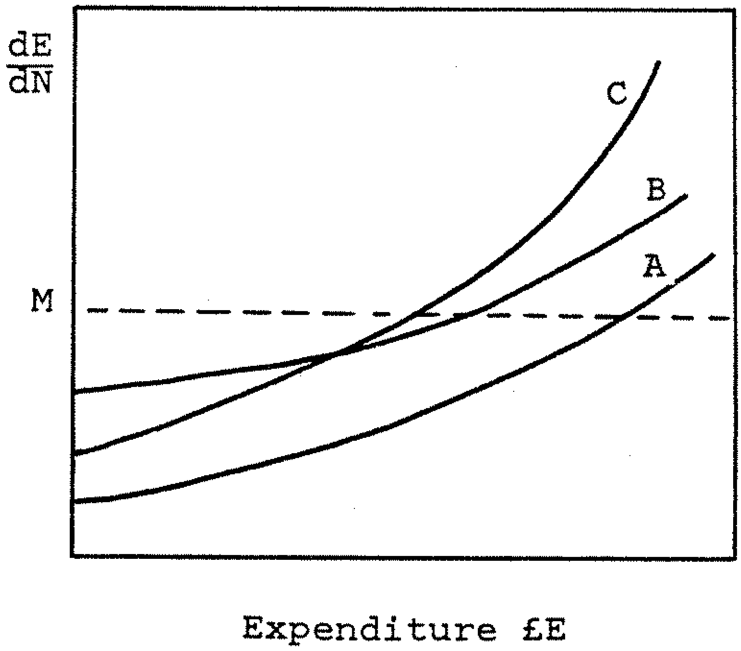


Fig. 4 Marginal Cost v. Expenditure

induction period before the effects of radiation become apparent, and this implies that there should be a difference in valuation of life in present worth terms between radiological protection measures and situations where the impact is more immediate, such as road accidents.

There have therefore been considerable pressures for over-expenditures by the nuclear industry on the reduction of risks associated with radiation exposures. This may not be beneficial in terms of the overall health and safety of the nation, even though the actual costs incurred by the nuclear industry may be relatively small in relation to their total expenditure.

THE GREENHOUSE EFFECT AND NUCLEAR POWER

The externality of greatest current interest is the greenhouse effect in which the products of fossil fuel combustion, inter alia, are projected to lead to increasing global temperatures with associated climatic changes and significant rises in sea level over a period of decades.

A great deal has been written about the continuing addition of anthropogenically produced greenhouse gases to the atmosphere and their potential long-term effects. Although it is not the only greenhouse gas, carbon dioxide, a product of all fossil fuel combustion, has received the greatest attention. Figure 5 indicates the approximate proportions of greenhouse gases being released and shows that carbon dioxide is indeed the most important single contributor, with energy production being the major source.

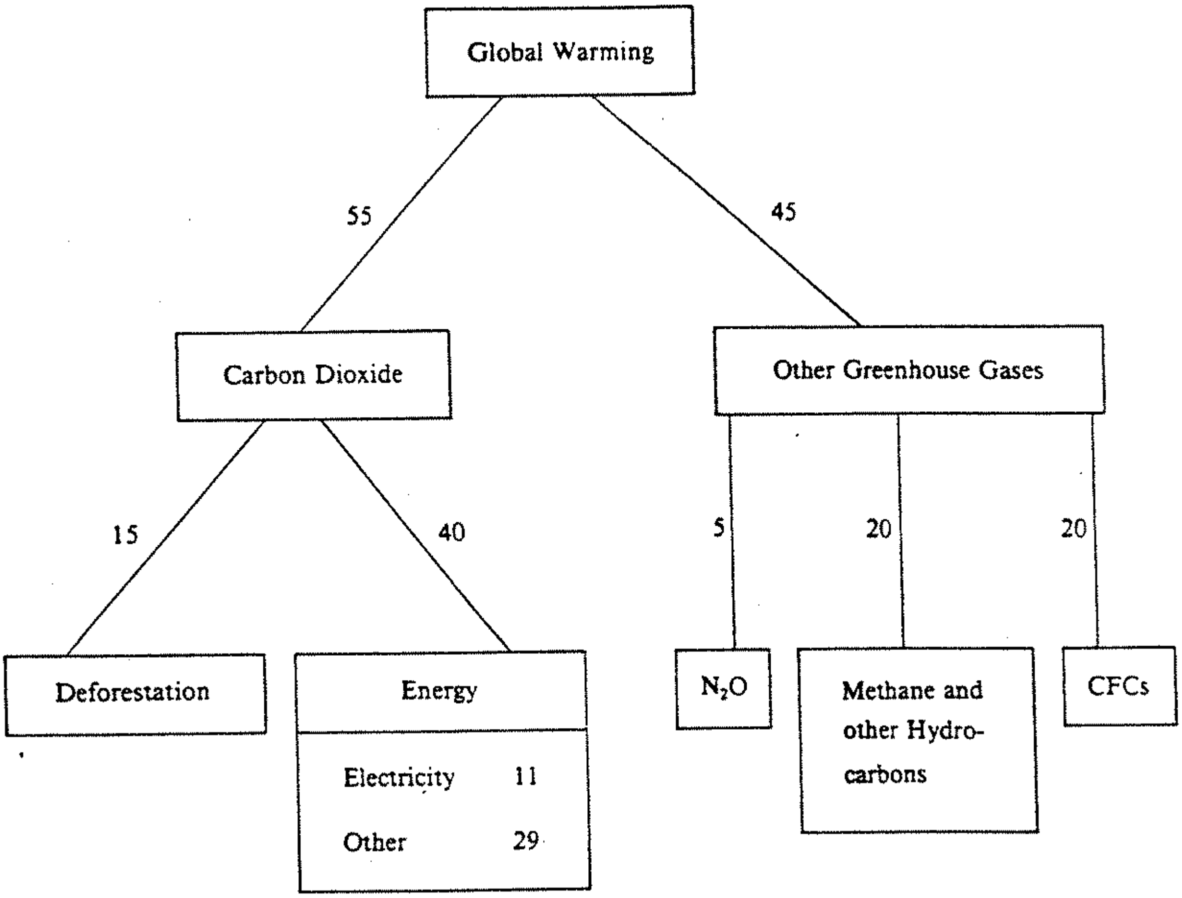
Despite the fact that there remains considerable uncertainty about the rate of future rise of greenhouse gases, there are growing calls for action to reduce emissions on the grounds that the risks to global climate and ecology are too great to be ignored. The uncertainties are large because man's contribution to the total atmospheric levels of carbon dioxide are small in relation to the whole and there are major transfers of carbon between the atmosphere, the oceans and vegetation which could materially alter the way which emissions to the atmosphere accumulate. There is also a range of atmospheric phenomena which could exacerbate or ameliorate the effects of the accumulation of greenhouse gases.

For these reasons and for those set out in the opening sections of this paper there is no meaningful way of setting a magnitude to the external costs attaching to fossil fuel burning which might arise from the greenhouse effect.

However, leaving these uncertainties on one side and accepting that some measures to reduce carbon dioxide emissions are desirable, a number of optional courses are, in principle, open. As indicated elsewhere (10) those capable of producing the most immediate impact would be energy conservation through improved efficiency or general economy, and the substitution of hydrocarbon fuels (particularly gas) for coal burning. In the longer term the substitution of

Figure 5

MAKE UP OF GLOBAL WARMING



All numbers are percentages of the total present global warming effect.

nuclear power and renewable energy sources for fossil fuel combustion becomes an important option.

Since many energy efficiency measures are likely to save money and since the costs of nuclear and coal-fired generation are broadly comparable (11), prudent environmental protection may be achieved at little or not cost. Questions then concern preferred routes.

The use of nuclear power has the potential, on a surprise free future with present trends continued, to reduce anthropogenic global warming effects by some 6-7% in 2020. But even a vigorous policy of switching to nuclear power in the industrial nations could only reduce the global warming effect by some 15% on the same timescale. This follows from the current and likely future patterns of use of fuels. In the very long term the contribution of nuclear and renewable sources could be considerably higher than this if they could be used for direct heating purposes, or if electricity were allowed to penetrate into a wider range of direct heating and transport markets. Taken together with energy efficiency this offers prospects of worthwhile reductions in carbon dioxide production, although reductions in atmospheric levels will be almost impossible to achieve in the medium term (10).

A number of authors have sought to attack investment in nuclear power as an option on specious grounds. In the first place nuclear has been criticised on the basis of an argument that the costs of construction of nuclear plant and the high rate of nuclear installation implied in high energy growth scenarios makes nuclear an unrealistic choice (12). What such critics fail to recognise is the fact that in broad terms the same logistic and financing problems apply to any supply option designed to meet the high energy projections they employ. It is equally true of the total costs of coal-fired electricity whilst the majority of renewable sources would be even more capital intensive and costly. The question of logistic constraints also applies regardless of the energy source adopted.

Keepin and Kats (12), in their frequently quoted paper, have developed energy scenarios and deployed the above cost and logistic arguments then finally concluded that even with high nuclear contributions carbon dioxide emissions would increase by 60%. This they use to imply that nuclear is an ineffective option. What they fail to point out, however, is that in the absence of the nuclear contribution the carbon dioxide emissions on their scenarios would have increased three-and-a-half fold. Set against that scenario the contribution of nuclear power would be very significant indeed.

Proponents of energy conservation have also been arguing that investment in conservation and energy efficiency is a highly cost effective means of reducing carbon dioxide compared with investment in new supply, generally using nuclear power to illustrate their case. It is a common characteristic of such arguments, which is again followed by Keepin and Kats, that they compare the marginal costs of improved efficiency in electrical appliances or electricity consuming plant with the full cost of alternative supply. Whilst there is no question but that some energy efficiency measures are highly cost effective and a significantly better investment than energy supply, it is not universally true of all efficiency improvements, and the manner in which the comparison is made can be seriously misleading. There are three separate cases that merit consideration.

The first of these is a situation in which there is a perceived long term need to reduce carbon dioxide emissions but where there is no immediate pressure. Under such circumstances there is no greenhouse incentive to accelerate the replacement of existing appliances or plant, and it would then be appropriate to look at the costs and benefits of substituting more efficient equipment or alternative electricity supply options as and when such replacement would take place naturally.

The second case is one in which there is concern about the reduction of carbon dioxide emissions in the short term and where this is considered to be of sufficient importance to write-off existing appliances and plant and substitute in their place new higher efficiency appliances or new non-fossil plant. In such a case the future cash flows associated with both energy efficiency and electricity generation would be affected and the full costs of the alternatives would need to be compared with the costs of continuation of existing practices.

The third situation is one in which one is examining the relative attractiveness of meeting incremental demand in the future with additional supply or endeavouring to contain demand at present levels by improved energy efficiency measures. This last case is the only one in which it may be reasonable to contrast the marginal cost of energy efficiency measures with the full costs of new supply.

In practice, improved energy efficiency and alternative means of supplying such energy as required after implementing appropriate cost effective energy efficiency measures are complementary methods of reducing greenhouse gas emissions. They should not be seen as being in conflict.

The following numerical example illustrates the sort of distortions that can creep into presentations which seek to contrast the cost-effectiveness of energy efficiency and supply routes.

Keepin and Kats (12) high-efficiency refrigerator/freezer is stated to save 280kwH per annum at a cost premium of $100. Taking the life of a new unit as 20 years (Keepin and Kats use 17 years) and its capital cost $500, a 5% discount rate leads to the tabulated results (the precise

Substitution Present Worth Investment Costs,
Present Worth Energy Savings and Levelised Costs/Coal Unit Saved

Case		1st Replacement	P. W. Cost	P. W. Saving	Levelised Incremental Cost/Coal Unit Saved
Fridge/freezer					
(a)	Normal cycle* with existing tech.	10 yrs	$394	-	-
(b)	Normal cycle advanced tech.	10 yrs	$493	3.61MWh	2.7c/KWh
(c)	Immediate substitution	0 yrs	$802	5.88MWh	6.9c/KWh
Nuclear Plant					
(a)	Normal cycle** coal replacement	15 yrs	$0.8bn	-	-
(b)	Normal cycle nuclear replacement	15 yrs	$1.33bn	64TWh	0.8c/KWh
(c)	'Immediate' substitution	0 yrs	$2.77bn	132TWh	1.5c/KWh

* 20 year replacement schedule

** 30 year replacement schedule

numbers are not important for the purpose of the illustration which is intended to indicate the different results obtained when comparisons are made on different bases).

The equivalent calculations for replacement power plants of 1,000MWe nett capacity, with lives of 30 years and levelised load factors of 72% are shown in the table. They are based on capital costs of $2.13 billion and $1.26 billion for nuclear and coal plant respectively (11).

These nuclear costs are both less than the corresponding costs for the replacement high efficiency fridge/freezers but the comparison does not take account of the fact that the substitution with nuclear power still incurs generation costs.

If the changes in electricity demand are marginal so that overall systems costs (overheads, transmission, profits) remain unchanged, the only nett difference between the costs of nuclear power and the fridge/freezer is the operation and fuel costs for the nuclear plant. For a PWR this is approximately 1.6c/kWh (11), and this would have to be added to the nuclear capital cost component derived above. From a national cost perspective, using the assumptions made in this illustrative analysis, a new nuclear station would be more attractive for carbon dioxide reduction then a new fridge/freezer.

The individual electricity consumer would see things differently because he would, at Keepin and Kats quoted electricity price of 7.8c/kWh, more than recoup his investment by buying the fridge/freezer. The unrecovered overhead costs would be distributed amongst other electricity users and have negligible impact on the fridge/freezer purchaser himself.

The position of the fridge/freezer would be improved in all cases if the more optimistic energy savings and lower incremental costs proposed by Friends of the Earth were applicable (13) or in non-marginal situations where utility overheads could be regarded as variable.

From this illustration it is clear that the relative attractiveness of routes to carbon dioxide reduction is less clear cut than Keepin and Kats would have readers believe. If carbon dioxide emissions have to be reduced the economic case for many energy efficiency measures is strong, but so is the case for providing that electricity which is needed from nuclear (and possibly other non-fossil) sources.

Markets and Energy Efficiency

It is widely recognised that free market forces have not been effective in improving the energy efficiency of consumer durables. There are, on the other hand, numerous examples of significant energy efficiency improvements in the field of industrial processes and processing, although even here the rate of change has been comparatively slow. The problems arise both from lack of awareness on the part of potential beneficiaries of what can be achieved, and from the fact that savings in future energy expenditure do not seem to have been valued highly relative to other pressures on the pockets of individuals and companies.

A range of measures has been proposed as means of encouraging the adoption of greater energy efficiency. These include regulation to impose higher efficiency standards in buildings etc, and labelling to give greater information to purchasers which will enable them to weigh up potential future savings against any capital cost or other differences between the products on the market. The provision of education and objective factual information is also frequently urged.

It is evident, however, that at the present time, even if it were possible to internalise the external costs imposed on society by different fuels, that market forces alone will be unlikely to produce an environmentally optimum mix of plant and appliances.

CONCLUSIONS

From the foregoing discussion it is concluded that there remain very considerable difficulties in trying to use market mechanisms to encourage patterns of investment that will bring about an optimal balance between energy use and environment. It is argued that there are virtually insuperable technical difficulties in determining the actual external costs associated with the use of different fuels and that this is particularly acute in the case of globally dispersed pollutants such as carbon dioxide.

Even where attempts have been made to internalise externalities, as in the case of radiological protection, the methods adopted and the wish of managements to be seen to be doing more than the minimum required of them combine to lead to over-expenditure which may well produce distortions which exacerbate the damage costs to the whole economy rather than reducing them.

Even in a completely rational world, however, and one in which it were possible to arrive at reasonably precise measures of the external costs of different energy sources there would still be conflicts of interest between individual companies and consumers whose priorities, both within countries and between countries, would differ from those of governments concerned with overall welfare maximisation. It would seem therefore that governments will not be able to rely on market forces alone, but that policy decisions will be required which will involve the deployment of a battery of measures aimed at steering energy use in the directions considered by government to be desirable. These instruments may include pricing mechanisms where changed patterns of fuel use are encouraged by the introduction of taxes, supplemented by the adoption of standards, regulations and educational programmes. The mix appears likely to remain an arbitrary one aimed at steering a course in broadly the desired direction, although the concept of optimisation would appear an unrealisable one in the foreseeable future.

Market forces alone, without government intervention, will not, at least in the UK, encourage a move out of coal into less environmentally detrimental energy sources. Privatisation of the electricity supply industry and prospectively of the coal industry will not make things easier. It is generally accepted that the non-fossil fuel electricity sources will not be favoured in the post-privatisation era, not least because private investors will look for higher rates of return and be reluctant to invest in capital intensive projects such as those involved in nuclear plant, tidal barrages or even aerogenerators. The Government has sought to rectify the situation so far as non-fossil sources are concerned by the introduction of the non-fossil fuel fraction and specific renewable source quotas, which will require the distribution companies to get a specified percentage of their electricity from such sources. A mechanism is being put in place to compensate them should this lead them to incur extra costs. This policy has been adopted by Government for diversity reasons rather than for environmental reasons, but could clearly be extended were environmental issues felt to merit it. The mix of plant is however a policy choice and not economically or environmentally optimised.

In the 1990s the nuclear contribution to electricity production, both in the UK and globally, is already determined by the plant in place or under construction. Even if a decision were taken that nuclear power should be expanded as rapidly as possible on environmental grounds it would be difficult to increase the nuclear share much above 20% by the year 2000 due to the lengthy planning and construction times associated with nuclear projects. It is for this reason that any shorter term changes required have to be sought via the substitution of hydrocarbon fuels for coal or via the more speedy introduction of energy efficiency improvements.

REFERENCES

1. European Energy Review, 21 April 1989, 287/5.

2. The Economist, 6 May and 13 May 1989.

3. Closing statement from 'The Changing Atmosphere: Implications for Global Security', Toronto, June 1988.

4. The Economist, 6 May 1989.

5. Warmer (International), no 21, summer 1989, p3.

6. R H Coase, The Problem of Social Cost, Journal of Law and Economics, 3, pp1-44, 1960.

7. J D Robb and A D Wrixon, Revised Estimates of the Monetary Value of Collective Dose, NRPB Report M157, 1989, NRPB, Chilton, Oxon.

8. Department of Energy, 'Sizewell B Public Inquiry', Volume 3, Chapter 35, pp6, 7, HMSO, London, 1987.

9. Examples are given in J R A Lakey and J D Lewins (eds), 'ALARA - Principles, common practice and consequences', Adam Wilger, London, 1987.

10. UKAEA Memorandum (No. 15) to the House of Commons Energy Committee hearings on Energy Policy Implications of the Greenhouse Effect, HMSO, 1989, pp96-103.

11. P M S Jones, G Stevens and K Wigley, 'International Comparison of Generation Costs', paper to Nuclear Energy Agency/Japanese Atomic Energy Society Conference on Good Performance in Nuclear Projects, Tokyo, April 1989.

12. B Keepin and G Kats, Energy Policy, 1988, pp538-561.

13. N Ridley, Policy Studies Institute Paper, June 1989.

14. Friends of the Earth, memorandum to House of Lords European Communities Committee Enquiry into Efficiency of Electricity Use, FOE, London, 1989.

REDUCING GREENHOUSE GAS EMISSIONS IN THE UK:
A study of the Electricity, Buildings, and Industrial Sectors

Stewart T. Boyle, Energy & Environment Programme Director and
Ian Brown, Research Director, Association for the Conservation of Energy

1. INTRODUCTION

Objectives

The overall objective of this study was to analyse, under a range of assumptions, possible carbon dioxide emissions from the UK energy sector between the years 1988 and 2005. Associated with this, was the objective of identifying possible technologies and policy responses which could affect the various scenarios developed.

Methodology

The study looked at all energy sectors within the UK, with the exception of the transport sector. For the sake of completeness however, brief mention is made of this sector since it is a rapidly growing source of C02 and tropospheric ozone emissions.

In each of the sectors two main scenarios are developed. These are a 'Business as Usual' scenario, whereby no specific policy measures are introduced to combat global warming, and a 'Efficiency' scenario, whereby a high level of intervention by government is assumed on matters such as building regulations, appliance standards and the like, leading to a high take-up of the various technologies assumed.

The study utilised a computer model of the UK Electricity Supply Industry (ESI) operated by the Science Policy Research Unit at the University of Sussex, a computer model of the domestic building sector, operated by the UK Department of the Environment's Building Research Establishment ('BREHOMES'), and some additional modelling work on the commercial/public and industrial sectors (non-electricity usage) by Earth Resources Research, in addition to the work performed by the Association.

2. UK GREENHOUSE GAS EMISSIONS AND TRENDS

Scientists and others who are concerned about the problem of global warming are increasingly focusing their attention on carbon dioxide (CO2) emissions. There are two main reasons for this. The first is that CO2 contributes as much to global warming as all the other greenhouse gases put together. The second is that CO2 is the dominant gas in fossil fuel pollution and cannot easily be removed by filtering or other processes. It can however be reduced quickly by cutting fossil fuel consumption through measures such as energy efficiency. Most of these measures also reduce emissions of other greenhouse gases such as methane (CH_4), nitrous oxides (N_2O), and tropospheric ozone (O_3).

About four fifths of net global CO_2 emissions come from the burning of fossil fuels. The UK, with only 1% of the world's population, produces 3% of the world's carbon dioxide from fossil fuels, amounting to an estimated 542 million tonnes of CO_2 per annum (ref.1). Western Europe as a whole produces 15%, North America 25%, Eastern Europe 26%, Japan and the Pacific countries 6%, China 11% and the other developing countries 16%.

In the UK, industrial processes, domestic buildings, transport and electricity generation are the main sources of CO_2 emission, producing 94, 90, 120 and 205 million tonnes of CO_2 per annum respectively. In the electricity generation sector, coal-fired stations account for over 90% of CO_2 emissions, with oil and gas-fired stations accounting for the rest.

<u>Sources of CO_2 in the UK by sector</u>

Electricity generation	205 Mt
Domestic*	90 Mt
Industrial*	94 Mt
Commercial/Public*	33 Mt
Transport ╫	120 Mt
Total ╞	542 Mt

* excluding electricity
╫ includes road, air and rail transport

╞ This study covered 92% of the total energy use in the UK. It does not cover the agricultural sector, nor does it take account of some industrial processes such as coking, or refining, or CO_2 produced from waste. The total is therefore lower than recent figures produced by the Energy Technology Support Unit (ETSU) and others.

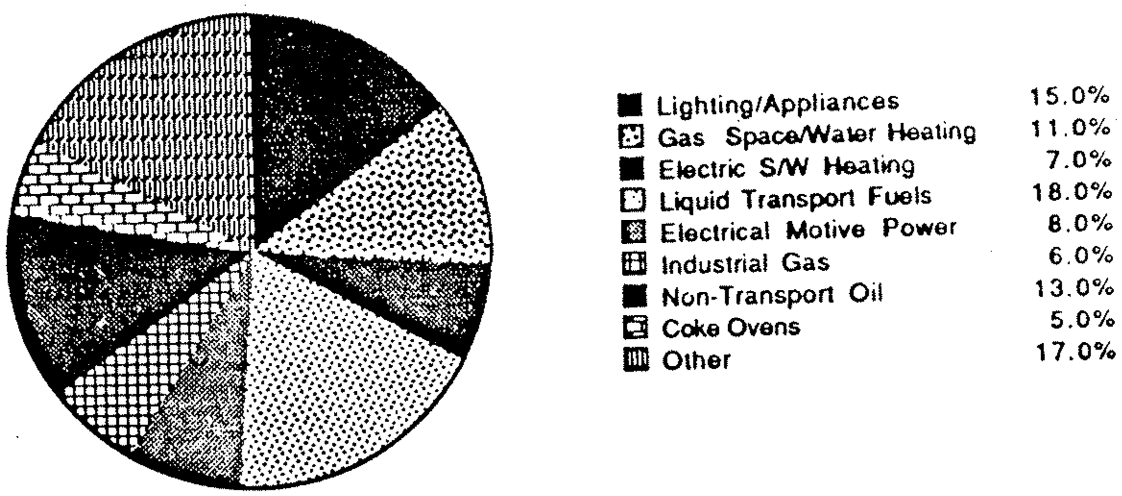
Analysis of energy end-use sectors identifies the following as significant CO_2 sources (see Figure 1):-

Gas space and water heating	- 11%
Electric space and water heating	- 8%
Liquid transport fuels	- 18%
Lighting/Appliances	- 15%
Electric Motive Power	- 8%
Industrial Gas	- 6%

These make up two-thirds of total emissions.

Figure 1

UK CO2 EMISSIONS BY END USE (1987)



3. FUTURE EMISSION SCENARIOS

A. Electricity Sector

Figure 2 shows the breakdown of electricity consumption and hence CO_2 emissions by end-use. Lighting, appliances, motive power and space/water heating constitute nearly 80% of the total. Projections of CO_2 emissions in the year 2005, using the CEGBs own forecasts, are shown in Figure 3. This shows a 17% increase (36 million tonnes of CO_2). This 'business as usual' scenario, plus the subsequent 'efficiency' scenario below, assume that 7000 MW of efficient combined-cycle gas-fired capacity and a 20% 'non-fossil fuel' quota (covering both renewables and nuclear power) are maintained under the imminent electricity privatisation legislation. (Ref 2)

The opportunities for CO_2 emission reductions lie mainly in areas such as lighting, (particularly in the commercial sector), appliances and motive power. Air conditioning and cooking provide smaller opportunities. A range of technological assumptions have been made for appliances, improved motors, the replacement of incandescent bulbs with efficient compact fluorescent and high pressure sodium lights, and more advanced air conditioning systems. Assuming a rapid uptake of technologies currently available on the market, and a near complete penetration, savings of just over 10% of CO_2 emissions in the electricity sector could be achieved by the year 2005.

A key factor in our analysis is the robustness, or otherwise, of electricity demand forecasts. Sixty per cent of the assumed increase in demand is suggested as arising in the commercial sector, particularly as a result of increased air-conditioning in offices (an assumed doubling in consumption), lighting (43% increase) and space heating (43% increase). We believe these increases to be based on a rather limited database covering the past 5 to 6 years, which has been extrapolated over the next 12-15 years. If for example, only half the projected demand increases in the commercial sector were to occur, two thirds of the industrial sector increase and no increase in the domestic sector, CO_2 savings would increase to over 15% by the year 2005.

A proactive scenario, whereby energy efficiency technologies which are currently available are aggressively promoted, where more realistic electricity demand forecasts are assumed (though they still allow an increase of more than 10% on current levels), and with an additional 3000 MW of non-carbon based supply, could bring about carbon dioxide reductions of greater than 22%.

Figure 2

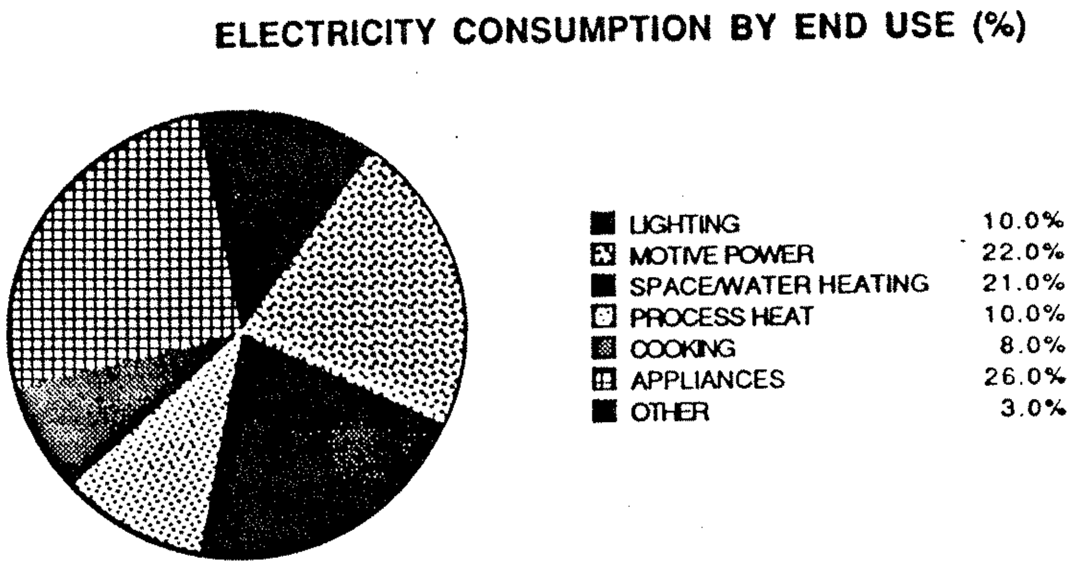
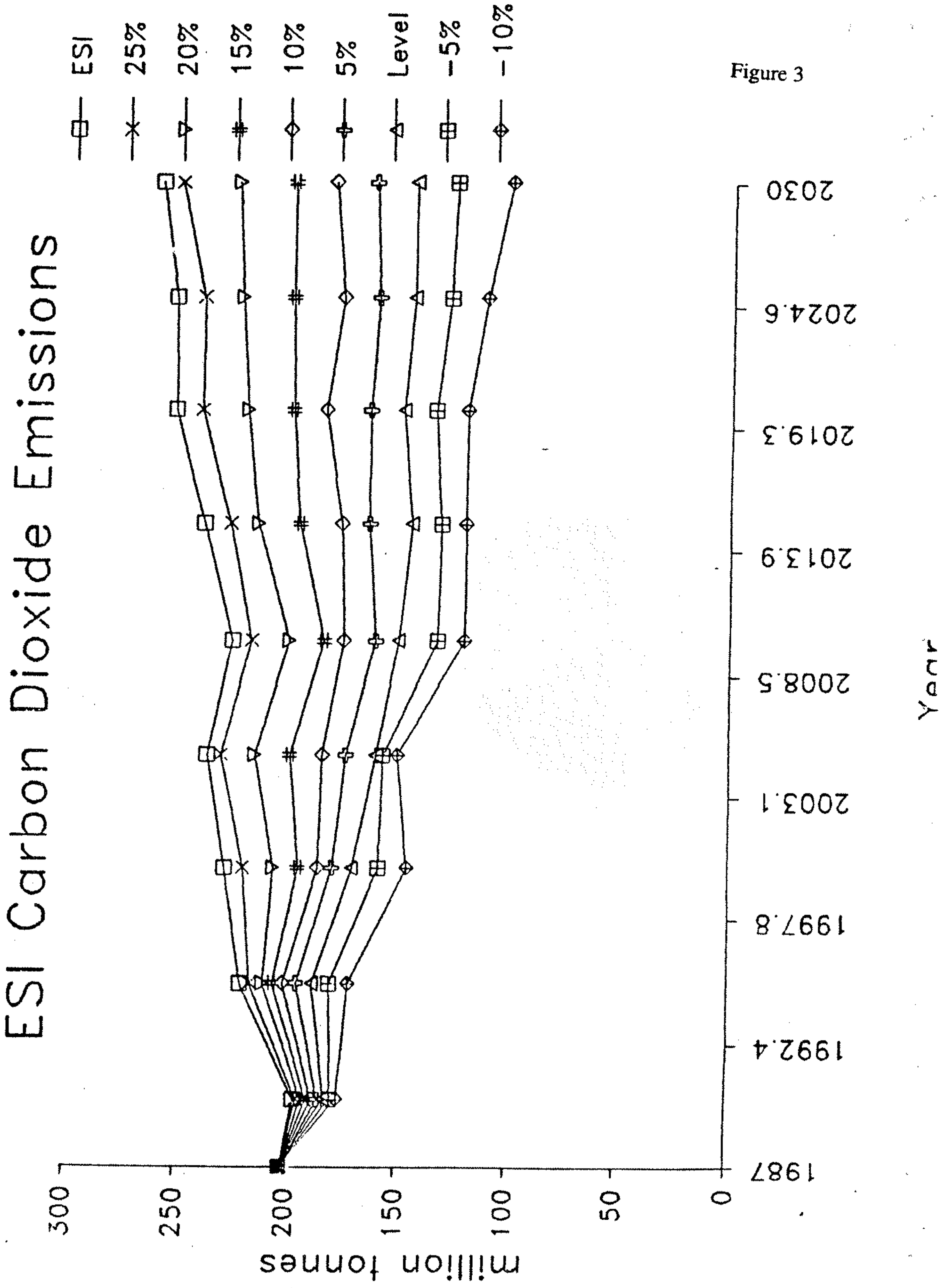

ELECTRICITY CONSUMPTION BY END USE (%)
LIGHTING 10.0%
MOTIVE POWER 22.0%
SPACE/WATER HEATING 21.0%
PROCESS HEAT 10.0%
COOKING 8.0%
APPLIANCES 26.0%
OTHER 3.0%

Figure 3



ESI Carbon Dioxide Emissions
ESI
25%
20%
15%
10%
5%
Level
-5%
-10%
million tonnes
300
250
200
150
100
50
0
1987
1992.4
1997.8
2003.1
2008.5
2013.9
2019.3
2024.6
2030
Year

B. DOMESTIC BUILDINGS SECTOR

Carbon dioxide trends over the past 17 years attributable to the UK domestic housing stock are shown in Figure 4. That related to the use of electric has been removed in order to avoid double-counting. Simple extrapolations under a 'business as usual' scenario, adjusted to take account of the growing number of households and slowly improving building stock, indicate an 11% increase by the year 2005.

Figure 5 indicates some of the general trend in total building stock heat loss and its relationship with carbon dioxide emissions. Although the overall trend is that both the average heat loss per dwelling, and total heat loss for all of the building stock has been falling, the trend has been complicated by the growing number of dwellings as family size falls and more single people seek homes, increasing comfort levels and the hard winters of 1985 and 1986.

The main scope for efficiency improvements lies in reducing heat losses in buildings and increasing the efficiency of heating systems. The latter can be significantly improved through a more rapid and widespread utilisation of gas condensing boilers. Although more efficient gas condensing boilers are available on the market, their level of uptake is slow. These boilers typically have efficiencies of 83% to 89%, which is 12% to 20% greater than conventional boilers, though conventional boiler efficiency can drop to as low as 60%, (ref 3). The market penetration level is less than 10%. Assuming that gas condensing boilers capture 90% of the current gas heating market by the year 2005 through a mixture of incentives and improved marketing, carbon dioxide savings of more than 10 million tonnes occur.

Assessing the impact of improvements in the thermal efficiency of buildings is more problematical, since any improvements may be partially taken by occupants as through increased comfort levels. Revised building regulations may be introduced in January 1990. These include floor insulation for the first time, as well as improvements to wall and roof thermal insulation values. The impact however will be small over the next 15 years. The reason is two fold. Firstly, UK building regulation standards are still low compared to other countries. Secondly, just over 1% of the building stock is being renewed each year through new build. By the year 2005 therefore, the estimated CO_2 reductions as a result of the revised building regulations are less than 3 million tonnes per annum, less than 4% of the total without the new regulations.

Retrofitting dwellings to improved thermal insulation standards is hence the key option within the domestic building sector for reducing CO_2 emissions. A 'high efficiency' scenario was developed which utilises an Energy Conservation Index by Milton Keynes Development Corporation (ref 4). A figure of 120 on this Index was chosen, as against 170 for the average UK dwelling. By assuming an aggressive retrofitting programme to 80% of the current UK housing stock, we can achieve a CO_2 reduction of 37 million tonnes by the year 2005. This would keep

Figure 4

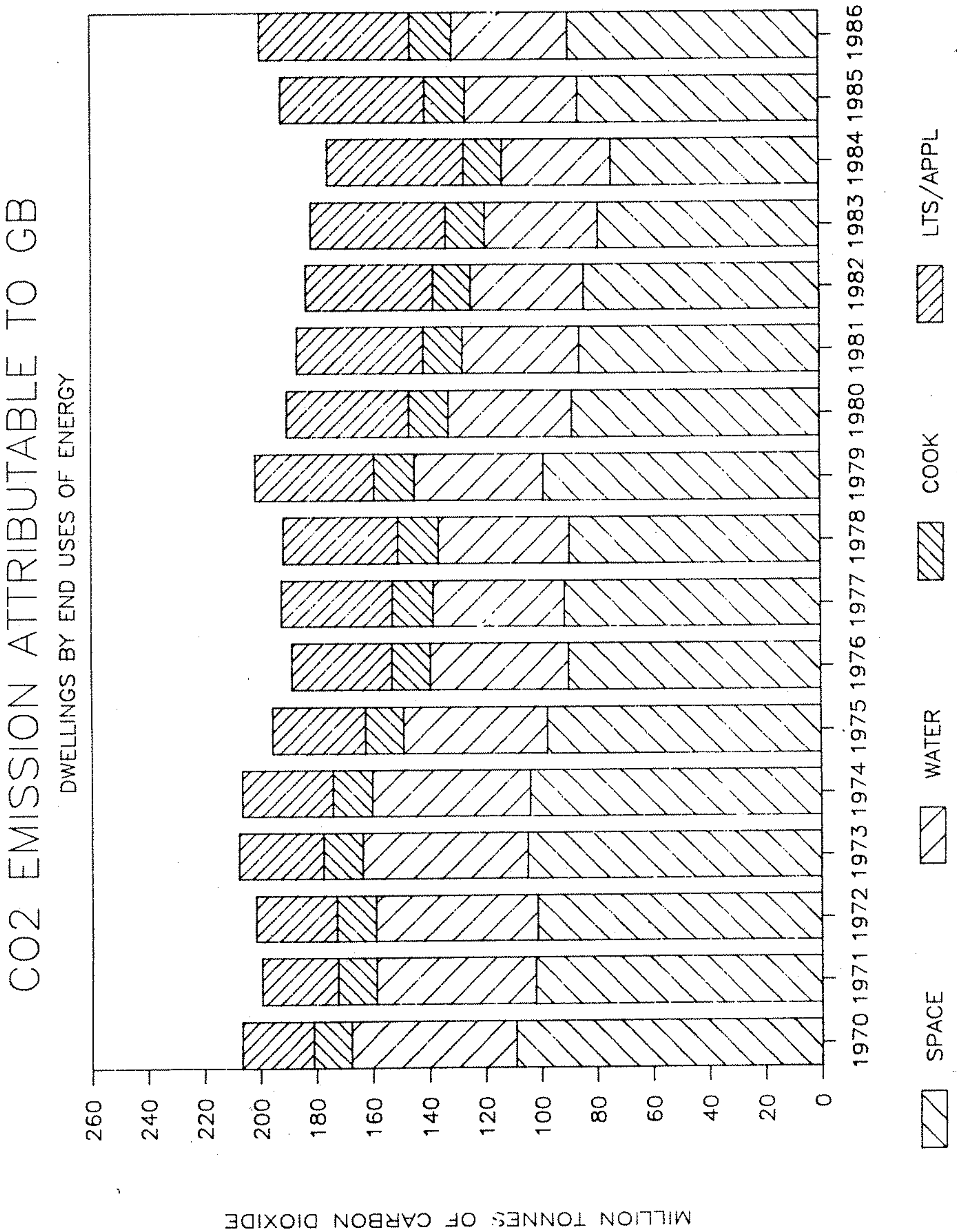
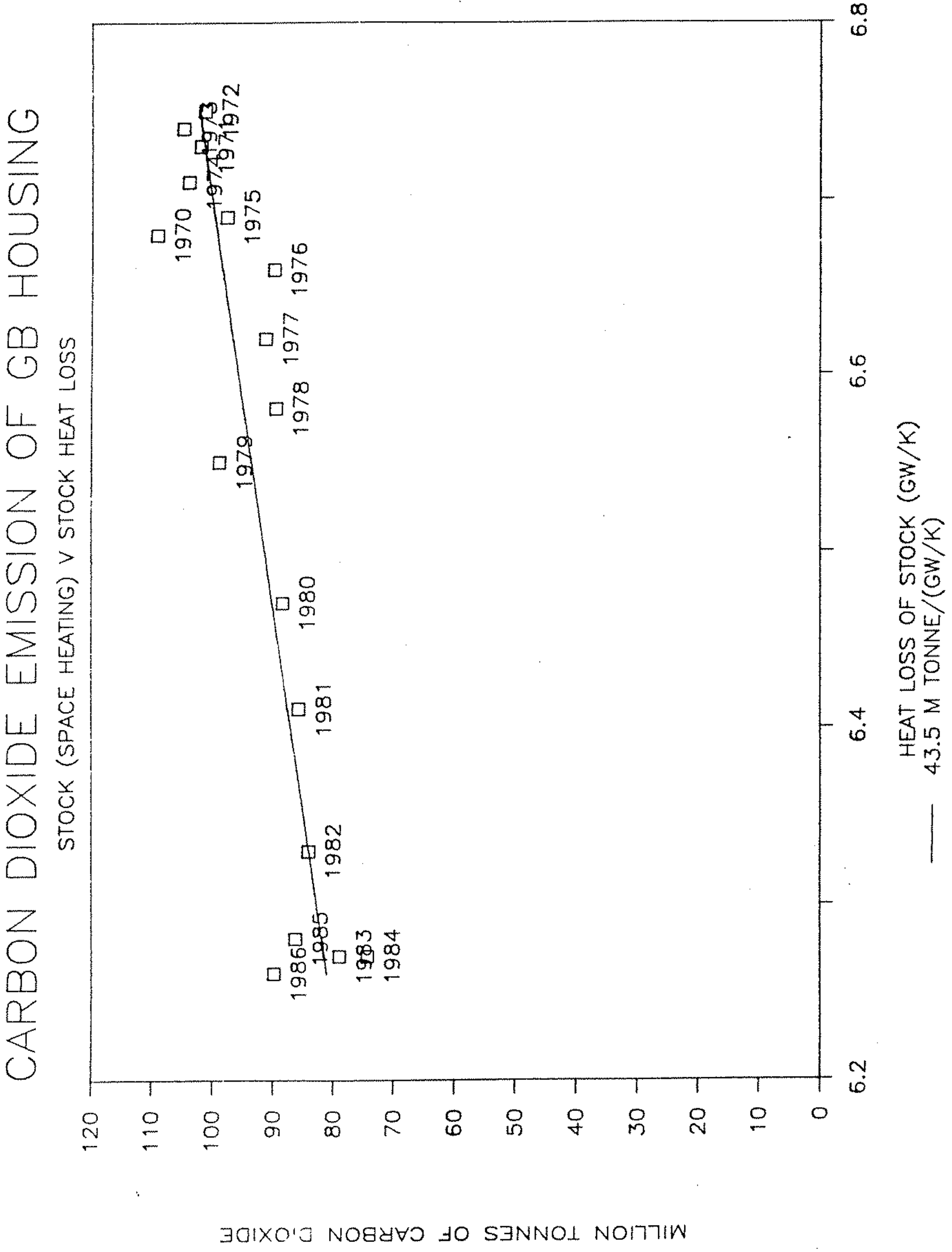

CO2 EMISSION ATTRIBUTABLE TO GB
DWELLINGS BY END USES OF ENERGY
SPACE
WATER
COOK
LTS/APPL
1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986
0 20 40 60 80 100 120 140 160 180 200 220 240 260
MILLION TONNES OF CARBON DIOXIDE

Figure 5


CARBON DIOXIDE EMISSION OF GB HOUSING
STOCK (SPACE HEATING) V STOCK HEAT LOSS
MILLION TONNES OF CARBON DIOXIDE
HEAT LOSS OF STOCK (GW/K)
43.5 M TONNE/(GW/K)
0
10
20
30
40
50
60
70
80
90
100
110
120
6.2
6.4
6.6
6.8
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986

space heating related emissions to a level 9% lower than that in 1987, despite there being 1.85 million additional households.

C. INDUSTRIAL AND COMMERCIAL/PUBLIC SECTORS
(non-electricity end-uses)

Industrial Sector

Data provided up to the year 2000 by the Energy Technology Support Unit from detailed studies in 1984 and 1988 (ref. 5), was extrapolated from the year 2000 to 2005. Under the 'business as usual' scenario, carbon dioxide emissions in the industrial sector increase by just under 30%. Increased use of coal at the expense of oil produces much of the increase. In contrast to the rapid and large increase in electricity use within the commercial/public sector, increases in CO_2 emissions from the use of fuels directly for space and water heating is relatively small, reaching 14% by the year 2005. Virtually all of the increase occurs as a result of gas space and water heating in a rapidly expanding service sector. CO_2 emission from gas increases by 130% (14 to 33 million tonnes). Emissions from solid fuels in this sector are assumed to fall to less than 2 million tonnes per annum (see Figures 6 and 7).

The efficiency potential has been estimated with the following conservative assumptions:

- maximum take-up of cost-effective energy efficiency measures (with cost-effective being measured as an assumed payback of 4-6 years for major changes to an energy-intensive process, and 2-3 years for minor changes to a non-intensive process)

- fuel switching from coal to gas.

Commercial/Public Sector

In the commercial/public sector, though the percentage savings at 50% of the 1986 figure are large (Figure 8) the overall CO_2 savings are relatively small, reaching 18 million tonnes under maximum technical take-up. In the industrial sector, the savings are more significant, amounting to 27 million tonnes, though the percentage savings are relatively low at 28% of the 1986 total (Figure 9). The energy efficiency measures covered include those such as building fabric measures, new and more efficient boilers, waste heat recovery, process integration and change, reductions in water temperatures from 70°C to 60°C, reductions in water use through flow controllers etc.

Figure 6

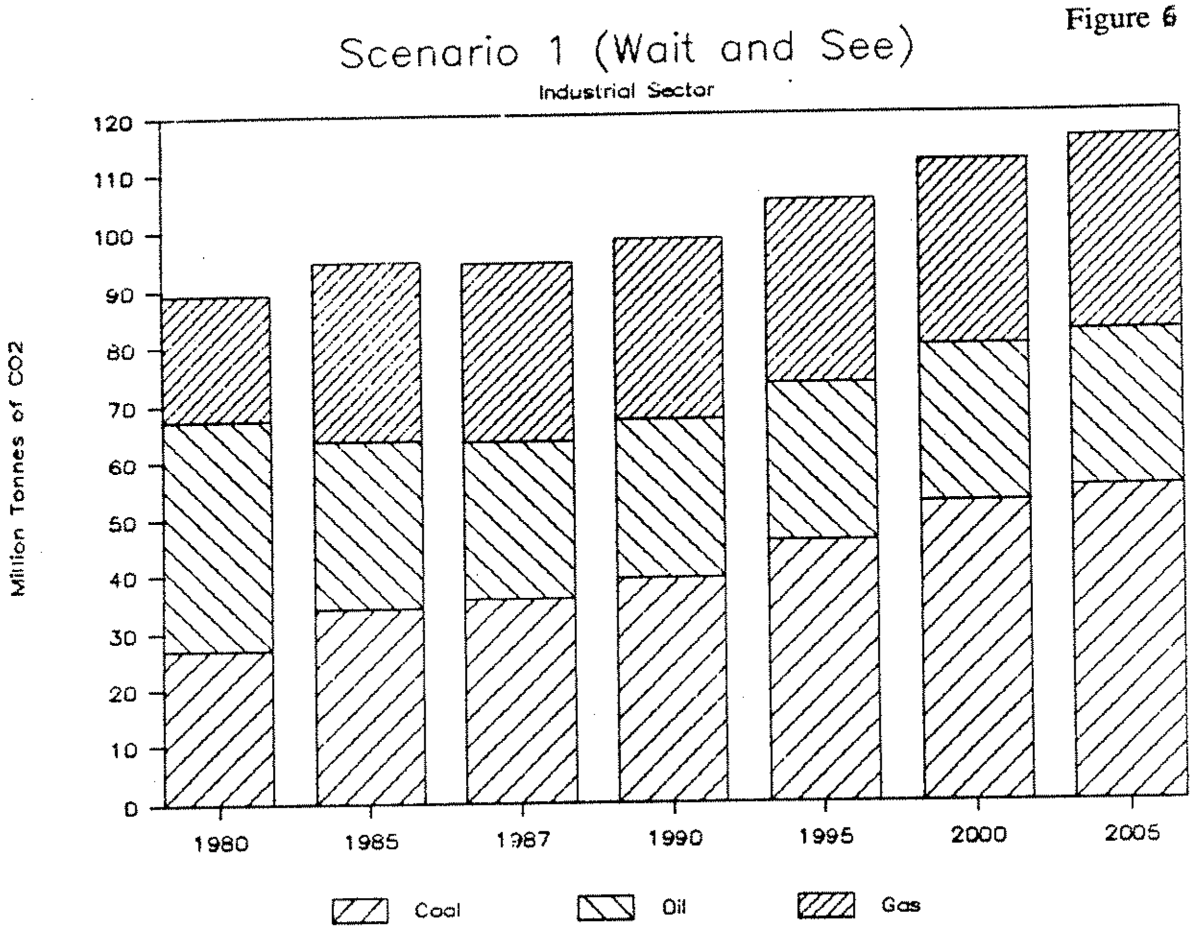


Figure 7

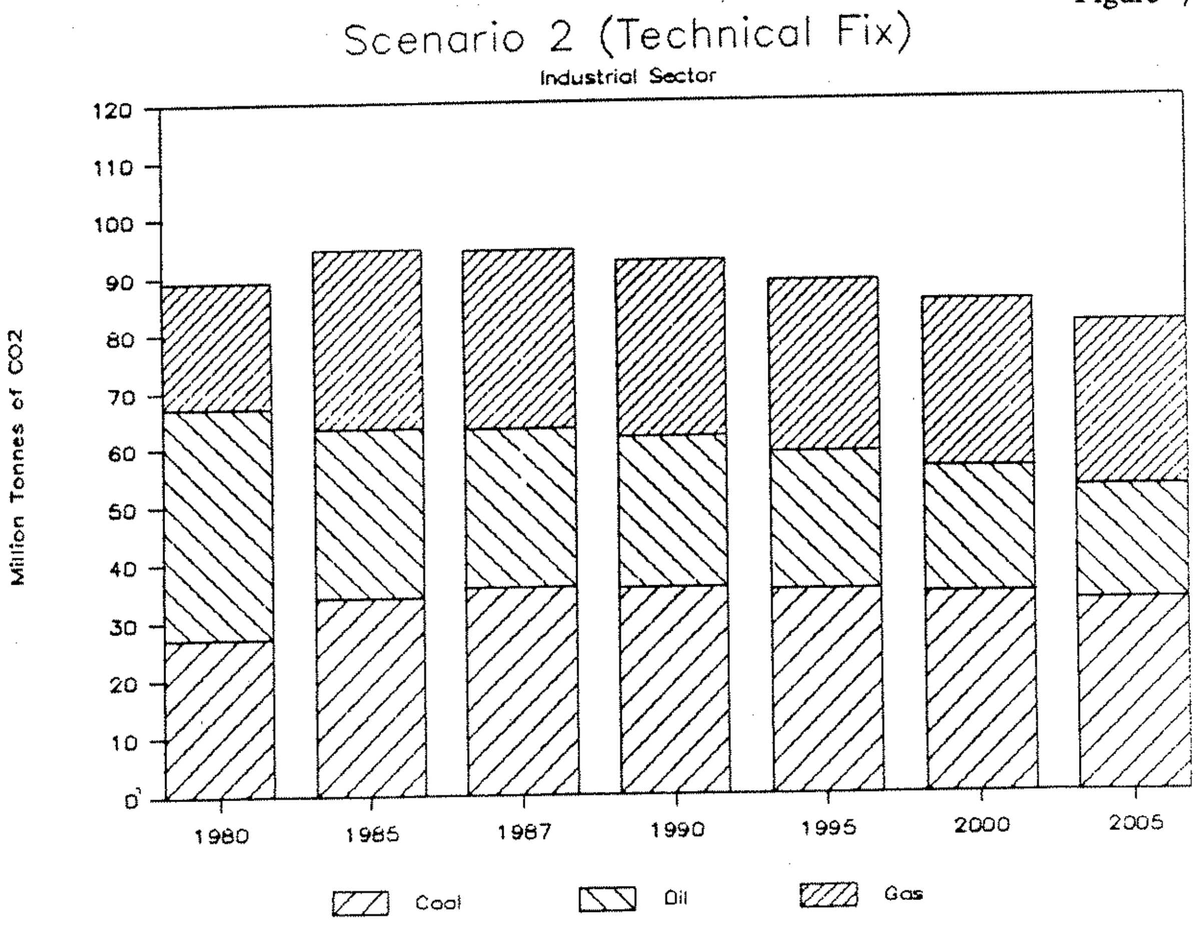


Figure 8

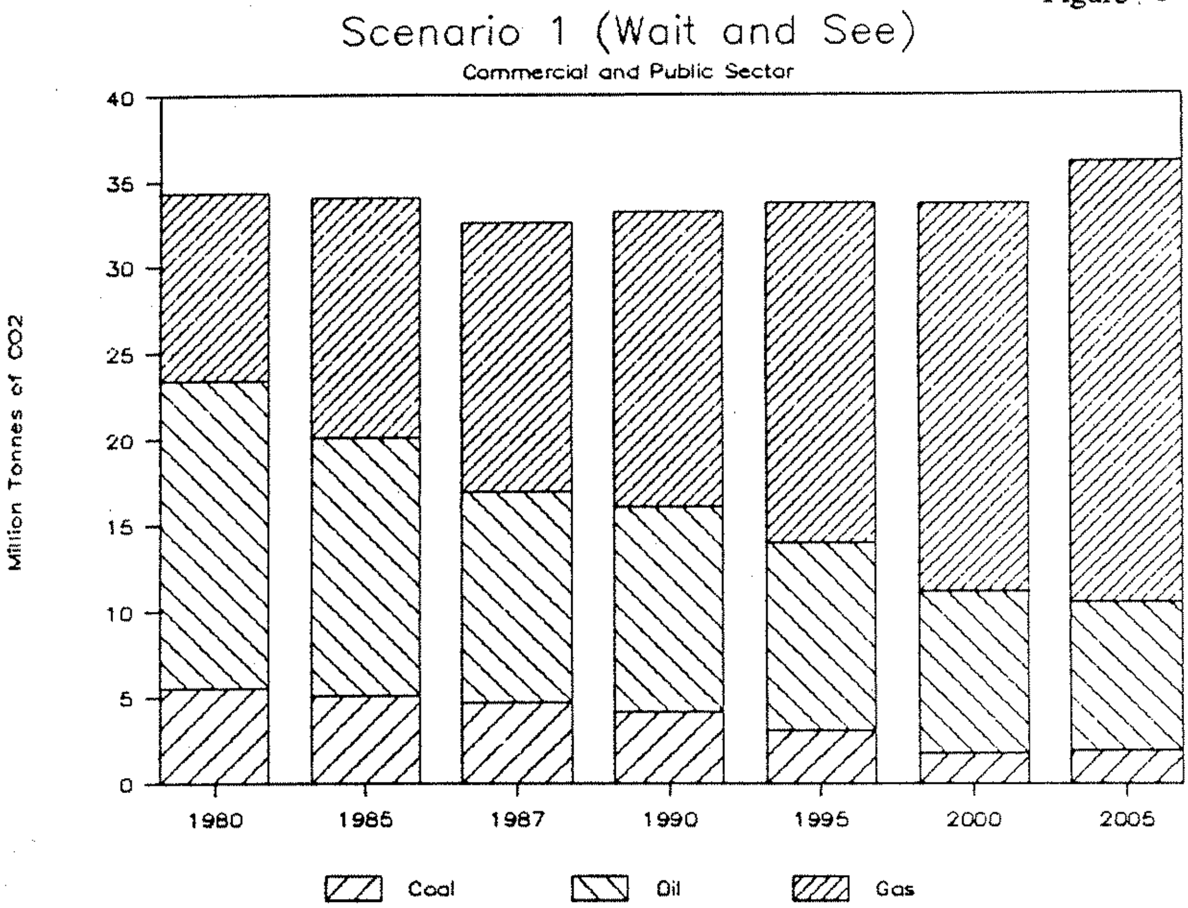
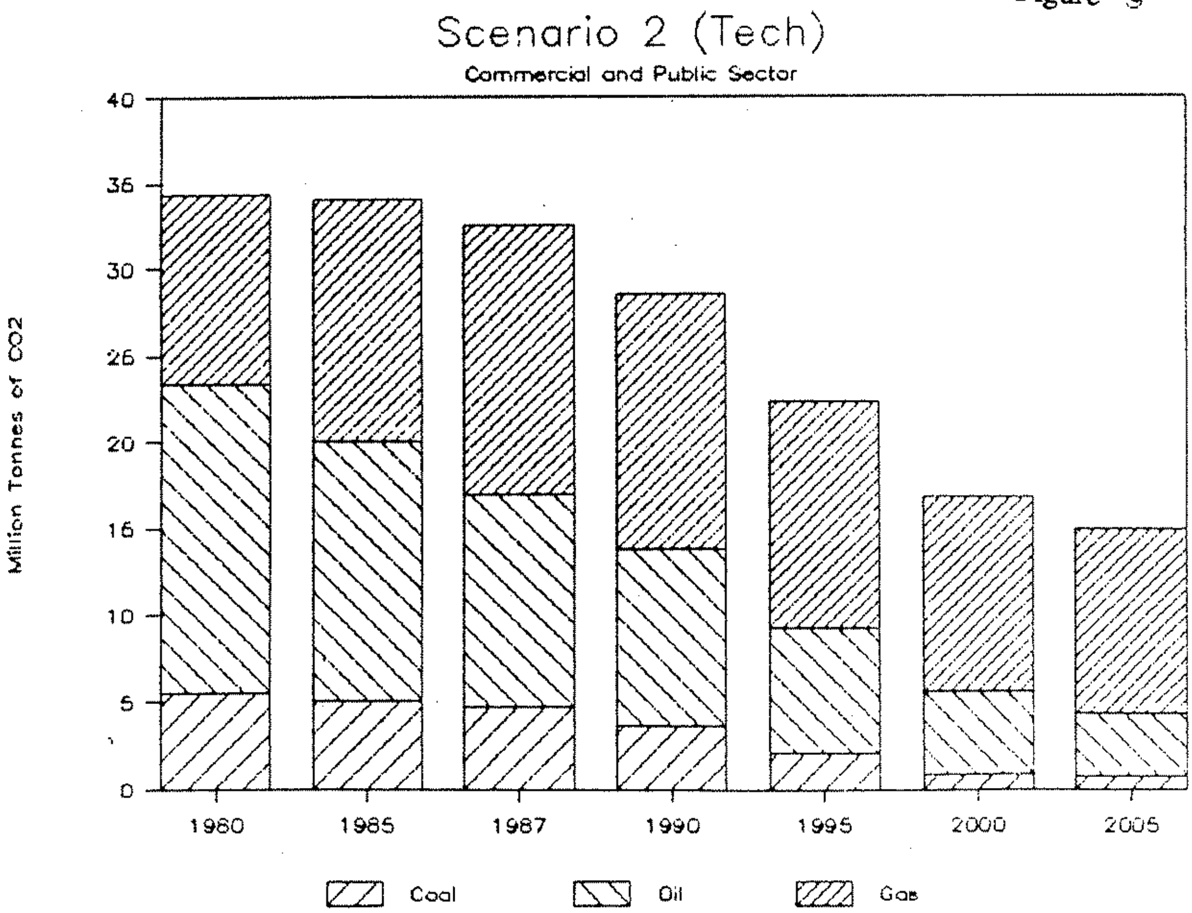


Figure 9



D. TRANSPORT SECTOR

In 1987, road transport in the UK was responsible for the emission of just under 100 million tonnes of CO_2, 4.5 million tonnes of carbon monoxide, just over 1 million tonnes of nitrogen oxide, and most of the UK's tropospheric ozone. Air and rail transport added a further 20 million tonnes. At the current rate of increase, emissions from vehicles will increase by 20 to 40% by the year 2005. The Government has published traffic projections which show an 80 to 140% increase by the year 2025 (ref.6). Recent work by Earth Resources Research for the World Wide Fund for Nature (ref.7) shows that a shift of even 1% per annum from private to public transport, and an increase in load factors from 1.7 to 2.1 people per car, would bring down CO_2 emissions from transport by 15% by the year 2005. Improved performance in miles per gallon would reduce emissions still further.

4. SUMMARY OF RESULTS

The 'business as usual' scenario allows an increase in annual UK CO_2 emissions of 15 to 20% by the year 2005. This represents an extra 84 to 108 million tonnes of CO_2 over the current level of 542 million tonnes.

The 'efficiency' scenario suggests that an aggressive approach, which encouraged the rapid take-up of more efficient technologies and removes the market obstacles which currently operate in the electricity sector, could reduce current CO_2 emissions by up to 23% from current levels.

5. POLICY IMPLICATIONS

Improved energy efficiency with changes in the electricity supply fuel mix and transport policy can deliver the 20% reductions in CO_2 emissions in the UK that the Toronto Conference has called for. Without positive action, however, reductions will not be made. The 'Business As Usual' scenario shows that, in the absence of any specific policy to improve energy efficiency, CO_2 emissions are likely to increase by up to 108 million tonnes per year, a 20% increase.

The market on its own is unlikely to deliver more than a small fraction of the full potential for energy efficiency because of barriers such as :

- The lack of information on how to improve energy efficiency;
- The fact that frequently the people who pay the fuel bills (tenants) are not those responsible for capital improvements (landlords);
- The significant difference between the 2 to 3 year payback periods required before businesses or individuals will invest in energy efficiency, and the 15 or 20 year payback period around which the energy supply industries plan. Because of this difference, a disproportionate amount of investment is going into expanding supply (to meet the inefficient demand) rather than into improving the efficiency of energy use.

What policies and actions should be taken if the full potential for energy efficiency is to be realised? If policies to promote energy efficiency are to be effective, they must be seen as a whole package, rather than as a 'mix and match' selection. No one policy option alone can ensure the necessary reduction in CO2 emissions.

A range of policies is available. Our study classified policies under three main headings : Information and Promotional campaigns; Regulations and Standards, and Subsidies and Taxation. Some of these will cost the Government nothing. While others will cost money, taxation measures would of course bring in revenue. All these policies will benefit consumers, and all will benefit the environment.

To pick individual policies without concern for the whole picture is exactly the ad hoc and piecemeal approach adopted by the UK Government to date : an approach which if continued will lead to the CO2 increases of the 'Business As Usual' scenario. If the CO2 reductions which energy efficiency can bring are to be achieved, the Government must look at the range of energy efficiency policies as a complete package. Policies which should be considered include:

A Information and Promotional Campaigns

General Information Campaigns
Industrial and Commercial Energy Survey Scheme
Home Energy Surveys
Labelling of Appliances

B Regulations and Standards

Appliance Efficiency Standards
Building Regulations

C Financial Incentives and Taxation

Financial Incentives
Contract Energy Management
Least Cost Planning
Taxation

REFERENCES

1. 'Digest of Environmental Protection and Water Statistics', Department of the Environment, No. 11 1988, HMSO.

2. Personal Communication, J. Skea (SPRU) to authors.

3. 'Condensing Boilers in New Housing', M. J. B. Trim, Energy Management. August 1988.

4. 'The Milton Keynes Energy Cost Index', Energy World Official Guide Book, 1986.

5. 'Energy Use and Energy Efficiency in UK Manufacturing Industry Up to the Year 2000', Dr. K. F. Langley, No. 3-Energy Efficiency Series, HMSO. 1984. 'Energy Use and Energy Efficiency in UK Commercial and Public Buildings Up to the Year 2000', H. Herring, R. Hardcastle, R. Phillipson: Chief Scientists Group, ETSU. 1988.

6. National Road Traffic Forecast, Department of Transport, 1984.

7. Memorandum by World Wide Fund For Nature to the Energy Committee. Energy Policy Implications of the Greenhouse Effect. 8th February, 1989.

THE GREENHOUSE EFFECT AND THE CONTROL OF CARBON DIOXIDE EMISSIONS

by P M S Jones
UKAEA and University of Surrey

Introduction

The reality of the greenhouse effect, which determines the temperature of the earth's surface by the infra-red absorption/transmission characteristics of the gases in the earth's atmosphere (principally of water vapour and carbon dioxide), is undisputed. The changes of temperature that may be being brought about by man's activities are currently the subject of scientific and political debate and intensive international research. The effects of such temperature rises, should they occur, are still largely unpredictable at a regional level so that their economic and social implications remain matters of speculation.

Nevertheless, the potential consequences are generally recognised to be sufficiently grave to merit serious consideration of methods of limiting or reducing the release of greenhouse gases to the atmosphere, even though the extent of control favoured varies from the draconian 20% reduction by 2005 on present levels called for by the 1988 Toronto Conference, to more modest proposals for pursuing only those reductions which can be achieved at zero or low cost, until such time as scientific evidence proves beyond doubt that more extensive measures are necessary.

The offending gases include inter alia carbon dioxide produced by fossil fuel burning and the destruction of forests; methane produced mainly by anaerobic decay of organic matter (refuse and plant material) and by animals as a by-product of the digestion of food; and chlorofluorocarbons (CFCs), which have been used extensively as aerosol propellants, refrigerants and foaming agents. Control of the latter has already been the subject of international agreements because of their more immediate impact on the earth's ozone layer.

Anthropogenic carbon dioxide from the net consumption of biomass or fossil fuel combustion is the gas attracting greatest attention in discussions of control of the greenhouse effect, since it is the major contributor to potential global warming and, apart from CFCs, it is the easiest to control (at least in principle).

This discussion paper examines from an economic and practical standpoint the relative merits of instruments available to government to achieve such control.

Possible Instruments

The problem, if such it is, of carbon dioxide emissions can be tackled either directly or indirectly, and both approaches could be either via physical regulation or through the mechanisms of the market. The basic approaches are:

(a) Direct control

The regulatory approach would set physical limits to the amount of carbon dioxide (and monoxide) that could be released by individual fuel users or other producers such as cement works, in order to set an upper limit on the total quantities entering the atmosphere.

The market approach would create limited tradeable 'property rights' relating to the amount of carbon dioxide that could be released, and allow potential fuel users to compete for these rights. A more detailed explanation follows below.

(b) Indirect control

One obvious method would be to physically ration carbonaceous fuels so that the maximum potential for carbon dioxide production was limited.

An equivalent effect could be achieved through the market by taxing carbonaceous fuels so that total demand was reduced to the desired level.

The Physical Controls

Emission controls are extensively used for oxides of sulphur and nitrogen from power plants, for radioactive emissions from nuclear plants and for other gaseous and liquid effluents produced by industry. These controls are, however, relatively easy to define, and compliance can be readily monitored because of the limited number of companies involved and the limited number of emission outlets (chimneys, pipes etc) per company.

The problem becomes much more difficult when the numbers are large (eg domestic premises) or the outlets are diffuse, as they are for fertiliser residues and farming wastes.

Carbon dioxide is produced not only by power stations and industrial use of fuels but also by domestic consumers and by all transport using hydrocarbon fuels. Its production is directly dependent on the quantities of fuel used, and a control of emissions is almost equivalent to a control of carbonaceous fuel use. The only economic options open to producers other than to reduce activity levels are either to switch fuels to those producing less or no CO_2 or to increase the efficiency of processes and combustion so that less fuel is consumed. The practicality of these alternatives will differ considerably between users so that the initial specification of limits would be a bureaucratic nightmare, complicated by the fact that fuel switching might reduce pollution from one activity but at the expense of increasing it in others. For example, fuel users switching from oil to electricity would transfer the problem to the power producers if they are dependent on fossil fuels.

Emission controls could be applied to the industrial sector but, unlike many effluents, carbon dioxide would need both flow and concentration measurements in order to monitor total releases, and this would add to the burden of enforcement.

It would be administratively simpler to ration carbonaceous fuels to impose an absolute constraint on carbon dioxide production. This itself demands decisions on individual and company needs and would be difficult to initiate. It has been done in the past however and, at a company level, is no different to the quota system introduced for milk production in the EEC.

Any rationing system would be better if introduced in an evolutionary manner to facilitate adaptation by consumers and to minimise the negative impacts. Inevitably there would be allocative and equity problems, and however it was presented it would be unpopular with some sections of the community. Nevertheless, rationing could be applied in ways that reflected the government of the day's judgements on priorities and needs, unlike the market based instruments discussed below.

Market Approaches (optimising)

Unlike the physical control mechanisms which essentially impose arbitrary constraints on pollution levels, albeit derived from some judgement of what is socially or politically desirable or acceptable, there are economic approaches that could, in principle if not in practice, 'optimise' emission levels.

The 'optimisation' can be considered in economic or welfare terms. The latter would consider social costs as well as the economic costs and benefits of pollution control.

In the case of carbon dioxide, long term social costs might include such factors as enforced changes of lifestyle or abode due to changing climate; effects on health and death rate arising from changes in regional availability of food and water; extinction of species unable to adapt to climatic change; etc. Some of the changes might be regionally beneficial, either economically or socially, and these too would need to be taken into account.

Were it possible to quantify and put value to the impacts, both detrimental and favourable, then, provided they could be related to changes in carbon dioxide emissions, the net external costs could be internalised via a tax on carbonaceous fuels linked to their carbon content. This would change fuel price relativities and lead fuel users to adjust their fuel choice, to improve efficiency of use or to adopt CO_2 removal procedures to minimise their costs in the new situation. Product prices would change, consumer purchasing would adapt and, through a process of iteration, a new balance of economic activity would be approached which would minimise the costs to society of fossil fuel use.

The ultimate minimum cost solution would reflect the optimum balance between detriments and benefits to society at large as any textbook on welfare economics will demonstrate. The arbitrariness of the physical control methods would be eliminated. The proceeds of the carbon tax would ideally be used to compensate those suffering detriment from the residual 'optimised' emission levels.

Unfortunately the practicalities make this an unrealisable ideal. The economic implications of growth in atmospheric carbon dioxide levels cannot be predicted with confidence let alone the social costs. Projected temperature rises on the best models are surrounded by considerable uncertainty. The regional implications of such rises and the general climatic effects cannot yet be predicted with confidence. Barring sudden changes arising from unanticipated mechanisms the effects will be slow to develop and questions of intergenerational equity as well as inter-regional equity arise. The latter could be a major effect if, as several models predict, global rainfall patters change radically and sea levels rise inundating low lying areas.

The alternative approach of creating property rights has also been advocated. If one had a closed economy in which both costs and benefits of fuel use and its environmental impacts were contained, where there was a complete understanding of the impacts by everyone, and where the impacts occurred concurrently with the fuel use, then the creation of rights to air of a specified quality (carbon dioxide content for example) or the issue of tradeable permits to release specified quantities of carbon dioxide would establish a 'market'.

In the former case those wishing to add carbon dioxide to the atmosphere would have to trade with individual members of the public to get them to surrender some of their rights, ie accept higher CO_2 levels . The public would only sell if the price compensated them for their losses while the company or fuel user would only pay up to the amount he judged to be equal to the cost of the alternative options open to him. These would include the measures listed previously and the option of closure of fuel using plants.

In the latter case companies could trade pollution permits on a similar basis, with those deriving the maximum added value from fuel use ending up with the major holding. Members of the public could also, in principle, purchase the permits (in small tranches) to limit the releases.

Unfortunately neither approach, in practice, could bring about an optimisation of welfare. In the first place economies are not closed when it comes to carbon dioxide and its effects. Secondly, the knowledge of impacts is almost zero. Thirdly, there are protracted time delays between CO_2 emission and the ultimate impacts.

Even if this were not the case the imbalance of resources between the individual and the firm would prevent effective trade. The creation of individual rights would prevent firms proceeding until they had gained agreement of a large part of the population to modify the air quality standards. Those unwilling to sell would have to be matched by others willing to surrender a greater share of their clean air rights to ensure that no-one suffered more pollution than he had agreed to. The allocation of licences to pollute, on the other hand, would make it impossible for individuals to influence emissions and exposures unless the majority found ways to act in concert. If this were possible non-participants would be gaining at the expense of participants so that there would be incentives to hold back.

Additionally the mere creation of rights raises allocative problems since subsequent transactions could have major redistributional effects within society and on a larger scale between nations.

Market Approaches (non-optimising)

It is evident from the foregoing analysis that the lack of knowledge and other market imperfections preclude the use of market approaches as a means of welfare optimisation. This does not mean that they cannot be used to change behaviour and control emissions. It does mean that emission levels have to be determined exogenously and are necessarily as arbitrary as they were for physical controls.

Under the circumstances a 'carbon tax' could be set at a value estimated to limit fuels use through the market to preselected levels - with the possibility of adjustment should the estimates prove too high or too low.

For the reasons described earlier, rights to clean air could be set to limit emissions at preselected levels but the market for rights would not work. Licences to pollute would be a more practical though imperfect instrument which could limit total emissions to any desired level. Such licences might be given away initially with allocations based on existing fuel use or they might be auctioned with the proceeds subsequently fed back to the community. The scheme could be limited to large industrial fuel users, exempting the individual and 'small' companies to overcome the inequality of scale. Alternatively a tiered system might be set up with, for example, industrial and individual licences which were not tradeable outside defined groups.

Both the tax and licence approaches would achieve rationing by price within an overall arbitrary level of emissions. In the absence of tiered licensing the marginal cost of a licence per tonne of fuel should at equilibrium equal the tax necessary to achieve the desired demand level. There are, however, differences.

In a fixed market trading situation fuel would be purchased and sold at a constant price, whereas in the licence case the existing holders would only sell at a price which compensated them for any consumer surplus they were enjoying. In a situation with rising potential demand the taxation system would adjust stepwise to produce compensating reductions. The licence trading system would be likely to lead to an inflationary spiral as users competed for shares of the fixed total emission allowance.

New entrants would always be able to get and use fuel on the tax option with costs of their entry spread among all fuel users through subsequent tax adjustments. They would have to buy their way in at their own expense in the licence case - a further inflationary influence and a considerable deterrent to enterprise and free competition.

Conclusions

All of the four basic approaches to limiting carbon dioxide emissions, should this be necessary, will necessarily involve the exogenous imposition of a total emission level based on judgemental or political factors. There is no simple route to optimisation by economic or regulatory means.

Practical considerations appear to rule out regulation on a source by source basis and the use of rights to clean air as policy instruments.

This leaves rationing by price or by quantity as the only realistic options. Rationing by quantity either directly or through the use of tradeable licences (which will revert to price rationing) could inhibit technological progress and the emergence of new firms and lead to economic inefficiency. The licence system could also be inflationary in periods of growing inherent demand.

On this basis the imposition of an adjustable tax on carbonaceous fuels appears the most practical and least intrusive and regressive approach. Its inflationary impact could be ameliorated by recycling the tax income. Since equity and welfare considerations would not enter directly into the determination of the tax level there would be no compensatory claims on the monies raised; a situation which might not prevail if the tax were seen overtly as an attempt at welfare optimisation.

If unintended inter-country redistributional effects are to be avoided tax levels should not be out of line with those in other countries - particularly the EEC, in view of the 1992 Single European Market. This could prove difficult if price elasticities differed significantly among countries and total emissions were determined by international agreements.