INDUSTRY COMMISSION

Costs and Benefits of Reducing Greenhouse Gas Emissions

Volume 1: Report

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15 November 1991

The Honourable John C Kerin, MP
Treasurer
Parliament House
CANBERRA ACT 2600

Dear Treasurer

In accordance with Section 7 of the *Industry Commission Act 1989*, we submit to you the report on Costs and Benefits of Reducing Greenhouse Gas Emissions.

Yours sincerely

GR Banks	TJ Hundloe	MS Common
Presiding Commissioner	Commissioner	Associate Commissioner

Acknowledgments

The Commission would like to express its gratitude to those who provided submissions, attended hearings or otherwise assisted the inquiry. In particular, the Commission is grateful tot he Bureau of Meteorology for allowing the secondment of Dr Geoff Love to the Industry Commission, and to Dr Ken Pearson of La Trode University and the Impact Project in Melbourne, for his assistance in model software development.

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ABBREVIATIONS

ABARE	Australian Bureau of Agricultural and Resource Economics
BAU	business as usual
CFC	chlorofluorocarbon
CPI	consumer price index
DASETT	Department of the Arts, Sport, Environment, Tourism and Territories
EC	European Community
ECE	UN Economic Commission for Europe
EFTA	European Free Trade Association
GATT	General Agreement on Tariffs and Trade
GCM	global circulation model
GDP	gross domestic product
GHG	greenhouse gas
GWP	global warming potential
ICSU	International Council of Scientific Unions
IPCC	Intergovernmental Panel on Climate Change
Mt	megatonnes
NHMRC	National Health and Medical Research Council
OECD	Organisation for Economic Co-operation and Development
Pj	petajoules
ppmv	parts per million by volume
SMS	safe minimum standard
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
WMO	World Meteorological Organization

TERMS OF REFERENCE

Greenhouse gas emissions

INDUSTRY COMMISSION ACT 1989

I, PAUL JOHN KEATING, in the pursuance of my powers under Section 7 of the Industry Commission Act 1989, hereby:

1. refer the following matters to the Commission for inquiry and report by 30 September 1991:

(a) the costs and benefits for Australian industry of an international consensus in favour of a stabilisation of emissions of greenhouse gases not controlled by the Montreal Protocol on Ozone Depleting Substances, based on 1988 levels, by the year 2000 and a reduction in those emissions by 20% by the year 2005;

(b) the new opportunities that could arise for Australian industry as a result of that international consensus; and

(c) how Australia would best prepare itself to respond to those costs and benefits;

2. specify that the Commission is to have regard to the established economic, social and environmental objectives of government; and

3. specify that the Commission is to take account of any recent substantive studies undertaken elsewhere.

P.J. KEATING

6 December 1990

[Note: The reporting date was subsequently extended to 15 November 1991 -- see Appendix A.]

OVERVIEW

This report is about the costs and benefits of reducing greenhouse gas emissions. It responds to a reference from the Government relating in particular to the costs and benefits to Australia of participating in a possible international consensus to reduce emissions by the year 2005 to a level 20 per cent lower than in 1988 (see facing page).

The reference followed the Commonwealth Government's adoption of that level as an ‘interim planning target’, which is contingent, to the extent that action involves net adverse economic impacts, on similar action being taken by major greenhouse gas producing countries. The target corresponds to that which emerged from an international meeting in Toronto in 1988. International action to limit greenhouse gas emissions is on the agenda for an intergovernmental meeting scheduled for June 1992 in Brazil. Negotiations to draft an international convention are presently in progress.

What are greenhouse gases and why reduce them?

The ‘greenhouse effect’ makes the planet Earth habitable for life. The atmosphere allows most incoming solar radiation to pass through and warm the surface of the Earth, which then radiates heat back into the atmosphere. Some of this heat is absorbed by greenhouse gases in the atmosphere and re-radiated back to the surface of the Earth, causing additional warming -- the greenhouse effect. The principal greenhouse gases are: water vapour, carbon dioxide, methane and nitrous oxide.

In recent years, however, many scientists have become concerned that the greenhouse effect is being `enhanced' by increasing emissions of greenhouse gases from human-related activities (including methane from certain agricultural activities, carbon dioxide from the burning of fossil fuels, and CFCs, which do not occur naturally). Using the output from complex models of the Earth's climatic system, scientists associated with the Intergovernmental Panel on Climate Change (IPCC) have predicted that this will lead to a warming of the Earth's atmosphere, accompanied by rising sea levels and other adverse global consequences.

These concerns have been taken seriously by many governments. They have recognised that if an enhanced greenhouse effect were a reality, it could not be ameliorated without government action and that, to be effective, action to address such a global phenomenon would need to be undertaken by all the major greenhouse gas producing countries.

Benefits of global consensus

The benefits of a global consensus to reduce greenhouse gas emissions would depend principally on the nature and extent of the bio-physical impacts avoided. This is a scientific question, on which the Commission does not presume to have any independent insights. For its interpretation of the science, it has largely drawn on the reports of the IPCC, which are generally accepted as reflecting majority scientific opinion.

In so doing, the Commission has found that *the current state of scientific knowledge does not allow any reasonable estimate to be made of the impacts that would be avoided by a global reduction in greenhouse gas emissions.*

The Commission has considered areas vulnerable to climate change (including primary production, the natural environment, human health and lifestyle) but has found that there is little knowledge about how these would be affected in practice. At the most general level, while there appears to be majority scientific opinion about the prospect of global warming, there remains uncertainty about its timing and extent. The models from which IPCC predictions have been made, based on an assumed doubling of greenhouse gas concentrations, have produced global warming estimates ranging from 1.9^{O}C to 5.2^{O} C. But these models, which share central features in common, are all incomplete in their representation of certain important but ill-defined physical processes, such as the roles of clouds and the oceans in the Earth's climate.

There is even more uncertainty about what some given amount of global warming would mean for living conditions on Earth. There is no confidence in estimates of impacts at the regional level, including Australia. Scientists have little understanding of the implications of global warming for rainfall patterns for example. Indeed it is likely that climatic impacts could be beneficial in some regions.

To allow benefits of reducing greenhouse gas emissions to be compared with costs, monetary values would also need to be assigned to the bio-physical impacts. Even if the impacts were known, this would be extremely difficult. Some impacts, such as those on agriculture, would be reflected in market price changes, but other impacts, such as those on natural habitats, would not.

Costs of global consensus

Estimation of the costs of an international consensus for emissions abatement is also a very difficult task, depending on:

- how emissions would otherwise have grown;
- the type of policy instrument(s) used to achieve reductions;
- the ability of the economy to reallocate resources out of greenhouse gas intensive activities, or to adopt greenhouse gas-saving technologies; and
- how trade is affected by the actions of other countries.

It would be impossible to assess the outcome of such an interdependent set of national and international responses without recourse to quantitative modelling. The Commission is nevertheless conscious of the inevitable limitations of any attempt to model such complexity. The task stretches current modelling capabilities to the limits -- especially given the magnitude of the reductions contemplated and the extended time period under consideration. However, a number of studies have attempted to quantify the effect of emission reduction policies on the world economy, most putting the costs at between 2 and 5 per cent of GDP.

Interpretation of such results is made difficult by the fact that the studies involve different emissions reduction targets and dates, as well as modelling the structure of the world economy differently. Moreover, none of the available models distinguish Australia separately. The Commission was obliged, therefore, to develop its own model, WEDGE, to explore the interactions of the Australian economy with others in response to limitations on greenhouse gas emissions. Little time has been available for this complex modelling task, and the results reported should be regarded as more illustrative than definitive. The Commission has also modified its ORANI model to explore some of the domestic aspects of the problem in greater detail.

The Commission’s simulations (revised since the draft report) indicate that a global cut in carbon dioxide emissions broadly comparable to the Toronto target would lead to a 1.5 per cent decline in Australia's national product. Such numbers can only have ‘ball park’ significance at best and rest on many simplifying assumptions spelled out in the report.

Adjustment costs are important

The projections relate to an economy that has already fully adjusted to the policy change. They abstract from the costs of workers or capital being idle in the interim -- which may be substantial. For example, ORANI model simulations of Australia acting alone indicate that under the other extreme of an inflexible economy, the GDP loss would more than double and there would be a larger fall in employment.

Action to reduce emissions will have different effects across industries. For example, reducing emissions of carbon dioxide would clearly have greatest impact on Australia's coal industry (the global simulations indicating up to a 60 per cent drop in production by 2005). This would be so whatever policy instrument was used to achieve the emissions reductions, although the economy-wide costs would differ. It follows that adjustment costs would also be highest in those regions of Australia that are dependent on coal mining. The Commission, while recognising the importance of these considerations, has not been in a position to investigate these specific impacts further.

Instrument choice influences costs

Abatement costs vary markedly between countries. Requiring each country to cut emissions by the same proportion, as modelled by the Commission, would not minimise the global costs of achieving a given target. Costs would be lower under a regime which allowed differential responses according to relative costs of abatement. When OECD simulations allowed rights to emit carbon dioxide to be traded internationally, the modelled cost to the Pacific region of meeting a Toronto-type target fell by 40 per cent.

On efficiency grounds, market-based instruments such as tradeable permits and taxes, are usually superior to regulatory controls. Other relevant criteria include the dependability of the instrument -- its ability to realise the target in a timely fashion -- and equity. While taxes may be less dependable in the short term than quantity controls (which include tradeable permits as they fix the total quantity of emissions allowed) the long time period and gradual changes involved in an enhanced greenhouse effect would allow scope for some trial and error in meeting targets.

Nations differ not only in their costs of abatement, but also in their ability to bear those costs. A regime which minimised global abatement costs would not necessarily be regarded as allocating those costs across nations in an equitable manner. Over and above any concern for equity itself, the distribution of costs across nations will affect incentives to participate in a consensus. Equity considerations could be addressed by additional aid transfers between nations, by the initial allocation of national emissions quotas under a tradeable permits regime, or by the redistribution of the revenue raised under an international tax regime. If consensus were regarded as essential, it may be necessary to accept a form which does not minimise costs in order to achieve general participation. The Commission has not been able to model the economic effects of subsidising abatement action by developing countries, but the costs could be substantial.

Costs rise sharply with deeper cuts

Larger cuts in carbon dioxide emissions than those based on the Toronto target would be needed to stabilise greenhouse gas concentrations. Deepening the cuts, however, could be expected to lead to a more than proportionate rise in costs. This is because the more sparing that economies became in their emissions of carbon dioxide, the harder it would be for them to reduce emissions further. This is illustrated by a sensitivity analysis conducted with the WEDGE model, which showed that a 50 per cent increase in the target could more than double the costs.

Diversification among greenhouse gases?

Modelling of an international consensus has focused on reduction of carbon dioxide -- the most important man-made greenhouse gas -- because of data availability. But the Government's interim planning target and the terms of reference relate to all greenhouse gases (other than CFCs). The added flexibility and choice from such broader targets, expressed in terms of carbon dioxide equivalents, could provide scope to reduce costs. In practice, the Commission has found that the costs to Australia of reducing emissions of methane -- the only other gas for which a reductions policy could feasibly be implemented at this stage -- would be much higher than for carbon dioxide.

Technological changes would reduce costs

Substitution away from greenhouse gas producing activities would reduce the costs of an international consensus. Of particular importance would be the development of less greenhouse gas intensive technologies. The possible impact has been illustrated by OECD simulations. These showed that when energy efficiency gains were reduced from an assumed annual rate of 1 per cent to a rate of 0.5 per cent, substantially higher taxes were required to achieve the same emission cuts, with income losses more than doubling in several regions of the world.

It is not known to what extent technological improvements in Australia would be induced by price increases (for example, resulting from a carbon tax) and the Commission has not been able to incorporate this factor in its modelling. The precedent of the oil price hike in the mid-1970s suggests that the world has a considerable capacity to economise use of energy in response to price incentives. Information made available to the Commission suggests that there is a large number of technically efficient potential improvements already available which could make a contribution to meeting the greenhouse gas targets. What remains unclear is the magnitude of the relative price changes required to make such technologies economically viable.

It has also been suggested that, particularly in regard to carbon dioxide emissions arising in the delivery of energy services, substantial reductions are available in Australia on the basis of technologies that are economically viable at current relative prices. The adoption of such technologies constitutes the so-called ‘no-regrets’ options in the greenhouse policy debate. It is claimed that these options are not taken up due to an incorrect assessment of economic viability because of market failure and/or institutional impediments. The Commission has been unable to resolve definitively the status of many such claims. The implications for policy in those cases consequently remain unclear. Where such claims can be related to policy questions there is a need for further analysis and research.

Possibility of non-greenhouse benefits

The net costs of action to reduce greenhouse gas emissions in Australia would be overstated in the models to the extent that activities which produce these gases generate external costs unrelated to climate, notably pollution. This is essentially an empirical question which the Commission has not attempted to investigate. The answer depends on the extent of such pollution in Australia, how Australians value the disamenities arising and the adequacy of existing institutional arrangements and controls.

Policy-making under uncertainty

It emerges that the available evidence on costs, and lack of it on benefits, does not permit any reliable assessment of their relative magnitudes. A decision about whether global action to abate greenhouse gas emissions is needed -- let alone the optimal amount -- cannot be made on a technical basis.

Instead, governments need to make subjective decisions about what action is appropriate, on the basis of such information as is available and their attitudes, on behalf of their populations, to risk and uncertainty. The choice of this ‘arbitrary standard’ is equivalent to an insurance decision. It is complicated by the question of timing. A balance needs to be struck between incurring costs early for unknown benefit and delaying action until more is known, but with the possibility of higher adjustment costs. A further relevant consideration is the possibility of climatic ‘surprises’.

It is in these circumstances that a risk averse global strategy can be understood. The Australian Government's general approach to environmental policy includes ‘dealing cautiously with risk and irreversibility’. Applied to greenhouse, it is reflected in the interim planning target. But it is also clear that in this case Australia cannot reduce risk merely through its own abatement actions, as its contribution to global emissions is negligible. This is recognised in the caveats to Australia's greenhouse policy, which make action conditional on similar action by other countries.

Non-consensus scenarios

Consistent with its terms of reference, the Commission has focused on the question of Australian participation in an international consensus including the major greenhouse gas producing countries. The emerging reality, however, is that such a consensus is unlikely in the foreseeable future. Countries accounting for some two-thirds of global carbon dioxide emissions remain opposed to global targets and/or to taking any action themselves. This situation is likely to endure so long as countries remain uncertain about whether costly current actions to reduce emissions would be a good investment, in terms of future climate-related benefits. Of relevance here is the IPCC's finding that it will take at least another decade to establish from climate records whether global warming due to an enhanced greenhouse effect is actually underway.

The main alternative (or interim) scenarios to a global consensus would appear to be:

- a commitment to stabilise or reduce emissions by a subgroup of developed countries; or
- a 'best endeavours' approach by individual countries, internationally supervised (possibly in addition to minimal universal commitments).

While these scenarios are not specified in the terms of reference, they warrant some investigation, given the prospect that Australia may be required to consider them.

Subgroup participation could be costly

Two possible subgroups are the OECD and the European Community (EC). The current US opposition to targets and timetables limits prospects for the former, but the EC already has a carbon dioxide stabilisation target which is not conditional on action by other counties.

The potential benefits from subgroup action obviously depend in the first instance on the subgroup's contribution to global emissions. The OECD (with 44 per cent) is more promising than the EC (12 per cent) in this respect, but in both cases feasible commitments would fall far short of the Toronto target on a global basis, and there is also potential for erosion of any reductions by continuing (or accelerated) emissions growth from other counties.

This has implications for the costs, as participants would either have to accept larger reductions themselves or ‘buy’ some action from other countries.

The main consideration for Australia in relation to costs is what difference it would make whether we joined or not. The answer to this question would depend on the country composition of the coalition, the coalition’s abatement target and instrument choice, and its policy on sanctions against non-members.

If Australia did not participate, it could benefit economically from increased trade competitiveness against group members, but would lose from reduced exports resulting from lower income and reduced consumption of energy in those countries. An additional complication arises if a coalition were to introduce trade preferences among members or sanctions against non-members.

If Australia joined, possible sanctions would be avoided, but at the cost of taking action domestically. WEDGE simulations conducted by the Commission suggest that the costs of domestic action would be substantially greater than the trade effects from other countries’ actions. The simulations also illustrate the point that larger emission reductions, say to achieve a given global target with fewer participants, would raise the costs more than proportionately. The considerations are nevertheless complex and evaluating a specific arrangement would require detailed empirical analysis.

Unilateral action: similar cost for little return

The Commission also examined the costs and benefits of unilateral action by Australia, in part because it was raised as an issue by participants and partly because of its relevance to consideration of a best endeavours arrangement. The Government has already said that it will not take unilateral action involving net costs. The Commission supports this approach. As implied by the preceding analysis, Australia could at best derive negligible climate benefits from its own abatement actions, but would probably bear costs not far short of those associated with group action. Similar considerations would apply to Australia taking more stringent action than other countries.

Opportunities for Australian industry

The Commission was asked to report on new opportunities which could arise for Australian industry as a result of an international consensus to reduce greenhouse emissions. The Commission's modelling suggests that most sectors of the economy would be adversely affected, but gains could clearly arise for individual activities. For example, there would be a range of new opportunities for industry in the areas of energy efficiency and alternative technologies in energy and farming, as well as in the provision of greenhouse 'sinks'. Predicting precisely which activities have most promise for Australian companies is not possible, as it depends on what happens in the rest of the world as well as Australia.

Best preparing

The Commission was also asked how Australia could best prepare itself to respond to the costs and benefits of an international consensus. Much of the Commission's preceding discussion of policy instruments and the coverage of an international agreement is relevant to this question. Given the many different forms that an international consensus could take, and the potential for greatly different outcomes for this country, Australia should continue its active participation in international negotiations.

The Commission would also emphasise that the best economic environment for the minimisation of adjustment costs and maximisation of opportunities resulting from an international consensus is one of structural flexibility. This underlines the importance of promoting microeconomic reform -- which in producing higher income levels can also help 'pay' for the costs.

The Commission has observed that uncertainty about the greenhouse issue extends to the community's understanding of government policy. Investment decisions in particular will be increasingly affected by such perceptions. It is important that industry be kept as well informed as possible about policy developments, so that it may plan its own cost-minimising strategies in a timely way.

The Commission has also identified a number of areas requiring further, coordinated research.

First it is clear that assessing the economic implications for Australia of various forms of international consensus, including agreements among subgroups of countries, will require further quantitative modelling. The Commission recommends that the Government continue to support development of capabilities in this area.

The Commission sees potential advantages in the use of market-based instruments to pursue a consensus target, both internationally and nationally, but judges that there is a need for more detailed investigation of how carbon taxation and tradeable permits would operate in practice at both levels.

The Commission has not attempted to quantify non-greenhouse environmental benefits (or costs) from reducing emissions. Research is needed on the extent of any such benefits, taking into account existing policy measures, and the implications for the net costs of reducing greenhouse emissions.

Action to reduce emissions of carbon dioxide would unavoidably have a major impact on certain industries, notably coal. Resulting structural and regional adjustment problems could be substantial and the Commission considers that there should be further research into such effects and policies to address them.

Finally, the Commission would like to re-emphasise that the major uncertainties associated with an enhanced greenhouse effect preclude policy decisions based on adequate technical information. Australia should continue to support and participate in the international scientific research program, especially to improve understanding of potential bio-physical impacts in our region.

1 INTRODUCTION

This inquiry is about the costs and benefits of reducing greenhouse gas emissions.

Specifically, the Government has asked the Commission to examine the costs and benefits for Australian industry of an international consensus in favour of a stabilisation of emissions of greenhouse gases at 1988 levels by the year 2000 and a reduction in those emissions by 20 per cent by the year 2005. The Commission has also been asked how Australia would best prepare itself to respond to those costs and benefits and about new opportunities that could arise for Australian industry as a result of such an international consensus. (The terms of reference are set out on the page facing the Overview.)

1.1 Background

The reference followed the Commonwealth Government's October 1990 announcement that Australia has adopted an interim planning target to reduce emissions of greenhouse gases (not covered by the Montreal Protocol dealing with chlorofluorocarbons) by 20 per cent, based on 1988 levels, by the year 2005. The Government also announced that it will not proceed with measures which have net adverse economic impacts nationally or on Australia's trade competitiveness in the absence of similar action by major greenhouse gas producing countries.

In setting this interim planning target, Australia was responding to world concern about the possibility of adverse, perhaps permanent, climate change arising from increased atmospheric concentrations of greenhouse gases (mainly carbon dioxide, methane and nitrous oxide) due to human activity.

A number of other countries have also announced reductions targets, and some have already taken action to reduce emissions. In these countries, as in Australia, implementation of targets has often been made conditional on similar action being taken by other countries.

Much work internationally and in Australia is being undertaken in relation to the greenhouse issue, and the Commission has endeavoured to keep abreast of relevant developments. (Appendix A gives an outline of inquiry procedures, lists the names of organisations and individuals consulted by the Commission, as well as seminars and conferences attended, and lists the names of participants.)

Within Australia, aspects of the greenhouse issue have also been examined within the Ecologically Sustainable Development (ESD) Working Groups set up by the Commonwealth Government. In preparing its final report, the Commission has been able to refer to the draft reports of those working groups. Their final reports, due at the end of October 1991, have not been available to the Commission.

In regard to emissions reductions, South Australia has announced support for the Commonwealth Government's interim planning target. New South Wales, Victoria, Western Australia and the Australian Capital Territory have supported targets to reduce carbon dioxide emissions. In most States, a range of measures have already been put in place to reduce emissions of greenhouse gases. (Appendix B outlines actions taken by the Commonwealth and State Governments on the greenhouse issue.)

Australia is currently participating in discussions aimed at formulating a negotiating framework for an international agreement aimed at securing reductions of global emissions of greenhouse gases (Appendix B). These continuing discussions are in preparation for the United Nations Conference on Environment and Development (UNCED) due to be held in Brazil in June 1992.

1.2 Scope of the reference

It is implicit in the terms of reference that Australia would be part of an international consensus to reduce greenhouse gas emissions. Since negotiations on this matter are continuing, the nature of any consensus is unclear at this stage, in terms of the gases it might cover, the targets it might specify, the measures by which such targets might have to be met, and the countries which might be included. Agreement to a consensus at UNCED along the lines specified in the Commission's reference is becoming less likely (see Chapter 7). However, for the purposes of this inquiry, the term ‘international consensus’ is taken to refer to a consensus among major greenhouse gas producing countries. In other words, an international consensus, in terms of the reference, would be one covering at least the present major emitters of greenhouse gases, and those countries projected to become major emitters in the foreseeable future. Although much of the report relates to the costs and benefits of such an international consensus, there is also some discussion of the prospects of such an agreement being reached and the implications for Australia of smaller group agreement and unilateral action.

The reference does not specify whether the targets are to apply to greenhouse gases in aggregate, or to each gas individually. The issue is important, as the costs and benefits of reductions can vary depending upon which gases are targeted. The Commission illustrates some of the relevant considerations in the report.

Not all emissions of greenhouse gases necessarily lead to equivalent increases in atmospheric concentrations. Various natural processes (described in Chapter 2) take up a proportion of the man-made emissions, reducing the net increase in concentrations. However, the ameliorating effect of such mechanisms is not clearly understood, and monitoring and enforcement of net emissions targets would be virtually impossible. The Commission's discussion therefore is generally concerned with specified targets applying to gross man-made emissions of greenhouse gases.

In the context of the terms of reference, 'costs and benefits' could have been interpreted narrowly to relate merely to the economic costs and benefits to Australian industry, directing the Commission to assess, for example, which industries are likely to expand and which to contract. However, it is important not to overlook the global nature of the greenhouse problem. Many of the benefits can only arise from international action to prevent adverse climate change. Further, although the reference relates to Australian industry, much of the material in submissions to the inquiry relates to costs and benefits for the Australian community as a whole. Policy guidelines in the Industry Commission Act also require the Commission to take an economy-wide view. For these reasons, costs and benefits have been interpreted in a broad sense to comprise the effects of potential climate change and of measures to reduce emissions on the Australian community generally.

1.3 Participants' views

During the course of the inquiry, 164 submissions were received (see Appendix A). They contain a wide range of views about a possible greenhouse problem, its possible climate impacts and its policy implications. Simplifying somewhat, however, it is possible to place many participants broadly into two distinct groups.

One group was concerned about the existence of an enhanced greenhouse effect, emphasised the possible magnitude of adverse climate impacts but saw the costs of making reductions in greenhouse gas emissions as relatively low. Participants in this group tended to take a global, rather than national, view, supporting action by Australia, even in the absence of an international consensus.

Other participants expressed doubt about an enhanced greenhouse effect, about the magnitude and even existence of possible climate impacts, and emphasised the costs which would be incurred in reducing emissions. These participants focused on the economic interests of Australians, and opposed unilateral action by Australia.

The Commission considers that part of its task is to assemble and analyse information which throws light on the relative merits of these two broad viewpoints.

1.4 Structure of report

In assessing likely costs and benefits, it is necessary to understand the state of scientific knowledge about an enhanced greenhouse effect. This is discussed in Chapter 2, which also briefly outlines reasons for the continuing increase in emissions of greenhouse gases. Chapter 3 discusses the various policy instruments governments could use to bring about reductions in those emissions.

Benefits and costs of an international consensus are dealt with in Chapters 4 and 5, respectively. The first covers the benefits from preventing adverse impacts of possible climate change, without ruling out possible beneficial climate effects of higher greenhouse gas concentrations for some regions. The reduction of emissions is expected to involve costs, but these costs could be moderated if cost effective emission reductions can be utilised, as some participants have argued. Chapter 6 addresses the question of weighing up the benefits and costs of a global consensus, noting that they are highly uncertain.

Assessment of benefits and costs, both climatic and economic, should allow for feedback effects. For example, in relation to climate, the feedback effects of clouds needs to be considered; in economics, the interindustry effects and the effects of international trade are important. Models have been constructed which allow for such feedbacks. As participants noted, and as noted at the Commission's modelling workshop (see Appendix H), such models have many defects. The Commission has indicated them where relevant. Nevertheless, the Commission has made use of models, as they offer the only way of attempting to assess the full extent of benefits and costs. Although the Commission has made further progress in its modelling work since completion of the draft report, and the results reported here supersede those of the draft, results from the economic modelling must still be considered as more illustrative than definitive.

Having discussed the costs and benefits of a global consensus, Chapter 7 considers some of the influences which might make the international consensus envisaged in the reference difficult to reach. Following on from this, Chapters 8 and 9 discuss how benefits and costs might change in the event of a smaller group agreement or if Australia were to take unilateral action to reduce emissions. Opportunities which might arise for Australian industry as a result of an international consensus are discussed in Chapter 10. And finally, some implications of the Commission's analysis for Government policy are drawn together in Chapter 11.

2 THE GREENHOUSE EFFECT

The greenhouse effect is a well understood natural phenomenon. But what is not clear is how increasing emissions of greenhouse gases from human activity will affect the world's climate. This chapter outlines the scientific evidence, and the associated uncertainties which build throughout the chain from observation to prediction, about the prospects for climatic change brought about by the release of greenhouse gases associated with human activity.

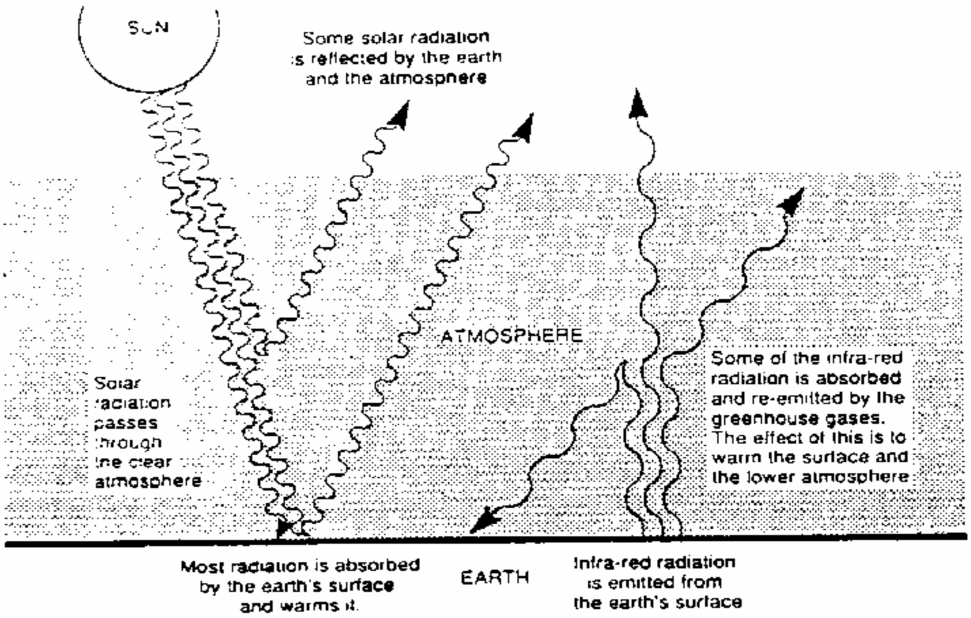
It should be emphasised at the outset that the Commission does not presume to have any independent insights into the scientific aspects of the problem. The Commission has taken as the basis for its understanding of the science the report by the Intergovernmental Panel on Climate Change (IPCC). In preparing its review of the science, the Commission has drawn on the detailed IPCC report from Working Group I (WG I) rather than the policy makers' summary. A number of submissions have drawn the Commission's attention to the fact that there are other interpretations of the science. The IPCC work and these alternative interpretations of the science are presented in simple terms in this chapter and in more detail in Appendix C.

2.1 What is the greenhouse effect?

The term ‘greenhouse effect’ describes the warming of the Earth and its atmosphere which occurs through the entrapment of energy by gases in the atmosphere. In essence, the atmosphere allows most sunlight (solar shortwave radiation) to enter and warm the Earth in a relatively unimpeded manner. As the surface of the Earth cools, it emits infra-red radiation, some of which is absorbed by the greenhouse gases in the atmosphere and re-radiated back to the Earth's surface, giving rise to additional warming (Figure 2.1).

Without the greenhouse effect the Earth would be much colder. In fact, the ability of the greenhouse gases to absorb infra-red radiation ensures an equilibrium temperature higher than would otherwise be expected. In other words, the greenhouse effect makes the planet habitable for life.

Figure 2.1: **A schematic illustration of the greenhouse effect**



Source: IPCC WG I 1990.

The greenhouse gases

The principal greenhouse gases are:

- water vapour, which occurs naturally;
- carbon dioxide, methane and nitrous oxide, which are emitted by both natural processes and through human activities;
- tropospheric ozone, which occurs naturally and as a consequence of reactions with other non-greenhouse gas pollutants; and
- chlorofluorocarbons (CFCs) which do not exist naturally, being totally attributable to human activity.

Excluding water vapour (by volume the most important greenhouse gas), greenhouse gases comprise less than 0.1 per cent of the atmosphere. That they are able to have such a substantial effect on the Earth's climate indicates how effective they are in trapping outgoing infra-red radiation. The efficiency of a gas in trapping infra-red radiation determines its potential to contribute to global warming. Greenhouse gas molecules do not remain in the atmosphere indefinitely -- all have finite lifetimes. As noted in the introduction, there are natural processes which convert them to some other form. These processes, called greenhouse sinks (see Box 2.1), operate with varying degrees of effectiveness for the different greenhouse gases, so that the average lifetimes of the gases vary substantially.

It is possible to combine the information describing the expected lifetime of a gas with that relating to its efficiency as a greenhouse gas and its present day concentration, to obtain its estimated Global Warming Potential (GWP -- this is described fully in Appendix C). The GWP has been arbitrarily set to one for carbon dioxide and is highest for CFCs, which contribute thousands of times the potential warming of carbon dioxide (see Table 2.1).

Table 2.1: **Atmospheric lifetimes, concentrations and global warming potentials of the most important greenhouse gases**

Gas	*Lifetime*	*Concentration 1989*	*Global warming potential* [a] *(Integration time horizon)*		
			20 years	*100 years*	*500 years*
	year	*ppmv* [b]			
Water vapour	0.02	3000	ngc [c]	ng	ng
Carbon dioxide	120	350	1	1	1
Methane	10	1.7	63	21	9
CFC-11	75	0.00025	4500	3500	1500
CFC-12	110	0.00045	7100	7300	4500
Nitrous oxide	150	0.310	270	290	190

[a] Table 2.1 gives the global warming potentials following the instantaneous injection of 1 kg of the gas into the atmosphere. These GWPs are relative to the warming potential of 1 kg of carbon dioxide. [b] ppmv - parts per million by volume. [c] ng - not given.
Source: IPCC WG I 1990.

Box 2.1: **The language of ‘greenhouse’**

The Commission has done its best in this report to avoid the use of technical expressions and jargon, which abound in the literature on the greenhouse effect (as in many other fields). In some cases, however, it would be more confusing to substitute another expression for the technically correct one. Some of the key words unavoidably used in any discussion of the greenhouse effect, including this report, are explained here. (See also Appendices C and D for scientific and economic terminology respectively.)

Anthropogenic: Attributable to mankind. Hence the commonly encountered expression ‘anthropogenic emissions’ simply means those emissions of greenhouse gases that are attributable to human activity. (Note that this includes emissions from farm animals.)

Sources and sinks: The ‘source’ of a greenhouse gas refers to its origin. For example the main anthropogenic source of carbon dioxide is the burning of fossil fuels. ‘Sink’ is the term used to describe those processes which absorb greenhouse gases (for example the ocean absorbs carbon dioxide), or which convert them to some other form (for example a forest absorbs carbon dioxide and through photosynthesis converts it to cellulose).

Feedback effect: A variety of greenhouse related feedbacks may be identified. For example, a positive feedback possibly contributing to the greenhouse effect is associated with the increasing concentration of water vapour brought about by higher temperatures; this increased concentration of water vapour leads to enhanced trapping of outward going infra-red radiation, leading to further global warming. An associated negative feedback would occur if higher moisture levels led to increased cloudiness; the negative feedback would then occur if the clouds increased the Earth's reflectivity to incoming solar radiation, thereby cooling the atmosphere.

Greenhouse effect: Refers to the warming of the Earth and its atmosphere that occurs through the entrapment of infra-red (longwave) radiation emitted from the Earth's surface. It is a natural process which makes life on Earth possible. The policy issue relates to whether this underlying effect is being increased by human activity -- known as the ‘induced’ or ‘enhanced’ greenhouse effect.

Scenario: An internally consistent account of the future state of a system, based on a model of the system reflecting current understanding of it. A scenario is not a forecast. Scenarios are used where current understanding is considered insufficient to support a forecast. Alternative scenarios are used to conduct sensitivity analyses so as to explore the range of uncertainty.

Trace gases: Gaseous constituents of the atmosphere which are present in very low concentrations. Their concentrations are generally of the order of parts per million (by volume), or less.

Biosphere: The part of the Earth where living organisms are to be found.

Palaeoclimate: A description of climate deduced from the examination of geologic data (particularly fossils and pollen remains).

Box-diffusion models: These are the simplest mathematical models of the Earth's climate system. They are ‘one-dimensional’ models in that the atmosphere and ocean are divided into a number of layers, each layer having a temperature equal to the global mean for that height/depth. The exchanges of energy between the layers are specified by a system of equations formulated to realistically reproduce the exchanges observed in the real world.

GCMs (General Circulation Models): In these models the world's climate system is represented on a three-dimensional array of grid points. The descriptions of physical processes given by the mathematics used in them represents a significant simplification of the real world. To assess the impact of changing conditions upon climate using these models the world's most powerful super-computers are required. Appendix C contains a more detailed description of these models.

The GWP for the greenhouse gases may be combined with their rates of release to derive an estimate of the proportion of the total potential warming each gas currently contributes. Given that the GWP has been evaluated for three different time intervals, the relative contributions of the current emissions vary depending upon the interval chosen. Table 2.2 shows the results of such calculations. From these results it can be seen that of the greenhouse gas releases attributable to human activity, carbon dioxide contributes at least 50 per cent of the potential warming and must therefore be considered the most important greenhouse gas.

Table 2.2: **Contribution of anthropogenic emissions to potential global warming (1990 emissions)**

Gas	*Current anthropogenic emissions*	*Proportion of total effects for differing integration intervals*		
		20 years	*100 years*	*500 years*
	Mt	%	%	%
CO_2	26000	51	68	81
CH_4	300	37	17	8
N_2O	6	3	5	4
CFC-11	0.3	3	3	1
CFC-12	0.4	6	7	6
		100	100	100

Source: IPCC WG I 1990.

Anthropogenic emissions

Evidence from the geologic and historic past has established that the composition of the Earth's atmosphere has been subject to continual change. In recent times, however, the pace of this change, attributable to the influence of human activity, has been pronounced. Indeed, over the last hundred years or so, anthropogenic emissions have contributed to a steady increase in the concentration of greenhouse gases in the atmosphere.

Atmospheric concentrations of carbon dioxide have increased from 275 parts per million by volume (ppmv) prior to the industrial revolution to around 350 ppmv today. This represents an increase of over 25 per cent. Water vapour aside, the other greenhouse gases featured in Table 2.1

occur in lower concentrations than carbon dioxide, but their global warming potentials are greater. For example, the concentration of methane has doubled from 0.8 ppmv since the mid-nineteenth century to 1.7 ppmv today, but per unit mass it is between 9 and 63 times more effective than carbon dioxide as a greenhouse gas (depending upon the time interval being considered). CFCs, which do not occur naturally, are even more effective.

The primary human source of greenhouse gases is the burning of fossil fuels such as coal, oil and natural gas. Other anthropogenic sources include leakage from gas pipelines and mines; decay of organic matter, predominantly in landfills and associated with wet rice cultivation; and emissions from domestic ruminant animals such as cattle and sheep. Deforestation has reduced absorption of carbon dioxide by trees.

The sources and sinks of the major greenhouse gases attributable to human activity -- carbon dioxide, methane and nitrous oxide -- are shown in Table 2.3. The principal human source of carbon dioxide is the burning of fossil fuels. Because fossil fuel forms of energy are fundamental to the world economy, reasonably reliable data for gross anthropogenic emissions of carbon dioxide from this source are available.

In comparison with the situation for carbon dioxide, the anthropogenic sources of methane and nitrous oxide are in general poorly monitored and at times not well understood. Emissions from domestic livestock, wetlands and improved pastures are not well quantified either nationally or globally (nevertheless, some estimates are provided in Appendix C). In the context of this inquiry, this lack of widely accepted quantitative data for the gross emissions of greenhouse gases other than carbon dioxide has unavoidably led to a greater focus on carbon dioxide emissions.

2.2 The enhanced greenhouse effect: IPCC report

The incontrovertible evidence linking increasing concentrations of greenhouse gases to human activity has led many scientists to postulate that the greenhouse effect will be increased beyond its natural extent, resulting in a warmer global climate -- an ‘enhanced greenhouse effect’. How great a problem this would represent depends on the nature and extent of the impacts on living conditions on Earth due to a warmer climate. Considerably more uncertainty attaches to this than to the prospect of an enhanced greenhouse effect as such, but there are significant gaps in the scientific knowledge of both. It is important in formulating policy to be clear about the present state of knowledge.

Table 2.3: **Sources and sinks of greenhouse gases**

Gas	*Sources*	*Sinks*
Carbon dioxide (CO_2)	fossil fuels [a] biomass burning [a] soil tillage [a] volcanoes oceans	oceans soil vegetation
Methane (CH_4)	rice paddies [a] ruminants [a] gas fields [a] coal mines [a] landfills [a] wetlands termites biomass [a] oceans	conversion to formaldehyde [b] (CH_2O)
Nitrous oxide (N_2O)	biomass burning [a] fertilisers [a] soil tillage [a] improved pastures [a] bacteria in soil oceans	conversion to molecular nitrogen [b] (N_2)

[a] Denotes a source either partially or completely attributable to human activity. [b] Refer Appendix C.

The IPCC WG I 1990 reports that:

- there is a natural greenhouse effect which ensures an equilibrium temperature around 33°C higher than that which would otherwise prevail;

- scientific observations record that there have been changes in atmospheric greenhouse gas concentrations, which can be unambiguously traced to human activity;

- these greenhouse gases influence the Earth's energy balance; and

- the recorded global air and sea surface temperature warmings of around 0.5^{0}C over the last 100 years are qualitatively consistent with, but do not `prove', the existence of a human-induced greenhouse effect.

While these points are generally accepted, there remain gaps in our knowledge of those factors which influence climate and of the interactive processes (eg feedback effects) which could modify the direct warming influence of the increasing concentrations of greenhouse gases.

Despite the careful attempts to analyse the observational record, it appears that the number and distribution of observations is not sufficient to unequivocally determine the extent of temperature change to date. For example, the polar and oceanic regions are not well represented, and monitoring stations in urban areas are influenced by the `heat island' effect (this point is discussed more fully in Appendix C). More importantly, the climate system is characterised by substantial natural variability and the length (and number of observations) of the climate record is too brief to assert that the apparent warming over the last century lies outside the range of natural variability.

Assuming emissions of greenhouse gases continue on a `business-as-usual' basis and temperature continues to increase, the IPCC expects it to take another decade before a causal connection between increasing greenhouse gas concentrations and global warming could be established with high confidence. Even if this connection were made, much uncertainty associated with the likely trend of future warming would remain.

Despite these inherent uncertainties, scientists have endeavoured to predict the future effects of climate change associated with increasing concentrations of greenhouse gases through the use of General Circulation Models (GCMs) of the atmosphere. GCMs are simplified mathematical models reflecting the known physics of the climate system (see Appendix C for a detailed discussion). As noted by a number of participants, the models are incomplete in their representation of certain physical processes including the roles of clouds and the oceans in the Earth's climate (see Box 2.2). Further uncertainties associated with the use of these models to predict future climate change include the following:

- the future rate of release of greenhouse gases is uncertain;

- the warming sensitivity of the atmosphere to increasing greenhouse gas concentrations is not yet known; and
- the length of time from increased greenhouse gas concentration to increased warming is also unknown.

Different research groups have used different techniques to simplify their descriptions of the atmosphere so that global climate simulations can be made. These differences lead to significant variations in global and regional forecasts from different models when the effect of a doubling of the atmosphere's carbon dioxide concentration is simulated. That is, while the models generally show reasonable agreement on the nature of the average temperature change of latitudinal bands around the Earth, there is a great deal of variation in the forecasts of changes to regions, particularly for rainfall.

Box 2.2: Clouds and oceans

Clouds reflect sunlight which tends to cool the Earth, but they also absorb infra-red radiation which has the opposite effect. The brightness, height, distribution and extent of clouds has a bearing on which feedback effect dominates. Recent satellite measurements confirm that clouds currently have a net cooling effect on the Earth. Climate change could affect clouds, altering the nature of these feedback effects.

It is known that the oceans affect the present climate and it is believed that their enormous heat retention capacity will slow any initial increase in global temperature. Global climate models should, in principle, couple the atmosphere with the oceans. However, this challenge has yet to be met adequately, with all GCMs simplifying ocean dynamics, treating them at coarse resolution or omitting them completely.

Table 2.4 summarises some of the GCM-derived research results. These results refer to the climatic consequences, in terms of global averages, of a doubling of the concentration of carbon dioxide, given the full adjustment of the climatic system to the new conditions. Results of particular note in Table 2.4 are the variability between models in their forecasts for global average temperature change and the change in global average precipitation.

Table 2.4: **A summary of some research results of doubling the concentration of carbon dioxide**[a]

	Investigators	*Year*	*Temperature effect*	*Precipitation effect*
			^oC	*% change*
Variable cloud: no ocean heat transport				
1	Schlesinger & Zhao	1989	2.8	8
2	" "	1989	4.4	11
3	Noda & Tokioka	1989	4.3 [b]	7 [b]
4	Washington & Meehl	1984	3.5 [c]	7 [c]
5	" "	1989	4.0 [c]	8 [c]
6	Wetherald & Manabe	1986	4.0	9
Variable cloud: prescribed heat transport				
7	Gordon & Hunt	1989	4.0	7
8	Hansen et al.	1981	3.9	n/a
9	" "	1984	4.2	11
10	" "	1984	4.8	13
11	Wetherald & Manabe	1989	4.0	8
12	Wilson & Mitchell	1987	5.2	15
13	Mitchell et al.	1989	2.7	6 [d]
14	" "	1989	3.2	8[e]
15	" "	1989	1.9	3 [f]
High resolution models				
16	Boer et al.	1989	3.5	4
17	Wetherald & Manabe	1989	4.0	8
18	Mitchell et al.	1989	3.5	9 [g]
19	McAvaney et al.	1991	2.1	3
20	Dix et al.	1991	4.8	10
21	Oglesby & Saltzman	1990	4.0	n/a
22	Wang et al.	1991	4.2	9
23	"	1991	5.2	10 [h]

[a] This table has been updated with information expected to appear in the next IPCC Scientific Assessment Report (McAvaney pers. com.). [b] Equilibrium not reached. [c] Excessive ice. [d] Cloud water scheme. [e] Alternative ice formation. [f] Variable cloud radiative properties. [g] Gravity wave drag. [h] As in 22 but with CO_2 at 330 ppmv and including trace gases.

Source: IPCC WG I 1990.

Global climate model predictions

Despite the differences between GCM models they have central features in common, and they all predict that the Earth's average surface temperature will rise as a result of increased greenhouse gas concentrations. The predicted global average temperature increase caused by an effective doubling of the atmospheric carbon dioxide concentration is termed the model's climate ‘sensitivity’. In GCM work and its description, carbon dioxide is used as a proxy for greenhouse gases generally. The results relate to an increase in all greenhouse gases equivalent to a doubling of the atmospheric carbon dioxide concentration. The projected climate sensitivity from the model results summarised in Table 2.4 is in the range 1.96^0C to 5.2^0C.

The reason for the variability in sensitivity between GCMs is the differences in methods used to represent the feedbacks between different processes. As noted in Box 2.1 feedbacks may be positive or negative. A positive feedback will cause a system to tend towards instability until checked by a damping effect. Box 2.1 provides a simple example of how this might happen. In the Earth's climate system feedbacks occur on a variety of timescales. The formation of clouds as a response to heating occurs on a timescale of hours, changing vegetation patterns as a response to changed atmospheric carbon dioxide levels will occur over a timescale of seasons to decades, changing feedback systems involving ocean currents may have response times of decades to centuries. The interaction between the countless feedbacks involved in the Earth's climate system, as summarised by the sensitivity parameter, is extremely complex and is as yet poorly understood.

The IPCC reported that the double carbon dioxide experiments predict that there will be a warming of the near surface layers of the atmosphere and a cooling of the stratosphere. They also predict that global average water vapour concentration will increase, particularly in the tropics, and that rainfall will increase year round in the tropics and high latitudes. The models generally show greater heating over the land areas and suggest that the warming will be greatest at the higher latitudes and least in equatorial regions. However, recent simulations with coupled ocean-atmosphere models (eg Cubasch et al. 1991a) show some cooling in the Southern Ocean with a doubling of carbon dioxide. The double carbon dioxide experiments represent, in effect, the transition of the Earth's climate from one equilibrium state to another. The Earth's climate system is, of course, never in equilibrium. Within this system there are a myriad of changes occurring continually, on all timescales, and these changes lead to changing interactions between the components of the climate system. The expectation is that should climate change occur in response to increased greenhouse gas concentrations, it would not occur suddenly. Rather, the climatic response would be spread over time and may be difficult to detect on a short timescale due to the interannual variability of climate.

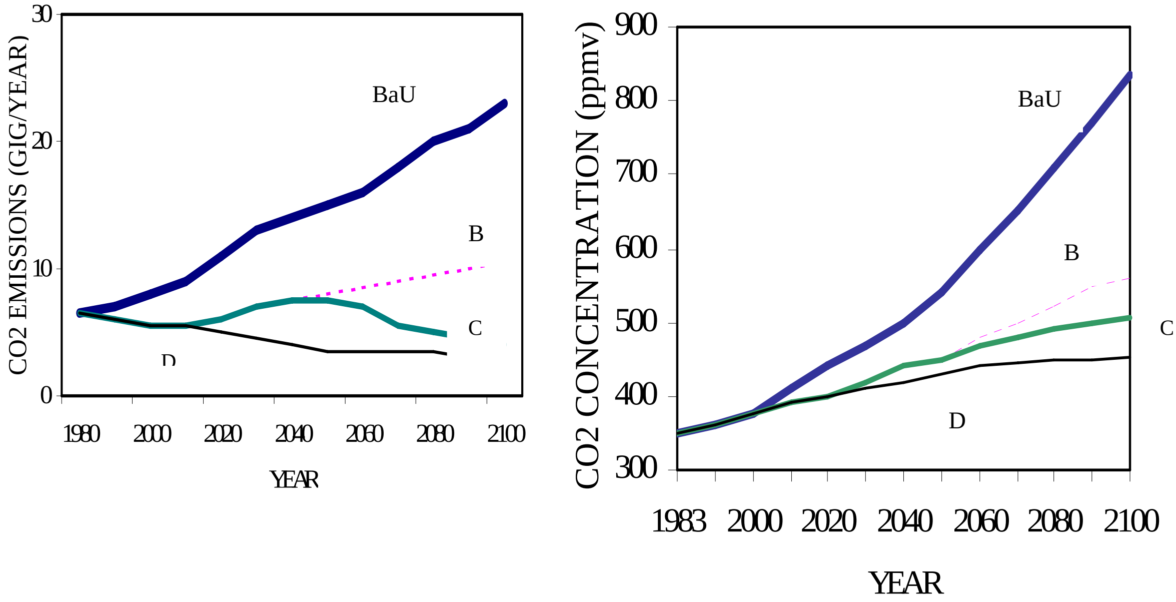
Because of the uncertainty associated with the changes over time of future releases of greenhouse gases from human activities, the IPCC Working Group I Report 1990 presents predictions derived from four IPCC Working Group III `policy scenarios'. The scenarios are:

- ‘BAU’ (business as usual): assumes that no steps are taken to limit carbon dioxide emissions;
- ‘B’: a stabilisation, or slight decrease in emissions until 2010 and then a modest rate of increase until 2100;
- ‘C’: a stabilisation, or slight decrease in emissions until 2010, a slight increase until 2050 and then a steady decrease through to 2100; and
- ‘D’: a stabilisation, or slight decrease in emissions until 2010, with a steady decrease continuing through to 2050 and then maintenance of emissions at a constant level through to 2100.

The projected rates of emission of carbon dioxide for the four scenarios are shown in Figure 2.2(a). The atmospheric concentration of carbon dioxide under the four scenarios are shown in Figure 2.2(b). Using a simple box-diffusion climate model (see Box 2.1 for a discussion of their characteristics) the IPCC WG I 1990 has translated these scenarios into likely rates of global warming. The results of such calculations are shown in Figure 2.2(c).

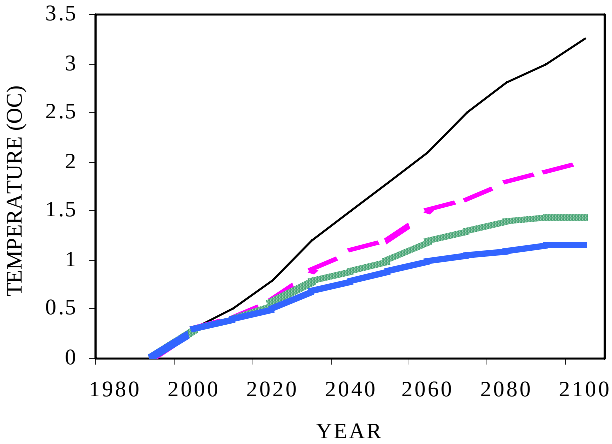
Because of their relative simplicity box-diffusion models are used to examine the time dependent effects associated with steadily increasing greenhouse gas concentrations. By their very nature these models cannot provide any insights into possible regional effects of global climate change. One crucial parameter for performing a box-diffusion simulation of the type reported in Figure 2.2 (c) is an estimate of the climate's sensitivity to an effective doubling of the atmospheric carbon dioxide concentration. The climate sensitivity used to derive Figure 2.2(c) was obtained from consideration of the results of GCM simulations. The value of 2.5oC was selected by the IPCC WG I for this sensitivity. As shown in Table 2.4, this value is at the low end of those determined from recent GCM simulations.

Figure 2.2(a): **Rates of emission of carbon dioxide, and, (b): Rates of change of the concentrations of carbon dioxide for the four IPCC WG III 'policy' scenarios**



Source: IPCC WG I 1990.

Figure 2.2(c): **Temperature rise for the four IPCC WG III 'policy' scenarios (corresponding to a climate sensitivity of 2.5^{0}C)**



Source: IPCC WG I 1990.

With scenario ‘D’ the forecast is for global warming of 0.75^0C by the year 2050, compared with a temperature increase of 1.75^0C for the BAU scenario (see Figure 2.2 (c)). By the year 2100 the temperature rises are 1.8^0C for scenario ‘D’ and 3.25^0C for the BAU scenario. Noting that because of natural climate variability the scientific community cannot unambiguously identify an historical 0.5^0C temperature rise as greenhouse related, it might be concluded that the warming differences between BAU and the most severe emission cuts considered here would be barely distinguishable before the year 2040. That is, the ‘payoffs’ in terms of climate change avoided by emission control measures put in place over the next decade would not begin to be apparent until the middle of the next century, according to these scenarios.

From these simulations, and the earlier descriptions of the greenhouse gas characteristics, the ‘payoff’ period for emission reduction strategies can be specified. Greenhouse gases generally stay in the atmosphere for a long time and thus the reduction of their concentrations is a long term process. If it is desired to limit ‘stocks’ (atmospheric concentrations) to a specified level by a specified time, the earlier reductions in ‘flows’ (emissions) are put in place the less stringent they need be. Also, because temperature rises are expected to lag greenhouse gas concentration increases by at least several decades (due to the buffering effect of the oceans) the effect of reductions in emissions would not be felt for several decades.

Appendix C reports data on the historical record on temperature change. By the average standards of the last million years, the Earth is currently in a relatively warm phase of its climatic history. The BAU scenario would see the average global temperature higher than it appears to have been in the last million years by the end of the next century. The rate of change of temperature on the BAU scenario would be much more rapid than appears to have been experienced in the last 10 000 years, and rapid by longer term historical standards.

Possible impacts of global warming

Global average temperature change is but one aspect of climate change. It would be accompanied by changes in other dimensions of climate, such as precipitation for example. What is primarily seen as being of concern is not so much climate change itself, as the impacts of that change. These require scientific study additional to that which produces climate change scenarios. Knowledge about the impacts of climate change involves more uncertainty than knowledge about climate change itself. Impacts would vary across different regions, and depend on regional climate change.

It is important to recognise that GCMs are not consistent in their regional predictions, so it is difficult to anticipate changes to regional climate. (This is discussed in some detail in Appendix C. Possible regional impacts of climate change are discussed in more detail in Chapter 4.) The following broad qualitative conclusions concerning the possible impact of global warming have been deduced from the analysis of the results of GCM simulations:

- A warming of the lowest layers of the atmosphere would, with a time lag, lead to a warming of the ocean. As the upper layers of the ocean warm they expand giving rise to an increase in sea level. It is possible that such an expansion could also be accompanied by an increase in water volume through accelerated ice cap and glacier melting. Forecasts by the IPCC WG I 1990 for sea level rise are for an increase of around 20 cm by 2030 and 65 cm (or averaging a rise of approximately 6mm per year) by the end of the next century, assuming that greenhouse gases continue to be emitted under a business-as-usual scenario. Recent work by Church et al. 1991 indicates a rise of around 4 to 5 mm per year through to 2050 from the IPCC business-as-usual scenario. It is expected that this work will be reported in the next IPCC WG I report.

- Changes in temperature, evaporation and rainfall, along with the carbon dioxide enrichment effect on plant photosynthesis and water-use efficiency would all impact on agriculture. In the mid-latitudes, for example, both increased rainfall variability and reduced available moisture could lead to a reduction in the productivity of many crops. In the high latitudes, longer growing seasons and increased rainfall in some areas suggest the possibility of higher agricultural production.

- Climate change associated with any induced greenhouse effect has the potential to change the yield from fisheries, alter the viable climate domains of wildlife, forests and other flora. It could also be expected that the normal ranges of insects and weeds would change and that diseases associated with particular regions (eg dengue fever, encephalitis, etc.) would expand their domains. These impacts, would of course, depend on the nature of the regional climate change which accompanies the global warming.

- It is possible that climate change could be heralded by increases in the frequencies of extreme and rare events (eg floods, droughts and tropical cyclones). Because the modern meteorological record is relatively short, and because extreme events have a finite probability of occurring several times in quick succession, it would take some time to confirm that the occurrence of such events was the result of climate change.

2.3 Surprises and dissent

The IPCC Working Group I summarise succinctly the scientific aspects of the greenhouse problem. However, they caution that despite their best efforts: '... the complexity of the system means that we cannot rule out surprises' (IPCC WG I 1990). While by definition it is not possible to anticipate a surprise, in broad terms it would seem that the surprises could take a number of forms:

- the regional effects of climate change associated with the enhanced greenhouse effect may be very different from those currently indicated by the GCMs (and it was in this context that the IPCC raised the issue of surprises); or

- the IPCC WG I consensus may either understate or overstate, by a significant amount, the magnitude of global warming associated with a specified level of atmospheric greenhouse gas concentration.

Surprises on a regional scale

The IPCC WG I 1990 Report notes that there is a high degree of variability between GCMs on the regional scale, suggesting that this part of the climate change problem is not yet completely understood. It would thus seem a possibility that significant regional effects associated with the enhanced greenhouse effect have not yet been simulated. It should also be noted that at this stage in the scientific analysis of the Earth's climate relatively less is known about the climate of oceans than of continents, and less about the climate of the southern hemisphere oceans than about those of the northern hemisphere. Accordingly it would seem that the possibility for surprises may be greater in the southern hemisphere, in areas where the climate is strongly controlled by maritime influences, than in other areas.

The magnitude of possible warming

A number of participants have drawn the Commission's attention to studies which suggest the possibility of an enhanced greenhouse effect outside the range of the IPCC's predictions. Daly (sub. D107) has pointed to the work of Newell et al. 1989[1] and Lindzen 1990[2] for support of the notion that uncertainties in the interpretation of the modern observational record, and uncertainties in the physics of the feedback processes associated with clouds and atmospheric moisture by scientists in the IPCC scientific assessment process, has led to an overestimate of the warming associated with the enhanced greenhouse effect. On the other hand Greenpeace Australia (sub. D117) cites the work of Leggett 1991[3] for support of the notion that there are possible positive feedbacks, whose effects have not been factored into conventional climate models, but whose presence could mean that the IPCC's predictions are substantial underestimates of the global warming to be expected from business-as-usual release of greenhouse gases.

These failures to estimate the magnitude of the enhanced greenhouse effect would also be expected to manifest themselves as errors in the rate of warming, though the complicating factors associated with the time delays being caused by the response of the oceans, and by natural climate variability,

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1 Newell et al. 1989 focus on the degree to which the scientists who prepared the IPCC WG I report may have overstated the warming to be deduced from an analysis of the modern, instrumental record of near surface land temperature.

2 Lindzen 1990 advances arguments that the damping effect of clouds on global warming from the enhanced greenhouse effect has been substantially underestimated. In testimony on 7 October 1991 to the US Senate Commerce, Science and Transportation Committee Lindzen somewhat modified his position, while continuing to argue that the current GCM modelling of the behaviour of water vapour in the atmosphere is unsatisfactory.

3 Leggett, Director of Science at Greenpeace, UK 1991 argues that positive feedbacks associated with clouds, other positive feedbacks associated with the release of methane trapped in methane hydrates and a `plankton multiplier' positive feedback effect could all operate to produce global warming in excess of that predicted by the GCM simulations reported by the IPCC WG I 1990 Report.

means that it is not a simple process to use currently available climate observations to readily choose between the hypotheses.

The implications of overestimation and underestimation by the IPCC would not be symmetrical. If the IPCC range represents an overestimate of warming due to an enhanced greenhouse effect, acting on the basis of it would essentially involve incurring unnecessarily large costs associated with reducing emissions. If the IPCC range represents an underestimate, acting on the basis of it would essentially involve experiencing a greater degree of climate change than anticipated. This leads naturally to the question of the estimation of the upper limit on warming due to an enhanced greenhouse effect, and to the question of the stability of the climate system.

Estimates of the upper limit of global warming have been made: Gifford, in evidence given to the Commission (Transcript p. 31) indicated a rise of around 10^{o}C was a possible consequence of burning all the Earth's fossil fuel reserves and Cline 1991a (following IPCC WG I) argues for 10.5^{o}C as a central estimate for the ‘very-long-term global warming’ as a result of business-as-usual emissions. These estimates are derived from an analysis, using ‘traditional’ climate models, of the implications of burning the Earth's entire fossil fuel reserves over the next two to three centuries.

The work of Leggett 1991 suggests that these could be underestimates. He argues that the ‘traditional’ climate models neglect important, positive feedbacks. This line of argument leads to questions of whether the Earth's climate system would be stable in the face of warming greater than 10^{o}C. In response to reference in its draft report to a possible runaway greenhouse effect, the Commission received several submissions addressing this issue. Prof. Henderson-Sellers (sub. D122) argued that:

> To the best of my knowledge there is no scientific evidence to suggest that a runaway greenhouse effect (ie an escalation in temperatures so large that the oceans would evaporate completely as might have occurred during the early evolutionary history of Venus) might occur as a consequence of human-induced greenhouse gas emissions.

This point of view was supported by Dr Manton, Chief Scientist of the Bureau of Meteorology Research Centre, in evidence given to the Commission (sub. D106).

While noting that there are dissenters from the consensus presented by the IPCC WG I 1990 Report -- including some scientists who have postulated other factors which could explain the observed increase in global temperatures -- and that their presence seems to give support to the IPCC's advice that surprises cannot be ruled out, the Commission feels that it is in no position to adjudicate on the strength of their claims. They are presented here to further illustrate the uncertainty that underpins economic analysis of the costs and benefits of adopting greenhouse gas emission targets. The Commission notes that an updated report from WG I of the IPCC is expected to be published in the first quarter of 1992. It is anticipated that this report will synthesise many of the new results emerging from the scientific community.

2.4 Why have concentrations increased?

There is no doubt that atmospheric concentrations of greenhouse gases have been increasing over the last 150 years as a result of human activity. There is majority scientific opinion that the concentrations will, with business as usual, go on increasing in the future, giving rise to climate change. What are the origins in human behaviour of past emissions sufficient to increase concentrations? This question needs to be considered if future prospects are to be understood, and appropriate policy responses developed.

Globally, anthropogenic greenhouse gas emissions have been increasing because the human population has been increasing in size, and because of rising average per capita levels of consumption. The impact of the human race on the biosphere generally has increased since the industrial revolution. Increased GHG concentrations are just one manifestation of this.

In terms of the enhanced greenhouse effect, the most important GHG is carbon dioxide, and the major source of emissions of this gas is the burning of fossil fuels -- oil, gas, coal. Since the beginning of the nineteenth century, per capita income growth has correlated very closely with per capita fossil fuel consumption. Nations with high per capita income levels tend also to have high per capita levels of fossil fuel use and carbon dioxide emissions. Table 2.5 illustrates this for six nations. The correlation between income and carbon dioxide emissions on a per capita basis is not perfect. Carbon dioxide emissions arising in fossil fuel combustion also depend on technical and economic efficiency. Japan is relatively efficient in using fossil fuel to produce goods and services, the USSR is relatively inefficient. China and India have low per capita emissions because they are at an early stage of economic development. However, they are also relatively inefficient in using fossil fuels to produce goods and services. China uses large amounts of coal to generate electricity at low thermal efficiencies. By virtue of their large populations, the total emissions of China and India represent significant contributions to the global total -- 11.8 and 3.1 per cent respectively (see also Table C8 in Appendix C).

Table 2.5: **Carbon dioxide emissions, national income and population: 1988**

	CO_2 a	*CO_2 b per cap*	*GD c per unit GDP*	*Population d per cap*	*CO_2 e*
US	21.39	1.09	19.59	248.2	5310
USSR	13.01	1.50	8.66	288.7	3756
UK	10.65	0.80	13.33	57.0	607
Japan	8.68	0.58	14.96	123.2	1069
China	2.37	7.54	3.12	1112.3	2638
India	0.84	3.03	0.28	833.4	699

[a] tonnes. [b] tonnes/thousands \$US. [c] thousands \$US. [d] millions. [e] Megatonnes.
Source: Based on Table 2.1 from Grubb 1990.

Table 2.5 indicates the broad nature of the historical experience in regard to carbon dioxide. In developed nations such as the US, the UK and Japan, economic growth to date has involved increasing fossil fuel use. The rate of increase was most rapid in the early stages of industrialisation, and has levelled off in the last two decades. If developing nations, such as China and India, follow the historical pattern, their per capita use of fossil fuels and hence per capita carbon dioxide emissions will increase rapidly in the future. This, in broad terms, is the background to the IPCC business-as-usual scenario discussed above. Emissions in the developed world increase rather slowly by historical standards, while in the developing world they increase rapidly by its historical standards. Given the large and growing populations of some developing nations, such as China and India, developments in such nations are seen as having a major impact on the future course of global emissions.

The situation in respect of the other greenhouse gases, and for other sources of carbon dioxide, is broadly similar. Increasing emissions have been driven by increasing population and increasing material living standards. For business as usual, the scenario is that both of these driving forces will continue to operate at the global level. (Anthropogenic emissions sources are discussed in more detail in Appendix C.)

There is no rigid relationship between population size, material living standards and greenhouse gas emissions. Countries at similar levels of per capita income, such as the US and Japan, can have very different per capita levels of carbon dioxide emissions, as shown in Table 2.5. Again, the USSR has a per capita income lower than does Japan, but its per capita emissions are higher. This type of data suggests that there is the potential at the national level, at least to some degree, to decouple emissions growth from income growth.

It also suggests some questions. Why do some nations have higher emissions per unit of income than others? This question is especially pertinent if it is accepted that the emissions give rise to problems associated with climate change. Why has the enhanced greenhouse effect not been factored into economic decision making?

Two components of the multi-faceted answer to this question are: the possibility of 'market failure' and lack of knowledge.

Atmospheric pollution in urban areas provides a good example of 'market failure'. A lack of enforceable private property rights over some environmental resources means that the market does not ensure that polluters bear the costs to others of their polluting activity, so that they operate that activity at levels which are excessive (see Appendix D). This situation is not, of course, confined to market economies: indeed, pollution problems generally in the USSR and Eastern Europe appear to be worse than in Western Europe. In non-market economies, the problem is however essentially the same as in market economies -- polluters do not bear the costs that they impose on others.

The greenhouse case exhibits aspects of such market failure. Individuals, countries and companies emit greenhouse gases irrespective of the costs (or benefits) those emissions might impose on others. Such emissions take place from both market and non-market economies: Table 2.5 above shows that the USSR is the source of relatively high carbon dioxide emissions both per capita and per unit of income.

Another element in the answer to this question is simply lack of knowledge. The scientific understanding of the relationships between anthropogenic emissions and the global climate system, sketched in Section 2.1 above and set out at more length in Appendix C, is of quite recent origin. The existence of the greenhouse effect itself has been known since the end of the nineteenth century. But substantial work on global climate modelling has a history of only a decade or so. It requires the availability of super-computers.

Current knowledge does not definitively establish that an enhanced greenhouse effect with adverse implications exists. As noted above, there are many major uncertainties, and it will be another decade before it is possible to say whether or not observed recent climate change has been driven by anthropogenic influences. Action on a problem requires not only scientific knowledge, but also widespread perception that it exists. In the case of the enhanced greenhouse effect, there has been widespread perception of the possibility of a problem for only a few years.

In the next chapter of this report, after briefly reviewing the international response so far, the Commission discusses issues relating to the choice of policy instruments for achieving greenhouse gas emission targets.

3 POLICY RESPONSES

In response to growing awareness of a potential greenhouse problem, the Toronto Conference on The Changing Atmosphere in 1988 urged the adoption of a goal of a reduction in global carbon dioxide emissions of 20 per cent, on 1988 levels, by 2005. It was not claimed that this target had any particular merit beyond representing an initial target which it might prove possible to get adopted at the political level. Adoption of such a target requires a judgment that preventative policy action is desirable, presumably on an implicit weighing of costs and benefits.

Preventative policy seeks to reduce the anticipated accumulation of greenhouse gases in the atmosphere with a view to reducing anticipated global warming. An alternative policy response would be to put in place measures to promote adaptation to a changed climate. Preventative and adaptive policies are not, of course, mutually exclusive.

Awareness of, and concern about, an enhanced greenhouse effect is now evident at the level of national governments and international organisations. These have organised and supported the scientific work which resulted in the publication of the IPCC report in 1990. The United Nations Commission on Environment and Development (UNCED) is organising a major international conference on environment and economic development to be held in Brazil in June 1992 (popularly known as the `Earth Summit'). It will be attended by heads of government. The intention is that one of the outcomes of this meeting will be an international framework convention on global preventative policy action in regard to the enhanced greenhouse effect: intergovernmental negotiations to this end are in progress.

The Commission has essentially been asked to evaluate the costs and benefits for Australia of participation in an international consensus to implement the Toronto targets (extended to all greenhouse gases). Among other things, these depend on what implementation mechanisms or policy instruments are specified in the consensus: in other words, on how the target is to be pursued internationally and nationally. This is of central importance not only to the economic consequences of the consensus, but also to its effectiveness in meeting the target itself. These questions of policy implementation, which have been little discussed thus far in the negotiations, are the subject of this chapter. They can only be sensibly discussed, however, with some appreciation of the special nature of the policy problem posed by an enhanced greenhouse effect.

3.1 Nature of the policy problem

While carbon dioxide is a natural component of the atmosphere and necessary for life, an enhanced greenhouse effect, where adverse in its impacts on mankind, would have some of the central characteristics of a standard pollution problem. The key feature in common is that those responsible for emissions of greenhouse gases do not account for the (potential) effects of their actions on others in their production and consumption decisions.

Quite a lot is now known about the nature of policies that can be used to control excessive pollution (see Appendix D). This knowledge can be helpful in thinking about policy measures that could be used to address an enhanced greenhouse effect.

One of the main points arising from this experience is the concept of an optimal level of pollution. As the term implies, this will generally not be zero. Rather, it will be the level at which the incremental benefit from pollution abatement equals the incremental cost; in other words, that level at which the net benefit from pollution reduction is maximised. In practice, optimal pollution levels have proven difficult to determine with such precision. Targets have instead tended to be set from a rougher expectation of benefits exceeding costs. Such targets are known as 'arbitrary standards', although in most cases they have some objective basis.

The underlying cause of excess pollution is a lack of enforceable private property rights in environmental resources. In some cases, it is possible to achieve a 'pure' market solution by the government allocation of property rights (for example to a stream or forest) as a basis for subsequent negotiation among the parties concerned. But for the 'big' pollution problems -- involving many people and/or resources in which private property rights cannot easily be created, like the air or the sea -- pollution control cannot be left entirely to market forces. Some government intervention is called for, and the task is to determine the most appropriate form and extent.

Economic theory suggests that policies which use price incentives to attain pollution targets are generally superior to regulatory controls in terms of the costs of meeting the desired standard. This is because they allow greater flexibility in individual responses, according to the relative costs of taking action. However, when questions of effectiveness and equity are taken into account, some individual measures will prove more suitable than others and combinations of measures will sometimes be needed. Both theory and experience suggest that there is no uniquely correct choice of instrument which applies in all circumstances.

In practice, pollution control legislation has traditionally made greater use of `command and control' than ‘economic' instruments. As noted in Appendix D, there are a number of possible reasons for this, ranging from ignorance, to perceptions that regulatory controls are easier to enforce and monitor, or ethical concerns about providing ‘rights to pollute’. In recent years, however, there has been growing recognition of the advantages of economic instruments and a significant rise in their application (see Appendix D of this report, and Appendix 3 of IC 1991c).

In attempting to relate some of this theory and experience to greenhouse, it needs to be borne in mind that an enhanced greenhouse effect differs in important respects from a standard pollution problem. Some of the more important special features include the following.

Complexity and uncertainty

Greenhouse is a very complex phenomenon, all of the interrelated aspects of which are attended by major uncertainties. Unlike many pollution problems, cause and effect are not well defined; as already shown, it is not even certain that an enhanced greenhouse effect is a reality, let alone the extent of its impacts. The possibility of climate `surprises', outside the predictions of the IPCC group, cannot be ruled out, however, and some take this to require a cautious approach to standard setting and instrument choice.

Global scale

Compared with standard pollution problems, there is a major difference in scale. Greenhouse is a global phenomenon. What is relevant to the prospects for climate change is the concentration of greenhouse gases in the world's atmosphere. This means that effectively addressing an enhanced greenhouse problem would require joint action by sovereign nations. Given that there is no international equivalent to the coercive power that a national government can apply within its borders, this implies a need for global consensus on emission reductions. Perceptions of national interest in each country thus become important.

This in turn raises two potential sources of difficulty in choosing appropriate policy instruments:

- a global agreement on emissions reductions would have to address perceived problems of equity between nations in different economic circumstances; and

- the scope for ‘free-riding’ would need to be overcome. A nation could hope to avoid the costs of reducing its own emissions, yet enjoy any climatic benefits arising from the actions of others.

Dynamics

There is an important difference in timing between an enhanced greenhouse effect and standard pollution problems. Emissions into the atmosphere now have consequences for concentrations which extend over long periods of time, from which any climatic consequences would follow only with considerable delay. This means that problems of intergenerational equity arise. Business as usual may mean the current generation imposing costs on future generations. Action now would mean incurring costs now to avoid anticipated future damage.

Diverse sources

The greenhouse effect involves several greenhouse gases, which have different origins and which vary in their global warming effects. Knowledge of the rates of anthropogenic emissions, and understanding of other sources and sinks, varies across the gases. Costs of action also vary across the gases but little is currently known about this.

The major greenhouse gas, carbon dioxide, is the one about which most is known. It is known that its dominant anthropogenic source is fossil fuel combustion, and that knowledge of the quantity of a particular fossil fuel burned is, to a reasonable approximation, knowledge of the amount of carbon dioxide released. However focusing on one contributor to the greenhouse effect could disadvantage some industries and countries, and may have perverse effects on emissions of other greenhouse gases.

3.2 The range of policy instruments

The implementation of a consensus target, as specified in the reference, could draw on a range of instruments at both the international and national levels. These are a subset of those mentioned briefly above in relation to pollution control. In particular, a `pure' market solution is not applicable in this case. The relevant instruments can then be divided into four broad categories:

- *Command and control.* As noted, this involves regulations, or direct control, of greenhouse gas emissions. It could take two main forms:
  - specification of allowable emission levels (either in absolute terms or as percentage reductions);
  - specification of production processes and/or machinery and equipment.
- *Market-based incentives*. These include policies which impact on the costs of production and/or output prices. There are three main possibilities:
  - taxation, involving either direct taxation of emissions or taxation of output or inputs associated with emissions;
  - subsidisation of emission reductions, either directly or through subsidies for the use or development of particular technologies;
  - allocation of emission permits which would be tradeable among current and potential greenhouse gas emitters and would thus attract market prices.

- *Information dissemination.* This category covers education and suasion (through training courses, publications and advertising) to change behaviour by increasing awareness among producers and consumers.

- *Government provision or financing of sinks.* This includes forestry plantations, agricultural techniques etc., and differs from the other instrument classes in that it is not directed to emission reduction at source.

Various combinations are possible. Regulation of processes or equipment could, for example, be combined with subsidisation, and adopted concurrently with a publicity campaign. Emissions taxation could be used to finance public financing of sink enhancement.

Most of these instruments could be applied internationally, as well as nationally. For example, global agreement to reduce emissions by 20 per cent could be applied as a series of regulations in individual countries, by an international tax, by a series of domestic taxes, by internationally traded permits, or by permits tradeable only domestically. Of course, domestic law in individual countries will normally be required to give effect to any international agreements to reduce emissions.

Each approach would achieve a global outcome with quite different effects on individual countries. A series of regulations, for example, would need to specify targets for each country, whereas under an internationally tradeable permit regime emissions levels for individual countries would not be specified in advance. Those levels would be the outcome of trading and, in all likelihood, would differ from country to country depending on the relative costliness in each country of reducing emissions. Thus, the costs to individual countries would also differ under different policy approaches. Further, those costs would depend upon what, if any, revenue transfers (subsidies) occurred between countries -- for example, as a result of sale of tradeable permits, or redistribution of taxation revenue. (This is discussed further in Section 3.4, below.) Which approach is best? The answer depends upon the criteria applied.

3.3 Criteria

As noted previously (and discussed in more detail in Chapter 7), international negotiations are in progress to attempt to achieve a consensus on greenhouse gas control. At this stage, it is uncertain what policy instruments a consensus would specify, and the basis on which they would be applied, since little international attention appears to have been given to this matter so far. Obviously, a range of ‘practical’ considerations will enter into these negotiations and will affect the final outcome. Not the least of these would be the relative bargaining strengths of the various countries.

In assessing the ‘theoretical’ merits of the various possible policy instruments, it is necessary to establish relevant criteria. Possibilities include:

- *Efficiency.* An efficient instrument is one which achieves its objective at the lowest possible resource cost.

- *Dependability.* This concerns the degree to which an instrument can achieve the desired target, both in the short and long run.

- *Information requirements*. Instruments differ in the amount of information required for their effective use by a regulatory agency.

- *Ease of monitoring and enforcement*. Monitoring is needed to judge compliance, and in some cases to assess payments. Enforcement problems arise if non-compliance is detected. Monitoring and enforcement are not costless and require appropriate information.

- *Flexibility.* The instrument should be capable of achieving its goal in changing economic circumstances. Some instruments may need frequent modification as circumstances change.

- *Equity.* This has to do with whether the costs and benefits of pursuing the target are appropriately distributed among and within nations, according to their contribution to emissions and their economic circumstances.

- *Continuing incentive.* An instrument might be preferred if it provides an incentive to seek to reduce emissions further over time.

These criteria, while usefully distinguished, are not mutually exclusive. A broad interpretation of ‘efficiency’ would encompass criteria relating to information, monitoring and enforcement, flexibility and continuing incentive. And an instrument's dependability in practice also depends on scope for monitoring and enforcement.

Further, which criteria should be given prominence depends upon the point of view of the assessor. The Industry Commission Act requires the Commission to give some primacy to criteria relating to economic efficiency and the interests of the Australian community as a whole. Others may be more concerned about international equity issues, for example, and so would be more concerned with criteria bearing on the distribution of costs and benefits among nations.

Before evaluating the various possible policy instruments against these criteria, some amplification concerning their relevance to an enhanced greenhouse effect can be made.

Efficiency

Put simply, the efficiency of an instrument indicates its ability to provide the desired level of abatement at the least cost in terms of national production foregone. As noted above, the total cost can comprise a number of elements in addition to those costs borne directly by emissions sources, including information, monitoring and enforcement costs.

In emphasising the importance of the efficiency criterion, Baumol and Oates (1979, p. 237) have observed:

> It is all too tempting to decry the economist's preoccupation with `mere' dollars and cents, when the issues at stake for environmental policy are so important for the health and welfare of the community. Yet efficiency and economy in environmental protection measures are obviously important ... Each time we institute a wasteful measure for the protection of the environment when a more efficient alternative is available, we effectively undercut some other valuable service. The problems of society are surely too urgent to permit that sort of casual misuse of critical resources.

Clearly a major obstacle to getting an international consensus along Toronto lines is concern about costs, both among and within nations. An efficient instrument would reduce the costs of meeting a given emissions target and, in this way, could make stringent targets more achievable and politically acceptable.

A number of participants in this inquiry stressed the importance to a cost-minimising response by Australia of a ‘comprehensive’ agreement, covering all greenhouse gases. The Australian Government's interim planning target calls for reductions in all these gases. Just as allowing different responses by different producers of a greenhouse gas can reduce overall costs, so too could a program which allowed trade-offs among gases. As noted below, however, there could be some difficulty in monitoring and enforcing a comprehensive agreement.

Not all components of the costs incurred with the different instruments change in proportion to the total. For example, one instrument may be less efficient overall than another, yet have lower administration costs. This may be one reason why regulatory measures have been favoured in the past.

It is also important to note that the instrument that is most efficient globally (minimises global costs), might not be that which minimises costs for Australia. For example, as noted later, a global tax would have different cost implications for Australia depending upon the tax base and how the resulting taxation revenue was distributed among countries. Similarly, an efficient Australia-wide instrument might not minimise the costs of each of the States.

Dependability

In a general pollution context, the importance of dependability as a criterion depends upon the toxicity of the pollutant, the time available in which to achieve the desired result, and the degree of confidence in the chosen target itself.

As noted, there is great uncertainty surrounding many aspects of an enhanced greenhouse effect and the present ‘Toronto-type’ targets are in the nature of ‘arbitrary standards’, there being no precise scientific or economic basis for them. Further, as the targets are expressed as a percentage of 1988 emission levels, meeting them implies ever-increasing reductions below emission levels at business-as-usual rates of growth. Even if those targets can be met, atmospheric concentrations of greenhouse gases will continue to increase for some considerable time. In the case of the Toronto targets, which relate only to carbon dioxide (unlike the consensus form referred to the Commission), ameliorating a continuing build-up of concentrations would require lower absolute emissions levels than required by Toronto.

These factors suggest that there could be little value in aiming for precise dependability, in meeting the Toronto target, at the expense of other criteria such as efficiency. Rather, an instrument that achieved results in the `right ball park' would seem to be satisfactory. Over time it could be varied so that the chosen target was more closely achieved.

In any case, whatever policy instrument is chosen, there could be cost advantages from phasing it in -- some degree of dependability would be sacrificed, in the initial years, to reduce adjustment costs (see Section 6.2).

Information requirements, monitoring and enforcement

To be effective, policy instruments must be based on reliable information, and be capable of monitoring and enforcement. (As mentioned, these criteria overlap with efficiency and dependability, broadly defined.) The previous discussion of the special features of an enhanced greenhouse effect suggests that they may be critical to the achievement of an agreed target. This is relevant not only to instrument choice, but perhaps more importantly to the gas coverage specified in an agreement. As noted above, a comprehensive agreement covering all greenhouse gases would in principle be the most efficient. Nevertheless, the Toronto accord singled out carbon dioxide, presumably on the basis of informational considerations.

Carbon dioxide

As there is relatively good knowledge about anthropogenic sources and sinks of carbon dioxide, adequate information is available on which to base a reductions program for carbon dioxide (to the chosen target). Monitoring and enforcement would be required whatever instrument was chosen, however. For instance, the monitoring agency would need to check that a source was not producing more emissions than it was allowed under regulation, or had permits for. In the case of a tax, emissions levels would need to be monitored so that the amount of tax due could be calculated. Similarly, penalties would need to be applied if emissions were excessive, or tax evasion practised.

In principle, each point source of carbon dioxide emissions would have to be monitored. However, in practice, a direct physical relationship will often exist between inputs (particularly fossil fuels) to a production process and carbon dioxide emitted. In these cases, administrative savings might be gained from monitoring inputs, rather than outputs. For example, despatches of gasoline from the relatively few refineries could be monitored instead of the carbon dioxide output by millions of individual vehicles. Costs would be minimised, particularly as those despatches are presently monitored for excise tax collection purposes. Monitoring of inputs could conceivably be feasible under each broad type of instrument. For example, input quantities could be regulated, inputs could be taxed, or tradeable permits applying to inputs could be established.

Obviously, in cases where a direct physical relationship between inputs and carbon dioxide emissions did not exist, such administrative cost savings measures would not be available. Further, carbon use in production cannot always be used as a proxy for carbon dioxide emissions. That would, in the case of a tax for example: tax carbon which does not convert to carbon dioxide, as in the production of some plastics; and omit to tax carbon dioxide emissions which do not arise from carbon use, such as some emissions from the production of cement -- in such cases, however, those emissions could be taxed separately, being figured from knowledge of the quantity of relevant inputs used.

As noted by the United Mineworkers' Federation of Australia, a danger with using carbon inputs as a proxy for carbon dioxide outputs is that it could dampen incentives for the development of cost effective ways of sequestering carbon dioxide, for example through its removal from chimney stacks or the development of more effective natural sinks. To overcome this problem, some degree of exemption would need to be made for those firms which employed such measures to reduce emissions.

Methane and nitrous oxide

Scientific knowledge about anthropogenic sources and sinks of methane and nitrous oxide is far from complete (see Chapter 2 and Appendix C). This rules out at present any far reaching measures aimed at reducing anthropogenic emissions of those gases to particular targets. For two reasons, however, this problem is not as serious as it might otherwise be: first, methane and nitrous oxide account for only the minority of the global warming effect of anthropogenic greenhouse gas emissions -- over a 500-year integration period, for example, carbon dioxide makes up 81 per cent of the warming (see Table 2.2). Second, more partial reductions measures can be used where they are capable of monitoring and enforcement and are cost effective compared to the reduction of carbon dioxide emissions. For example, it might be relatively efficient to monitor and enforce regulations limiting leakage of methane from gas production fields and from pipelines. Such reductions should, of course, count towards the overall reductions target.

Equity

There are many equity questions associated with the greenhouse issue. Aspects of equity concern the distribution of costs and benefits between different generations, between different countries, and between groups within countries at particular times.

Policy instruments differ as to their implications for the distribution of the costs of pollution reduction. If emissions are taxed, polluters pay governments which can use the revenue for a variety of purposes -- for example to channel funds to developing countries, to reimburse the poorer members of society, or to reduce other taxes. Such revenues do not arise with command and control approaches. With tradeable permits governments could initially sell the permits, and get revenue, or they could issue them free, in which case an allocation rule has to be decided.

In establishing instruments to reduce greenhouse gas emissions, therefore, decisions would have to be made on such matters as the allocation of the global reductions target between countries, whether a tax should be production- or consumption-based, whether taxation revenue would be redistributed among countries, whether permits would be tradeable internationally or domestically, and how permits would be initially allocated. These matters, which all impinge upon equity, are discussed briefly in the next section, and also in various other parts of the report.

A decision to exempt emitters of methane and nitrous oxide from reductions action could be regarded as inequitable by producers and users of products which produce carbon dioxide emissions, such as coal. In addition, as noted above, such a decision could forego some of the possible efficiency advantages of a comprehensive reductions program.

It is important to note that, whatever the initial distribution of costs of a policy instrument designed to reduce emissions, market conditions will affect their final incidence. For example, a tax on emissions associated with the manufacture of a product will be partly passed on to purchasers of that product. A tax on a final consumption product such as petrol, may be partly passed back to petroleum retailers, wholesalers and refiners. Similarly, costs associated with command and control instruments, and with tradeable permits, will be redistributed among different community groups between countries, and within a country.

Such redistributional effects complicate analysis of equity considerations. Such analysis needs to include, for example, examination of the final incidence of cost, and the use to which any taxation revenue was put.

3.4 Assessing possible instruments

By and large, participants' comments centred around whether an emissions reduction program could be justified, rather than on the `best' policy instruments for making required reductions. Nevertheless, some comments about policy instruments were given by participants.

Organisations associated with the production or use of coal generally opposed the use of carbon taxes. Either they opposed reductions outright, or they considered that any reductions program should comprehensively cover all sources of carbon dioxide and the other greenhouse gases such as methane and nitrous oxide.

Some participants recognised ‘theoretical’ efficiency advantages for market-based instruments. The New South Wales Government:

> favours the use of market mechanisms over command and control mechanisms where appropriate on the grounds of greater efficiency ... If properly applied, market-based mechanisms will tend to reduce greenhouse gas emissions in a more cost effective manner than direct regulatory intervention. This is because producers and consumers can act independently in accordance with the price mechanism to choose the most cost effective method of reducing emissions. In contrast, command and control approaches tend to be less flexible and may impose indiscriminate additional costs on the community, particularly if the responsibility for reducing emissions does not fall first upon those who can do so at least cost. (Sub. 100, p. 21)

ICI Australia Ltd stated that it was:

> opposed to economically and technologically inflexible direct command policies ... tradeable permit systems appear to have advantages if circumstances warrant policy intervention. (Sub. 45, p. 8)

Other participants considered that command and control policies had a part to play. The Australian Conservation Foundation said:

> In general, the approach which would lead to the quickest and most efficient achievement of environmental objectives should be used. In most cases, we believe that this will involve a mix of regulation and the use of economic or market instruments. (Sub. 46, p. 38)

Similarly, the Department of the Arts, Sport, the Environment, Tourism and Territories said:

> DASETT considers that the coordinated application of regulation and market measures in addressing the greenhouse issue is the most appropriate course. DASETT's recently completed studies on Tradeable Emissions as a Greenhouse Response Measure ... and Carbon Tax as a Greenhouse Response Measure ... both highlight the complexity and difficulties of applying market measures (such as a carbon tax or tradeable emissions permits) at the national and international levels. These reports also stress the view that economic instruments and regulatory measures are most cost effective when applied in a complementary manner. (Sub. D154, p. 6)

Command and control

A regulatory approach at the international level would involve setting emissions targets for each nation consistent with the global target. Economic theory suggests that this would not, for the world as a whole, be the least cost way of realising that target. This is because such an instrument does not allow the marginal costs of abatement to be equalised between countries. If monitoring and enforcement problems could be overcome, however, it would be a relatively dependable approach, ensuring that the global target, as the sum of the national targets, would be achieved. As noted above, however, there might be little value in aiming for precision in the greenhouse case.

Such a consensus could take one of two subforms. It could specify the means by which each participating nation was to realise its target, or it could leave this for decision by each nation. The latter would involve smaller perceived infringements of national sovereignty, and would be better from an efficiency viewpoint because each nation would be able to adopt policies which best suited its circumstances. Prescribing command and control at the national level could limit the use of potentially more effective measures such as information dissemination, market-based measures, or development of greenhouse gas sinks.

A central question with this type of consensus would be the allocation of the global emissions total among nations, which in turn determines the distribution of the global costs of abatement. This would be seen as a matter of equity, and would strongly affect the costs to nations of participating. A simple program of equal proportional cutbacks for all nations would be seen as unfair to developing countries which are, by and large, dependent on fossil fuel use for industrialisation. It has been suggested that emissions allocations be based on population size. This would favour large developing nations but be disadvantageous to small nations, such as Australia. Other means of allocation, such as by land area, would be less damaging to Australia, but more damaging to small densely populated countries.

Emissions taxation

Global emissions taxation would involve agreement to tax greenhouse gas emissions at uniform rates per unit. Economic theory suggests that such a consensus, by equalising marginal costs of emissions abatement, would achieve some level of emissions reduction at the least cost possible to the world economy. However, as London Economics observed, this approach would not guarantee the precise attainment of the global target:

> By and large, taxes are not levied on products or activities with a view to regulating the quantity produced in precise ways. (Sub. 89, p. 13)

As noted above, lack of dependability may not be a major fault but if precise attainment of the target was considered necessary, a trial and error process would be required. Even then, tax rates might require continual adjustment as relative input and output prices changed. Such a continual revision process could bring efficiency losses through adjustment costs and uncertainty. Set against this, as Pearce (1991, p. 942) notes, carbon taxes have the advantage that they ‘can be easily modified as new information comes to light’. This could be important in the greenhouse case.

This type of policy instrument could also take two forms. The tax could be levied by an international agency, with the revenues accruing to it, or it could be levied by nations within their borders. An international greenhouse gas emissions tax agency would be the recipient of very large revenues. This would involve perceived losses of national sovereignty. The use of the revenues would be contentious. A rule which allocated them to nations on a per capita basis could have similar implications to allocating emissions quotas on this basis in terms of the international distribution of, post tax, costs.

If tax collection were to be left to individual nations the problem of deciding upon a revenue sharing rule would be avoided. There would, however, be problems in devising systems for the harmonisation of national tax regimes -- in other words, how to achieve equality between nations by allowing for the existing taxation regimes in the various countries. In the case of carbon dioxide emissions from fossil fuel combustion, some problems could be avoided by taxing fossil fuels themselves at rates based upon their carbon content. In this case, an international consensus could require national taxation of fossil fuel consumption or of fossil fuel production. The international incidence of taxation would vary according to the tax base adopted. As a major fossil fuel producer and exporter, Australia could expect to be differentially affected as between the two tax bases.

Some of these dependability, efficiency and equity issues would also arise if Australia were to apply emissions taxation on a national basis rather than as part of a global taxation instrument. For instance, decisions would still be required about: the stage in the production chain to levy the tax, for example, whether it would be on production or consumption; whether it should be a new tax or should replace existing taxes (such as on fuels); the rate at which it should be levied; and how the revenue collected should be used.

Subsidisation

A potential way of reducing emissions would be for governments to subsidise reductions, either directly or through financial assistance to use or develop particular technologies. Economic theory suggests that some forms of subsidisation could achieve reductions on a least-cost basis. As with taxes, however, a subsidisation approach could not guarantee precise attainment of the global target. Further, to remain efficient, subsidies would need to be varied as relative input and output prices changed.

In practice, it is difficult to imagine governments agreeing to an international consensus which specified subsidisation as the instrument to be used. A basic problem is that this would be seen to violate the `polluter pays principle'. Another is the difficulty of raising the vast amount of revenue required. Yet another problem would be harmonising such subsidies, on a global basis, with existing taxation regimes. Nevertheless, as discussed, it is likely that an international consensus would call for financial transfers -- subsidies -- from developed to developing countries.

Tradeable permits

Economic theory suggests that tradeable permits would be dependable and would realise the target for emissions reduction at least cost (in markets with a reasonable degree of competition). Further, they would avoid the harmonisation problem discussed above for emissions taxation. The central question with a consensus of this form would again be the initial allocation of permits across nations. This would raise problems of perceived equity similar to those involved in a command and control approach.

While tradeable permits are thus very attractive in principle, there are some difficulties to overcome in devising a workable system. The tradeable permit itself would have to be adequately defined so that permit holders had confidence in the value of their property right -- otherwise, trading would not occur. In addition, it would be desirable to preserve some flexibility to vary the total quantity of permits as new information about greenhouse came to light. To be sure that the desirable properties obtain, it would be necessary to allocate permits to individuals and firms rather than to countries. Otherwise, for example, a country could use the less efficient instrument of quantity regulation to ‘allocate’ quota within its borders. But this raises some obvious national sovereignty problems and in practice permits would probably have to be allocated to and traded by governments. It could then be left to countries to choose their own method of keeping emissions to the level of their permit holdings in the expectation that they would choose more efficient, rather than less efficient, instruments. Like taxes, tradeable permits could involve movements of revenues between countries.

At a national level also, equity considerations would arise in the initial allocation of tradeable permits. Whether they should be auctioned, or given away, for example, is more an equity than an efficiency issue if the market is a viable one.

In recent times, tradeable permits are being used more extensively in environmental matters generally. (Some examples are discussed in Appendix D. Also see Appendix 3 in IC 1991c.) For example, in Australia, transferable quotas are being used in the southern bluefin tuna fishery. Australia has also recently established a system of licences and quotas to control manufacture, export and import of CFCs and halons, and products containing those substances. Quotas were issued in line with 1986 activity levels, and charges are payable quarterly to recoup the administering department's costs. Quotas are tradeable, and trades have taken place.

It is apparent that there is growing recognition by policy makers in Australia and overseas of the advantages of tradeable permits. This growing acceptance of the merits of price incentive instruments such as taxes and tradeable permits was also reflected in recent OECD workshops on the applicability of these instruments in reducing greenhouse gas emissions.

Information dissemination

It was noted that one of the characteristics of the greenhouse issue is lack of knowledge about the impacts of 'business as usual'. This not only makes it very difficult to set an appropriate standard, but also to achieve any self corrective behaviour by market participants. Such a response could be engendered to some extent by wider public knowledge of the external effects of production and consumption decisions. However the `problem of the commons' (essentially, the incentive to free-ride and ignore any external costs) would remain even with perfect information about cause and effect.

Information may be a more useful corrective measure where it can be used to show firms and households how they can reduce emissions with a payoff to themselves. Lack of information (ignorance) is often cited as a cause of wasteful energy use, for example. This additional or compounding form of market failure could be most directly and thus efficiently addressed by provision of information.

The effectiveness of such an approach will depend on the extent of ignorance, how receptive people are to education (or suasion) and the costs of information dissemination. Resources would need to be expended in assembling and processing information, training, publication, advertising and so on. These costs could be significant, particularly if individuals or households are targeted.

Government provision or financing of sinks

As noted above, it is desirable for policy instruments not to stifle incentives for industry to research and develop ways of sequestering carbon dioxide and other greenhouse gases in a cost effective manner.

In addition, there may be a case for government funding or additional government funding for existing known sinks, for example to expand the areas of forests. At this stage, the potential of sinks to take up the quantities of carbon dioxide (and other greenhouse gases) required to reduce net emissions to the Toronto target is rather problematic. Argument for such additional government funding would need to be based on cost effectiveness relative to direct emission reduction instruments. But recognisance would have to be given to any possible adverse consequences which could arise from the greater use of sinks -- for example, expansion of forests could adversely affect food production potential.

3.5 Concluding remarks

This brief review of the policy measures available to implement an international program to reduce greenhouse gases suggests that market-based measures have distinct advantages over command and control. Tradeable permits in particular have most attraction as, in principle, they combine the best features of taxes and quantitative controls in meeting efficiency and dependability criteria. However, while recent developments in other areas suggest that governments have become more cognisant of the relative cost effectiveness of market-based instruments, it is by no means clear that an international consensus would use such instruments, at least at the international level.

Clearly, for a potential consensus participant, the issues that arise in considering the implications of alternative ways of implementing a consensus target are complex. What is clear is that for any nation the costs of participation would vary with the form of consensus. Less general statements require a basis in quantitative modelling of the international economy, to analyse effects on trade patterns, and of the national economy of interest, to analyse responses to trade effects and the domestic policies adopted as part of the international agreement. Quantitative modelling is necessary because policy action would induce interrelated effects of differing signs and sizes in a very complex system -- the global economy. To judge the direction of the final effect on some variable of interest, such as Australia's national income, would be a task beyond the capabilities of purely qualitative analysis, or intuition.

4 BENEFITS OF AN INTERNATIONAL CONSENSUS

The objective in seeking to reduce greenhouse gas emissions is to reduce the global warming for which they are thought to be responsible. The basic proposition is that if global temperature increases can be contained, the detrimental effects which a consequent climate change may entail can be reduced. The benefits of an international consensus to reduce greenhouse gas emissions can thus be seen as the benefits of reducing climate change. However, the existence of those benefits is conditional on there being a causal link between greenhouse gas emissions and climate change, and an estimate of their magnitude requires, in turn, knowledge of the direct and indirect effects any climate change would have.

In this report the discussion of benefits is associated with reducing the detrimental effects of climate change, while the discussion of costs relates to the cost of taking action to reduce the emission of greenhouse gases. This should not be taken to imply that there are no benefits, other than those related to climate change, from limiting the emission of greenhouse gases, or that a warmer climate would not be beneficial for some. Indeed, for some regions or activities within regions, a warmer, carbon dioxide enriched climate is likely to be advantageous.

The Commission's terms of reference ask about the benefits for Australian industry. If adverse climate change is reduced, or avoided, there may also be benefits to Australia directly, as, for example, in the context of health. But, as noted in Chapter 2, there are no reliable forecasts of climate impacts at even a broad regional level on which to base an assessment of benefits to Australians. Much of the discussion in this chapter therefore relates to the possible global impact of climate change, with the caveat that even at this level there is a high degree of uncertainty about how the emission of greenhouse gases will affect the physical, social, economic and environmental features of the planet.

4.1 The nature of the benefits

The benefits which could result from avoiding climate change take a variety of forms which range from the direct lifestyle benefits of not having to adapt to a changing weather pattern, to the avoidance of the total submersion of large tracts of land. Some benefits would be very difficult to quantify. For example, there are both theoretical and practical problems involved in placing a value on flora and fauna which may not survive a rapid change in climate or habitat, and in valuing the benefits (or costs) to human health and lifestyles of avoiding climate change. These are discussed further in Section 4.2.

Other benefits may have an identifiable value at some time in the future, but because the time at which they would accrue is indeterminate, they too would be difficult to quantify for comparison with the current cost of securing them. The time dimension of climate change is important in terms of both its impact and the assessment of benefits from avoidance.

The term 'impact' is commonly used in discussion of the effects of climate change, and a change in the frequency of `extreme events' such as tropical cyclones would certainly impact on the regions affected. However, for increases in temperature, rainfall and sea level, use of the word impact is potentially misleading. Rather, there would be a gradual increase in global mean temperature, the effects of which could take decades to become noticeable because of the large interannual variability of climate; similarly for the benefits of reducing greenhouse gas emissions. There would be a considerable delay between the time that action was taken to reduce greenhouse gas emissions and the time that any benefits in the form of an influence on the climate would accrue. This is one reason why the benefits of reducing greenhouse gas emissions are so difficult to measure.

The following discussion examines some of the areas where the avoidance of climate change has the potential for economic, social and environmental benefits.

Agriculture

Increases in the concentration of carbon dioxide in the atmosphere, any climate effects apart, are likely to have a significant, beneficial effect on plant growth, although the growth response would depend on the species. Plants are generally categorised by scientists as belonging to either a ‘C3’ or ‘C4’ group, according to their biochemistry. It is widely accepted that plants in the C3 group (wheat, barley, rice, soya beans, root crops and legumes) would benefit more than plants in the C4 group (maize, sorghum, millets, sugarcane) from an increase in atmospheric carbon dioxide. Furthermore most of the world's troublesome weed species are C4 plants which occur in C3 crops, suggesting that C3 crops would be further advantaged.

The beneficial effects of higher levels of carbon dioxide in the atmosphere could be more than offset by the effects of a warmer climate. Since the productivity of agriculture is directly related to temperature and soil moisture, heat stress and reduced soil moisture caused by a warmer climate would be detrimental to agriculture. If the growing time for plants was reduced they may develop less before maturity and have lower yields. Some crops are limited in their growth patterns by the incidence of frosts, snow and bushfires. Some varieties of stone fruit for example require a frost to set the fruit.

The large scale impacts of any global warming would vary substantially between and within regions. In areas where lack of soil moisture is limiting production (low rainfall areas) increased evaporation may more than offset increased rainfall, in which case there would be positive benefits in avoiding climate warming, but this would not be a universal outcome. In regions where water resources are currently more than adequate for agriculture, and production is limited by low temperatures, policies to avoid climate change would be detrimental.

The effects of global warming on agriculture are usually related to the present location and pattern of production, but the likelihood of agriculture migrating or adapting in response to a gradually changing climate should not be ignored. The scope for such adjustment, and hence its cost, would depend on the rate of any climate change and may be less for some horticultural activities than for crops or pastures.

Forestry

Climate change would affect forests directly through changes in temperature and precipitation regimes. As noted previously it is not possible to accurately forecast the regional variations of these parameters should the climate warm. However GCMs do provide a ‘first guess’ at possible changes. Using the forecasts of temperature and precipitation from the Geophysical Fluid Dynamics Laboratory GCM the possible changes to vegetation globally, caused by an effective doubling of carbon dioxide, have been investigated (Leemans 1989). He reports:

- a 20 per cent decline in vegetation in high latitude areas classified as boreal forest, tundra and polar desert;

- an increase in warm climate savannas at the expense of subtropical forests, warm deserts and t ropical rainforests, in that order; and that

- 35 per cent of the area described as ‘closed forest life zones’ will be located in climatologically inappropriate areas after warming.

The interaction of human activity and any climate warming also poses a potential threat to the world's forests. Current estimates indicate that annually approximately 1 per cent of the Earth's vegetated area is being deforested and another 1 per cent degraded. Efforts to restore forest areas in the face of climate change could prove unsuccessful because it is in the regeneration phase that forests are most sensitive to their environment.

Apart from the direct climatic effects of changing temperature and precipitation, climate warming could also lead to other changes which could affect the viability of forests:

- Interactions between a warmer climate and air pollution, particularly raised ozone levels, would increase the stress on plants. Also, increased rainfall carrying the pollutants from the burning of high sulphur content coal could lead to the further acidification of sensitive soils which already threatens forests in Europe and North America.

- The distribution of insects, pests and their associated predators is closely related to climate. Damage to northern hemisphere forests by spruce budworm and bark beetles has been attributed to recent occurrences of warmer weather. Forest monocultures, typical of managed forests, are considered to be more susceptible to disease infestation in warmer climates (IPCC WG II 1990).

- The possibility of fire damage may increase with elevated temperatures unless rainfall increases substantially to offset losses due to increased evapotranspiration (the transfer of water vapour to the atmosphere by the combined action of transpiration and evaporation).

Biological diversity

It is estimated that the world currently hosts some 10 million species, and that human activity is reducing this number 1000 times faster than would occur from the action of natural forces (EPA 1989). Loss of species can be brought about by changes in habitat, predator/prey relationships and physiology. It is difficult to fully document the occurrence of species loss because approximately 70 per cent of today's species are thought to remain uncatalogued (Cline 1991b).

The greatest concentration of species diversity is found in tropical rainforests. These forests account for only 7 per cent of the land area yet contain at least 50 per cent of all species (IPCC WG II 1990). Because the plant species which form tropical forests have evolved in areas where the seasonal variations in rainfall and temperature are slight, they generally have very narrowly prescribed physiological requirements. Any climate change which threatens tropical rainforests threatens to reduce significantly the diversity of species.

The possible poleward migration of mid-latitude forests with climate warming could threaten species if migratory paths were not available to species which are dependent on these forest habitats. Climate warming could also pose a hazard to the mid-latitude mammalian fauna which require moderate temperatures for their breeding cycles. The rate at which climate could change is clearly important to the ability of species to adapt.

One participant in this inquiry said that increased atmospheric concentrations of trace gases like carbon dioxide could change the palatability of plant browse which could lead to changes in the availability of food for some vertebrate herbivores and affect the quality of their habitat (Williams sub. D153, p. 4).

The benefits which would accrue from avoided species loss may be valued in one of four ways:

- the use of current species, for example in the production of medicines;

- retaining the option to use the species for future production;
- the fact that the existence of the species has some inherent value for some people (just as a work of art has an inherent value); and
- the role of the species, possibly now unknown, in the functioning of the biosphere as a life support system.

Assessing these non-market values which arise from biological diversity is not a straightforward activity (see Appendix D).

Water resources

An adequate supply of water is essential for both natural ecosystems and a wide range of human activities. An important factor in regional water supplies is the `run off', which is the water available for use outside the immediate rainfall area. While the implications of global warming on regional climate are unclear, regional water supplies will be altered if there are changes to the regional climatologies of air temperature, precipitation, cloud cover, wind speed, humidity or atmospheric carbon dioxide concentration.

A survey of possible regional impacts of global warming on run off is presented by IPCC WG II (1990). This survey uses a variety of scenario data largely drawn from GCM double carbon dioxide simulations and to a lesser extent from palaeo-climate studies. While the survey does not reveal any conclusive trends, a number of results emerge:

- where both temperature and rainfall increase, run off can either increase or decrease depending upon the balance between increased evaporation and increased available water; and
- in the drier subtropical areas, climate change scenarios generally have higher temperatures, decreased rainfall and substantially reduced run off.

The balance between temperature, rainfall and run off is a delicate one which may be changed by the action of other variables. For example, evapotranspiration from plants is reduced in a carbon dioxide enriched environment. Some researchers have shown that taking this reduced plant water loss into consideration when evaluating water budgets for regional climate scenarios derived from double carbon dioxide simulations can lead to a 40 per cent to 60 per cent increase in run off estimates (eg Idso and Brazel 1984; Aston 1987). One element of controversy surrounding this work is the applicability of the assumption that the carbon dioxide concentration will be doubled when the global mean temperature derived from these simulations is reached. Cline (1991b) argues that the amount of carbon dioxide build-up would be considerably less than two-fold for the doubling of carbon dioxide equivalent of all greenhouse gases, which is the basis for the simulations. He argues that while the equivalent doubling of carbon dioxide is expected to occur around 2030, by then the actual carbon dioxide concentration will have increased from its present levels of around 330 ppmv to only about 440 ppmv. The increases in concentrations of the other greenhouse gases which contribute to the equivalent doubling of carbon dioxide have no effect on the evapotranspiration of plants, thus the increased run off occurring in some simulations may not be observed. This point is also relevant to consideration of the potential effects of climate change on plant growth.

Human health and lifestyle

Because humans are able to build artificial environments they can live in climatic regimes with daily mean temperatures ranging from above 35^{o}C to less than -35^{o}C. Furthermore, most people experience a greater range of temperatures in their daily lives than the potential change in global mean temperature over the next century. Nevertheless global warming could have adverse consequences for human health. The most direct consequence would be an increase in heat stress, particularly among the elderly and very young (see IPCC WG II 1990; Cline 1991b; NHMRC 1991). Heat stress occurs for some people when temperature rises above a threshold level on a certain number of consecutive days. Higher mean temperatures could result in an increase in the frequency of temperatures above given thresholds.

The combined effect of a rise in temperatures and changing regional precipitation regimes would have a variety of consequences for human health. For example the habitats of mosquitos and other disease carriers might change, exposing new populations to the threat of malaria, dengue, and other diseases. If some agricultural communities were not able to adapt to changing climate, nutrition would suffer and community health may deteriorate.

Global warming, should it occur, would lead to changes in regional and seasonal patterns of energy usage. In colder climates the number of days in which heating was required would decline, whereas in warmer climates the use of air conditioning would increase.

Cline (1991b) presents evidence that leisure activities could be affected by rising temperatures, citing skiing as a recreation activity threatened by rising temperatures. Cline (1991b) also notes that outdoor leisure activities in tropical areas may become less attractive in a warmer world, while there would be compensating benefits in cold areas.

Coastal and marine environments

Various estimates of future sea level rise have been made. They are very difficult to compare because they relate to different time periods and make different assumptions about future greenhouse gas concentrations. They usually report both a range of possible outcomes and a best estimate. At the time of the Toronto conference the estimate was for a 30 cm rise, but within a range which extended from 20 cm to 150 cm by the middle of the century. Estimates made since then have generally reduced the upper limit of the range, although wide ranges of possible outcomes are still reported. A recent estimate by Australian oceanographers is for a 15 cm to 70 cm sea level rise by the year 2050 (Church et al. 1991).

The IPCC WG I provided as their best estimates of sea level rise resulting from global warming figures of around 20 cm by the year 2030 and 32 cm by 2050. The range given for the 2050 estimate was from 16 cm to 51 cm. Such a sea level rise would largely result from expansion of warmed upper layers of the ocean, with a smaller contribution coming from water released by increased melting of the polar icecaps and glaciers.

A sea level rise would:

- displace coastal wetlands and lowlands;

- erode shorelines, including beaches;

- exacerbate coastal flooding, particularly during such severe weather events as tropical and mid-latitude cyclones;
- increase the salinity of estuaries;
- threaten freshwater aquifers in low lying areas;
- alter tidal ranges in rivers and bays; and
- decrease the amount of light reaching water bottoms.

Sea level rise would impact on plant and animal life inhabiting the coastal fringe, agriculture, and communities dependent upon fresh water in low lying aquifers, tourism, and the built environment (eg ports and harbours, canal estates, etc.). The precise nature of these effects would be determined by the types of species and human activities inhabiting the changing environments.

Climate change could also affect the operations of the fishing industry. It is possible that a 2^{O}C rise in sea surface temperature would alter fish spawning areas and change their distribution patterns during their maturation phase (IPCC WG II 1990).

Human settlements

The IPCC WG II identified the most vulnerable human settlements as being those exposed to natural hazards such as coastal or river flooding, severe drought, landslides, severe wind storms and tropical cyclones.

The populations of developing countries, residents of coastal lowlands and islands, populations in semi-arid grasslands, and the urban poor, especially in large cities, were said to be the most vulnerable to climate change. According to the IPCC WG II, in coastal lowlands such as in Bangladesh, China and Egypt, as well as some small island nations, inundation due to sea level rise and storm surges could lead to a significant migration of people.

4.2 Quantifying the benefits

Quantification of the benefits of reducing greenhouse gas emissions would require the development of two scenarios. The first would be a 'business-as-usual' scenario in which no action was taken to limit the emission of greenhouse gases. An assessment of the nature and extent of climate change and damage caused by such change would be compared with the damage resulting from the alternative scenario in which greenhouse gas emissions were reduced to some target level. The difference between the two scenarios would be the benefit, or damage avoided, resulting from action to reduce emissions.

The development of these two scenarios would require the assembly of information on the chain of events between the emission of greenhouse gases and climate damage, on the timing of the flow of benefits from emission reductions, and on the value of the two streams of climate induced damage. Each of these is discussed below with attention being given to the elements of uncertainty associated with these important features of an analysis.

Information requirements

Physical effects

The chain of physical events of interest includes the emission of greenhouse gases, their concentration in the atmosphere, the effect of those concentrations on climate, and the impact of climate change on the environment. The uncertainty associated with each of these is summarised in Box 4.1.

To calculate the level of future emissions for the business-as-usual scenario, estimates of future rates of population and economic growth, and of technological change (especially for transport and energy generation) are needed. Such information requirements are common in the field of economic forecasting and do not pose any special difficulty in this case, although confidence in their accuracy for a time period which extends beyond a decade is low.

Box 4.1: **Certainty and uncertainty about greenhouse**

Certainty

- There is a natural greenhouse effect
- Atmospheric greenhouse gas concentrations are increasing as a result of human activities

Uncertainty

According to the IPCC the major scientific uncertainties relate to:
- sources and sinks of greenhouse gases and their chemical reactions in the atmosphere
- the role of clouds in the greenhouse process
- how oceans exchange energy between the Earth and the atmosphere and how they influence the rate of climate change and regional effects
- the role of the polar ice sheets and their effect on sea level in a warmer and wetter climate

Because of these scientific uncertainties there is:

- no firm forecast of the amount of warming to occur as a consequence of the enhanced greenhouse effect
- a low level of confidence in predictions of changes to rainfall patterns even at the most general level
- no confidence in estimates of any aspect of climate change at the regional level
- no evidence that weather variability and extremes of weather will change in the future
- little understanding of how natural systems could adapt or evolve in a greenhouse gas enriched environment

Forecasts over several decades are required for greenhouse analysis. Forecasts of future greenhouse gas emissions under the alternative scenario are much easier to make because the level of emissions at certain times is defined by the targets which have been set, and all that is required is an assumption about the path taken towards those targets, and that the targets are met.

It is at the next steps in the analysis that major uncertainties arise. These relate to the anthropogenic effect which increasing emissions of greenhouse gases have on the atmospheric concentrations of those gases, and the effect those concentrations have on climate. A comprehensive discussion of these scientific aspects of the greenhouse effect is contained in Appendix C and is summarised in

Chapter 2. In brief, relationships between greenhouse gas emissions and concentrations in the atmosphere are very complex, and incomplete understanding injects uncertainty into forecasts of future atmospheric concentrations of the gases. These complexities and uncertainties appear to be minor in relation to those associated with the effect increasing concentrations of greenhouse gases have on the Earth's climate.

Detailed knowledge of climate change at the regional level is an essential prerequisite for an adequate description of the impacts of climate change. Knowledge of global temperature and rainfall change averages is of little use if the changes are not uniformly distributed around the globe, or if other aspects of climate change, about which we have little knowledge, impact on the environment. Yet models used to predict future climate cannot reliably go far beyond forecasting the direction of global average temperature and rainfall change induced by a greenhouse gas enriched atmosphere. They do show that any global warming will be unevenly distributed, with warming being greatest at the higher latitudes and least in equatorial regions. The existing temperature differential between the equator and the poles would thus be reduced. Rainfall is predicted to increase year round in the tropics and high latitudes.

Beyond these quite general estimates, the various models diverge to such an extent that confidence in their predictions is very low. The IPCC WG I reported low confidence in regional estimates based on high-resolution GCM models, even though the estimates referred only to broad ranges of change for temperature, rainfall and soil moisture, and included the whole of Australia as one region. For the Australia region the IPCC reported that the models did not produce consistent estimates of changes in soil moisture, and that the area average estimates for temperature and precipitation hide large variations at the subcontinental level.

More recently Cubasch et al. (1991b), constructed two coupled atmosphere-ocean models by combining one atmospheric circulation model with two different ocean circulation models. The effects of increased greenhouse gas concentrations were simulated in each of the coupled models so created and the results compared. Cubasch et al. report that agreement between the two coupled models can only be found in the global averages, and in their predictions that the middle and high latitudes of the Northern Hemisphere warm faster than the rest of the globe, with some regional cooling in the Southern Hemisphere. At the regional level the difference between the results of the models is reported to be quite large. This is an important finding given the nature of the experiment. It demonstrates the sensitivity of a single atmospheric circulation model to different representations of ocean circulation and highlights the uncertainty which must be attached to estimates of the nature and extent of climate change at the regional level.

An indication of the information required to determine the impacts of climate change can be obtained from the previous section of this chapter which contains a broad description of the nature of the benefits which could arise from taking action to reduce greenhouse gas emissions. For example, for agriculture, knowledge of the response of crop yields to absolute and perhaps seasonal changes in temperature, rainfall, and soil moisture would be required. For crops which are traded, that information would be required for all regions of the globe, since a favourable climate is just one of the determinants of whether and what type of agriculture is practised in a particular region. In the case of wheat, for example, increased yields would not necessarily lead to increased export demand if conditions for wheat growing improved worldwide. Areas could switch from crops to grazing or from traded to non-traded products depending on how world market conditions were affected by the many dimensions of climate change.

In the case of sea level rise, the information requirements range from the extent of shoreline erosion to the effect on the ecology of coastal wetlands. For biological diversity, an important consideration would be the ability of species to migrate or adapt to relatively rapid changes in climatic conditions.

The degree of uncertainty associated with knowledge of the impact of climate change is compounded by the fact that information on two separate levels of climate damage (or the difference in damage between two climate change scenarios) is required, since, if predictions are correct, there would already be a commitment to climate change, whether or not action is taken to reduce emissions.

The timing of the flow of benefits

The nature of the greenhouse effect is such that there are long delays involved in each of the physical processes described above. In Section 2.2 it was explained that the delays are such that the globe may already be committed to some warming even if the most severe emission reductions considered by the IPCC WG I were implemented, and that the potential benefits of such reductions would not begin to be realised until the middle of next century.

Although climate models uniformly predict an average global warming for business as usual, there is little precision in estimates of when that warming will occur. Discussion of dates tends to be in units of decades, rather than years. A major reason for this is a limited understanding of how long it will take the oceans to respond to a warmer atmosphere – the IPCC WG I refers to decades or centuries. Yet every other aspect of the greenhouse effect, climate change and its impacts, is derived from the warming of the atmosphere.

There is thus a great deal of uncertainty about this important aspect of an analysis of the benefits of reducing greenhouse gas emissions.

Valuing climate induced damage

In standard cost-benefit analysis, money values are assigned to physical impacts to obtain cost and benefit flows associated with a project. These flows extend over time and are both reduced to present value terms (discounted) and compared in order to evaluate the project. There are two sorts of difficulty in adopting this approach to the benefits arising from policy to reduce greenhouse gas emissions. The first concerns assigning money values, the second discounting (see Appendix D).

For many of the components of potential benefits, there are no markets in which money values can be observed as prices. Examples are species losses and environmental degradation. Techniques have been developed to generate surrogate market prices, and these have been applied to many environmental attributes. These techniques are surveyed in Appendix D where it is suggested that none is particularly suitable for a greenhouse analysis although the contingent valuation technique, which attempts to value environmental assets, is nominated as the least imperfect.

Contingent valuation analysis typically ascribes values to environmental attributes by conducting surveys to determine how much people would be willing to pay to preserve or prevent damage to specified features of the environment. The technique is limited by the capacity of respondents to perceive adequately the hypothetical situation with which they are confronted and is most relevant when closely related to their own personal experience. In the case of greenhouse, respondents would be required to consider a wide range of complex hypothetical changes to the environment which would not be familiar to them, and which would be more relevant to future generations than to themselves.

The issue of discounting is contentious. Even at low rates of discount, values in the distant future have little impact on current decisions. In the greenhouse context, some see this as meaning that cost-benefit analysis with positive discounting will give insufficient weight to the distant future benefits of climate change impacts avoided by current action. It is argued that the only way to avoid this is to use a zero discount rate, and that this is justified by concern for the welfare of future generations. However, a concern for intergenerational equity does not of itself imply that a zero discount rate is necessary. Future generations may be richer than the current one, notwithstanding potential global warming.

The issues surrounding the choice of discount rate are examined in Appendix D. An important point, of relevance to potential global warming, is that there are two distinct contexts in which the choice is made. One is that of project appraisal, where standard cost-benefit analysis is appropriate, and where what is at issue is project selection on efficiency criteria. A zero discount in this context is clearly inappropriate. A different context is that where what is at issue is the distribution of consumption in aggregate across time and generations -- intergenerational equity. In this context, it is argued that a zero discount rate may be appropriate, depending on assessments of the prospects for continuing economic growth, and on the ethical position to be adopted.

Greenhouse-related matters are complex, because both efficiency and distributional questions are involved. Further, some argue that some of the benefits to be achieved by reducing greenhouse gas emissions simply cannot be made commensurable with costs by monetary valuation. An example would be species extinction. This argument relates to efficiency and equity. It does not require any adjustment to a discount rate. It does imply that decision making using discount rates determined in the usual ways should be subject to constraints. In the case of the species extinction example, it is argued that the constraint would require the avoidance of such in project selection. This approach would be consistent with imposing constraints to ensure sustainability.

For the purposes of the present inquiry, however, it is not necessary to resolve these issues. Whatever the merits of the above arguments, they are in practice overtaken by the inability to identify and quantify the benefits themselves.

Available estimates

The Commission is not aware of any studies which estimate the benefits of taking action to reduce the emission of greenhouse gases within a specified time period to target levels such as those in the terms of reference for this inquiry. As noted above, this would require the comparison of two well defined scenarios for business-as-usual and policy-determined climate change, and the value of their impacts.

A small number of studies do attempt to estimate the potential damage of global warming. They usually relate to a doubling of the atmospheric concentration of carbon dioxide equivalent by some time before the middle of next century and refer to a specific region or activity within a region. Within these parameters they provide estimates of climate damage under one business-as-usual scenario. *However such estimates cannot be equated with the benefit of achieving a Toronto-type emission reduction target (see Appendix C) because they relate to only one of the two streams of potential damage which are relevant to an estimate of benefits*. If increasing concentrations of greenhouse gases cause climate change, action now would not prevent all of that change from occurring because of the long time delays in the climate system. An estimate is also required of potential damage which could not be avoided even with action to reduce emissions.

Of the studies which estimate damage under a business-as-usual scenario those of Nordhaus (1991) and Cline (1991b) are the most ambitious. Each examines the impact on the US economy of the warming associated with an effective doubling of atmospheric concentration of carbon dioxide. The Nordhaus estimates refer to a 3°C warming likely to occur sometime in the second half of the next century, whereas Cline provides two sets of estimates. He argues that because of the time lags associated with warming, the Earth is already committed to some temperature increase and policy action should be focused on avoiding a very long term warming of around 10°C by the year 2250. He provides estimates for that scenario and for another in which global warming of 2.5°C occurs.

The Nordhaus study concludes that the most substantial impact would be associated with the coastal protection required to counter a sea level rise of 50 cm over the next century. He estimates the impact on agriculture to be large, but of indeterminate sign, with changes in temperature, precipitation and carbon dioxide enrichment all having an influence. On the basis of the variables considered, the net damage to the US economy is estimated to be 0.26 per cent of national income. A summary of his results is presented in Table 4.1. The total (central estimate) figure given treats the impact on farms as minus US$0.45 billion, this being the mid-point between US$10.6 billion damage and US$9.7 billion benefit from climate change.

Although Nordhaus provided estimates of the impact of climate warming upon US national income, and those estimates have been widely quoted, that was not the primary purpose of his research -- he described the estimates in Table 4.1 as 'rough'. His objective was to establish a method for thinking about policies to slow climate change (discussed in Appendix D) and he was careful to emphasise the tentative nature of his conclusions:

> Estimates of both costs and damages are highly uncertain and incomplete, and our estimates are therefore highly tentative. (Nordhaus 1991)

Nordhaus based the damage estimates in Table 4.1 on the work of others. For example he used studies undertaken by the US Environmental Protection Agency (EPA) as a guide for agriculture, sea level rise, and energy requirements. He made no provision for non-marketed goods and services not included in national accounts, and so did not include damage associated with loss of biological diversity or change to human health and lifestyles. However he suggested that his central estimate of 0.26 per cent of national income could be raised to about 1 per cent to allow for these unmeasured and unquantifiable factors, but acknowledged that such an adjustment would be entirely ad hoc.

Table 4.1: **Estimates by Nordhaus (1991) of the annual damage caused by climate warming associated with the effective doubling of carbon dioxide, to various sectors of the US economy**

(US$ billions, 1981 prices: positive indicates a benefit; negative a loss)

Sector	*Impact estimate*
Farms -	
impact of greenhouse warming and carbon dioxide fertilisation	-10.6 to +9.7
Forestry, fisheries, other	small + or -
Construction	positive
Water transportation	?
Energy and utilities -	
electricity demand	-1.65
non-electric space heat	+1.16
water and sanitary	negative ?
Real estate (land rent component of sea level rise) -	
loss of land	-1.55
protection of coast	-3.74
Hotels, lodging, recreation	?
Total (central estimate)	-6.23
Per cent of US national income	-0.26

Source: Nordhaus 1991.

Cline provides estimates of damage for both a 2.5^{O}C and a 10^{O}C temperature rise. He considers a wide variety of climate impacts and his estimates of damage include categories for species loss, human life, and leisure activities. His aggregate damage estimate for the US economy of a 2.5^{O}C temperature rise is 1.1 per cent of GDP, which is similar to the Nordhaus 'adjusted' estimate, and for the very long term 10^{O}C scenario the estimate of damage amounts to 6 per cent of GDP. Table 4.2 summarises Cline's results.

Cline also based his estimates on existing studies. However he questioned most of their analyses and found reason to increase many of their damage estimates. For example he claims that an adjustment should be made to the EPA's damage estimate for agriculture because of an overstatement of the fertilisation effect of a doubling of carbon dioxide in the atmosphere. For electricity requirements he uses the same basis as Nordhaus (EPA estimates) but reports an estimate several times higher. Where comparisons can be made in other areas there is little agreement.

An important conclusion which can be drawn from a comparison of these two studies is one which both authors themselves emphasise. Estimation of prospective damage from global warming is very difficult, far more difficult than estimating the costs of greenhouse gas emission reductions. There is limited information on which to base such a study and there is little agreement on how to interpret the data which are available. That there is a wide variety of results is a reflection of the inadequacy of data and techniques used to make the estimates. In the Commission's view these studies provide some valuable insights into the nature of damage which might be associated with climate change and serve as a useful basis for the assembly of a taxonomy of potential impacts. But their methods involve such large uncertainties that the Commission regards the estimates arising to be unreliable and an inadequate basis for sound policy conclusions. That major uncertainties are involved does itself have implications for policy analysis and conclusions. This is discussed in Chapter 6 and Appendix D.

One of the major deficiencies of existing studies is their inability to take account of the complex interrelationships of climate change. Estimates of the potential regional damage of climate change tend to lose sight of the global nature of the problem. Most are made as if climate change only occurs in the region under study and that adjustments will be confined to that region.

Table 4.2: **Estimates by Cline (1991b) of the annual damage to the US economy from global warming**

(US$ billions, 1990 prices)

Sector	*$2xCO_2$ ($2.5^{O}c$)*	*Very long term ($10^{O}C$)*
Agriculture	17.5	95.0
Forest loss	3.3	7.0
Species loss	4.0	16.0
Sea level rise -		35.0
dikes, levees	1.2	
wetlands loss	4.1	
drylands loss	1.7	
Electricity requirements	11.7	67.0
Non-electric heating	-1.3	-4.0
Human amenity	Xa	Ya
Human life	5.8	33.0
Human morbidity	Xm	Ym
Migration	0.5	2.8
Hurricanes	0.8	6.4
Construction	+/-Xc	+/-Yc
Leisure activities	1.7	4.0
Water supply	7.0	56.0
Urban infrastructure	0.1	0.6
Air pollution -		
tropospheric ozone	3.5	19.8
other	Xo	Yo
Total	61.6+Xa+Xm+Xo +/- Xc	338.6+Ya+Ym+Yo +/- Yc*

(* X and Y are indeterminate values)

Source: Cline 1991b.

Estimates of damage are made on the basis of existing patterns of production and trade and, in particular, existing patterns of land use and population distribution. Yet if climate does change in the manner anticipated by many analysts, the global distribution of population may change and there may be disruption to existing patterns of world trade. In that event the global economic effects of climate change will have a bearing on localised regional effects. This is not to say that knowledge of physical regional effects is not important. Such knowledge is essential for the calculation of the benefits of reducing emissions, but it is required on a worldwide basis.

4.3 Estimating benefits for Australia

The benefits of avoiding climate change tend to be focused on a few economic sectors. As Nordhaus (1991) has emphasised, however, there are many activities in every economy on which climate change would have little direct effect. Following Nordhaus, Table 4.3 sets out a sectoral breakdown of Australia's gross domestic product for 1989-90 by sensitivity to climate change. Agriculture, forestry, fishing and hunting are classified as ‘most sensitive’ because their levels of output are directly dependent on climate. The ‘least sensitive’ category includes activities such as wholesale and retail trade, which are generally conducted in controlled environments.

According to this classification 4 per cent of the economy is highly sensitive to climate change, about 24 per cent moderately sensitive, and the remaining 72 per cent negligibly sensitive. This compares with estimates for the US of 3 per cent highly sensitive, 10 per cent moderately sensitive and 87 per cent negligibly affected by climate change. However, there are several reasons why it should not be concluded from this comparison that Australia's economy is more vulnerable to any global warming than that of the United States.

First, the allocation to categories of sensitivity is necessarily somewhat arbitrary; second, features of the environment sensitive to climate change are not considered; third, there is no indication whether activities would be adversely or beneficially affected; and finally, indirect effects of climate change and the flow-on effects between sectors are ignored. This sensitivity indicator thus relates only to the direct effects on activities included in the National Accounts. As Cline (1991b) points out:

> it is misleading to cite the low shares of climate-sensitive sectors as prima facie evidence that the benefits of global warming abatement are likely to be small.

Table 4.3: **Breakdown of Australian gross domestic product by sensitivity to climate change, 1989-90 financial year**

	National income	
Sector	*Value ($millions)*	*Percentage of total*
Gross domestic product	372 172	
High sensitivity		4.08
Agriculture, forestry, fishing and hunting	15 193	4.08
Moderate sensitivity		23.91
Electricity, gas and water	11 264	3.03
Construction	27 603	7.42
Recreation, personal and other services	16 302	4.38
Ownership of dwellings	33 803	9.08
Negligible sensitivity		72.01
Mining	17 030	4.57
Manufacturing	59 352	15.95
Wholesale and retail trade	67 680	18.18
Transport, storage and communication	27 502	7.39
Public administration and defence	13 248	3.56
Community services	41 740	11.22
Finance, property and business services	46 102	12.39
Import duties	3 901	1.05
less imputed bank service charge	(8 548)	(2.30)

Source: Australian Bureau of Statistics (1990) Australian National Accounts: National Income and Expenditure 1989-90, ABS Catalogue No. 5204.0, Table 15 - Gross Domestic Product at Market Prices, by Industry ($ million), p. 12.

Information needs

The Commission's reference is quite specific about the benefits to be considered. They are the benefits to Australian industry of an international consensus in favour of a stabilisation of emissions of greenhouse gases not controlled by the Montreal Protocol on Ozone Depleting Substances, based on 1988 levels, by the year 2000 and a reduction in those emissions by 20 per cent by the year 2005. The base case, or business-as-usual scenario, is therefore the future flow of damages from a policy to do nothing about greenhouse gas emissions, and the alternative scenario is the future flow of damages if emission reductions are achieved as specified. The difference between these two damage estimates would be the benefits of international action to reduce emissions.

The first step in such an analysis is to establish what is known about the potential climate change under the two scenarios. For this, reference can be made to GCMs, or climate scenarios can be constructed by supplementing the output of GCMs with information at a detailed regional level.

As already explained, GCMs have as yet little to offer in terms of predicting the climatic effects of global warming at the regional level. As reported earlier in this chapter, the IPCC WG I has low confidence even in those regional estimates based on high resolution GCMs. In terms of the ability of GCMs to reproduce today's observed climate, the IPCC reports that they perform better for the Northern than the Southern Hemisphere. Pittock (1991) reports that the two models which perform best in this sense for the Australian region are the ‘CSIRO4’ model and the UK Meteorological Office model, with the CSIRO model being the marginally better model, despite generally predicting too much rain. No GCM reproduces the El Nino-Southern Oscillation phenomena which have a major influence on Australia's climate.

Australia has a number of GCMs, including those maintained by CSIRO (the ‘CSIRO4’ model), the Bureau of Meteorology, and Melbourne University. These GCMs are modified versions of the numerical models used by the Bureau of Meteorology to provide daily weather forecasts. In common with other GCMs they are subject to a continuous process of development as deficiencies in their specification are identified and knowledge of atmospheric processes improved. *No Australian model makes claims to being capable of providing reliable regional predictions which would be useful for this inquiry.*

Scenarios

The absence of a reliable regional climate forecasting model is not of itself reason to abandon attempts to describe the possible impacts of climate change. An alternative approach is to construct plausible scenarios of climate change by supplementing the broad insights available from GCMs with the detail provided by current regional observations of weather patterns and with evidence from the distant past (palaeo-climatic records). Such an approach was first adopted on a large scale in Australia in 1987 when the CSIRO Division of Atmospheric Research coordinated a project to investigate the sensitivity of the nation to climate change. More than one hundred scientists and engineers were asked to consider a single scenario of climate change and sea level rise and, within their area of expertise, to prepare a paper on the likely impacts of such change. The papers were refereed and presented at a conference at Monash University in late 1987 and subsequently published by CSIRO Division of Atmospheric Research (CSIRO 1988). They were grouped into the broad categories of coastal impacts, hydrology and water resources, natural environment, agriculture, and impacts on society.

The scenario to which the authors responded is reproduced in Box 4.2. It included larger climate changes than being considered in this inquiry, for example sea level rise of 20 cm to 140 cm. The time period under consideration was 50 years. The relevance of the studies to this inquiry is limited by the fact that they concentrated on the physical impacts, with no attempt being made to place values on those impacts. A number of other scientists have used the same scenario to assess the sensitivity of a variety of activities to possible climate change. The following climate impacts for Australia have been based on that scenario.

Box 4.2: **A greenhouse climate scenario for Australia**

The scenario reproduced below describes possible changes to the climate of the Australian region, over the next 50 years, arising from increasing greenhouse gas concentrations. It was prepared by CSIRO in 1987 (see CSIRO 1988) to form the basis for a range of impact studies. Since that time CSIRO has issued a more detailed Australian region greenhouse climate scenario (see Section C4, Appendix C).

TEMPERATURE A rise of 2 to 4^{O}C in the annual mean temperature is predicted with the greatest warming in the south and in winter, and the least warming in the north. Some regional variations in this general picture might be expected due to changes in cloudiness, air-sea temperature differences, etc. Oceanic temperatures will tend to lag behind atmospheric temperatures by 10 to 20 years.

RAINFALL Higher spring, summer and autumn rainfall by up to 50 per cent in those regions deriving such rain from the southward penetration of tropical/subtropical air during the Australian monsoon season is expected. This change will be a maximum at the southern limits of the summer rainfall regime. Winters will be generally drier by 20 per cent or more in those areas deriving such rain from the eastward passage of mid-latitude high and low pressure systems and associated frontal storms with the possible exception of Tasmania and southern Victoria.
Daily maximum rainfall will increase by the order of 20 to 30 per cent with some change in the frequency distribution of rainfall.

SEA LEVEL For the sea level a general rise of 20 to 140 cm is expected, which needs to be added to any local tendency due to subsidence etc.

TROPICAL CYCLONES The southern limit of tropical cyclones (as determined by sea surface temperatures >27^{O}C) is expected to shift some 200 - 400 km further south and the maximum intensity may increase by 30 - 60 per cent. The frequency of occurrence of tropical cyclones may change.

SNOW LINE The snow line would on average rise by about 100m per 1^{O}C warming, however local variations related to changes in storm frequency may be significant.

WIND SPEEDS Wind speeds could decrease by 20 per cent north of 36^{O}S, but should increase south of 36^{O}S due to changing north-south temperature gradients.

EVAPOTRANSPIRATION Evapotranspiration could decrease due to higher stomatal resistance at higher ambient carbon dioxide concentrations, but generally greater leaf area may partially compensate.

Source: CSIRO 1988.

For forestry, a change from the present climate would have the potential to affect Australia's forest industries in a number of ways:

- increased carbon dioxide concentrations could lead to an increase in productivity, depending upon complex interactions between the trees and their environment (the availability of soil moisture and nutrients is important in this regard);

- changes in temperature and soil moisture (because of changed precipitation patterns) would be expected to cause changes to the vegetation in the long run;

- changes in climate affects the viability of pests which limit tree growth; and

- changes in the climate may change the frequency and intensity of bush fires which would in turn change the nature of the vegetation.

The impact of a doubling of carbon dioxide on Australia's softwood (pinus radiata) plantations would be an increase in dry weight production at all levels of soil moisture, given that the soil contained adequate phosphorus (Barlow and Conroy 1988). The impact of the temperature and precipitation changes outlined in the CSIRO (1988) scenario, in the absence of carbon dioxide enrichment, is a decrease in forest productivity. Given an increase in plant efficiency expected from the elevated carbon dioxide levels, in combination with the temperature and precipitation changes, then overall productivity is increased according to Booth and McMurtrie (1988).

For the Eucalyptus species elevated carbon dioxide levels would increase the leaf and canopy rates of photosynthesis and also greatly increase water-use efficiency (Barlow and Conroy 1988).

The Resource Assessment Commission, in its Forest and Timber Inquiry Draft Report (1991), said that it could not determine with precision the effects of expected global warming on Australia's forests or on the Australian wood and wood products industry. It reported that most forests would respond to global warming by increasing productivity, but the extent of the increase may be offset by increased risk of disease and pest outbreaks. It noted that the distribution of some forest species may be adversely affected by changing regional climates, with increased risk of extinction of some forest-dependent species. In Australia there is a dearth of information on the biology of our wildlife species.

This means that for most species it is not possible to predict how they would respond to changes in temperature and in the amount and distribution of rainfall. If the climate does change, the process will be a continuous one. For species which are unable to live within the changed climatic environment, survival would require migration paths available for them to move to more favourable environments. It is also not clear that given continued climate change the required environments would continue to exist. For example, some alpine flora are restricted to isolated mountain tops, and should the climate warm there may be no readily available natural migration paths, or destinations within a reasonable proximity, available. An analysis of the impact of the CSIRO (1988) climate scenario on the range of two threatened species indicates that the continued existence of the long-footed potoroo, without human intervention, would be doubtful, and much of the area currently inhabited by the antilopine wallaroo would become unsuitable for it (Busby 1988). Arnold (1988) examined the impact of the CSIRO (1988) scenario on the distribution of nine species of honeyeater native to Western Australia and found that the viability of the species would be threatened.

The CSIRO (1988) scenario has been used by a number of scientists to evaluate the possible impact of global warming on Australia's water resources. For a catchment in a high summer rainfall regime (for example, one located in south-eastern Queensland) the increased rainfall is forecast to increase stream flows by 280 per cent annually, whereas for a catchment in a predominantly winter rainfall area (for example, one located in South Australia) stream flows are forecast to decrease by 25 per cent annually (Nathan et al. 1988).

Apart from changing stream flows, the changing precipitation and temperature patterns could also affect the aquifers which supply ground water to agriculture, industry and domestic users. An analysis by Ghassemi et al. (1991), on the impact on Australian aquifers of a climate change consistent with the CSIRO (1988) scenario indicates that:

- the alluvial aquifers of eastern Queensland, which are now suffering from over pumping, would be advantaged by increased summer rainfall;

- the shallow aquifers of the arid and semi-arid zones (for example, the Amadeus basin), would be advantaged by increased recharge;

- the Perth basin, unconfined aquifer, would suffer from reduced rainfall;

- aquifers affected by salinity (for example the Murray basin) would be disadvantaged by increased rainfall; and

- coastal basins could be affected by sea level rise and salt intrusion (Perth, Bundaberg, the Burdekin delta and Western Port basins).

The possible first round health effects on Australians of the CSIRO (1988) climate scenario have been identified by the NHMRC (1991) as being:

- an increase in the loss of life due to heat stress. Groups particularly at risk are:

  - the elderly;

  - the physically and mentally handicapped;

  - individuals with chronic conditions;

  - people obliged to live in substandard housing;

  - people obliged to perform strenuous work, often in protective clothing (for example, fire fighters);

- a change, and possible expansion in the range of diseases. These diseases include: dengue, Australian encephalitis and epidemic polyarthritis. These diseases are confined to relatively warm, moist areas suited to the mosquito species which play a role in their transmission. Warmer, wetter summers could result in higher background levels of these diseases, with a wider spread both seasonally and geographically, and more frequent occurrence (Liehne 1988); and

- an increase in respiratory diseases. About 800 deaths annually are now certified as due to asthma, and any increase in rainfall and temperature may stimulate plant growth (and hence increase pollen), and increase moulds and, near the coast, dust mites, with a concomitant increase in asthma attacks (Curson 1991; NHMRC 1991).

Lifestyle changes associated with a warmer climate could possibly be:

- the direct consequences of the changed climate on leisure and other activities (for example, one result could be fewer opportunities to snow ski but greater opportunities to water ski). Galloway (1988) shows that a rise in mean temperatures of 2^{o}C would shorten the average Australian ski season from 160 to 130 days; and

- changes to seasonal north/south migration patterns as southern winters become milder and northern summers more humid.

Australia has an estimated 52 310 km of low lying coast (OECD 1991b). Of this coast 3110 km is classified as densely populated (more than 10 inhabitants per km^2). The densely populated coastline includes 245 km of city waterfront, 500 km of beach and 75.6 km of harbours. The primary impacts of rising sea level on this coastline would include:

- the flooding and inundation of coastal wetlands. These wetlands and associated mangrove areas provide a valuable resource for fish, birds and other marine life. For some commercial fish species the wetlands are a key feature of the reproductive cycle. The Coast and Wetlands Society advocated that land adjacent to existing wetlands should be set aside to allow for migration onto newly flooded country (sub. 10);

- the ‘drowning’ of coral reefs. This is not expected to occur unless the rate of sea level rise exceeds around 10 mm per year. The IPCC (1990) best estimate is for a rise of around 65 cm by 2100. This estimate would indicate that Australia's coral reefs would not be in danger. The OECD (1991b), after an assessment of the likely impact of sea level rise on Australia's reefs, concluded that damage would be minimal. In fact, it has been argued (Hopley and Kinsey 1988) that a rise of 8 mm per year, or less would enhance Australia's coral reefs;

- inundation and erosion of coastal beaches and barrier islands. Such beaches provide a valuable recreational resource. The OECD (1991b) argues that one way to preserve this resource would be to pump sand onto the beaches;

- salt water intrusion into aquifers and rivers (see discussion under the section on water resources); and

- flooding and inundation of rural dry land, cities and harbours. In the Australian situation assets of substantial value may need to be protected by levees.

An example of a possible climate change impact on the fishing industry may be found in the Australian region. It has been observed that the number of prawns caught in northern Australia in a prawn fishing season is highly dependent upon the wet season rainfall over northern Australia

(Love 1987). Should an increase in rainfall in this area be a result of climate change then one consequence would possibly be an increase in the stock of prawns.

There has been considerable progress in model development and scenario building since the 1987 CSIRO project, but there is still much work to be done before any single scenario could be presented as a forecast. A recent, more detailed, CSIRO scenario for Australia is reported in Appendix C. That scenario forms the basis of current CSIRO research into the regional impact of an enhanced greenhouse effect on behalf of several State Governments. Progress reports on that research indicate that modifications which have been made to CSIRO's GCM will facilitate more reliable regional climate simulations in the future (CSIRO 1990). Some work has also considered the impact on Australia of extreme climate events.

In a paper prepared for a DASETT-CSIRO workshop on climate change, Flood (1991) presented some preliminary estimates of the costs and benefits of climate change on the built environment. He considered three climate change scenarios ranging from mild to catastrophic. For the mild scenario he concluded that there may be overall savings from a warmer, wetter climate. This result derives from less energy use for domestic heating and cooling outweighing the cost of cyclone and flood damage. For a severe climate impact he attributed a high cost to population movement and resettlement caused by drought, whereas for a catastrophic climate change he predicted that the major impact would be through damage caused by cyclones and storms.

Further impact estimates were presented at a workshop on impacts and adaptation to climate change which was held recently at Macquarie University (Impacts and Adaptation Workshop May 1991). A paper presented by Joy (1991) provided estimates of the average annual cost to Australia of a wide range of natural climatic disasters, the estimated total average annual cost of which was given as about $1.25 billion. The paper concluded that the most costly natural disasters are floods (31 per cent of total), droughts (24 per cent of total), and cyclones (21 per cent of total). Storms are the most common insured disaster, accounting for about 45 per cent of all claims. Disasters which are not insurable are drought, storm surge and coastal erosion. Joy reported that droughts, floods, cyclones, storms, bushfires, storm surge and coastal erosion are normal climatic phenomena in Australia, but an increased frequency of the extremes of any of these would be both expensive and difficult to manage.

A major limitation of all of the work referred to above is that each impact is examined in isolation from the effects of impacts elsewhere in the economy. While the studies provide a necessary input into an understanding of possible impacts, ideally they should be examined in an economy-wide context. A tentative step in that direction is made by Godden and Adams (1990) in an examination of the enhanced greenhouse effect on Australian agriculture. They use the ORANI general equilibrium model of the Australian economy to investigate the effect on Australian agriculture of a decline in wheat yield (an assumed direct effect of climate change) and reduced export demand for Australian black coal (arising from the assumed imposition of carbon taxes overseas). Their simulations show that climate effects which damage one agricultural activity may be sufficiently offset by indirect effects elsewhere in the economy that agriculture as a whole may gain from the greenhouse effect, even if the economy as a whole is also damaged. Their results show losses for wheat, but gains for other grains, sheep, wool and beef as the terms of trade change in response to reduced export demand for Australian black coal.

Godden and Adams acknowledge that a much wider range of possible impacts should be included in the analysis, and that it is desirable to link the domestic economic model with a world trade model before any policy conclusions are made. However their work illustrates the inadequacy of studies which fail to take account of the complex interrelationships in the economy.

4.4 Summing up

The Commission has been unable to provide an estimate of the climate related benefits to Australia of an international consensus to reduce greenhouse gas emissions. The Commission cannot place a value on the future flow of damages for a business-as-usual scenario or for a scenario in which the nominated emission reductions are achieved. There is no reliable information on which to base such estimates.

Each of the necessary steps in setting up such benefit estimates is attended by major uncertainty. Beyond the scientific uncertainties attending climate change itself is inadequate knowledge of the physical impact of potential climate change, a problem compounded by not knowing what form of climate change to evaluate. Then there is the task of placing a value on the impacts, even if they were known with certainty. The timing of their occurrence is unknown and for many potential benefits, such as preserving biological diversity or maintaining certain lifestyles, there is no market in which a price can be observed. Essential information on the form an international consensus will take is not available. Even with perfect knowledge of the physical impacts, future patterns of land use and industrial structures could not be determined without knowing the form of an international consensus and how it would affect the development of nations and the patterns of world trade.

The Commission sees little value in conducting a partial analysis of the benefits. Any climate problem caused by the emission of greenhouse gases will require global action if it is to be effectively addressed. In that event the benefits which accrue to Australia will depend as much, if not more, on the action of other countries as on any action Australia takes. If an analysis of the impacts of climate change does not take an international perspective, policy responses may be based on misleading information. The Commission has no wish to publish estimates of benefits which, of necessity, would be purely speculative. Given the present state of knowledge, the Commission can only respond to its terms of reference by reviewing some of the work that has been done in identifying possible areas of impact.

The inability of the Commission to measure the benefits of reducing greenhouse gas emissions points to a need to improve knowledge of the science of greenhouse, of the impacts of climate change, and to further develop techniques for valuing the environment. However, it is likely that there will always be major obstacles to measuring the benefits of greenhouse abatement strategies.

The Commission is aware that progress is being made in each of these areas. A major international effort is being directed at reducing the scientific uncertainties, with Australian scientists at the forefront of research. Scientists and engineers have also turned their attention to the estimation of potential regional impacts and economists are refining techniques to value non-market assets and developing models of the world economy. The proliferation of conferences, seminars and workshops on greenhouse issues is testimony to the effort being devoted to the subject.

5 COSTS OF GLOBAL CONSENSUS

This chapter examines factors that will determine the possible costs facing Australia from a worldwide consensus to reduce greenhouse has emissions. It outlines how these costs would arise and explores various ways in which they could be reduced. Reflecting the uncertainty surrounding the estimates, indications are provided of how sensitive the cost estimates are to certain key policy settings, and to key economic and technical relationships.

The costs to Australia of an international consensus would depend on the specific targets adopted for reducing greenhouse gas emissions, and the mechanisms put in place to achieve those targets. Australia would be affected both by its trading partners and competitors to reduce their emissions.

As a participant in the global economy, Australia has an interest in its trading partners' prosperity. Whatever costs they incur in meeting their greenhouse obligations, we will eventually bear a share of them. And as a major fuel exporter, Australia has a special interest in international fuel markets. Any fall in global prices, and reduce our national income.

The size of these international effects can be influenced significantly by the policies used to achieve the required emission reductions. A tax on production of carbon emitting fuels, for example, would allow Australia to collect the revenue from the tax whereas a consumption-based tax allows those who but our exports to collect the revenue. Allowing countries to but the rights to emit carbon, say, through the use of so-called tradeable permits also has the potential to reduce abatement costs, both globally and to the countries concerned.

Within Australia, these international effects would interact with the actions Australia takes to cut its own emissions. Chapter 9 explores the ways in which Australia could minimise these effects and concludes that having a flexible and adaptable economy is a key ingredient in ensuring that the costs of meeting the consensus are minimised. The application if fuel saving technology would also be an essential element both in Australia and internationally. Fortunately, it appears that there are more fuel-efficient ways of doing things, and the take up of these methods would provide means by which countries could minimise the costs of meeting a Toronto target.

5.1 Required reduction in emissions

The growth in emissions expected between now and 2005 will determine the size of the policy response required to reach the Toronto target. This expected growth will therefore play a large role in determining what a global consensus will cost Australia.

International energy use

Energy use accounts for 60 per cent of worldwide anthropogenic greenhouse gas emissions (IEA 1990), with the remainder being due to industrial processes, agricultural activities, and changed in land use (such as large scale clearing of forests). Any international consensus would clearly have major implications for international energy use. The actual reductions in emissions that will be required by the year 2005 is shown in Table 5.1. Global energy consumption is forecast to be 55 per cent higher than in 1987. Importantly, this table illustrates the different growth rates in energy use that are expected in different parts of the world, ranging from 26 per cent in the OECD countries, to 119 per cent in the developing economies.

Projections of global carbon dioxide and methane emissions based on the estimates of future global energy consumption (IEA 1989b) are also shown in Table 5.1.[1] If 1987 emissions are used to proxy those prevailing in 1988, the reduction in global carbon dioxide emissions from fossil fuels necessary to comply with the Toronto objective by the year 2005 would be of the order of 47 per cent. If methane emissions are also required to meet the same target, they would need to reduced by 51 per cent.

Table 5.1: **Projected global energy use and associated emissions, 1987 – 2005[a]**

By County	*Energy use* 1987	2005	*CO_2 emissions* 1987	2005	*Methane emissions* 1987	2005
	Petajoules		*Mt*		*Mt*	
OECD[b]	164 751	207 288	10 078	12 480	15	19
(percentage increase)		(26)				
CENTRALLY PLANNED ECONOMICS [c]	103 079	173 627	7 218	11 554	11	20
(percentage increase)		(68)				
DEVELOPING ECONOMIES	53 120	116 309	3 351	7 353	5	13
(percentage increase)		(119)				
WORLD						
Oil	126 399	170 235	8 671	11 678	11	15
Natural Gas	64 351	124 348	3 391	6 553	14	26
Solid Fuels	94 329	144 570	8 584	13 156	7	10
Nuclear	16 284	26 963	-	-	-	-
Hydro & Other	19 594	31 108	-	-	-	-
TOTAL	320 960	497 224	20 646	31 387	31	31
(percentage increase)		(55)				

[a] 1988 not available. [b] Australia, Austria, Belgium, Canada, France, Greece, Italy, Japan, New Zealand, Spain, Turkey, United Kingdom, USA and West Germany. [c] Bulgaria, China, Czechoslovakia, East Germany, Hungary, Poland, Romania, USSR and Yugoslavia. [d] Rest of the world.
Source: Commission estimates based on IEA 1989b.

As energy use is projected to grow more rapidly in developing economies than in the world as a whole, so also are the associated greenhouse gas emissions. Thus although the developing economies were responsible for only 16 per cent of carbon dioxide emissions in 1987, they account for 37 per cent of the projected increase between 1987 and 2005. In consequence they would need

1 The emissions coefficients used in Tables 5.1 and 5.2 are discussed in Appendix G. They cary according to fuel quality and the temperature and pressure of combustion and there is thus considerable uncertainty over their true value. In addition to this uncertainty several other assumption underlie the projections of future energy consumption. These are discussed in IEA 1989b.

to reduce their emissions (relative to baseline projections) more than the industrialised economies in order to comply with Toronto. While in OECD countries would need to reduce carbon dioxide emissions in 2005 by an average cut back by 62 per cent.

Energy use in Australia

Forecasts of energy consumption, carbon dioxide and methane emissions in Australia are shown in Table 5.2. Forecasts of future emissions were derived by combining the energy use figures given in Table 5.2 with the technical relationships linking energy produced and greenhouse gases emitted (see Appendix G).

Table 5.2: **Energy consumption and associated emissions, by fuel type – Australia**

	Energy use			*CO_2 emissions*			*Methane emissions*		
By Fuel type	*1998*	*2000*	*2005*	*1988*	*2000*	*2005*	*1988*	*2000*	*2005*
		PJ			*Mt*			*Mt*	
Black coal [a]	1051	1523	1660	94	136	148	0.11	0.15	0.17
Brown coal [b]	449	592	494	42	53	57	-	-	-
Renewable biomass [c]	170	213	224	-	-	-	-	-	-
Renewables [d]	57	72	79	-	-	-	-	-	-
Petroleum products	1397	1724	1840	96	188	126	0.03	0.03	0.04
Natural gas	619	881	1058	33	46	56	0.11	0.15	0.19
Total fossil fuel	3485	4690	5052	2562	353	376	0.24	0.34	0.39
Total non-fossil fuel	227	285	303	-	-	-	4.1-15	4.8-15.7	4.9-15.8
Total	3712	4975	5355	267	353	378	4.6-15.5	4.8-15.7	4.9-15.8

[a] Black coal and coke. [b] Brown coal and briquettes. [c] Wood and bagasse (sugar cane). [d] Hydro and solar electricity. [e] Conversion sector converts primary fuels (for example, black coal, crude oil) into derived fuels (for examples, electricity, petroleum products).
Note: Annual figures calculated by averaging consecutive financial year.
Source: Commission calculates based on ABARE 1991, ANZEC 1990, Wilkenfeld 1991 and Williams 1989.

These projections indicated that Australia would need o cut carbon dioxide emissions in 2005 by about 44 per cent to meet the Toronto target. This is slightly greater than the cut of 35 per cent required on average for OECD countries (Table 5.1).

It should be emphasised that *some technological and efficiency improvements are incorporated in the projections of future energy use for Australia* (ABARE 1991). These improvements reflect those believed likely to occur over the next 15 years in the absence of any specific measures to reduce emissions: that is, under ‘business as usual’. It these improvements were achieve, then the energy demand and emissions figures in Table 5.2 would be higher.

Achieving these emission cuts would impact on Australia domestically and through its trade links with other countries. The trade effects would be determined by how other countries react to the emission cuts they would be required to make.

5.2 Global impact of emissions cuts

The projected emissions figures given above indicated that a global reduction in carbon dioxide emissions of about 47 per cent I the year 2005 would be required to meet the Toronto target. Emission cuts of this order would have significant economic implications for Australia through trade and financial linkages. The effects of a consensus on the economies of Australia’s major trading partners would be particularly important. The more severe the effect of a worldwide commitment to reduce emissions on the economies of Japan and the OECD countries, as major markets for Australian exports, the more severe would be the effects of a consensus on Australia.

If could be assumed that there was a fixed relationship between aggregate production and greenhouse emissions, achieving the Toronto targe would require about a 47 per cent lower level of GDP in 2005 than would otherwise be the case. In reality, however, GDP is unlikely to fall by anywhere near this magnitude because of four kinds of structural changes that would help to reduce emissions relative to aggregate output:

- There would be substitution away from greenhouse-gas intensive forms of energy production - for example, from brown and black coal to solar and natural gas. The pace of that substitution will be governed by the relative cost of these different sources and the delay inherent in making new sources of power available. It takes several years to build a replacement power station.

- There would be substitution of currently available capital for fossil fuels, through say, the construction of hydro and nuclear plants and through the installations of emissions control equipment etc.

- There would be change in the composition of production away from energy intensive items, that is, items which consume relatively large amounts of energy, to less energy intensive ones.

- Technical change would be stimulated to produce new kinds of capital equipment, energy and other products with lower emissions level.

Many economic studies have attempted to quantify the effect of emissions cuts on the global economy. Some of these are summarised in Box 5.1. While the results of these studies are difficult to compare, as they generally target different reductions in emission levels over considerable different time frames, the reductions in energy consumption, could lead to a reduction in worldwide incomes by as much as 8 per cent. However, most studies put the cost of global consensus at around 2 to 5 per cent of world GDP – well below the figure produced by the simple analysis referred to above.

While all these models are simplifications of a ver complex interaction of economic and technical factors, they at least enable the influences listed above to be analysed in a consistent framework. Within this framework, they show households reducing their consumption of carbon-intensive products as they become dearer. Likewise they show firms choosing less carbon-intensive production techniques become available. Few if any however, contain mechanisms allowing the development of energy-saving techniques to be accelerated in response to higher energy prices (technological progress is treated as *autonomous).* This reflects the limitations of current knowledge of the nature and effectiveness of such mechanisms.

The results are clearly also influenced by the assumptions made in the models. In particular the models assume that prices and wage rates are flexible and adjust so as to clear markets. For labour markets, this may in interpreted as assuming a fixed rate of unemployment. The models also assume that over time capital is reallocated from less profitable to more profitable industries, until rates of return are eventually equalised across the economy.

Some of these models simulate the effects of various policy settings on the economy at a single point in time, after adjustment has occurred and resources have been reallocated between users. Others simulate the path of the economy through time. But even these models do not simulate short run professes of adjustment to policy changes, in which markets may not clear and resources may lie idle. While the Commission recognises the potential weaknesses which exist in these model, and the care which must be taken when interpreting results, it believes that are the best tools currently available to quantify the potential economic effects of cutting emissions.

Box 5.1: **Worldwide effect of carbon dioxide emissions reductions**

Many studies have endeavoured to estimate the effect of a global consensus to reduce worldwide emissions. Care must be taken in comparing these studies, espeically since each envisages a different reduction target and targe date.

The results of the major studies are presented below.

Study	Country or Region studies	Emissions reduction from business as usual case (per cent)	Target date for emission cut	Fall in end-year GDP from business as usual case (per cent)
Manne & Richels (1990a)				
	USA	Cuts differ by	2100	2.5
	Other OECD	country but for	2100	1.8
	Eastern Europe	the world as a	2100	2.5
	China	whole equal	2100	10.5
	Rest of World	75 per cent	2100	4.0
Whalley & Wigle (1990) [ab]	World			
National producer taxes		50	2030	4.4
National consumer taxes		50	2030	4.4
Global tax		50	2030	4.2
Ceiling on per capita emissions		50	2030	8.5
OECD (1991a)	World	c	2020	1.8

[a] Target date and results apply to average values over the period 1990-2030.

[b] Welfare effect measured Hicksian Equivalent variations.

[c] Target is to reduce emissions in OECD and USSR to 80% of 1990 levels by 2010, to limit emissions to 50% above their 1990 level by 2010 in China and energy-exporting LDCs, and to stabilise emissions worldwide between 2010 and 2020

Source: Hoeller et al. 1990, OECD 1991a.

The OECD's 'GREEN' simulations

The most recent and comprehensive analysis of the economic effects of reducing global greenhouse gas emissions was conducted by the OECD (1991a). The OECD modelled the effects of a international consensus using a model which is designed to simulate how the world economy would respond over time to carious carbon tax regimes. This is known as the GREEN model and is briefly described in Box 5.2 (see also Appendix G). To capture the mechanisms set out above it allows substitution in production between the major fuel types – including non-fossil fuels – and between energy and capital. The model thus allows substitution away from carbon-intensive fuels such as coal, towards oil and gas, and away from fossil fuels toward other energy sources such as hydro, solar and nuclear fuel. The model also allows firms to reduce their overall energy requirements by adopting more capital-intensive techniques. Finally, it incorporates technological progress in the form of an autonomous energy efficiency improvement, set as 1 per cent per year in each region in the central-case simulation.

The OECD used GREEN to model an international agreement similar to but less onerous than the Toronto targe (see Box 5.2). It involves a global reduction I carbon dioxide emissions of 37 per cent by 2020, rather than the likely 47 per cent reduction needed by 2005 to satisfy the Toronto target. On this account, OECD results probably underestimated the costs of Toronto. Furthermore, the only the OECD countries and the USR actually cut their emissions to 80 per cent of 1990 levels by 2010 and stabilised thereafter. Emissions from China and the energy-exporting LDCs were assumed to increase by 50 per cent between 1990 and 2010 and were stabilised thereafter, while other regions were assumed not to participate in the agreement. The OECD results do not, therefore, refer to a 'global' consensus.

Box 5.2: **The GREEN model**

GREEN is a multi-region, multi-sector, dynamic model developed by the Organisation for Economic Co-operation and Development (OECD) to analyse the economic consequences of reducing international carbon dioxide emissions.

The model focuses on production, trade and consumption in six regions (North America, Europe, the Pacific area, energy exporting developing countries, China and the USSR), and trade between these regions and the rest of the world. This gives rise to one of the main strengths of the model, its ability to handle changes in international trade flows that results from the policies to curb greenhouse gas emissions. Australia, New Zealand and Japan are grouped together as the Pacific region.

Since the main man-made sources of carbon dioxide emissions are from the burning of fossil-fuels, GREEN includes the main interrelationships involved in energy production. Industries can substitute between electricity, fossil-fuels (coal, oil and natural gas) and a composite non-fossil based fuel (hydroelectricity, solar and nuclear. Similarly, producers can substitute between energy and capital, while consumers can substitute between energy and other goods.

The OECD used GREEN to analyse to different emission reduction strategies to reduce global carbon dioxide emissions by 37 per cent by 2020. The key features of the policies analysed are:

<u>Carbon tax</u>

* Levied by each region on the consumption of fossil-fuels (prior to any other forms of indirect taxation) at the rate necessary to meet the regional target.
* The rate at which the tax is levied is hight for those fuels with a higher carbon content, for example coal, and caries over time
* To achieve the 37 per cent global reduction:* OECD countries & the USSR are required to reduce emissions to 80 per cent of their 1990 levels by the year 2010 and stabilise thereafter, and Energy-exporting LDCs (Less Developed Countries) and China are allowed to increase emissions by 50 per cent from their 1990 level by 2010 and stabilise thereafter.

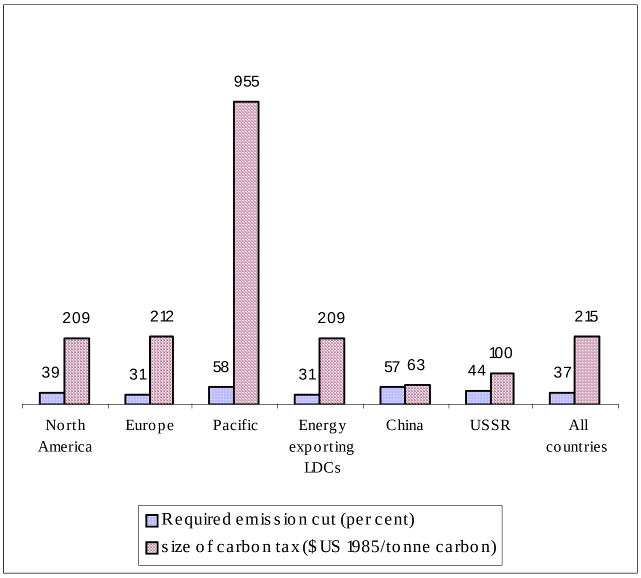
<u>Tradeable permits</u>

* Global emissions to be reduced by 37 per cent by 2020.
* Each country was initially allocated emission rights equal to the upper bound on emissions imposed in the no-trade situation. Trade in these rights are then allowed with other countries at the prevailing world price.
* The government collects the proceeds of any emissions permits sold. The amount by which emissions are to be reduced caries between regions as permits are traded.

The model does not include any potential climatic benefits that may arise from reducing greenhouse gas emissions and does not deal with non-carbon dioxide greenhouse gases, such as methane, chlorofluorocarbons and nitrous oxides. The model deals with a time horizon covering the period to the year 2020.

The emission reductions required under this Scenario and the taxes required to achieve them are listed in Figure 5.1. The required emission reductions differ a cross countries because of different baseline projections for economic growth and carbon intensity. The tax is paid by industry and is determined by the amount of carbon dioxide emitted by fossil fuel combustion during the production process. The worldwide average tax required in the year 2010 was estimated to be $123 per tonne of carbon (1985 US$) by 2020. There would, however, be considerable regional variation in the tax required, with the Pacific region standing out as requiring a much higher tax than the average (Figure 5.1).

Figure 5.1: **Emission cuts simulated in the GREEN model and the carbon tax required to achieve these reductions**



The results from GREEN suggest that the effect of such taxes could be to reduce worldwide real GDP by around 1.8 per cent I the year 2020. Household real income would also fall. Energy-exporting LDCs would be particularly disadvantaged, with their income projected to fall by 7.4 per cent. The Pacific would experience a loss of income of around 2.4 per cent (Table 5.3). As the OECD's Pacific region comprises Australia, New Zealand, and Japan, the reasons for the very high tax and relatively large GDP loss are of considerable interest. The OECD argues that the Pacific has the highest rate of carbon dioxide emissions of all OECD regions under business as usual, so that the Toronto target requires a higher degree of abatement here than elsewhere. As in other regions, moderate reductions in emissions can be achieved relatively easily by reducing coal usage;

Table 5.3: **Cost of achieving a 37 per cent reduction in carbon dioxide emissions in the year 2020a**
(per year)

North America	-0.8
Europe	-0.9
Energy exporting LDCs	-2.4
China	-7.5
USSR	-2.3
Total	-2.2

a Cost is measured in terms of changes in household real income.
Source: OECD 1991a.

but once coal usage has been virtually eliminated, further emissions reductions become much more costly. Thus the results illustrate the general rule, that the cost of abatement rises sharply as reduction targets are raised.

As Japan dominates the economies of the region, however, it is probable that the need for a high tax is true only for Japan. In particular, with higher initial reliance on coal combustion than Japan, and with less rapid projected growth in aggregate output, it is likely that Australia could meed the Toronto targe with a considerably lower tax rate.

The cost and tax estimates are very sensitive to the assumed ease of substitution between energy source. In the GREEN model, when the parameter describing how easy it is to swap one fuel for another (the so-called elasticity of inter-fuel substitution) was increased by 67 per cent and the price responsiveness of the supply of non-carbon fuel was increased by 150 per cent (from .2 to .5) the average tax required in 2020 was cut in half. There was considerable variation across regions – the tax fell by less than 30 per cent in China and the energy exporting LDCs compared with a fall of over 60 over cent in North America.

Because of the lower taxes required to cut emissions, the cost of achieving the cuts full. A comparison of the GREEN model results with the larger substitution elasticities is given in Table 5.4. For many countries the higher elasticities more than halved the cost of cutting emissions.

Table 5.4: **Impact of hight inter-fuel substitution elasticities on the cost of controlling emissions**

	Low elasticity case[c]		*high elasticity case*[d]	
Country	*Carbon tax*[a]	*household real income*[b]	*Carbon tax*	*Household real income*[b]
North America	209	-0.8	81	-0.3
Europe	213	-0.9	97	-0.2
Pacific	955	-2.4	440	-0.6
Energy exporting LDCs	209	-7.5	161	-4.4
China	63	-2.3	45	-2.8
USSR	101	-0.6	58	0.1
Total	215	-2.2	109	-1.1

[a] US$1985 per ton of carbon. [b] Percentage change. [c] Fuels substitution elasticity equal 1.2, supply elasticity of carbon-free resource equal 0.2. [d] Interfuel substitution elasticity equals 2.0, supply elasticity of carbon-free resource equals 0.5.
Source: OECD 1991a.

The OECD points out that the ease of substituting between energy sources in response to an increase in the price of one form of energy probably rises as the replaced, providing alternate sources of energy becomes easier. For this reason the high elasticity case summarised in table 5.4 is more likely to apply if policy is implemented over a long time period.

The cost estimates are also sensitive to the mechanism used to achieve the emission reductions. Possible methods of reducing emissions and their impact on the cost are considered in the following section.

5.3 Costs of abatement depend on instruments used

As discussed in Chapter 3, an international agreement to limit greenhouse has emissions could take one of several forms. Among other possibilities, it could involve allocating fixed emissions quotas to each country, or assigning tradeable permits. These choices would affect both the worldwide cost of reducing emissions, and the way in which the cost is shared between countries.

Production- and consumption-basted taxes

The achievement of an international consensus through production-based taxes, in which the revenues from the taxes accrue to producers of energy such as the OPEC countries and Australia, would lead to different distributional effects than the achievement of a consensus through consumption-based taxes under which the revenues would accrue to countries on the basis of their energy consumption. In particular a consumption-based tax would benefits major energy importers such as japan and the European Community countries relative to a production tax. The opposite applies to energy exporters like Australia.

The possible international distribution of gains and losses under production- and consumption-based taxes are illustrated in Table 5.5. While Australia would collect a greater share of the global tax revenues under a production-based tax, its export prospects would suffer from the economic contraction of its major trading partners, which would be more severe than under a consumption-based tax.

Uniform reductions in emissions, requiring each country to impose a different tax rage, are but one way in which the world could meet the terms of a consensus. Alternatively, each country could impose the same tax rate and achieve a different reduction in emissions. Uniform taxes levied per unit of fuel produced or consumed would have certain efficiency advantages, although, as noted in Chapter 3, it might be difficult to work out what tax rate is needed to achieve the desired global emissions reduction.

Table 5.5: **Cost of achieving a 50 per cent reduction in global emissions with production- versus consumption-based taxes** [a]

	Production -based tax	*Consumption -based tax*
European Community	-4.0	-1.0
North America	-4.3	-3.6
Japan	-3.7	0.5
Other OECD[b]	-2.3	-2.1
Oil exporting countries	-4.5	-18.7
Developing/centrally planned	-7.1	-6.8
World	-4.4	-4.4

[a] Cost is measured as the dollar value of the change in consumer welfare expressed as a percentage of GDP. [b] Includes Australia

Source: Whalley and Wigle 1991.

Tradeable permits

If it were possible to monitor each country’s emissions and impose sanctions for exceeding the limits agreed to under s consensus, it might be preferable to allow each country to choose how to meet its obligations under the consensus rather than requiring each to impose a uniform tax rate or achieve a given reduction. This would allow countries to choose a policy mix which minimises the domestic costs of reducing emissions based on the energy intensity and efficiency of their economies.

Such flexibility might be achievable by making the rights to emit greenhouse gases tradeable. For example, China is very inefficient in its use of energy relative to Japan (Whalley 1991). This energy inefficiency means that China has a much higher level f emissions relative to GDP than the rest of the world, making it cheaper from China to reduce its emissions, in terms of the cost per tonne of carbon, than it would be for more energy efficient countries to achieve the same emissions reduction. Consequently a lower tax per tonne would be required in China than elsewhere to achieve the same percentage reduction in emissions.

Alternatively, other countries could pay China to reduce its emissions. This would be cheaper than other countries making the same reductions domestically, and also, by providing China with the revenues, would create an incentive for China to ut its emissions despite its abundance of brown coal reserves which consumption over the next few decades. A systems of internationally tradeable permits is one way in which countries could in effect 'buy' their emission reduction in countries where achieving such reductions are cheaper. The OECD's analysis, for example, indicates that the cost to the Pacific region of a Toronto-type agreement could be reduced substantially if, rather than have each region reducing its emissions by the same amount, the reductions were concentrated where the resultant costs were lower. This is simulated by letting the rights to emit carbon dioxide be traded internationally so as to ensure the price of emissions permits was equated between regions. This is equivalent to equating a carbon tax between regions, but also takes into account the effects of income transfers between regions associated with the purchase and sale of permits. When this was done in the OECD's work, the estimated cost to the Pacific region of achieving a Toronto-type agreement feel by 40 per cent (Table 5.6).

Table 5.6: **Reduction in cost achievable through trade in emission rights [a b]**

	NO Trade	*Trade*	*%Cost Reduction*
North America	-0.77	-0.68	11.7
Europe	-0.85	-0.82	3.5
Pacific	-2.43	-1.46	39.9
Energy exporting LCDs	-7.46	-4.30	42.4
China	-2.30	+2.38	203.5
USSR	-0.61	+0.74	221.3
Total	-2.18	-1.10	49.5

[a] Percentage changes in 2020 compared with baseline.
[b] Cost is measured as changes in household real income.
Source: OECD 1991a.

In the tradeable permits simulation countries with high abatement costs, such as the Pacific region, buy permits from countries with low abatement costs, such as China. The Pacific region avoids some abatement costs, while China earns revenue by selling permits. This suggests that tradeable permits are a better policy option than fixed quotas. However, the choice of the best policy option to reduce greenhouse has emissions would also need to take into account the costs of administering the policy, including the cost of ensuring that the policy was being implemented correctly and adhered to. The OECD's work did not take this cost into account and so their analysis mainly highlights the theoretical advantages of trading emission rights which are outlined in Chapter 3. The practicalities of such a policy are yet to be established.

Trading emissions rights will enable some countries to earn billions of dollars in foreign exchange and it is quite possible that the revenue gained could more than offset the income lost from cutting emissions. A country will gain from these effects if its initial allocation of permits enables it to sell permits in sufficient quantity. This was the case for China and the USSR in the OECD work (Table 5.6).

These results clearly indicated that the costs of meeting a global emissions target depend critically on the policy put in place to achieve the target. However, the choice of the best policy would require much more analysis than indicated here. It would depend on the feasibility of monitoring alternative policies and on the cost of this monitoring. The choice of the instrument would also be a 'political' decision as billions of dollars will be at stake for certain countries depending on the outcome of such a debate. In particular, the implications for developing countries would be critical. Because of their rapid prospective growth in energy use, these countries would be especially severely affected by the Toronto targets; but for the same reason, their participation would be essential to any global emissions strategy. Gaining their participation is thus likely to be one of the dominant issues determining the choice of policy put in place to cut emissions (see Chapter 7).

The countries in a consensus, the policy used to cut emissions and the size of the cut in emissions would all be key factors determining the cost Australia would face in an international consensus. Australia's own actions will also affect the cost it would face. In the following section these factors are brought together to provide insights into the possible costs Australia would face from an international consensus.

5.4 Implications for Australia

The discussion thus far has highlighted that the cost Australia would face in an international agreement would depend on the size of the required cut in emissions both in Australian and overseas and would also depend on the policy instrument chosen to achieve the cuts. The way these factors will impact on Australia will have three components:

- the tax imposed within Australia would lead to a reallocation of resources away from carbon producing and using industries to other industries, with an overall effect on GDP;

- the prices Australia receives for its exports and pays for imports could change because:

  - the carbon taxes imposed by other countries would induce a worldwide reduction in real income which would cause a contraction in demand for Australia’s exports, driving down their prices;

  - the carbon taxes would shift export demands away from fuels and fuel-intensive manufactures, further decreasing export prices for these commodities; and carbon tax

  - carbon taxes in other countries may raise the price Australia has to pay when it imports items affected by those taxes.

Australia would be significantly affected by all these factors. The sectors most heavily affected by a domestic carbon tax would be Australia’s mineral industries. Australia has a large and efficient mining and minerals processing sector and a tax which drove resources out of this sector would reduce real incomes in Australia.

Similarly Australia would be penalised by the terms of trade effect of the introduction of a carbon tax globally. As would be expected, Australia’s exports are concentrated towards supplying the world’s more advanced economies and are heavily biased towards supplying minerals in raw and processed form and energy intensive manufactures (Table 5.7). Accordingly, carbon taxes which reduced activity in overseas countries would contract Australia’s exports in total but would have a particularly severe effect on fuels and fuel-intensive exports.

Table 5.7: **Australia's export by commodity and destination**
(per cent of 1988 exports)

Destination	*Coal*	*Other Minerals*	*Energy intensive ------ Manufactures ----- Meals*	*Other*	*Other*	*Total*
New Zealand	0	4	11	75	11	100
United States	1	13	6	46	34	100
Japan	21	8	21	22	28	100
Korea	20	11	21	29	19	100
ASEAN	2	7	27	42	46	100
China	0	7	4	42	46	100
All destinations	11	7	16	35	31	100

Source: WEDGE model database.

The important question is how great these effects are likely to be. The GREEN model cannot provide a satisfactory answer to this question, as its 'Pacific' region brings Australia together with Japan and New Zealand. The Commission has accordingly constructed a multi-country multi-sector model in which Australia is separately identified. The model, which is known by the acronym WEDGE (**W**orld **E**nvironment **D**egradation **G**eneral **E**quilibrium Model), simulates production, consumption, and trade in 34 commodities in nine world regions. Rather than tracking economic growth and adjustment through time, the model simulates the effects of policy changes on the world economy at a single point in time. The simulations presented in this report have been conducted in an economic environment designed to reflect adjustment possibilities over the medium run (see Box 5.3).

In its treatment of how energy prices affect production techniques, WEDGE follows GREEN in allowing substitution between different sources of energy, and between energy, capital and labour. Otherwise the economic structure generally follows the OECD's WALRAS model (OECD 1990). Like GREEN WEDGE treats the state the technology as autonomous.

Box 5.3: **The WEDGE model**

The **W**orld **E**nvironmental **D**egradation **G**eneral **E**quilibrium (WEDGE) model was developed by the Commission to assess the costs to the world economy of implementing greenhouse has emission controls.

In this general equilibrium, comparative-static model, the work is divided into nine regions, with a focus on the Pacific area; the regions are Australia, New Zealand, Canada, the United States, Japan, the Republic of Korea, the European Community, ASEAN, and a rest-of-the-world aggregate. The model distinguishes thirty-four commodities which are produced by single-output industries. Two commodities (coal, and oil and gas) are primary energy sources and two (petroleum and coal products, and electricity) provide secondary energy.

Industries can substitute between all energy sources in their production processes. A full production structure also describes how industries substitute between primary factors (labour, capital, and agricultural land) and energy, and how these inputs are combined with materials. Private and public consumption are accounted for, as well as the demand for investment purposes. Regional models are linked through trade flows. The level of regional, commodity and activity disaggregation allows economies to adapt to emission control policies.

The Commission used the WEDGE model to simulate a greenhouse consensus involving reductions in carbon dioxide emissions of 40 per cent in each region. The simulation was conducted in a medium run environment in which primary factors can move freely between industries, but not between regions.

Like most other general equilibrium models, WEDGE can be used to estimate changes relative prices, but not in the price level, either in individual regions or in the world as a whole. This is because it does not model the monetary sector of the economy, so that it cannot determine changes in inflation or in nominal exchange rates (although it does estimate changes in real exchange rates). For this reason the WEDGE simulations reported below assume fixed nominal exchange rates, and fixed world average factor prices. All price results from the model can therefore be interpreted as price change relative to the world average factor price, expressed in common currency units.

The model accounts fro energy-related carbon dioxide emissions in each region, but not for other anthropogenic carbon dioxide emissions, not for emissions of other greenhouse gases. It does not incorporate any climatic benefits of reducing greenhouse gas emissions.

Further details of the WEDGE model are provided in Appendix G.

As noted in the preface to the draft report, the modelling work presented at that time was preliminary only. Since then the model has been substantially revised and extended. The country coverage has been completed by adding a region, the ‘rest of the world’, containing all countries not included elsewhere, and the treatment of energy demand has been improved. These and other amendments have inevitably affected the numerical results now presented, which supersede those in the draft report. The insights supported by the results however remain largely unaffected.

In modelling as international consensus to reduce greenhouse gas emissions, the question arises of how the reductions would be distributed across countries. Under the Toronto proposal (as discussed in Section 5.1), the required cuts in emissions, relative to baseline projections, would be greater in the developing economies than in the industrialised economies. On the other hand, as discussed in Chapter 7, the industrialised economies have on the whole shown more interest than the developing economies in pursuing greenhouse avoidance policies.

Rather than speculate about the likely distribution of emission reductions across countries under an international consensus, the commission has modelled a scenario involving uniform emission reductions relative to baseline in all world regions. The size of the reduction has been set at 40 per cent. This is less than the estimated 47 per cent reduction required to achieve the Toronto global target for 2005, but greater than the estimated 35 per cent which the Toronto proposal would required on average of OECD countries. It is also close to the estimated simulations have been conducted which different global targets, to illustrate the relationship between the size and the cost of the global reduction.

As shown on Table 5.8, the estimated tax rate required for the 40 per cent reduction in carbon dioxide emissions caries widely between regions. The tax rate in Australia is relatively low, $34 per tonne of carbon dioxide in 1988 US dollars, or $40 pr tonne in 1988 Australian dollars. This reflects low initial fuel prices and moderately good opportunities for substituting away regions with dearer fuel or fewer substitution options required higher taxes.

Table 5.8: **Carbon tax required to achieve a 40 per cent reduction in emissions in each WEDGE region**

Country	*Required tax (US$ 1988 per tonne CO_2)*
Australia	34
United States	38
European community	102
Japan	59
Korea	98
ASEAN	91

Source: Revised WEDGE model results

The cost of reducing carbon dioxide emissions in each region appears as a contraction in aggregate output (shown in Table 5.9 by the estimated percentage decrease in real net domestic product). The output decline varies across regions; Australia, with a decline of 1.5 per cent, lies near the middle of the range. This reflects the opposing influences of the relatively low uni abatement cost and the high initial carbon intensity of the Australian economy. As indicated by the low carbon tax, the cost of abatement, per tonne of carbon dioxide, is low; but the high carbon intensity means that the amount of abatement required, in tonnes of carbon dioxide, is large relative to the size of the economy. As with GREEN, the variation in carbon taxes across countries suggests that the assumed distribution of emissions reductions across countries is not efficient. There would be scope to achieve the same global reduction at lower global cost, using tradeable permits or some other mechanism to redistribute the emissions reductions so as to equalise abatement costs across regions.

Table 5.9: **Macroeconomic effects of a 40 per cent reduction in emissions in each WEDGE region** (per cent)

Variable	*Australia*	*United States*	*European Community*	*Japan*	*Korea*	*ASEAN*
Real net domestic	-1.5	-1.2	-1.3	-0.6	-3.8	-1.9
Terms of trade	-1.2	-0.3	0.7	0.6	1.5	-2.0
Real national expenditure	-1.7	-1.2	-1.2	-0.5	-3.3	-2.7
Factor price index	-0.2	0.2	3.1	3.1	-4.2	-1.5
Output price index	3.0	5.2	4.8	4.8	8.9	6.2
Export price index	4.4	5.0	5.7	5.7	7.0	4.0
Volume of imports	-3.1	-2.0	-5.9	-5.9	-8.3	-4.4
Volume of exports	-2.0	-2.1	-9.4	-5.0	-9.4	-2.7

Source: Revised WEDGE model results.

The cost to each region of the international consensus depends not only on its own abatement actions, but also on the actions of its trading partners and competitors. Australia, as a major coal exporter, would suffer from weakening demand for coal in export markets. This reduction in export demand is largely responsible for the simulated deterioration in Australia's terms of trade, estimated at 1.2 per cent. The terms-of-trade deterioration combines with the reduction in output to reduce national income. This in turn is reflected in a reduction in real national expenditure, estimated at 1.7 per cent.

The aggregate trade results for Australia reflect the adjustments imposed by the decline in real national income and the loss os coal export markets. The decline in national income leads to a fall in demand for imports, and therefore in the required level of exports; while the loss of coal export markets must be offset by increases in non-coal exports of decreases in imports. The net outcome is an estimated contraction of 3.1 per cent in aggregate imports, and 2.0 per cent in aggregate exports. The contraction in aggregate exports is the net effect of a sharp decline in fossil fuel exports, and moderate growth in exports of non-fuel commodities.

The trade effects of the global consensus are important, not only because they contribute to the continuing effect of the consensus on national income, but also because of their implications for macroeconomic adjustment. To offset the effect on the balance of trade of the loss of coal exports, Australia needs to enhance the competitiveness of its other traded-goods industries. This required traded-goods prices (expressed in common currency units) to be reduced relative to those of our trading partners and competitors. The task is accomplished in the simulation by reducing wage rates and returns to capital relative to other regions. Factor prices in Australia fall by an estimated 0.2 per cent, against price increases in other industrialised economies ranging from 0.2 per cent (in United States) to 3.1 per cent (in Japan). Together with the 3.2 per cent decline in Australian factor prices relative to output prices, this helps to indicate the size of the macroeconomic adjustment pressures that Australia would have to absorb.

As would be expected, Australia's energy and energy-related industries are adversely affected by the greenhouse consensus (see Table 5.10). The decline in Australian coal production reflects a loss of export markets, due to other countries' abatement action, a fall in domestic demand due to Australia's own action, and a rise in costs in the Australian coal industry, which is itself relatively fuel-intensive. Output increases are observed in export industries which are not carbon-intensive; wheat output expands by an estimated 8 per cent, and output of minerals other than fossil fuels by 13 per cent. Some import-competing manufacturing industries also expand. These sectoral results give some indication of the microeconomic adjustments required.

Table 5.10: **Effect of a 40 per cent reduction in global emissions on Australia's fuel related industries**

(per cent)

Industry	*Output*	*Exports*	*Outputs prices*
Coal	-61	-57	7
Oil and gas	-29	-34	8
Petroleum and coal products	-20	-3	6
Basic iron and steel	-4	-8	16

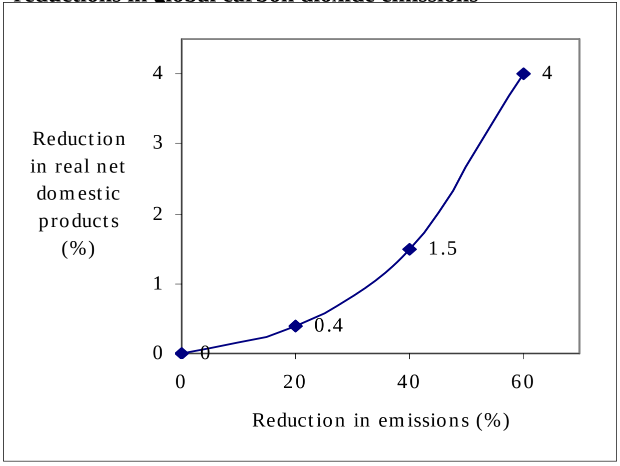
Source: Revised WEDGE model results.

As noted at the beginning of the chapter, the cost of an international consensus would depend on the targets specified. The Toronto agreement proposed a 20 per cent decline in carbon dioxide emissions between 1988 and 2005 in each country but, as detailed in Chapter 7, few countries have committed themselves unconditionally to achieving this. On the other hand, the Commonwealth Government' interim planning target, while conditional, is more stringent than Toronto, since it applies not only to carbon dioxide but to all greenhouse gases not already subject to controls. Furthermore, stabilising emissions of emissions of greenhouse gases at any given level would require progressively stronger abatement action over time, as growing economies would have to become progressively less greenhouse-gas-intensive.

For these reasons it is important to consider how the emissions targets affect the cost of abatement. The Commission has accordingly simulated carious targets for global carbon dioxide emission reductions, besides the 40 per cent reduction describe above. As shown in Figure 5.2, the cost of abatement is sensitive to the reduction target. Small reductions in emissions can be achieved using only low-cost measures, but larger reductions require costlier measures, so that the cost of abatement increases more than proportionately with the amount of the reduction.

Thus in Australia, as the target is raised by 50 per cent (from 40 to 60 per cent), the cost more than doubles. Broadly similar results are obtained for other regions.

Figure 5.2: **Effect on Australia of alternate target reductions in global carbon dioxide emissions** [a]



[a] Results derived from simulations in which emissions are reduced by the required percentage in each country
Source: Revised WEDGE model results.

As in the GREEN model, the cost of abatement depends on the ease with which firms can replace more carbon-intensive with less carbon-intensive forms of energy, and energy with non-energy inputs. Table 5.11 shows how the estimated cost of abatement falls when different substitution possibilities are assumed. For the high-substitution case the elasticity of substitution between different forms of energy was increased from 1.2 to 2.0, and the elasticity of substitution between energy and capital from 0.5 to 1.0. This reduced the estimated decline in Australian real domestic product by a quarter, from 1.5 to 1.1 per cent.

Table 5.11: **Effect of a 40 per cent reduction in global emissions on output in each WEDGE region, under alternative energy-substitution assumptions**

(percentage changes in real net domestic product)

	Energy substitution possibilities		
	Low[a]	*Standard*[b]	*High*[c]
Australia	-2.8	-1.5	-1.1
United States	-1.8	-1.2	-0.8
European Community	-2.3	-1.3	-0.9
Japan	-1.6	-0.6	-0.4
Korea	-7.4	-3.8	-2.6
ASEAN	-3.5	-1.9	-1.2

[a] Elasticity of inter-fuel substitution set at 0.5, elasticity of fuel-capital substitution at 0.2.
[b] Elasticity of inter-fuel substitution set at 1.2, elasticity of fuel-capital substitution at 0.5.
[c] Elasticity of inter-fuel substitution set at 2.0, elasticity of fuel-capital substitution at 1.0.
Source: Revised WEDGE model results.

The Commission's best estimates of likely future emissions levels in the year 2005 (Table 5.1) suggest that they will need to be cut by something approaching 50 per cent to achieve the Toronto targe. The Commission's preliminary model results indicate that costs increase with the level of emissions reduction at an increasing rate, as shown in Figure 5.2. This, with the likelihood of reduction of the order of 50 per cent being required, suggest that t he role of new technology in improving fuel efficiencies will be very important. These issues are addressed in the following section.

5.5 The role of new technology

The key to reducing costs is the development and adoption of new, more efficient technologies. Provided it is financially viable, the importance of fuel-saving technology cannot be overstated, as it offers a means of reducing the impact on Australia's standard of living of any given targe for emissions reductions.

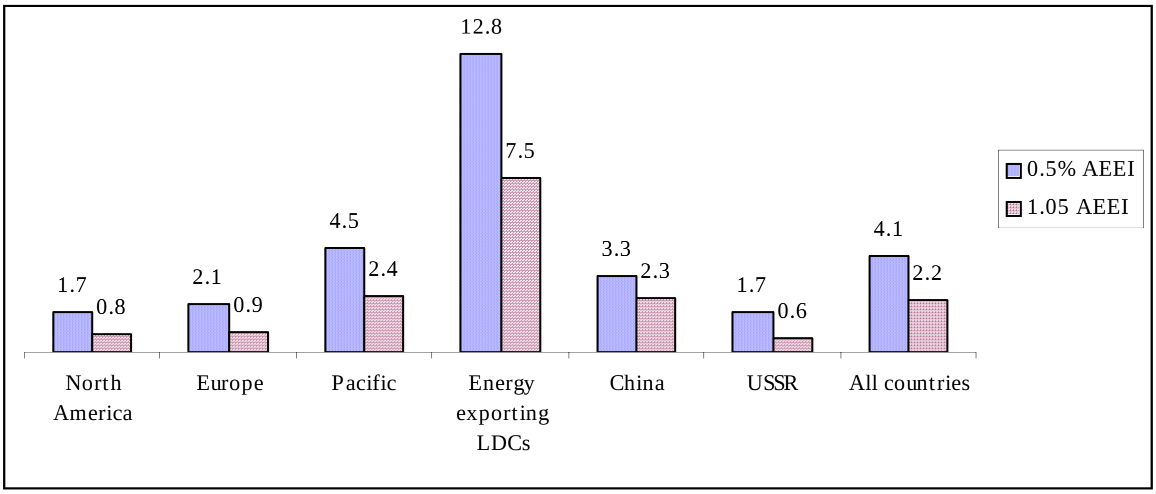
It is unlikely that the adoption of fuel-saving techniques will be economically viable in all situations because of the different circumstances and factors involved. For example, first home buyers may not install home insulation because of cash flow problems even though they would save money over the longer term through lower fuel bills over the life of the house.

Box 5.4 summarises some of the key factors that would need to be taken into account when evaluating the economics of introducing new technologies. Real interest rates, the life span of assets and fuel prices all play a role in determining the cost effectiveness of new technologies.

New technology should not be introduced where it is not economically viable; to do so would only exacerbate the overall cost to the economy of cutting greenhouse has emissions. Rather is should be adopted by energy users through choice. If informational barriers exist, as has been suggested by numerous authors (Greene 1990, Wilkenfeld Sub. 9), then these need to be overcome through the provision of information. For example, consumers should be informed about the likely net energy savings obtainable through new technology, as well as the capital costs involved.

The important role technological improvements can play in reducing the cost involved in cutting greenhouse gas emissions can be seen from the OECD's work. In their modelling, a 1 per cent year autonomous energy efficiency improvement (AEEI) is assumed. In one experiment the OECD halved the rate of autonomous technological improvement and found that substantially higher carbon taxes were required to achieve the Toronto-type objective. Consequently, for several economies, the cost of achieving the Toronto-type agreement more than double (Figure 5.3).

Figure 5.3: **Impact of technological improvements on the cost of cutting greenhouse gas emissions** (percentage change in real household income)



Source: GREEN simulation results.

Box 5.4: **The economics of saving energy**

It is often argued that people should be encouraged to save energy through conservation and the use of more modern, efficient technology. New technology can, however, be expensive, and people will not be inclined to invest in it if it costs more than they will save through lower energy bills.

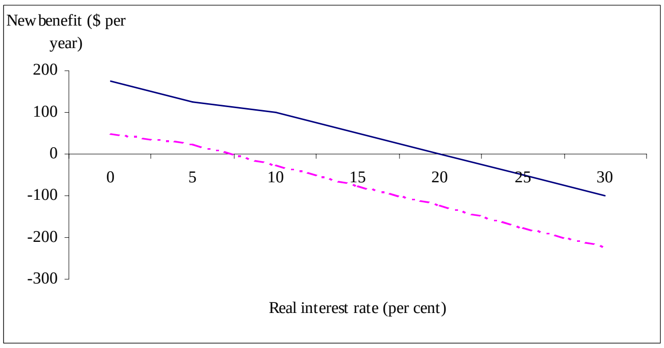
For example, BTR Nylex (1989) has estimated that insulating a 12 square home could save 32 per cent of its heating and costing requirements. For the average such home this could reduce energy demand by 14 per cent, or between $75 and $200 a year. The cost of insulting a new 12 square house is estimated to be $950 (BTR Nylex 1989). This can be converted into an annual use charge, (a) for comparison with the annual energy savings by using the formula:

$$A = P/[(1-e^{-rn})/r]$$

Where P is the initial cost outlay ($950), r is the real interest rate, n is the lifetime of a house (assumed to be 70 years); and e is the natural logarithmic base (2.71828)

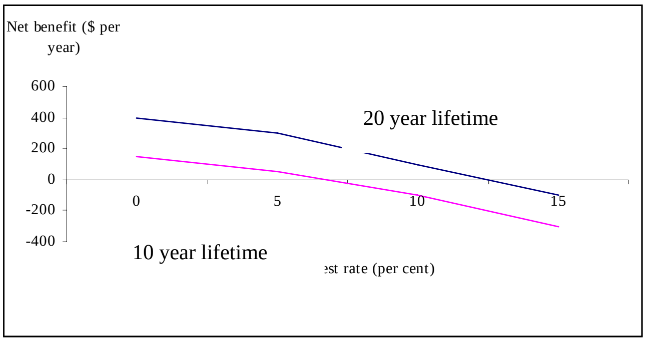
Net benefits from home insulation under alternate real interest rates are graphed for two average yearly electricity bills of $520 and $1330. At the upper end of the electricity expenditure figures, home insulation would provide net benefits even for very high real interest rates of up to 20 per cent. In contrast at the lower expenditure level, insulation would only yield net benefits at real interest rates of below about 10 per cent.

New benefits from home insulation



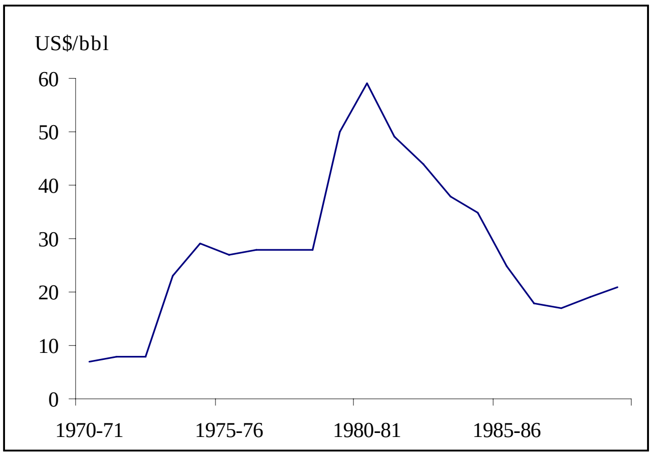
As another example, CRA (1989) has estimated that fuel savings of 58 per cent could be achieve in new cars, but would also raise the cost of a new car by 25 per cent. As can be seen in the future below, for a new car costing $20,000 before the efficiency improvement, with an average yearly expenditure on fuel of $1,165, and assuming an average life-span of 10 years, the new fuel efficient cars would only be worth purchasing at interest rates below 7 per cent.

Net benefits from efficient new cars



These two examples illustrate some of the main factors influencing the incentive to invest in energy saving technology. In particular, high interest rates raise the cost of using new technology by making it more expensive to service the initial purchase price. Also important, however, are the expected life-span of the new technology and its initial cost. The longer the equipment is expected to last, and the cheaper it is to purchase, the greater the incentives to buy technology which can save energy and reduce greenhouse gas emissions.

Table 5.4: **Real world oil prices** [a]
(1990US$)



A principal factor driving the adoption of fuel saving techniques would be higher fuel prices. These are predicted higher fuel prices. These are predicted to rise dramatically whether carbon taxes or quotas are introduced to cut greenhouse gas emissions (Table 5.12). Some insight into the ability of the world economy to adjust to higher fuel world economy to adjust to higher fuel prices can be gained from reactions to the oil price shock of the early seventies. Through their ability to restrict world oil supplies, OECD countries were able to raise the price of crude oil from under US$60 per barrel real in the early eighties *Figure 5.4). the world economy has thus already been through a period of energy price rises of a greater magnitude than those predicted to occur if Toronto-type agreements are introduced.

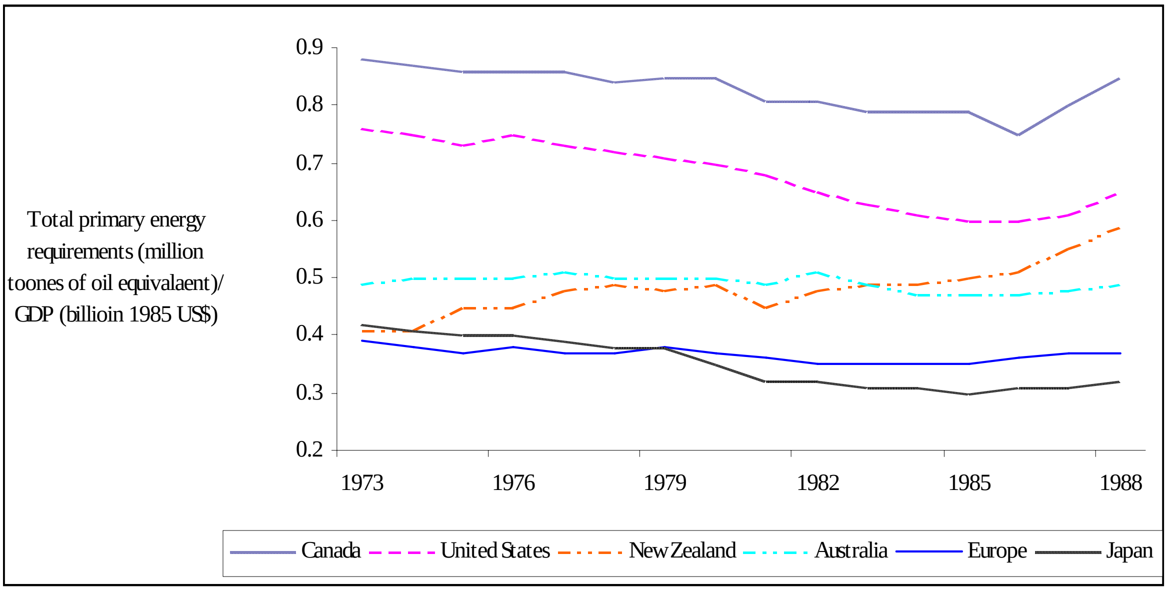
Table 5.12: **Increases in real domestic energy prices by source in 2020**
(percentage increases compared with baseline)

	North America	*Europe*	*Pacific*	*Energy-Exporting LDCs*	*China*	*USSR*
Coal	531	299	759	569	245	332
Crude oil	72	68	263	112	18	193
Natural gas	88	68	281	86	24	157
Refined oil	59	64	229	77	16	167
Electricity	41	36	83	49	49	75

Source: GREEN simulation results related to the consumption based carbon tax (see Box 5.1).

Partly in response to this relatively large increase in real oil price, new techniques were introduced which enabled the world economy to substantially reduce its dependence on oil. As shown in Figure 5.5 over the period 1970 to 1989, the world's largest economies substantially reduced the amount of energy used to produce outputs. The adoption of fuel saving techniques has slowed in recent years in line with the drop in real oil prices since the early eighties. What is surprising about Figure 5.5 is the very small change in the energy intensity of the Australian economy over the period 1973 to 1988.

Figure 5.5 : **Energy intensity in IEA countries, 1973-1988**



Source: IES 1987, 1991.

Torvanger (1991) examined the factors that contributed to the reduction in aggregate manufacturing carbon dioxide intensity for nine OECD countries. Increased fuel efficiency contributed the most to reduce carbon dioxide intensity of industry. A shift away from the production of carbon intensive manufactured goods was also important as was reduced emission coefficients in electricity generation due to a greater reliance on nuclear power and gas.

The demonstrated capacity of the world economy to economise on the use of energy in periods of higher fuel pries is a strong point in favour of achieving emission reductions through a price mechanism, such as a carbon tax, rather than through regulation. The price option allows individuals to choose how best to reduce emissions. Regulation on the other hand requires the bureaucrat to judge how this is best done. Clearly the price option has been very effective in the past and there is no reason to suggest that it would not be as effective if needed in the future.

The world's economies have, in the past, responded to the need for greater fuel efficiency. But are there sufficient technological improvements that could be utilised in the future? Fortunately it appears that there are an extraordinarily large number of technically efficient measures that can raise energy efficiency, and hence reduce emissions of greenhouse gases. For example, Greene (1990) claims that efficiency improvements in residential and commercial heating and lighting; greater use of cogeneration in the manufacturing sector; improved fuel efficiency in the road transport, motor vehicles and agricultural vehicles; shifting a greater proportion of freight from road to rail; and improved energy efficiency in the mining sector, could reduce energy requirements in 2005 by 36 per cent, and carbon dioxide emissions by 19 per cent. While this is less than half the reduction that would be required under the Toronto targe, it would nevertheless be a substantial contribution to the overall reduction required. That is not clear to the Commission is the cost-effectiveness of these improvements (see the case studies in Appendix F).

A slightly less ambitious program of efficiency improvements has been suggested by Wilkenfeld (Sub. 9). He argues that efficiency improvements of 27 per cent are possible in the electricity sector, and 18 per cent in the use of petroleum products. These efficiency improvements could, it is argued, allow total emissions to be reduced by 20 per cent and energy used by 17 per cent. The breakdown of these potential reductions by sector is shown in Table 5.13.

Table 5.13: **Potential energy and carbon dioxide savings by sector**

	Energy use		*Carbon dioxide*	
	Percentage Reduction	*Share of savings*	*Percentage reduction*	*Share of savings*
Industry	10.6	22.6	13.8	26.4
Transport	17.7	40.6	17.6	22.7
Commercial	34.0	10.6	33.7	16.3
Residential	27.2	20.3	32.0	29.3
Other	15.0	5.8	15.0	5.0
Total	17.0	100.0	20.2	100.0

Source: Wilkenfeld (Sub, 9).

Thus there would seem to be scope for significant reductions in emissions to be achievable through the use of fuel-saving technology. Although new techniques may not be viable at existing energy prices, the may become viable if energy prices fully reflected all the economic and environmental cost involved. The suitability of current energy prices has been explored elsewhere by the Commission (IAC 1989, IC 1991a) as has the more general issue of resource pricing (IC 1991b).

5.6 Summing up

The cost of an international consensus to Australia would depend on four key factors:

- the required reduction in emissions in Australia and elsewhere;
- the policy instruments used to achieve the reduction;

- the scope for introducing fuel-saving techniques; and
- the flexibility of the Australian economy in handling the required reallocation of resources and the necessary reduction in real factor prices.

The cost of abatement would be very sensitive to the emission targets for Australia. If would also depend to some extent on the targets for other countries, since large reductions in other countries would detract from Australia's export prospects, by reducing demand in export markets generally, and markets for coal in particular.

As an energy exporter, Australia might be less adversely affected by a consensus involving through production taxes on fossil fuels than by a consensus involving consumption taxes. In common with other countries, it would probably be better off under a tradeable permits agreement than one which imposed fixed country quotas, provided that the tradeable permit system could be effectively and efficiently enforced and that permits and quotas were allocated on the same basis.

Emission reductions of the order of those proposed under the Commonwealth Government's interim planning target, applied to energy-related carbon dioxide emissions alone, might impose continuing costs on the Australian economy of the order of 1 to 3 per cent of net domestic product, depending on the flexibility of Australian energy demand. The costs would also be sensitive to the availability of new fuel-saving technology. Adjustment costs would depend on the required speed of reduction in emissions, and on the capacity of the Australian economy to cope with the associated changes in resource allocation and factor prices. Further discussion of the adjustments required in Australia is provided in Chapter 9.

6 WEIGHING COSTS AND BENEFITS OF GLOBAL CONSENSUS

The reference to the Commission is concerned with the costs and benefits to Australia of an international consensus to reduce emissions of greenhouse gases. Implicit in this is the issue of what the net costs or benefits might be. This chapter addresses the weighing of costs and benefits.

Several participants argued that such a weighing up was important. In particular, there was concern that the benefits of preventing climate change should not be overlooked. This view came from two groups. One group warned against implicitly accepting that benefits were small, and therefore that emissions reductions were not desirable. For example, in responding to the Issues Paper, the Friends of the Earth accused the Commission of a ‘misguided emphasis on costs’ (sub. 43). The other group considered that a lack of proper attention to benefits would encourage excessive reductions. For example, the Australian Mining Industry Council was concerned that:

> there are no estimates of the benefits of implementing policies to reduce emissions. While alternative approaches to achieving such standards can be compared, and a least cost policy identified, this tells us nothing about the net benefits to the Australian economy or to the world economy. Optimal policy should be based on a comparison of marginal benefits and marginal cost. (Sub. 16, p. 8)

Some participants recognised that weighing up costs and benefits was not going to be easy. The Victorian Government summed up several likely problems saying that ‘it is extremely difficult to conduct this traditional form of cost-benefit analysis’, and that ‘it would not be sensible to simply employ traditional cost-benefit analysis techniques to assess the costs and benefits of Australian participation in an international agreement to reduce GHG emissions’.

These views have been confirmed by the Commission's attempts to estimate costs and benefits. As should have become apparent from the preceding two chapters, a definitive, quantitative weighing up is not possible. Nevertheless, the Commission believes that much of relevance has emerged from its attempts to do so. This includes insights about the impact of uncertainties on how targets for greenhouse gas emissions reductions can be established and the influences that determine the magnitude of costs and benefits, both globally and for Australia.

6.1 The decision framework: a global perspective

An essential feature of the greenhouse problem is its global nature. It is useful, therefore, to begin a discussion of weighing the costs and benefits of an international consensus by adopting a global perspective. Some participants argued that this is the only proper perspective on the problem.

Optimal emissions abatement

In principle, policy should aim at a target which is an optimal level of emissions. Assuming that abatement were required, then the optimal program of emissions abatement would be that for which the marginal cost of abatement is equal to the marginal benefit. (This principle is discussed more fully in Appendix D.) It should be clear by now that application of this methodology to the greenhouse issue is limited in practice by poor information, particularly about benefits of abatement. An early attempt to use the methodology is that by Nordhaus (1991, p. 936) who observes that:

> the appropriate level of control (abatement) depends critically upon three central parameters of the climate-economic system: the cost of control of Greenhouse gases, the *damage* to human societies from greenhouse warming, and the *time dynamics* as reflected in the rate of discount of future goods and services along with time lags in the reaction of the climate to emissions. (emphasis added)

The quantification of these three `central parameters' involves very great difficulties:

- On the cost side, there is the complexity of determining how costs vary with abatement levels in a world in which activities within and between countries are interdependent, and changing over time with technology and patterns of demand.

- On the benefits side (that is, benefits of avoiding climate-related impacts) there is not only the problem that the impacts of ‘business as usual’ are not known, but also that a movement from that baseline caused by any given level of abatement is not known either.

- Added to these pervasive uncertainties about levels of costs and benefits is the problem of their timing. Costs start accumulating from the time an abatement policy is initiated, whereas benefits arising are delayed into the future. The question of how changing costs and benefits over time should be reduced to comparable numbers (discounted) is an area of controversy and involves ethical considerations as well as questions of economic efficiency (Appendix D).

Nordhaus approaches these problems by taking a global view of economic activity and a simple dynamic specification of emissions, concentrations and economic growth. The analysis focuses on a single trade-off between future and present consumption.

As noted in Chapter 4, Nordhaus' benefit estimates are derived from the work of others which excludes non-marketed goods and services and ignores costs associated with loss of biological diversity or changes to human health and lifestyles. Using additional ad hoc judgments about central values for each of the three parameters of the problem, Nordhaus finds the optimal level of abatement of emissions to be 11 per cent, of which 2 per cent comes from reduction of carbon dioxide, and 9 per cent from CFC reduction.[1] For each parameter, high and low values are also considered, reflecting the uncertainties involved in their estimation. Nordhaus (1991, p. 936) reports that:

> The efficient [optimal] degree of GHGs control would be essentially zero in the case of high costs, low damages, and high discounting; by contrast, in the case of no discounting and high damages, the efficient degree of control is close to one-third of GHG emissions.

Nordhaus does not explicitly address the question of decision making in the face of risk and/or uncertainty. By implication, the approach adopted involves assigning higher probabilities to the central cost and benefit estimates, and making the decision which maximises the expected value of net benefit. The Commission considers that the state of knowledge is such that probabilities cannot

1 These are revisions from his previous total estimate of 17 per cent, of which 1/2 per cent comes from trees, 4 1/2 per cent from carbon dioxide and 12 per cent from CFCs. See Nordhaus 1990a.

reasonably be assigned in this way. Further, as noted in Chapter 2, taking no action to limit the rate of increase in greenhouse gas concentrations may involve climatic `surprises' based on relationships not incorporated in the global climate models. Given these two considerations, it is not possible to apply the Nordhaus methodology to derive a reliable estimate of the optimal global emissions reductions target. It is necessary to approach the target setting problem within a framework which explicitly addresses the uncertainty issue. (Appendix D reviews in detail some of the basic ideas involved.)

Assessing specified targets under uncertainty

The existing frameworks for explicitly incorporating uncertainty into decision making relate primarily to situations where the problem is to select from among a number of separate options. The sort of question that can be addressed within such frameworks is: it has been proposed that greenhouse gas emissions be cut by k%, should this proposal be adopted? (This is the form of question that is implied by the terms of reference for this inquiry.) If a negative answer is given, the question can be recast in terms of a smaller cut in emissions; if positive, the exercise can be repeated to see if a larger cut should be adopted.

Given a question in this form, the analytical framework can be presented in terms of what is called a `pay-off matrix' (see Box 6.1). What this shows is the net costs and benefits of either taking action (say, implementing the Toronto target) or not taking action, according to whether or not there really is a climate problem, which is itself unknown.

Box 6.1: **A pay-off matrix for greenhouse uncertainty**

	States of nature	
	No climate problem	A climate problem
Strategy		
Business as usual	0	-x
Abatement action	-y	+z or –z

If there is no consensus and it turns out that there is no climate problem, the cost of doing nothing is zero. The other entries in the matrix are based on this reference point. If given business as usual it turns out that there is a climate problem, costs arise shown in Box 6.1 as -x: avoiding these costs would give rise to benefits of x. If there is abatement action when there is no problem, costs are incurred for no associated benefit, shown here as -y. If abatement action is taken and there is a problem, costs and benefits arise. If the action were such as to completely avoid climatic impacts, the bottom right entry in the matrix would be x-y, which could be positive or negative. However, proposed actions are not anticipated to completely avoid climatic impact, so this entry is shown as +z or -z, which could be a net benefit or a net cost.

The decision maker's problem is to select a strategy. Given that the situation is one of true uncertainty, and that firm probabilities cannot be assigned to the two `states of nature', all of the information available is displayed in the pay-off matrix. Solving the problem necessarily involves adding some information, which must come from the decision maker's attitude toward different outcomes. A 'cautious' approach would involve identifying the worst outcome of each strategy and selecting the strategy with the smallest of these (called `minimax', refer Appendix D). An 'adventurous' approach would involve identifying the best outcomes and selecting the strategy offering the largest outcome ('maximax'). There is no objective way of deciding whether a cautious or adventurous approach is better. Where, as in the case of an enhanced greenhouse effect, the decision maker is acting on behalf of society, the choice between approaches will involve the political process.

Practical problems

The example indicates the nature of the problem of determining a target level in the face of uncertainty, but it assumes away several practical issues.

First, the model does not address the problems arising from costs and benefits being displaced in time. It does not, in other words, deal explicitly with the question of discounting. For illustrative purposes it can be taken that all of the entries in a pay-off matrix have been appropriately discounted to present value terms. This is convenient, but merely ignores the substantive problems associated with discounting, discussed elsewhere in this report.

Second, the example assumes that the possible states of nature can be reduced to just two -- either there is or there is not an enhanced greenhouse effect. The review of the physical science of greenhouse shows that this is a gross oversimplification. In terms of global average temperature change alone, for example, GCMs reported by the IPCC gives a range of 1.9^{O}C to 5.2^{O}C consequent upon a doubling of carbon dioxide equivalent greenhouse gas concentrations. It is not possible to place firm probabilities upon each of the possible outcomes.

Third, it assumes that uncertainty attaches only to the occurrence of the alternative outcomes and that pay-offs resulting from a given climate outcome are known. This assumption is manifestly false. In Box 6.1, the value of x cannot be estimated (see Chapter 4). The Commission has made some estimates of y (see Chapters 5, 8 and 9), which could be regarded as rough approximations. But this does not help in deriving z.

As discussed in the following chapters, problems arise at the following levels:

- the extent of climate change for `business as usual' is uncertain;
- the bio-physical consequences of given climate change are uncertain (see Chapter 4);
- valuation of all bio-physical impacts, even if they were known, is not possible (Appendix D);
- the extent to which any proposed greenhouse gas reduction program would offset climate change is uncertain; and
- the costs of any proposed program to reduce greenhouse gas emissions are uncertain (see Chapters 5, 8 and 9).

Further complications arise. First, the costs of a global consensus for a target reduction in GHG emissions would be expected to vary with the means by which the target was to be achieved (see Chapter 3). Second, the incidence of costs and benefits across rich and poor nations could reasonably be argued as relevant to the merits of a program for emissions reduction. Third, a reduction in GHG emissions could bring about other environmental benefits which should be set against any costs of the reduction program.

The areas in which quantification is required if costs and benefits are to be weighed has been considered in the preceding chapters of this report. Estimates available in the literature have been noted. The Commission is unable to use them to form a view as to whether, at the global level, the benefits of a 20 per cent reduction in greenhouse gas emissions on 1988 levels achieved by 2005 would exceed or fall short of the costs of such a program. Moreover, given the uncertainties presently attaching to such estimates, the Commission takes the view that the weighing of costs and benefits is not a matter which can be definitively resolved on an objective basis. It necessarily involves subjective or judgmental considerations, as shown above.

Insurance

Choosing whether to adopt a GHG reduction target has features in common with the consideration of whether development which carries the risk of species extinction should be allowed. In both cases it is impossible to assign probabilities to alternative states of nature and the appropriate entries in the pay-off matrix are not known. The `safe minimum standard' approach (SMS) was developed in the latter context and can be applied to considering the greenhouse problem (Appendix D).

Referring back to the illustrative pay-off matrix (Box 6.1), the SMS view would be that there are strong grounds for taking x to be larger than either y or z -- for example, the possibility of an abrupt major shift in climate (an adverse climatic ‘surprise’) which would suggest that costs would exceed those involved in an emissions reduction program. If that program is assumed to eliminate the climatic surprise possibility, then x must be the largest prospective loss and the adoption of a consensus strategy is indicated on the minimax approach.

Leaving aside climatic surprise, there is the possibility that the enhanced greenhouse effect could itself cause species extinction. This could entail the loss of resources of large future value to mankind, presently unknowable.

On these arguments, and following a minimax approach a global emissions reduction program would be adopted whatever its cost. This would be the case whatever the best guess at the size of x. The so-called ‘modified safe minimum standard’ approach seeks to meet this difficulty by proposing that an emissions reduction program should be adopted unless its costs are unacceptable. Thus, modified SMS re-formulates the question to: how much is society willing to pay now to insure against unknown future contingencies?

Emissions abatement is not the only form that insurance could take. Manne and Richels (1990b) point out that there are two other ways in which resources diverted from current consumption could be used to provide insurance against future greenhouse contingencies. These are on research to improve scientific understanding and reduce uncertainty; and on research and development for new energy supply technologies. It need not therefore be a case of putting resources into just one of these. Rather, the issue becomes one of determining the best allocation of resources across the three forms of insurance.

Manne and Richels use a model to illustrate how this question can be formalised, and to provide some indicative answers (see Appendix D). The analysis assumes that any greenhouse danger will be identified early enough to avoid long-term irreversible damage. This assumption is not necessarily appropriate in the case of an enhanced greenhouse effect. It is necessary for the Manne and Richels analysis and the results derived. Manne and Richels find that the `near-term policy implications are clear'. These are that:

> There is less need for precautionary emission cutbacks if we undertake significant expenditures to reduce climate uncertainty and to develop new supply and conservation options. Better climate information reduces the need to hedge against a potentially hostile future. Improved supply and conservation technologies will enhance our ability to deal with such a future if it should occur.

In this respect, the insurance approach is a `hedging strategy'. Its merit lies in that some level of global emission reductions can be put in place at the same time as further research efforts are brought to bear. In the event of improved information suggesting that climate change will not arise, the hedging approach would have avoided the costs of needlessly undertaking a full emission reduction strategy. On the other hand, should further research indicate a prospective greenhouse problem, emission reductions and research on technological improvements could be increased. From a pragmatic viewpoint, this approach avoids the controversy inherent in deciding simply whether or not to reduce emissions. However, if it is not known that uncertainties will be resolved before any irreversible commitment to major damage (itself uncertain), the approach loses much of its intuitive appeal.

It should also be noted that the Manne and Richels approach described here involves the assumption of risk neutrality on the part of the decision maker. Risk neutrality involves being indifferent between an offer of $x for certain and the offer of a gamble which would over many repetitions yield a gain of $x. A decision maker would be risk averse if he/she preferred the certain outcome to the actuarially equivalent gamble. Many would argue that risk aversion is the appropriate stance for social decision making in regard to an enhanced greenhouse effect. In the Manne and Richels model, risk aversion would imply larger precautionary emissions cutbacks than would risk neutrality.

In sum, it is clear that the pervasive uncertainty about an enhanced greenhouse effect requires a subjective decision by government about what action is appropriate. Since an optimal emissions level cannot be computed, any action must be in the form of an arbitrary standard. The Toronto target, though insufficient to stabilise greenhouse concentrations, can be seen as a form of hedging or insurance. The rest of this chapter concentrates on the costs and benefits to Australia which could arise from policy measures designed to bring about global reductions in emissions to Toronto levels.

6.2 Costs and benefits to Australia

Taking a national perspective does not mitigate the enormous problems that are involved in weighing up the costs and benefits of a global consensus to reduce greenhouse gas emissions. Indeed, weighing up costs and benefits for Australia introduces additional considerations which make the task even more complex. It involves problems which can usefully be put into two broad groups:

- An international consensus could take one of a number of different forms. That the costs to Australia would differ according to the form of consensus is perhaps reasonably self-evident. But it also true that the benefits to Australia could vary with the form of consensus.

- If the form of consensus is taken as given, there remains the problem of uncertainty as to the magnitudes of Australian costs and benefits. This problem was considered above from the global perspective. It is compounded, especially in regard to benefits, when an Australian perspective is adopted.

These two aspects of the weighing up problem for Australia are considered in turn.

The form of consensus

As noted previously, a Toronto type consensus in favour of a stabilisation of (non-CFC) emissions of greenhouse gases could take a number of different forms. At the general level the main alternatives are:

- A system of quantitative regulation across nations with each being allocated an emissions quota.
- A system of tradeable permits whereby each nation would be allocated permits in the amount of its quota, but also being allowed to increase/decrease its quota by buying/selling permits.
- A system of uniform international taxation of greenhouse gas emissions.

Mixed systems are, of course, conceivable, but the issues can be brought out by considering these broad alternatives.

Assuming that monitoring and compliance can be assured, the first two alternatives have the characteristic of being relatively dependable (provided that the quota allocations are enforceable and add up to the global emissions target). A system of international taxation would not guarantee target realisation -- the resulting emissions reductions could exceed or fall short of the target, according to the tax rate set. As the tax could be varied over time in the light of outcomes, imprecise attainment of the target in the short term would not be of crucial concern in the greenhouse case given the long lead times involved and the fact that the Toronto target in itself lacks any precision.

The alternatives also differ with respect to cost minimisation at the global level. Setting aside monitoring and compliance costs, fixed national quotas would not be the least cost alternative, and could involve substantial avoidable costs to the world as a whole. On the other hand, tradeable permits and uniform international taxation would minimise costs worldwide.

The model results of Whalley and Wigle (1990 and 1991) and OECD (1991c) referred to in Chapter 5 above are consistent with these propositions.

A consensus which minimised global costs need not, however, minimise costs to Australia. The incidence of costs across nations will vary according to the broad type of consensus, the detailed means of national implementation and the economic circumstances of each country. The cost implications for Australia of a uniform international taxation regime would, for example, depend upon the agreed manner in which the revenues arising were to be disbursed to nations. The modelling results from Whalley and Wigle reported in Box 5.1 illustrate how national costs arising from each nation using taxation to achieve its national emissions quota would vary according to whether the tax base was fossil fuel production or consumption. The modelling work of the OECD illustrates the differential cost of fixed quotas achieved by national consumption taxation and allowing permit trading.

Preferred forms of consensus?

The question naturally arises as to which form of international consensus would yield the most favourable cost-benefit outcome for Australia. In the Commission's view it is not possible to provide a definitive answer to this question. If it is assumed, however, that Australian benefits would be the same whatever form a consensus took, the question reduces to comparing Australian costs across different forms of consensus.

While the range of possible forms is wide, only a small subset has been quantitatively modelled to date. Many of the modelling results available so far derive from studies in which Australia is not distinguished as a separate nation, but is combined with others with different economic characteristics and international trading patterns. They also relate only to the reduction of carbon dioxide emissions, not to the reduction of all (non CFC) greenhouse gas emissions referred to in the terms of reference. Some results which distinguish Australia separately are reported from WEDGE but they all relate to carbon taxation regimes. The results reported in Chapter 5 above suggest, however, that tradeable quotas would offer some advantages to Australia as compared with fixed quotas for each country (to be realised by taxing fossil fuel consumption).

Intuition is a poor guide to assessing the cost implications for Australia of any particular form of international consensus. Taxes collected by an international agency with the revenue shared among nations on an equal per capita basis would appear not to serve Australian interests, for example. However, the obvious basis for this conclusion, Australia's relatively small population size, overlooks the possible consequences for Australian exports, resulting from higher incomes in other countries following redistribution of the tax revenue. Results reported by Whalley and Wigle (1990 and 1991), subject to the caveats noted above, suggest that these second-round income effects on trade flows are significant but would not in fact offset the first round losses to Australia. Nevertheless, the example shows the need for detailed empirical analysis of particular forms of consensus.

Without such analysis, only the most general conclusions are supportable. A consensus which involved fixed national quotas and required each nation to realise its quota by quantitative regulation of emissions, as opposed to domestic taxes or tradeable permits, would, for example, impose avoidable costs on Australia, and all other nations. Relevant issues are discussed in more detail in Chapter 3.

If the desirability of an international consensus is taken as a given, then the form of consensus which minimises Australian costs may not be acceptable to some potential signatories. In such a situation, Australia would face a trade-off between reaching a consensus and minimising the costs involved. The difficulties confronting realisation of an international consensus are discussed in Chapter 7 of this report. They imply that substantial aid from the developed to less developed nations might be a necessary (though perhaps not sufficient) condition for the participation of the latter. Such redistribution would impose costs on Australia not presently captured in the Commission's modelling.

The terms of reference for this inquiry specify an international consensus in favour of reducing all (non-CFC) greenhouse gas emissions. The original Toronto declaration related only to carbon dioxide emissions. As discussed in Chapter 2 of this report, and in more detail in Appendix C, scientific understanding in regard to sources and sinks is less incomplete in the case of carbon dioxide than in the case of the other greenhouse gases. As should be obvious by now, the Commission is unable to quantify even in broad terms the differences in costs and benefits, to the world or Australia, which would arise as between a greenhouse gas targeted consensus and one targeted on carbon dioxide alone. Again, the possibility of a trade-off arises. While targeting all greenhouse gases could mean lower costs from consensus to Australia, targeting of some gases is presently infeasible.

Uncertainty about consensus costs and benefits

If the form of consensus were known, weighing costs and benefits would not entail the problems just discussed. Major problems would nevertheless remain.

On the cost side, any precise estimation would still be beyond the capabilities of existing models. The problems with the models of the global economy were discussed above and would be applicable in this context. The problems attending the use of existing economic models to assess the response of the Australian economy to the external change that a consensus would imply, and to any domestic action such as carbon taxation, are also discussed at several places in this report (see Chapters 5, 8 and 9, and Appendix G). For instance, as the database of the ORANI model, used in Chapter 9, does not incorporate emerging technologies such as renewable energy, energy efficient appliances, and changes in iron and steel technology, overall reductions costs could be overestimated. Against this, however, the model assumes away many adjustment costs and economic rigidities which apply in reality and, on this basis, would tend to underestimate overall costs. Given these problems the modelling results can be little more than illustrative.

On the benefits side, the major problem is that estimation is, at every stage from climate change itself through to valuation of the human impacts, even more uncertain than it would be from a global perspective. As discussed in Chapter 4, the confidence which can be placed in assessments of likely climate change is even less at the regional level than at the global level. Consequently, assessment of the likely bio-physical impacts on Australia of `business as usual' globally is subject to massive uncertainty. This then carries over to estimation of any damage in Australia which would be avoided by a consensus on emissions reduction.

The general principles which can illuminate the problem of decision making in the face of uncertainty, discussed previously, also apply when an Australian perspective is adopted. All of the considerations which militated against using anything other than imaginary numbers when adopting the global perspective apply with greater weight when adopting an Australian perspective. Any attempt by the Commission to set up a pay-off matrix for Australia for Toronto-type targets, even in order of magnitude terms, would run the risk of lending credence to numbers which would be essentially speculative.

Commenting on the Commission's draft report, DASETT said:

> In the light of the injunction in the Commission's terms of reference to ‘have regard to the established economic, social and environmental objectives of government’, DASETT considers that the Industry Commission should give greater consideration to the precautionary principle in the context of climate change. (Sub. D154, p. 1)

The Prime Minister has noted that achievement of the Government's environmental goals ‘will involve, inter alia, ... dealing cautiously with risk and irreversibility’ (Hawke 1990). Applied to greenhouse, this position is reflected in the interim planning target. But it is also clear that in this case Australia cannot reduce risk through its own abatement actions, as its contribution to global emissions is negligible. This is recognised in the caveats to Australia's greenhouse policy, which make action conditional on similar actions by other countries (Kerin and Kelly 1990).

The timing of action to reduce emissions

The Commission's reference is about levels of emissions to be achieved by the years 2000 and 2005 under an international consensus. This leaves some latitude at both the global and local levels as to when abatement action should start, and as to the path to be followed towards those targets. Trade-offs need to be made between early and late commencement times, and there appears to be more scope to make those trade-offs at the domestic than the global level. As discussed in Chapter 7, there are considerable obstacles to the early achievement of a global consensus to reduce emissions in accordance with a global target.

The timing of commencement of emission reduction action, and its path, will affect both benefits and costs.

On the benefits side, it is the concentration of greenhouse gases in the atmosphere which is important, and the scientific evidence shows that, from the point of view of the accumulation of gases, there is a clear benefit in starting early rather than late. But that benefit can only accrue from global action. Unilateral domestic action to commence reductions in advance of a global consensus would have a negligible influence on atmospheric concentrations. In terms of translating a lower concentration of gases into a lesser climate impact, the scientific evidence indicates that within the next fifty years there would be no effect (see Chapter 2).

A further consideration relates to the valuation of benefits. Chapter 4 concluded that at present the scientific uncertainties about climate change are such that it is not possible to make reliable estimates of the benefits of reducing greenhouse gas emissions. Action taken early would thus be taken with inadequate knowledge of the value of potential benefits, whereas the longer action is delayed the better will be our scientific understanding of the greenhouse effect, although as noted in Chapter 4 it is likely that there will always be major obstacles to measuring the benefits of abatement strategies.

For costs, the question of timing is essentially about whether or not to incur costs in advance of the effective implementation of global action. The case for early action hinges on the adjustment cost issue, the choice being between spreading adjustment costs over a longer, or shorter time period. The Australian Conservation Foundation considered that:

> to delay ... would be counterproductive ... since it is easier to reduce current emissions to below 1988 levels than it will be to wait for the inevitable international protocol on greenhouse gases and then attempt to reach the reduced level. (Sub. 46, Summary)

But the issue is not that simple, even if such a protocol were inevitable. A policy to incur additional costs in the form of early action would allow the economy more time to adjust. Alternatively, notice now of action to be taken in future will begin to condition investment decisions without causing premature plant replacement. If action is delayed, with income growth and technological progress, the economy may be in a better position to accommodate any necessary adjustment. For example there may have been rapid advances in technologies to produce energy from renewable sources, and these may have been accompanied by large decreases in price. The cost of switching from fossil fuels to renewables would thus be lower in the future. Society's time preference is also important in this regard.

Another dimension to this issue is whether making cuts sooner rather than later could give Australia a head start in taking advantage of new opportunities arising from global emissions reductions. This strategic issue is discussed in Chapter 10.

In weighing costs and benefits a balance needs to be struck between incurring costs early for unknown benefit, and delaying action with the risk that some adjustment costs may be larger, but in the light of some knowledge of the benefits. A decision to take early action leads to consideration of the appropriate level of costs to incur. In terms of the discussion earlier in this chapter the question would be ‘what insurance premium should be paid?’ The Australian Coal Association considered that ‘no-regrets’ policies could be implemented early but that:

> measures with high costs but highly uncertain benefits [ie returns] and measures with low benefit: cost ratios, should be reserved for later application. (Sub. 36, p. 22)

‘No-regrets’ policies

Many submissions from participants, as well as several published studies, suggest that a range of specific emissions reductions measures could be pursued often at relatively low or negligible costs. Pursuing these ‘no-regrets’ measures, as a first step towards reducing emissions of greenhouse gases, could reduce the economy-wide costs of making emissions reductions and, as a bonus, bring benefits through reducing other external environmental costs arising through fossil fuel use. Appendix F presents a series of case studies covering many reductions possibilities.

However, in many instances the estimates about the extent of emissions reductions possible from individual measures, and about their cost effectiveness, vary markedly. This uncertainty adds to the difficulty of assessing costs to Australia of reducing emissions.

6.3 Summing up

In the face of genuine uncertainty, decision making necessarily involves subjective judgement. By definition, the decision maker's problem cannot be resolved on a technical basis. Input from the natural and social sciences can illuminate the dimensions of the problem, but cannot determine the correct decision. This applies when an enhanced greenhouse effect is considered from an Australian perspective as much as it does when adopting a global perspective. Indeed, the uncertainties are even greater in the Australian case.

The Commission finds itself unable to answer the question implied by (a) in the terms of reference for this inquiry. It is not now possible to say whether an international consensus along the lines specified would involve net costs or benefits for Australia. At the level of Australian industries, the outcome is also uncertain. What the Commission's modelling does suggest is that most sectors would lose overall from the demand and trade effects of the consensus (coal being the heaviest loser).

While it seems unlikely that the uncertainties surrounding the potential impacts of an enhanced greenhouse effect can ever be eliminated completely, there is some prospect of reducing them. There is a very large international research effort now in progress directed at improving understanding of the science of climate change, and of its bio-physical implications. Australia is involved in this, and similar work is in progress in Australia itself. Internationally and nationally, work in the social sciences appears to be less well advanced, and receiving less support.

In the absence of adequate knowledge about climate benefits from abatement, it is understandable that many studies have dwelt on costs. What the Commission's work has shown, however, is that while there is a better basis for estimation of cost effects than climate effects, the complexity of the economic interactions, especially when considered over time, are such that it is difficult to be confident about the ability of existing economic models to get it right. Nevertheless, it is the Commission's view that the results presented in this report are useful, provided that their limitations are understood.

The Commission is more confident in commenting on those instruments which imply lower costs for Australia for implementing a given consensus. However, only the most general conclusions can be drawn without detailed analysis -- as noted above, intuition may be a poor guide to assessing the cost implications for Australia of a given form of consensus or the instruments employed to achieve it. On balance, both internationally tradeable permits and uniform global taxes would appear to offer some advantages to Australia in comparison with fixed national quotas.

While the uncertainties defeat any objective assessment of whether or how much insurance is appropriate at the global level, the calculation for an individual country like Australia is in one respect at least relatively simple. Regardless of what is judged to be appropriate action at the global level, there would be little point in Australia taking costly actions by itself to reduce emissions alone. This is recognised in the Government's greenhouse policy (and discussed more fully in subsequent chapters).

This does not mean that nothing should be done in the absence of a consensus. It does raise the issue of what can be done without incurring net cost. As noted above, the scope for ‘no-regrets’ policies is unclear. Some actions which the Commission considers should be pursued are mentioned in Chapter 11.

Because of the important linkage between costs and benefits for Australia and the action of other countries, the next chapter looks at the prospects of achieving an international consensus along the lines specified in the reference and considers alternative scenarios.

7 ACHIEVING AN INTERNATIONAL CONSENSUS

The discussion thus far, in responding to the terms of reference, has concentrated on the costs and benefits of a global consensus to reduce greenhouse gas emissions. As indicated at the outset of this report, however, the attainment of such universal agreement to implement the Toronto targets is by no means a foregone conclusion. There are some important hurdles confronting a comprehensive agreement of that kind. It is important to consider these influences and their implications for the range of plausible outcomes, because they may have quite different costs and benefits to the assumed consensus. That is the object of this chapter.

7.1 State of play

The Toronto targets -- as reflected in the Commission's terms of reference -- emerged from a large and widely represented conference in June 1988. It was not a formal intergovernmental meeting and the targets did not have broad political support. Since then, however, they have become the basis for national strategies by some countries including Australia, and a focus for meetings of an intergovernmental nature (see Box 7.1 and Appendix B).

Included among these was the Second World Climate Conference, convened in late 1990 and organised by the World Meteorological Organization. This conference was divided into a scientific/technical session and a Ministerial session and was attended by representatives of more than 130 governments. The scientific session produced conclusions about climate change, and recommendations for greater research efforts and information, while the Ministerial Declaration recognised `that climate change is a global problem of unique character' requiring a global response, and urged the elaboration of strategies for the staged reduction of all greenhouse gas emissions (Second World Climate Conference, 1990).

Box 7.1: **Chronology of some international events on greenhouse**

In 1979, the First World Climate Conference issued an appeal to nations to initiate the research necessary to foresee and prevent potential changes in climate induced by human activities that might be adverse to the well being of humanity. In 1992, the United Nations Conference on the Environment and Development is planned to be the venue for the adoption of an international framework convention on climate change. Between the two meetings, numerous conferences have addressed a wide variety of issues. This box provides a brief chronology of this activity.

October 1985, A Joint UNEP/WMO/ICSU Conference convened at Villach, Austria with scientists from 29 countries assesses role of CO_2 and other GHGs on climate change. This meeting produces an international consensus statement that receives widespread attention from the scientific and policy communities.

September 1987, 24 countries and the EC sign the Montreal Protocol on Substances that Deplete the Ozone Layer.

June 1988, the WMO and the UNEP establish the Intergovernmental Panel on Climate Change and schedule the Second World Climate Conference for June 1990.

June 1988, the Toronto Conference on The Changing Atmosphere: Implications for Global Security addressed the global threats posed by climate warming and called for countries to reduce CO_2 emissions by 20 per cent of 1988 levels by 2005 and for the negotiation of an international framework convention on global climate change.

December 1988, UN General Assembly resolution recognises climate change as common concern of mankind and instructs IPCC to report on elements for inclusion in framework convention.

March 1989, 17 heads of government issue the Hague Declaration calling for a new world environmental order.

November 1989, Meeting of government ministers issue the Noordwijk Declaration on Atmospheric Pollution and Climate Change calling for all countries to join in the ‘compilation of elements’ for an international framework convention.

August 1990, IPCC First Assessment Report released.

October/November 1990, The Second World Climate Conference takes place. The conference had two purposes, the first to review the first decade of the World Climate Programme and the second was to undertake a review of the IPCC's First Assessment Report as a lead in to negotiations on an international framework convention.

February 1991, first session of the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change held in Washington DC.

June 1991, second session of the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change held in Geneva. Third held in September in Nairobi. Fourth and fifth sessions planned for December 1991 and February 1992. A further session may also be held sometime before June 1992.

June 1992, United Nations Conference on Environment and Development (UNCED) to be held in Rio de Janerio, Brazil, at which it is intended that an international framework convention will be adopted.

The next landmark meeting is the United Nations Conference on Environment and Development (UNCED) to be held in June 1992 in Brazil. This conference, which will include a Heads of Government meeting, will deal with a range of issues of which climate change is only one. As noted, in the lead up to the conference, a series of international negotiations are being conducted among national delegations, to formulate a framework convention on climate change which contains general obligations and principles for addressing the greenhouse issue. These negotiations have confirmed the quite disparate views and positions of individual countries about the need for and possible nature of any collective action.

While it is true, as some participants in this inquiry have observed, that many countries have set themselves Toronto-type targets for reductions in emissions of carbon dioxide, few have made unqualified commitments and even fewer have taken action to reduce emissions through general taxation or quota-type measures. Nevertheless, as noted by Poterba (1990) Sweden, Holland and Finland have some carbon taxes and the EC Commission has been canvassing the possible implementation of carbon taxes within the Community. It is also true that it is early days yet and some countries' positions have already shifted considerably over time (in both directions). This is likely to continue in the future. For instance, the Australian Conservation Foundation noted that changes in the Japanese position at a recent negotiating session:

> reflected an internal policy debate within the Japanese Government which at this time is unresolved. (Transcript, p. 885)

They also commented that it was:

> acknowledged by most participants in the policy debate that the US policy position is unstable and could change. (Transcript, p. 885)

The changing nature of some countries' positions has made it difficult for the Commission to determine precisely what the latest positions are. Nevertheless, a summary view, which updates previously published information with the assessment of officials from the Australian Government and international agencies, is presented in Table 7.1 along with each country's contribution to global carbon dioxide emissions (comparable data for methane emissions is contained in Appendix C).

Table 7.1 **Summary of emission reduction policies in selected countries**

Country	*Carbon dioxide emissions*[a]	*Emission target*	*Qualification/comment*
United States	20.04	Opposed to adopting targets and timetables for CO_2 emissions. However, a Climate Change Strategy has been put in place which aims to reduce emissions in the year 2000 to a level equal to or below 1987 levels.	Emission target includes all GHGs including those already covered by Montreal Protocol. Energy reforms and carbon taxes proposed as main instruments. A major reforestation program has been initiated.
Brazil[b]	18.79	No stated position on targets.	If targets are agreed, then different targets and aid for developing countries.
China	10.49	Has not committed itself to emission targets.	Accepts in principle that global targets should be set.
USSR	10.04	Opposed to targets.	Believes there is insufficient scientific evidence.
India	4.75	Opposes adoption of targets that would reduce or limit GHGs.	Only developed countries should stabilise and reduce emissions.
Germany	4.73	Adopted CO_2 reduction target of between 25 and 30 per cent of its 1987 emissions levels by 2005	Strategies rely on improving efficiency and technology.
Japan	4.41	Stabilisation on a per capita basis in the year 2000 at about 1990 levels. Efforts to be made to stabilise total amount of CO_2 emissions by 2000 1990 levels. Methane should not exceed present levels and emission of other GHGs should not be increased.	Strategies to achieve these targets include: adjustments to regional and urban structures, at transport systems, the production of energy supply and lifestyles. Improved waste management and enhancement of GHG sinks.
Indonesia	4.29	Opposed to targets for GHG emissions on the grounds of scientific uncertainty.	Considers general policies on the environment will suffice.
UK	2.71	Set a target of up to 30 per cent reduction in presently projected levels of CO_2 by 2005 provided other countries are prepared to address their share of greenhouse emissions.	Taking ‘no regrets’ policies to meet target in the first instance but recognises that, in long term, taxes or other instruments required.
Mexico	1.91	No set targets for GHG reductions.	Will think about setting targets when developed countries act.

[a] Percentage of global CO_2 emissions for 1987. [b] Largely attributable to deforestation.

Table 7.1 **Continued**

Country	*Carbon dioxide emissions*[a]	*Emission target*	*Qualification/comment*
Canada	1.89	Stabilisation of CO_2 and other GHGs at 1990 levels by 2000. Any greater reductions should be based on a program of targets agreed internationally.	Strategies for limiting emissions include: improvements in energy efficiency, alternative fuels and tree planting programs.
France	1.62	Committed to limiting CO_2 emissions from fossil fuels to 2 tonnes of carbon per capita by 2000 provided other nations take similar steps.	Adaptive & preventive measures based on `no regrets' policies. A task force has been formed to examine a carbon tax.
Australia	1.42	Stabilisation of all GHGs at 1988 levels by 2000 and 20 per cent reductions in all GHGs by the year 2005 provided other countries take similar action.	Will not proceed with measures that have a net adverse economic impact nationally or on trade competitiveness in the absence of similar action by major GHG producing countries.
Saudi Arabia	0.80	Opposes mandatory targets.	Supports voluntary reductions.
Netherlands	0.63	Stabilisation of CO_2 at the 1989-90 level by 1995 at the latest and a 3-5 per cent reduction on average 1989-90 levels of CO_2 emissions by 2000.	Strategies to meet targets include: reduction in planned coal usage, improvements in energy efficiency encouraged by subsidies, transport sector policy.
Denmark	0.29	Reduction of CO_2 emissions from the energy sector by 20 per cent from 1988 levels by 2005.	Strategies include: improved energy efficiency and the imposition of a carbon tax.
Sweden	0.27	Work toward stabilisation of total CO_2 emissions in Western Europe at current levels by 2000.	CO_2 tax on emissions from non-traded sector introduced on 1 January 1991.
Norway	0.21	Stabilisation of CO_2 at 1989 levels by 2000. Supports reductions of 20 per cent by 2005 in line with Toronto target.	Limited CO_2 tax in place. Reinforcement of energy conservation programs.
EC	12.03	Stabilisation of emissions at 1990 level by 2000.	Fuel switching and efficiency improvements in energy and transportation considered most important sectors. Favours combination of CO_2 tax and energy tax but not all countries are agreed to specific EC target.

[a] Percentage of global CO_2 emissions for 1987

Source: Various publications and discussions with Australian Government and international agency officials.

The countries depicted in that table can be broadly placed in one of four categories:

- First, there are those countries that have set themselves emission targets on a unilateral basis, without necessarily requiring other countries to take similar action. This group comprises some OECD countries including Canada and a number of countries in Western Europe, as well as the EC. In all, they would account for about 15 per cent of current global emissions of carbon dioxide. The targets are generally consistent with Toronto, but are not binding; nor are they being pursued through instruments that will necessarily achieve them. For example, the largest emitter in that group, Canada, has essentially adopted a ‘no regrets’ strategy which at this stage is considered unlikely to achieve the targeted reduction.

- The next group of countries includes those which have set provisional targets contingent on action by others. Australia is in this group, requiring `similar action by major greenhouse gas producing countries'. The other countries in this category are also OECD members, including Japan, the United Kingdom and France. They would collectively contribute about six per cent of current global carbon dioxide emissions.

- The third category includes a diverse group of countries who are opposed to any international agreement which would commit them to targets and/or timetables. The USSR, some East European countries, China, OPEC members and other developing countries, including India are members of this group. So too is the United States which, while pursuing greenhouse stabilisation and reduction strategies (see Table 7.1) is opposed to an international agreement on timetables and targets. In all, this group contributes over two-thirds of current global emissions. In some cases, however, the position of developing countries is dependent on the extent to which they would receive special treatment, including financial and technical assistance. This would seem to apply to Brazil and Mexico, for example.

- The fourth category consists of countries which have yet to state a position, most of whom are developing or East European countries. They are individually relatively small emitters, but together account for the remaining one-tenth of current global emissions.

In summary, it seems clear that there is a very wide range of stances among countries -- including those that are currently, or will soon be, substantial emitters of greenhouse gases. It is equally apparent that an effective consensus involving Toronto-type targets will not be possible until this disparity in the positions of individual countries is reduced.

7.2 Influences at work

History reveals that no international agreement among sovereign nations is easily made, especially where there are important and differential effects on the countries concerned. International agreements about the environment are no exception. Yet, as outlined in Chapter 2, effective reduction of greenhouse emissions would not be possible without a commitment by at least the major contributing countries. At this point it appears that countries accounting for the bulk of global emissions are not prepared to make an international commitment of the Toronto-type, as specified in the terms of reference. Whether they will in time decide to do so largely depends, at the most general level, on their individual perceptions of what is in their national interest.

The Commission has examined the experience of several international agreements on environmental issues, such as the agreements on CFCs and acid rain, to see whether they can provide any guidance about the influences that will determine the scope of an international agreement on the greenhouse issue (see Appendix E). Each of these agreements has its own unique history. Nevertheless, this experience yields a number of general lessons:

- Before the formulation of an agreement can gain any real momentum it has to be established, and accepted by potential signatories, that a problem exists. This is obviously the most basic requirement of all.

- The strength of commitment of individual countries to participate in international action then largely depends on the extent to which they perceive net costs or benefits to themselves from such action.

- Where the direct costs and benefits of international action are not evenly spread among countries, redistributive mechanisms are often necessary to gain the support of those who feel relatively disadvantaged. Typically, redistributive mechanisms not only provide incentives for participating countries, but also impose penalties on non-participating countries.

- The trade-offs necessary to harness widespread support for an agreement and the ability to enforce its provisions are important factors in determining its effectiveness.

- Formulating and implementing an international agreement is generally a lengthy process. Two of the more time consuming phases are establishing that a problem exists and bargaining over the distribution of the costs and benefits associated with remedial action.

Applying this experience to the greenhouse issue suggests that there are three broad economic aspects that will be fundamental to each nation's sense of national interest -- and hence to the prospects of an effective agreement. These are: a) the perception of the impacts of any climate change; b) the perceived costs of complying with an agreement to reduce greenhouse gases and, following from that, c) the existence of incentives for participation (or penalties for not participating).

Perceptions of climate impacts

As noted in an earlier chapter, there are two aspects to the greenhouse problem: one is the potential global warming effect of anthropogenic emissions; the other is the effect of any such global warming on living conditions on earth. While some scientific uncertainty remains about the first, there is considerable uncertainty about the second.

The experience with other agreements would suggest that a Toronto-style consensus, requiring significant reductions in emissions, is unlikely to be achieved until this uncertainty has been considerably reduced. In the case of acid rain, for example, the scientific aspects of the problem and the impacts on vegetation were reasonably well established prior to international agreement. (Indeed the evidence was clearly visible to the people of the countries concerned.) In the case of CFCs, lack of persuasive scientific evidence of a link with ozone depletion delayed agreement for more than a decade after the problem was initially identified in international forums (see Appendix E). It was not until a strong scientific consensus had developed that negotiations picked up momentum and led to the Montreal Protocol. (For a brief comparison of the ozone and greenhouse issues, see Box 7.2.)

Box 7.2 **If Montreal why not Toronto ?**

The Montreal Protocol on reducing CFCs has been cited as a hopeful precedent for a comparable treaty on greenhouse gases. And while there are some obvious similarities between the ozone and greenhouse issues, such as their global nature, there are also important differences. The following comparisons, while somewhat simplistic, give an indication of why it may be much harder to achieve global adoption of Toronto type targets than it was to obtain widespread commitment to the Montreal Protocol.

Test	CFCs	GHGs
Scientific understanding of the problem	The potential for CFCs to affect the ozone layer was first suggested in the early 1970s. While controversial at first, research on the matter provided strong empirical evidence that CFC emissions did indeed lead to ozone depletion in the stratosphere.	That GHGs play a role in the global warming process is fairly well known. However, uncertainties about feedback effects mean that it will be at least another decade before a strong causal link can be established between GHGs and global warming.
Understanding of the impacts	From the mid to late 1980s there was mounting evidence that ozone depletion would have a serious impact on human health as well as damaging crops and affecting marine and other ecosystems.	The IPCC impacts report notes that estimates of the effects of climate change are difficult and that confidence in regional estimates is low.
Immediacy of impact	In the early 1980s it was discovered that the level of ozone depletion was much greater than previously thought with up to 95 per cent on the ozone over Antarctica disappearing every Spring.	Warming differences between the BaU scenario and the most severe emissions reduction program considered by the IPCC would be barely distinguishable before 2040
Economic scope	Only 16 major producers of CFCs with production concentrated in Japan Europe and the US. CFCs used in relatively small number of activities.	GHGs derive from activities of central importance throughout economies (including energy, agriculture).
Availability of technological solutions or alternatives	While alternatives did not exist at the time the Protocol was signed, the chemical industry indicated in 1986 that it was a lack of regulatory and market incentives, not the absence of a technical solution, that was blocking the development of CFC substitutes.	While technologically feasible alternatives to the production of energy exist (eg nuclear), the existence of alternatives to other GHG producing activities (eg wet rice cultivation producing methane) are less certain.
Confidence in measuring costs and benefits	While uncertainty remained, the US EPA estimated the cost of regulating CFCs at between US$ 20 and 40 billion between 1989 and 2075 but that potential savings to the US of implementing the Protocol were in the order of US$ 6.4 trillion.	The high level of uncertainty about the impacts of global warming make it impossible to determine with accuracy the potential benefits of reducing GHGs by a targeted amount.
Perception of benefits from business as usual	No nation perceived benefits from reduced levels of stratospheric ozone.	Some nations perceive benefits from global warming.

Sources: IPCC WGI (1990), IPCC WGII (1990), Morrisette et al. (1990), UNEP (1989).

Many governments are clearly concerned about the global aspects of the greenhouse problem -- especially the potential for serious damage to some of the poorest countries. But as long as these effects remain unproven, the main concern for many will inevitably be the possible effects of climate change on their own countries. As noted, there is considerable uncertainty at this level and thus scope for different assessments.

A complicating factor is that while some regions would be adversely effected, others could benefit. Some countries which have been non-committal or expressed opposition to targeted reductions, may well see themselves as beneficiaries of any enhanced greenhouse effect. There has been some suggestion that this is true for the USSR, for example, and may well apply to China as well, while some assessments in the United States have promoted the view that climate impacts in that country would not be serious.

The IPCC report on impacts, although heavily qualifying its findings, may have given some countries cause to take an optimistic view. According to some scenarios for agriculture, for example, countries potentially benefiting from global warming in that sector could include the USSR, Japan and China, as well as Australia and New Zealand and parts of Northern Europe and South America (see IPCC Working Group II 1990, also Nordhaus 1991).

Another feature of greenhouse which influences perceptions of impacts and distinguishes it from most other environmental issues, is the very long time scale involved. As already noted, it is anticipated that it will take around a decade to be able to establish from climate data whether global warming is underway. And the predictions about climate change, discussed in Chapter 4, are based on a doubling of carbon dioxide concentrations some 50 years (two generations) hence. This would tend to encourage some countries to adopt a strategy of waiting for additional information, at least before taking any costly action.

Costs of reducing emissions

While the possible impacts of climate change are uncertain and very far off, at least by the standards of most policy choices, the costs of reducing emissions are both tangible and immediate once countries move beyond no-regrets options. In such circumstances, it might be expected that the costs would become the dominant focus of national public debate and that domestic political pressures would tend to favour inaction.

The costs of reducing emissions are likely to vary considerably among countries-- depending on resource endowments, consumption patterns, the composition of international trade and the intensity and efficiency with which energy is used. Costs also depend on the rate of population growth, as emphasised by the Business Council of Australia (1991).

As discussed previously, the most important source of carbon dioxide is the combustion of fossil fuels for energy. Energy underpins economic activity and in the normal course of events countries anticipate increased energy use as their economies grow. The prospect that a commitment to reduce greenhouse gas emissions will necessitate constraining energy consumption and possibly sacrificing economic development is a concern for many countries. Developing countries have the most at stake in this respect.

Table 7.2: **Projected global energy use and carbon dioxide emissions: 1987 and 2005**

	Energy use (petajoule)		*Carbon dioxide emissions (Mt)*	
	1987	*2005*	*1987*	*2005*
OECD	164 751 (51)	207 288 (42)	10 078 (49)	12480 (40)
Centrally planned	103 079 (32)	173 627 (35)	7 218 (35)	11554 (37)
Developing	53 120 (17)	116 309 (23)	3 351 (16)	7 353 (23)
World total	320 960	497 224	20 646	31 387

Figures in brackets are percentages of global totals.
Source: Table 5.1.

As shown in Table 7.2, the developing country share of energy use is likely to rise from its 1987 level of 17 per cent to over 23 per cent by 2005, with carbon dioxide emissions growing at a similar rate. This is both an indication of the relative costs of these countries having to cut back emissions, and of the necessity of including them in an agreement for it to be effective in reducing emissions.

While other international agreements have also given rise to costs, most have not struck at such a central component of national economies as the energy sector. They have tended to be less significant and either more focused in effects (whaling, CFCs) or amenable to less disruptive remedies (scrubbers and low sulphur coal used for acid rain). Substitution has generally also been possible at lower cost. As one writer has observed:

> Economically, what is at stake is 2 or 3 orders of magnitude greater for fossil fuels than for CFCs, and the prospects for technological replacement of CFCs are much brighter. (Schelling 1990, p. 31)

The scope to use different fuel types to reduce carbon dioxide emissions also varies substantially among countries. For countries such as Australia and the United States, with large reserves of the various fossil fuels, switching fuels may be a relatively low cost method of reducing carbon dioxide emissions. For other countries such as China, whose fossil fuel reserves are dominated by brown coal, fuel switching might be relatively costly, as it could require substantial imports of the alternative fuel and the accompanying technology as well.

On top of these direct costs, different countries would face differing costs as a result of changes in trade patterns. Coal exporters would experience reduced demand for example, while gas exporters could gain. Some countries have more at stake than others if energy trade were to change significantly. Most OPEC countries, for example, would be severely affected and understandably are opposed to a consensus.

As earlier chapters have shown for Australia, however, it is extremely difficult to get any precise estimate of the domestic costs of international consensus, because of the complex interactions within and between economies. This in itself adds to uncertainty and could be an additional factor inhibiting consensus.

Then there is the important question of the relative ‘capacity to pay’ of different countries. Most developing countries, as well as those in Eastern Europe and the USSR (now known as ‘economies in transition’), are preoccupied with more pressing economic problems than greenhouse. The cost of investing in potential climate improvements a century hence could be perceived as very high, when measured in terms of foregone opportunities to improve the lot of their existing populations.

Poland, for instance, told delegates at the White House Conference on Global Change that ‘due to a difficult economic situation in Poland... we are not able at this moment to take up obligations to reduce carbon dioxide emissions’ (quoted in Morrisette and Plantinga 1990, p. 29).

Incentives to participate

Given the perception of high costs for many participants, it is generally recognised that a greenhouse gas consensus would need to include cost reducing and redistributing mechanisms. This has been an important part of other international agreements.

A general way of reducing costs for participants would be to incorporate instruments which allow differential responses according to the costs of doing so. Carbon taxes and tradeable permits are in this category and have been much discussed in relation to greenhouse, but more by economists and economic agencies than by negotiators. The fact is that in practice such instruments have not been frequently used. Of the agreements reviewed by the Commission, only the one on CFCs came close to having such an arrangement at the international level, and it played only a supplementary role. Others all involved fixed quotas (Appendix E). This mirrors the predominant experience with domestic anti-pollution policies, although Australia has recently implemented a tradeable permits regime to control CFC emissions (see Appendix B) and the use of market instruments has been rising in recent years.

Shifting the burden

Given the difficult economic circumstances of many developing and East European countries, it would seem that a consensus along Toronto lines would not be possible in the absence of special provisions for these countries. This position has already been forcefully argued by China, Brazil, and India for example.

There are precedents in the Montreal Protocol on CFCs and other treaties for some (wealthier) parties providing financial and technical assistance to those in need. To assist many developing countries to meet something like the Toronto target, however, could require more assistance than developed countries would be prepared to provide. It seems likely at this stage that, at least for some countries, any reductions on their part would need to be ‘paid for’ by developed countries.

An alternative (or perhaps complementary) approach would be to provide easier conditions for some countries. A number of countries have already proposed easier conditions for certain groups of countries in the intergovernmental negotiating process currently underway. Such arrangements could include more lenient starting dates and targets and again there are precedents in a number of other agreements. The Montreal Protocol allows developing countries to delay implementation of CFC reductions for up to ten years in recognition of the possible need to increase CFC consumption as economic development progresses. Under the European Community's Large Combustion Plant Directive to limit acid rain emissions, major European industrial countries face reductions of 60 -70 per cent by 2003 while Spain has been granted a concession which reduces its emissions obligation (see Appendix E).

There is of course the possibility that, in the case of greenhouse, the terms and conditions for developing countries would need to be so lenient as to put at risk the global target itself, an issue to which we return.

Sanctions and enforcement

The alternative to providing a `carrot' for participation is to use a `stick'. There are precedents of countries within an agreement using trade and/or financial sanctions against those who refuse to join. For example, parties to the Montreal Protocol were required to ban the import of bulk CFCs and halons from non-member countries by the beginning of 1990 and ban the import of all products containing CFCs and halons by 1993. Another example is the Packwood-Magnuson Amendment to the US Fishery Conservation and Management Act (1976) which requires the US Government to take action against any country whose citizens compromise the objectives of the International Whaling Commission. An offending nation automatically loses half its allocation of fish products able to be taken from US waters. If a nation refuses to improve its behaviour within a year, its right to fish in US waters is revoked (Barrett 1990).

Apart from their GATT implications, such actions have the economic disadvantage of imposing additional costs on the countries within the agreement -- although they may at the same time confer political benefits, depending upon the competitiveness of the countries against which trade barriers are raised. In the case of greenhouse, such a strategy, to have a chance of success, would need to include the largest trading powers. Given the economic drawbacks of sanctions, it is difficult at this stage to envisage the United States or Japan becoming sufficiently committed to the need for a consensus to take such action, although this need not apply to the EC.

Where countries are under pressure to join an agreement, but are not committed to its objectives, or see them as too onerous, the existence of potential loopholes in the agreement or perceived difficulties in monitoring compliance can act as incentives to join. Apparent loopholes in the Whaling Convention, for example, have allowed Japan, South Korea and Iceland to kill large numbers of whales for ‘scientific’ purposes.

Given the well known difficulties of enforcing international treaties, most existing agreements have placed emphasis on monitoring and review mechanisms (see Appendix E and Grubb 1989). For countries that would comply with their greenhouse target obligations, the effectiveness of such arrangements would presumably be an important determinate of their preparedness to participate. Otherwise any benefits could be eroded by the non-compliance of others. For other countries, however, effective monitoring/enforcement mechanisms could act as a deterrent to participation -- as the scope for ‘free-riding’ and cost avoidance would be reduced.

It is reasonably simple in principle to monitor (gross) carbon dioxide emissions, although it would obviously require the cooperation of the countries concerned and there may be some scope for disguised cheating, depending on the instruments used. If, however, a greenhouse target were stated in terms of greenhouse gases generally, there would be great difficulties in effectively monitoring compliance. Methane emissions are hard to measure; the other gases virtually impossible (see Appendix C). The negotiation of such an approach would also be more difficult, and would need to focus on particular emission sources where information was reliable.

7.3 Prospects of consensus with Toronto-type targets

Participants in this inquiry had a range of views about the likelihood of early international agreement. DASETT (sub. 82, p. 6), for instance, commented:

> the development of a convention and protocols that contain commitments to effective reductions in greenhouse gas emissions is inevitable.

In its submission, the Victorian Government expressed the view that agreement on a protocol to reduce carbon dioxide emissions will take a number of years beyond 1992 to negotiate (sub 74, p. 3). The Australian Conservation Foundation considered that 1995 was:

> the most likely time by which we would have a convention in place with a stabilisation or a first emissions reduction step for the developed countries. (Transcript, p. 886)

It seems clear that there are serious obstacles to the early achievement of a consensus along the lines specified in the terms of reference. At the core of this is the pervasive uncertainty about what greenhouse actually means for many countries. This uncertainty will not be quickly resolved. It will be at least a decade before the existence of an enhanced greenhouse effect could be confirmed from the climate records; obtaining reliable predictions about impacts on particular countries is expected to take considerably longer than that, and may not be possible.

Even once the perception of an international problem becomes well established, experience shows that formulating the precise terms and conditions of an agreement to deal with it is normally a time consuming process. For instance, the negotiation of the EC Directive on acid rain took five years. This was under relatively favourable conditions: only twelve countries were involved, all members of the same political group and roughly at the same stage of economic development. The circumstances surrounding the negotiation of an agreement to reduce greenhouse gas emissions are less favourable -- many more countries are involved and, as noted, there are substantial differences in economic development, climate, fuel mixes, consumption and production patterns, all of which have implications for the costs and benefits facing different countries.

Even if a consensus on controlling greenhouse gases was eventually reached, experience indicates that some countries might not ratify the agreement. For example, 159 countries signed the Law of the Sea document but, even after 15 years, only 39 countries had ratified the agreement: 21 countries less than required for the treaty to enter into force (see Appendix E).

Then there is the added difficulty that, depending on the nature of the consensus and the instruments required to implement it, some countries may lack the means of meeting a commitment to reduce emissions even if they wanted to (see Morrisette and Plantinga 1990). This point was emphasised by the United Mineworkers' Federation of Australia in relation to price incentive instruments:

> the debate ... fails to pay due recognition to the level of development of taxation and public administration systems in most countries and therefore their ability to comply with any international agreement. (Sub 118, p. 3)

7.4 Alternative/interim possibilities

It would appear that the achievement of a consensus with Toronto-type targets, including all major greenhouse gas producers, will be extremely difficult to achieve and would in any case take a considerable period of time. In the meantime, the main possibilities would appear to be either a weaker consensus including all the main contributors, or a commitment to stabilise or reduce greenhouse gases by a subgroup of countries, or perhaps some combination of the two.

It is also possible that there will be no international agreement at all. However, most countries will not want to be totally uncooperative. A number of factors may encourage countries to participate in an agreement, even when they perceive it to have economic costs. For example, there may be concern to be seen as a good ‘international citizen’. Alternatively, countries may participate in an agreement because of the political credit it brings -- credit they may then use to extract concessions from member countries on other matters. Some countries may also decide to participate in an agreement because it gives them a voice in matters which concern them. A number of developing countries attended the final negotiations of the Montreal Protocol, for example, because they were concerned that the Protocol, with or without their participation, would impede their economic development (UNEP 1989).

A weaker consensus?

In negotiating international agreements a trade-off must often be made between the severity of commitments and the number of members. In general, the more strict the commitments, the fewer the countries which will accept them. An agreement on greenhouse is clearly no exception. This trade-off poses particular difficulties in the case of greenhouse, however, because of its global nature and the scope for non-members to offset the contribution of members. Widespread membership could thus be seen as an overriding concern.

One response might be to reduce the global target to a point where all countries could accommodate it. Given present positions, however, that might have to be very low. Indeed, it would seem that the most that could be achieved in the way of a *uniform* commitment in the foreseeable future, including at the UNCED meeting, would be a very general statement of principles or endeavours, with no binding commitments. This was essentially what the Vienna Convention for the Protection of the Ozone Layer amounted to. The obvious weakness in a single ‘lowest common denominator’ approach is that some countries may have been prepared to go considerably further.

This raises the possibility of a consensus with differential commitments among countries or country groupings. The necessity for such an approach, in particular to accommodate developing countries, was emphasised by the Australian Conservation Foundation's representative on the Australian delegation to the UNCED:

> The international jargon really talks about burden sharing equitably amongst countries, of differentiating the obligations according to capacity to pay, capacity to achieve change and historical contribution to the problem. (Transcript, p. 886)

Such a highly differentiated set of commitments could prove very difficult to negotiate and embody formally in an international convention. One way around this would be to have differential requirements of a non-binding kind. An approach of this sort was first proposed by Japan under the heading ‘pledge and review’ and has since become a focus for discussion in the negotiations (RIIA 1991).

Pledge and review

As the name suggests, a ‘pledge and review’ arrangement would allow countries to nominate their own targets or other actions, which would then be subject to regular review in an international forum. The approach has obvious pragmatic attractions in a situation, such as greenhouse, in which positions of individual countries differ widely and in which some countries, like the United States, may be willing to take action but not be willing to legally commit themselves in an international forum. Such arrangements could also accommodate a range of relevant actions, including provision of assistance to developing countries. The review process would allow progress to be monitored and could put some pressure on countries to uphold their pledges, as well as providing a continuing forum for discussion and provision of new information about the greenhouse issue itself.

The flexibility and voluntary elements of pledge and review have drawn criticism from some countries and organisations, with one environmental group labelling it ‘hedge and retreat’. The main concern is about whether such an approach could deliver a sufficient reduction in emissions. How it performs in this respect can really only be evaluated against the likely alternatives. If, for example, the alternative was a more ambitious fixed commitment to which only a small number of countries were prepared to adhere, then an approach involving much smaller pledges by a larger number of countries could, in practice, add up to a *larger* global outcome. (A 20 per cent cut in carbon dioxide emissions by the whole of the European Community would, for example, be equivalent to only a 2.4 per cent cut in total global emissions).

A further advantage of a pledge and review ‘consensus’ is that even if it didn't encourage some countries to stabilise or cut emissions, it could inhibit them from increasing emissions in response to cut backs by others. The ongoing forum provided by the review process could be useful in this respect. Developing countries have expressed concern, however, about such reviews violating their sovereignty (RIIA 1991). This would seem a further unpromising sign of the limited scope for achieving any sort of substantive agreement that includes these countries. As noted previously, an effective monitoring process would be an essential part of any international agreement.

Despite the practical attractions of pledge and review, the Australian Conservation Foundation informed the Commission that it is ‘a dying issue’ as originally proposed and is now seen more as being merely additional to ‘basic and specific commitments within the convention’ (Transcript, p. 889). Such commitments -- to the extent that they involved emission targets -- are expected to relate only to developed countries. This brings us to the second of the alternatives identified above.

Subgroup action?

It is conceivable that a convention could be agreed which, apart from containing some broad `motherhood' statements that every nation could accept, involved more specific and substantive commitments to control emissions by a subgroup of countries. For analytical purposes this can be considered as equivalent to the situation of a subgroup of countries simply taking action on their own regardless of a consensus.

It is common for international agreements to begin with a relatively small group of like-minded countries. For example, the GATT began with a dozen industrialised members and now has 100, including some of the least developed countries. Similarly, the Montreal Protocol had been ratified by just 29 countries and the EC when it came into force in 1989. By the end of 1990, however, the provision of technical and financial assistance for member countries and the imposition of trade sanctions against non-member countries had encouraged another 27 countries to ratify the Protocol.

One advantage of a small group is that it is easier to negotiate with less people. Having fewer means little of course if the views of those involved are far apart. For this reason, successful agreements have often commenced with countries that are in similar economic and political circumstances. In the greenhouse context, that would mean countries that are at similar stages of development and with comparable economic structures, and possibly already associated through regional or other institutional arrangements.

The OECD and the EC are possible candidates in this regard. At present the prospect of an OECD-wide agreement is limited by the opposition of the United States (and Turkey) to targets or timetables, as well as by the fact that the willingness of several other countries (including Japan and Australia) to implement their planning targets is contingent on action being taken by all major greenhouse gas producing countries.

There would seem a greater prospect of a subset of OECD countries such as the EC `going it alone'. Indeed, the EC Commission has proposed a stabilisation and reduction target for the region as a whole that is not conditional on action by other countries. The agreement aims to stabilise Community emissions at the 1990 level by the year 2000 with further reductions thereafter. Provision was made for cuts made by Germany, Denmark and the Netherlands before the deadline, to offset slower emission reduction programs by other countries, including the Community's poorer Mediterranean members. Nevertheless this target may be difficult to put into effect. An indication of this is the recent backlash against the EC Commission's carbon tax proposals by European Energy Ministers.

A deterrent to subgroup action is, by definition, the more limited scope to influence global emissions, at least for a given level of domestic cost. (Even the OECD as a whole accounts for only 45 per cent of current global carbon dioxide emissions, and the EC for just 12 per cent.) This could be mitigated to the extent that the group saw non-greenhouse benefits from taking action. Implementation of the EC stabilisation program for carbon dioxide emissions, for example, may be expected to have some impact on Europe's acid rain problem.

A subgroup might also be encouraged to take action in the belief that any net costs would merely be an investment in bringing other countries (including the main emitters) on board, as happened in the case of the Montreal agreement on CFCs. The behaviour of the group itself could be influential in this respect. One way might simply be through example, and there are cases of this having happened in the past. But the bottom line is that unless countries already perceive net benefits, broadly defined, from participation, the behaviour of other countries is unlikely to be decisive. In the case of greenhouse this could mean that an `advance guard' could have a long wait.

The wait could be shortened, however, through the use of sanctions -- such as through trade policy. The imposition of ‘green’ tariffs against non-member countries would, for instance, reduce any competitive or trade advantage that may accrue to countries as a result of non-abatement. An alternative would be the establishment of a ‘green common market’ in which member countries reduce tariffs within the group. Another suggestion has been for countries that join a consensus to erect a ‘carbon tax trade fence’ around themselves so that goods from non-participants are subject to an import tax reflecting the estimated carbon emitted during their manufacture (see Grubb 1989). As noted, however, the imposition of such trade barriers would impose costs on the importing as well as exporting countries.

An alternative possibility is that a small group could choose simply to go for a lower target, to reduce the costs, in view of the absence of action elsewhere. But this would further weaken the potential for any climate benefits from action.

Summing up

An international consensus in the form specified in the Commission's terms of reference seems unlikely in the foreseeable future, particularly for the UNCED meeting next year. Alternative or interim possibilities include:

- a uniform consensus containing only general principles and endeavours without commitments;
- more substantial commitments of a best efforts kind by individual countries, possibly subject to an international review process; or
- an agreement to control greenhouse gases among a subgroup of developed countries.

In practical terms, the Australian Government may soon be faced with the need to respond to proposed arrangements of this kind. Some of the implications for costs and benefits to Australia are considered in the next chapter.

8 BENEFITS AND COSTS OF PLURILATERAL AGREEMENTS

Previous chapters have explored the possible costs and benefits of a global consensus to reduce emissions. As just discussed, however, there are considerable obstacles to the attainment of a full international consensus in the near future. This chapter considers how benefits and costs might change if less than a global consensus were achieved. Given the range of possible outcomes, the Commission has not attempted to assess separately the costs and benefits of a system of individual country commitments applying in addition to an international consensus on ‘basic’ commitments. Some such outcomes could be close to a full international consensus in effect, some close to smaller group (‘plurilateral’) agreements, and some closer to a series of unrelated unilateral actions.

Although prospects are uncertain, it was noted in Chapter 7 that one or more agreements between groups of countries might be reached earlier than an international consensus involving many countries. The chances of such plurilateral agreements are enhanced where countries have similar views of the benefits of reducing emissions, similar economic systems, close political ties and where the costs of reducing emissions are relatively low. Examples of such groups include the European Community (EC), and the Scandinavian countries. An EC agreement is possible (failing an international consensus to make meaningful cuts in emissions) as the available evidence is that the EC considers that its initial target could be met without significant cost, and that group of countries clearly already has strong political and economic ties. Prospects for an OECD agreement do not appear strong at present, mainly because of the attitudes of the United States and Turkey.

A recent paper presented to the Commission's modelling workshop by Piggott et al. (1991) suggests that incentives for groups of countries to engage in emissions reductions could be ‘surprisingly strong’ (p. 4). On the assumption that a worldwide 50 per cent cut in emissions is justified, their model suggests that the EC, for example, could justify a cut of 30 per cent on a subgroup basis. The basic reason for the result is that it is assumed that small reductions are at higher marginal benefit and lower marginal cost than is true with larger reductions. The authors note, however, that 'the assumption of a 50 per cent cut being optimal in this way is strong and in no way do we mean to assert that it is necessarily realistic' (p. 4). What the model does indicate is that countries which believe the climate benefits from emission reductions are large, and the costs of reductions are small, could have incentives to group together to make emissions reductions on a subgroup basis.

8.1 Climate benefits from plurilateral agreements

Emissions of greenhouse gases from any country would add to an enhanced greenhouse effect (see Chapter 2), as this depends upon global concentrations of greenhouse gases. Thus, climate benefits from a plurilateral agreement would depend upon the reduction in global emissions which the countries involved were able to achieve. Obviously, from a climate perspective, it would be desirable to have as many as possible of the significant greenhouse gas emitting countries involved in any plurilateral agreement. The United States, Brazil, China and the USSR together account for well over one-half of emissions of carbon dioxide. In regard to methane emissions, Canada, the United States, China and India similarly account for well over one-half (Table 8.1).

At present, the five major emitters of carbon dioxide -- United States, Brazil, China, USSR and India -- have either stated their opposition to reductions targets, or have no commitment to targets (Table 7.1). Although the United States has a climate change strategy aimed at reducing emissions, the non-participation of these countries in an international agreement would greatly limit the extent of any possible climate benefits from reducing emissions of carbon dioxide. The USSR, China and India are also opposed to targets, or have no target, for methane reductions.

Table 8.1: **Greenhouse gas emissions by nation: 1987**
(percentage of world total)

Country or group	*Carbon dioxide*	*Methane*
Groups:		
OECD	41.07	63.61
EC[a]	12.03	6.14
Countries:		
USA[b]	20.04	12.97
USSR	10.04	4.95
China	10.49	9.98
Canada[b]	1.89	36.00[d]
Brazil	18.79[c]	2.35
India	4.75	9.05
Australia[b]	1.42	1.40
Other	32.60	23.30
Total	100.00	100.00

Note: Total for carbon dioxide does not add due to rounding.
[a] All members of the EC except Greece are members of the OECD. [b] Also a member of the OECD. [c] Largely attributable to deforestation. [d] Believed to be largely attributable to natural gas leakage.
Source: Tables C8 and C13 in Appendix C.

The EC currently accounts for about 12 per cent of global carbon dioxide emissions and about 6 per cent of methane. An agreement by the EC countries to reduce emissions could thus have some possible effect on climate impacts from greenhouse gas emissions. However, it would be limited -- as noted previously, a 20 per cent cut in the EC's carbon dioxide emissions would reduce global emissions by 2.4 per cent at most. Assuming the EC then maintained emissions steady at that reduced level, business as usual in the rest of the world would have overtaken that cut in about 2 years.

Unless the major greenhouse gas producing countries are part of a plurilateral agreement, the potential to achieve climate benefits for the global community generally, and for Australia, must be limited. Clearly, an agreement by a group such as the EC would bring little climate benefit by itself. Any value in such an agreement would arise only if it acted as a nucleus for other countries to join or to take unilateral emissions action.

A particular problem is that a less than global agreement would leave open the possibility that industries could relocate to avoid emissions reductions. The Australian Coal Association considered that the aluminium industry, for example:

> will migrate not only to locations where power supplies can be made available from emissions free sources ... but also to locations where governments do not impose equivalent taxes and controls. (Sub. 36, p. 24)

Such movements could negate the emissions reductions by countries in the agreement. To counter this, those countries might possibly discriminate against outside countries. Any such action might reduce the incentives for industries to relocate, and assist in maintaining emissions reductions.

8.2 Costs to Australia of a plurilateral agreement

The costs to Australia of a plurilateral agreement would differ from costs under both a global agreement and unilateral action. The nature and extent of costs would depend upon many factors including: which countries formed part of the agreement; whether Australia itself joined in; what degree of market power those countries could wield; whether countries in the agreement extended trade concessions to each other; and whether trade discrimination or other sanctions were invoked against countries not in the agreement. Other important factors include the nature of the targets, the reductions measures specified (if any), and what would be done with any revenue from carbon taxes.

Analysis of these complex interactions requires the use of economic models which allow specification of different country groups, with feedback of the effects of changes in trade patterns and flows, and of international income changes and redistributions, into domestic economies. Both the GREEN and the WEDGE models, referred to in Chapter 5, can be helpful.

Two simulations with the OECD's GREEN model, described in Box 5.2, examine the effects of a 37 per cent global cut in emissions. In these simulations, growth in emissions in the rest of the world, which accounts for 13 per cent of emissions in the base year, are unconstrained. Emissions from countries accounting for 87 per cent of global emissions in the base year are constrained as described in the box. Thus, although the simulations do not control 100 per cent of emissions they provide an indication of the cost of one kind of international consensus. This was estimated to be about a 1 to 2 per cent reduction in real household income depending upon whether trade in emissions rights was allowed.

A third simulation by GREEN, a plurilateral scenario, required the 37 per cent global average reduction to be obtained from the industrialised countries (defined as the OECD countries and the USSR) alone. In this case, costs increased to 7 per cent of real household income. This illustrates the commonsense conclusion that the fewer the countries involved in an agreement, the higher the aggregate cost to them of achieving any given global reduction target.

The WEDGE model, described in Box 5.3, can be used to examine more closely the implications for Australia of various kinds of plurilateral agreement. The first case considered below is an agreement among EC member countries to reduce carbon dioxide emissions. The EC countries appear more likely than other groups to enter a plurilateral agreement, although the WEDGE model projections for Australia can also be taken as indicative of what would happen to Australia were some other relatively small groups of industrial countries to agree to cut greenhouse gas emissions. A second case considered is the implications for Australia of a bigger group of countries entering a plurilateral agreement. For illustrative purposes the WEDGE model examines a cut among OECD member countries excluding Australia, although as already noted the United States is at least one important OECD member that is currently opposed to reduction targets.

The WEDGE model is also used to look at the implications were Australia to join either a small club such as the EC, or a big club such as the OECD. In all cases, the plurilateral agreement is taken to be an agreement among members to cut carbon dioxide emissions by 40 per cent, even though in a less than global context such cuts would be insufficient to achieve a Toronto-type target on global emissions. Were this to be taken into account in framing a less than global agreement, however, the members may consider agreeing to reductions of more than 40 per cent in order to have a greater impact on global emissions. This would be more likely were the group considering plurilateral action already reasonably large. In a final plurilateral scenario, the WEDGE model considers a larger emissions cut of 60 per cent by the OECD including Australia.

These scenarios can help to give some indication of how the economic costs to Australia would change in different plurilateral scenarios. They do not capture the way in which the climate benefits would change, although this would need to be taken into account in any final decision by Australia to join a less-than-global consensus. They do not examine the possibility of trade concessions being accorded between member countries or of sanctions being imposed on non-member countries, and equally importantly do not consider the possibility that capital would move between countries in response to the changes in profitability that a plurilateral agreement would bring.

An EC-alone agreement

Reductions in emissions of greenhouse gases by the EC countries could be expected to reduce EC demands for Australia's fossil fuel exports. It would also lead to increased prices and some loss of national income in those countries. This would reduce the ability of the EC to purchase non-fuel goods and services from other countries, and so would be expected to have some adverse effect upon Australia's non-fuel exports.

Set against this, however, Australia's trade competitiveness against members of the EC would be enhanced. Australia could provide a greater share of the EC market, at least for non-fuel products, and this could offset the loss of trade referred to above. Further, Australia's gain in competitiveness could open up opportunities to compete successfully against the EC in third markets. However, the competitiveness of countries such as the United States, Canada, Japan and those in EFTA would also be enhanced compared with the EC countries. Each of those countries or groups currently sends a greater proportion of their exports to the EC than does Australia (Table 8.2). They may therefore be better placed than Australia to take advantage of new opportunities in that market, although they might be more affected than Australia by the reductions in trade associated with the income effect.

Table 8.2: **Trade between developed country groups**

(percentage of trade)

		North America	*Japan*	*EC*	*EFTA*	*Australia New Zealand South Africa*	*Total*
North America	Exports	33.9	10.8	20.0	2.6	2.6	69.9
	Imports	28.2	17.2	16.6	2.9	1.2	66.1
Japan	Exports	36.5	-	17.5	2.9	4.0	60.9
	Imports	27.8	-	12.2	2.5	7.2	49.7
EC	Exports	8.5	2.0	60.2	10.9	1.5	82.5
	Imports	8.5	4.2	60.1	9.3	1.2	83.3
EFTA	Exports	8.9	2.5	56.4	13.8	1.2	82.8
	Imports	6.8	4.2	61.8	13.6	0.8	87.2
Australia	Exports	12.4	26.1	13.0	2.1	5.5	59.1
	Imports	26.5	19.2	22.0	4.3	4.5	76.5

North America refers to the United States and Canada. EC refers to Belgium, Denmark, Federal Republic of Germany, France, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain and the United Kingdom. EFTA refers to Austria, Finland, Norway Sweden and Switzerland
Source: GATT International Trade 89-90, vol. II, Geneva (1990) and ABS (1990).

The WEDGE model's projected effects of an EC-alone agreement show a slight expansion in Australia's total exports because our competitiveness is projected to improve against at least some third countries (Table 8.3).[1] On the other hand, Australia's import prices rise because of the inflationary pressure in the EC and because of Australia's dependence on the EC as a source of imports. In response, import volumes fall as Australia switches towards domestically produced goods and services. The slight fall in domestic income is a net result of several conflicting factors -- a slight expansion in export and import-competing activity, offset by a decline in national expenditure and by having to pay higher prices to the rest of the world, and the EC in particular, for those imports we continue to buy.

1 The price variables in WEDGE should be interpreted as showing Australia's price changes *relative* to the world average output price, which is the numeraire chosen for these experiments. In this sense, the price variables measure changes in Australia's relative global competitiveness.

Table 8.3: **Macroeconomic effects in Australia of various plurilateral agreements on carbon dioxide emissions reductions**

(per cent)

Variable	*EC cuts by 40 per cent*	*OECD excluding Australia cuts by 40 per cent*	*EC together with Australia cuts by 40 per cent*	*OECD including Australia cuts by 40 per cent*	*OECD including Australia cuts by 60 per cent*
Real net domestic product	-0.01	-0.06	-1.42	-1.47	-3.94
Real national expenditure	-0.04	-0.21	-1.38	-1.54	-3.97
Export price index	1.07	2.10	1.41	2.45	6.56
Import price index	1.23	2.87	1.28	2.93	6.87
Terms of trade	-0.15	-0.77	0.13	-0.48	-0.31
Volume of exports	0.02	-0.21	-1.73	-1.97	-4.26
Volume of imports	-0.13	-0.95	-1.54	-2.38	-4.38

Source: Revised WEDGE model projections.

An OECD agreement excluding Australia

Were a group the size of the OECD to cut carbon dioxide emissions by 40 per cent, Australia, whether or not it joined the group, would benefit from the correspondingly greater reduction in global greenhouse gas emissions. Offsetting this is the fact that action by this larger group would also have greater spill over costs to Australia. It would mean a greater fall in demand for Australia's fossil fuel exports. Emissions reductions elsewhere in the OECD would also produce inflationary pressures and reduce incomes in those countries, reducing their demands for non-fuel exports. Were Australia able to avoid importing the inflationary pressure, its competitiveness against the other OECD countries would nevertheless improve markedly. It could use this to help offset the decline in the overall size of the OECD market by taking a larger share of that market.

The WEDGE model results highlight, however, how difficult it would be for Australia to avoid importing the inflationary pressure from the other OECD countries. This severely limits the competitive edge that Australia would gain from not being a party to the plurilateral agreement, and therefore limits the expansion in non-fuel exports. While import competing activities would gain, total exports would fall. This, combined with the adverse impact on Australia's real income of a decline in the terms of trade, leads to a larger projected net loss of real income for Australia than in the EC-only scenario.

An EC-based or OECD-based agreement including Australia

If Australia were to join the EC or the OECD in meeting some joint target to reduce emissions, the nature of the calculations would change somewhat.

For a start, Australia would now face an initial loss of income arising from the costs of making its own reductions in emissions, as would the other countries in the agreement. The modelling suggests that costs to Australia of reducing its own carbon dioxide emissions would be an important component of the overall cost to Australia of joining a plurilateral agreement. They are discussed in more detail in the next chapter in a unilateral context which takes account of capital flight from Australia. Broadly, the costs arise because of the need for Australia to scale back its carbon dioxide emitting activities. Despite the importance of fossil fuels in Australia's exports, Australia also produces a significant share of the fossil fuels consumed domestically. While 65 per cent of Australia's black coal and over 10 per cent of its petroleum products and natural gas are now exported, Australia's remaining fossil fuel production goes to meet domestic needs. Cutting back Australian consumption of fossil fuels entails cutting back Australian production, with spill over effects on incomes throughout the economy.

In a plurilateral context, the costs to Australia from its own action are exacerbated by the actions of the countries it joins in the agreement. As well as a contraction in Australia's fossil fuel production for its own use, there is a contraction in fossil fuel exports to other partners in the agreement. These additional costs would tend to be larger, the bigger is the group of countries that Australia joins, other things being equal.

The impact on non-fossil fuel exports, and the net impact on Australia's terms of trade, are somewhat sensitive to the size and characteristics of the group of countries Australia joins. Non-fuel exports increase as resources in Australia are reallocated away from fossil fuel production, but the size of the expansion in non-fuel exports also depends on Australia's change in competitiveness against both member countries and non-members. Australia’s competitiveness against other member countries depends on whether Australia finds it easier or more difficult than them to achieve the required 40 per cent reduction in emissions. Its competitiveness against non-members depends on the nature of non-members’ trade links with member countries. The WEDGE results show, however, that when the inflationary pressure from Australia's own domestic action is added to the inflationary pressure it imports from other member countries, the increase in non-fuel exports is insufficient to offset the decline in fossil fuel exports, so that total export volumes fall.

The implications of plurilateral agreements on Australia's terms of trade are the net result of two conflicting factors -- action by other members of the agreement, which reduces demand for Australia's exports and depresses Australia's terms of trade, and Australia's own action, which reduces Australia's supply of exports and improves Australia's terms of trade. When Australia joins a small group such as the EC, the improvement brought about by domestic action dominates. When Australia joins a larger group such as the OECD, the terms of trade deterioration brought about by action elsewhere dominates. In either case, the terms of trade changes have a corresponding impact on Australia's real income, in addition to the effects arising from changes in production and trade volumes.

The costs to Australia of plurilateral action could be further strengthened, or ameliorated, by discriminatory action by the group against non-members. Such measures, which could include trade preferences extended by group members to each other, and trade sanctions against non-members, have been advocated in some quarters. For example, the 1990 Inter-parliamentary Conference on the Global Environment urged GATT members:

> to take the necessary steps to establish a Green Common Market for Trade and Technology in which participants agree to assume an appropriate and comprehensive range of sustainable development strategies and practices while gaining complete and open market access, free of duties, tariffs, quantitative restrictions and other direct and indirect market barriers.

While trade preferences between group members would advantage Australia (assuming there was no retaliatory action from non-members), trade sanctions against non-members might not be to Australia's advantage. For example, a tariff on imports from non-abating countries could force

Australia to switch imports from low cost sources outside the group to higher cost countries in the agreement (‘trade diversion’). Further, it could draw resources in Australia into import competing industries at the expense of the export and non-traded sectors. These costs could offset, at least to some extent, any gains to Australia from increased trade to and from members of the group.

Finally, the costs to Australia would increase significantly in a plurilateral agreement in which group members agreed to make more stringent cuts in emissions to offset lack of action outside the group. When the OECD including Australia cuts carbon dioxide emissions by 60 per cent instead of 40 per cent, the reduction in Australia's real income is projected to more than double, falling by 3.9 per cent instead of 1.5 per cent. Significantly, the costs to Australia of joining an agreement to make stringent emissions reductions on a subgroup basis are also significantly higher than the costs to Australia of a global consensus on more moderate cuts. Since the OECD accounts for only 40 per cent of global carbon dioxide emissions, a 60 per cent reduction by the OECD would reduce global emissions by only 24 per cent (Table 5.1). Yet the cost to Australia of joining a subgroup agreement that would reduce global emissions by only 24 per cent is more than double the cost of joining a global consensus that would reduce global emissions by 40 per cent (Table 5.9).

8.3 Weighing up

The potential climate-related benefits from a less than global agreement depend upon which countries take part, the nature and extent of their greenhouse gas emissions, and what actions they take to reduce emissions and to discourage emissions growth by other countries.

Effective global reductions in emissions would require the inclusion of the major greenhouse gas emitting countries, present and future, in an agreement. At present this does not appear likely. Given the limited potential benefits from action by a smaller coalition of countries -- and Australia's own negligible contribution to global emissions -- Australia would need to give careful consideration to the costs of joining any such agreement. The Commission's modelling suggests that, leaving aside any sanctions, the costs of participating in a plurilateral agreement among developed countries could be substantially greater than not participating, since the overall costs would be dominated by the cost of Australia's own action. Moreover, the costs could be expected to rise more than proportionately with any additional reductions needed to achieve a global target, in the absence of action by other countries.

Much of this is also relevant to the case of an international system of individual country commitments, possibly in addition to an international consensus on 'basic' commitments. In particular, Australia should only consider making significant pledges if the main greenhouse gas emitting countries were to do likewise. Otherwise, Australia could face considerable costs for negligible potential climate benefit. The possible nature and extent of costs would require analysis on a case-by-case basis. However, some insights can be gained by considering unilateral action by Australia.

9 BENEFITS AND COSTS OF UNILATERAL ACTION

The Commission has examined the costs and benefits of unilateral action by Australia in part because it was raised as an issue by participants and partly because of its relevance in the context of individual country commitments in addition to international consensus on ‘basic’ commitments. Whether or not unilateral or individual country action is likely in practice, examining unilateral action also provides more detailed insights on the costs to Australia of its own domestic action. These costs appear to be an important component of the costs of joining a plurilateral agreement or global consensus.

Many participants commented on the possibility of unilateral action by Australia. As noted in Chapter 10, some considered early action would give Australia a strategic edge in taking advantage of new opportunities. Some considered that the greenhouse problem was so serious that Australia should do everything in its power to reduce emissions. Many participants, however, commented upon the global nature of the problem, the small contribution to it by Australia, and the possible costs to Australia of unilateral action. For example, the NSW Government said that:

> International consensus and concerted international action is needed if the Greenhouse Effect is to be effectively addressed. Unilateral action by Australia to achieve a given emissions reduction target may damage the Australian economy without significantly reducing global greenhouse emissions. (Sub. 100, p. 2)

This view was supported by the Business Council of Australia:

> Unilateral action by any one country will simply serve to damage that country's competitiveness. Such unilateral action may also have the perverse effect of exacerbating the global CO^2 situation. (Sub. 42, p. 3)

9.1 Climate benefits from unilateral action

Australian emissions account for around 1.4 per cent of global emissions of carbon dioxide and methane respectively (Table 8.1). Data for the Australian share of other greenhouse gases is not reliable, but there is little doubt that Australia also accounts for very small proportions of global emissions of those gases. Reductions of the scale proposed in the Government's interim planning targets imply reductions by 2005 of about 44 per cent for carbon dioxide, and up to about 50 per cent for methane on business-as-usual projections. These reductions implemented unilaterally would account for about two-thirds of one per cent of global emissions in 2005.

Any global climate effect from these reductions would obviously be marginal at best, and take place some considerable time into the future. Indeed, any benefit might not even be apparent given the present state of measurement technology. While regional effects of climate change are very uncertain, the effect on Australia's climate of unilateral reductions by Australia would have to be extremely small.

Further, if Australian industries relocated overseas to avoid making emissions reductions -- as several participants considered would happen if Australia took either unilateral action or significantly greater action than other countries -- the extent of global emissions arising from Australia's restrictions would be lessened. This would reduce any climate benefits globally, and to Australia, still further.

9.2 Costs to Australia of unilateral action

To assess the effects of unilateral action by Australia to reduce greenhouse gas emissions, account must be taken of a large number of factors, as discussed earlier in relation to a global consensus. These include:

- current and projected emission levels;
- targets for reductions in emissions;
- available policy instruments; and
- the capacity of the economy to adjust to the policy change.

These factors are of critical importance in ascertaining the costs involved in any unilateral action.

Current emission levels and targets

Any analysis of policies to reduce greenhouse gas emissions in line with some target requires a clear understanding of current emission levels and the date(s) by when any proposed action to reduce emissions is to be achieved. Emissions would grow over time due to economic expansion and population growth, but to some extent this could be offset by lower energy intensity in production and the advent of new technology.

There is considerable uncertainty attached to forecasts of future economic growth and the relationship between economic activity and emissions of greenhouse gases. The more rapid our economic growth, the larger would be the required reductions in emissions to meet a Toronto-type target by a given date, other things being equal. Continued growth thereafter would then begin to raise emissions above their target level again.

Current Government policy is to push for microeconomic reform of the Australian economy. Underlying this objective is the desire to boost our economic performance, so that we can better compete with the rest of the world and increase our material standard of living. Perversely, achieving higher material standards of living may exacerbate the problem of greenhouse gas emissions, but it also provides the wherewithal to help meet the costs of reducing emissions. Previous estimates of the economic benefits from microeconomic reforms by the Commission indicate that they would outweigh current estimates of the costs of policies to constrain greenhouse gas emissions. And some reforms advocated would also help to reduce emissions. Finally, microeconomic reform is intended to improve the economy's capacity to adapt to changes in economic circumstances which would be very helpful if Australia has to cut back significantly on emissions of greenhouse gases.

There are a number of different time paths by which to meet a target to reduce greenhouse gas emissions in the year 2005 to 80 per cent of their level in 1988. Three examples are:

- Emissions could be reduced immediately to 80 per cent of their 1988 level and stabilised thereafter. As the economy expands and population growth occurs over time, emissions per capita or per unit of GDP would have to be reduced further to hold emission levels constant.

- Emissions could increase until 2005 and then be reduced to the desired target. Based on the emission projections set out in Chapter 5, this would require a 44 per cent reduction in emissions from the level projected for the year 2005 (in the absence of any reduction strategy).

- Emissions could be constrained in two stages which would comply literally with the wording of the Commission's terms of reference. In the first stage emissions would be reduced to their 1988 level by the year 2000, and for the second stage, emissions would be further reduced to 80 per cent of their 1988 level by the year 2005. It would be easier, and less costly, to meet the first target than the second.

For illustrative purposes the Commission has modelled the consequences of a 44 per cent reduction in emissions levels, equivalent to the reduction required by Toronto from the levels that would otherwise prevail in 2005. Nevertheless, in the absence of a detailed picture of what the economy in general would look like in 2005 under a business-as-usual scenario, the Commission has been forced to impose the 44 per cent reduction in a model of the economy, the ORANI model, which represents its position in 1980_81. The exercise is in this sense an illustrative one, rather than one based on a true forecast of the path of the economy to the year 2005.

The costs of reducing emissions are not likely to be proportional to the size of the required reduction. As energy use becomes more efficient, each successive reduction would cost more for any given unit of emissions reduced. This is illustrated and discussed in greater detail in Chapter 5 (especially Figure 5.2). In its draft report the Commission was limited to examining the impact of a smaller emissions reduction of 20 per cent in a unilateral context because it could not at that stage correct the errors incurred in approximating these non-linear impacts of larger changes using a linear model. Revisions have since been made to the ORANI model's solution procedure and the results reported here for a 44 per cent emissions reduction are free of linearisation errors. Because of this and improvements to the model's structure, the results reported in the Commission's draft report have been overtaken by those reported here.

New technology represents one important means of achieving reductions. As the costs of emission abatement policies rise, this will provide a strong incentive for emitters to develop and utilise new technologies which reduce their requirements for greenhouse gas emitting inputs. The Commission has been unable to assess the extent to which total emissions can be reduced through the advent of new technology at current prices. At future prices such proposals are more likely to be economically viable and, as a result, emissions would be lower.

It should be noted, however, that the forecasts for greenhouse gas emissions in 2005 by ABARE (1991) that are used in this report, already assume declining emission rates resulting from the adoption of known technologies that are expected to be economically viable even in the absence of specific policies to reduce emissions. For every one percentage point of growth in GDP over the period to 2005, ABARE's projected emissions of carbon dioxide and energy consumption are projected to increase by only 0.88 per cent.

Policy instruments available

Policy measures could take a variety of forms, from regulation, quotas to emit greenhouse gases, tradeable permits, emissions taxes, or subsidies to reduce greenhouse gas emissions. (These possible policy instruments are discussed in greater detail in Chapter 3 and Appendix D.)

It is important, regardless of which policy instrument is chosen to reduce emissions, that emissions, or consumption of the inputs generating those emissions, are capable of being monitored to assess compliance. The monitoring costs may be high if many sources of emissions are involved.

Tradeable permits and emissions taxes are the most efficient means of reducing greenhouse gas emissions at the lowest cost. The Commission has considered the effects of taxes on greenhouse gas emissions. It has focused mainly on the taxation of fossil fuels, consumption of which is the major contributor to greenhouse gas emissions, particularly carbon dioxide. Nevertheless, the results can be interpreted more broadly as showing the direction of the impacts from the tax equivalent of a range of options to reduce greenhouse gas emissions.

Considerations in imposing carbon taxes

Ideally, any tax on greenhouse gas emissions should be levied as close as possible to the point at which emissions take place. This will maximise incentives to reduce emission rates. Due to the nature of the chemistry involved, production of greenhouse gases is directly related to the quantity and type of inputs used, although some variation exists in the quantity of gas per unit of input. Thus it may be administratively easier to tax the inputs used, rather than the emissions. Monitoring costs are likely to be lower on this basis. This is particularly so in the case of carbon dioxide emissions arising in the combustion of fossil fuels -- black coal, brown coal, petroleum products and gas.

In designing a tax regime for carbon dioxide emissions from fossil fuels several issues need to be addressed:

- At what stage in the production chain will the tax be levied? For example, will the tax be levied on consumption or production of fossil fuels?
- At what rate should it be levied and how is the revenue collected to be used? For example, is it a new tax or does it replace existing taxes (including existing taxes on fuels)?
- Will exports be taxed? If exports are to be exempted then does this apply to both primary and secondary exports? If the latter are included in the exemption then how will exporters receive rebates for the tax paid on the consumption of fuels in processing?

Production versus consumption taxes

Nearly all emissions of carbon dioxide from fossil fuels occur from their combustion, which suggests a consumption-based tax. However, a tax on methane emissions would involve a combination of production and consumption-based taxes, because some emissions occur in production, for example natural gas, while others are emitted when consumed, for example, the use of petroleum products by motor vehicles.

While a consumption-based tax on carbon dioxide would be desirable in principle, it would require monitoring a very large number of fossil fuel users. Because the number of producers and importers is much smaller, a domestic consumption-based tax could be levied at the point of production or import, with production destined for export being exempt. A consumption tax collected in this way would be related to the carbon dioxide content of fossil fuels, rather than to emissions, and so would reduce incentives for innovations to reduce emissions in subsequent processes. As noted in Chapter 3, this could possibly be countered by a rebate scheme for the adoption of measures to reduce emissions per unit of fossil fuel use.

Revenue implications

An emissions tax will raise significant revenue, which could be used to increase Government expenditure, retire debt, fund research into new technologies, compensate those most adversely affected or reduce other taxes. The Australian Conservation Foundation, for example, argued for a levy applied to fossil fuels based on carbon content, the revenue from which should be:

> hypothecated for funding of an expanded R, D&D program for renewables and energy efficiency and financing of costs associated with other policy proposals. (Sub. D137, p. 5)

In contrast, Kimberly-Clark Australia Pty Ltd argued that:

> the Government will need to make it clear that, for example, a carbon tax will be revenue neutral. Funds raised by penalising greenhouse emissions will be offset by reduced Government revenue raising elsewhere. (Sub. D114, covering letter p. 1)

They viewed this as essential in order to `sell' a package of economic measures to reduce greenhouse gas emissions.

The Commission has not been able to model the implications of various hypothecation suggestions and unless otherwise stated, has assumed for the purpose of its analysis that any additional revenue is used to reduce other direct taxes, with the Government's real borrowing requirement held fixed.

Taxing exports

Given the objective of reducing Australian emissions, exports of fossil fuels should be exempt from any Australian tax as the emissions associated with their consumption occur overseas. They may of course be subject to tax overseas.

‘Secondary exports’ (that is, exports using fossil fuels as inputs) would remain subject to Australian tax. Taxing secondary export production's use of fossil fuels would make those Australian exports less competitive on international markets than those of our competitors (if they do not control greenhouse gas emissions).

The effective taxing of secondary exports, while excluding primary exports, would induce a shift away from Australian processing of our agricultural, mineral and manufacturing industries and towards cheaper foreign processing. In short, Australian production would move away from the high value-added end of processing towards the lower end, without reducing global emissions. In essence, part of our emissions and value-added would be exported overseas.

The ORANI-Greenhouse model

Once decisions have been made about the target constraint on emissions, the policy instrument to control emissions, and the coverage or base of the instrument, the economic effects of the policy can be addressed. Given the complex interactions involved, this requires some form of economic modelling framework.

The model of the Australian economy used by the Commission to examine the implications of unilateral action is a comparative static model called ORANI. Its advantage over WEDGE in this context is that it provides much more detail on the implications for individual industries. It also allows for the possibility of capital outflows from Australia, one likely response to unilateral action. ORANI presents estimates of deviations from underlying growth rates after adjustments to the economic change under investigation have taken place. There is no explicit time dimension to the ORANI model. A time period is inferred according to the economic assumptions imposed on the model.

Given the focus on the economic effects of reducing greenhouse gas emissions, the Commission has used a specific purpose version of the ORANI model (Appendix G). This is used to examine the introduction of alternative tax regimes designed to reduce greenhouse gas emissions by 44 per cent. The emissions tax is levied on domestic consumption of fossil fuels (and other appropriate activities for methane).

In the initial simulation in this chapter, a ‘long term’ timeframe is assumed. This is defined as a timeframe in which industry capital stocks are allowed to adjust and real wage flexibility is assumed. It therefore allows for a high degree of flexibility in the way in which labour and capital can be reallocated among industries to minimise the economic impact of a unilateral reduction in emissions. It further recognises that capital in Australia would be required to earn the going world rate of return, despite the unilateral action, and that some capital may therefore be driven offshore. A long run ORANI simulation is also characterised by other economic assumptions and values for certain behavioural parameters (Dixon et al. 1982, Dee 1989). Thus the results of the simulations show the changes in economic variables in response to the policy change imposed (a tax on greenhouse gas emissions) after sufficient time has elapsed for the economy to adjust flexibly to the new policy. This is not consistent with a scenario in which emissions were allowed to increase until 2005 and an unanticipated policy package then put in place to reduce them by 44 per cent to achieve a Toronto target on emissions levels. It is perhaps more consistent with a scenario in which a policy reduction of 44 per cent in 2005 is announced well in advance, so that investment plans and employment prospects can begin to adjust in advance.

The results are the net outcomes of all the changes imposed on the model and these induced behavioural responses. They abstract from changes that occur along the adjustment path to the new equilibrium position.

By only taxing domestic fossil fuel consumption, including imports, primary exports of fossil fuels are exempted from the impact of the tax but secondary exports are not. The tax revenue is assumed to be redistributed through lower direct taxes so that the Government's real borrowing requirement is held constant. As noted, the labour market is assumed to be flexible with real wages adjusting to changes in the sectoral demands for labour.

By not modelling the introduction of the tax over time, the results cannot show the path the economy might take in adjusting to the introduction of an emissions tax. The path taken could be crucially important in terms of garnering and maintaining public support for a carbon dioxide tax policy. The results nevertheless show the broad overall effects of introducing such a tax, after full adjustment by the economy.

A 44 per cent reduction in carbon dioxide emissions

The discussion that follows first considers the direct and indirect effects of Australia unilaterally reducing carbon dioxide emissions by 44 per cent through the imposition of an emissions tax per tonne of carbon dioxide. Subsequently the implications are explored for targeting different combinations of gases.

Tax rate required

A decision by Australia to introduce unilaterally a tax on carbon dioxide emissions from fossil fuels would directly increase the price of fossil fuels in proportion to their carbon content. Black and brown coal would be taxed more heavily than petroleum products and gas. Due to the carbon free nature of renewable energy sources, such as hydro- and solar-electricity, they would not be taxed.

According to the model, as shown in Table 9.2, a tax of $21.75 per tonne of carbon dioxide (in 1988 dollars) would be required to reduce emissions of carbon dioxide by 44 per cent. This is equivalent to a tax of around $80 per tonne of carbon. The direct impact of this tax would be to increase the ex-mine or ex-well prices of fossil fuels to buyers by around 156 per cent for black coal (in 1988 prices), 271 per cent for brown coal, 78 per cent for crude oil and 50 per cent per cubic metre of gas. The final percentage cost increase to users would be lower, however, because to the base cost would be added the costs of transport, distribution and other indirect taxes.

Direct and indirect effects

The increase in domestic fossil fuel prices is projected to curtail domestic consumption, and activity in the fossil fuel producing industries. Outputs of the brown coal and black coal industries are estimated to fall by around 62 per cent and 26 per cent respectively, while gas output is projected to fall by 19 per cent and petroleum products output is projected to fall by 11 per cent.

Higher fossil fuel prices would feed directly into the operating costs of user industries. The extent to which the increase in costs would translate into higher prices would depend on the shares of fossil fuel costs in the total costs of users and their ability to substitute away from energy consumption. For example, fossil fuels account for almost 40 per cent of total costs for the electricity industry (Table 9.1).
The main industries that are likely to be most affected directly or indirectly by higher fossil fuel prices are shown in Table 9.1. The value of their total sales is provided as a guide to relative size.

The industries likely to be affected most are energy generation and distribution (electricity, petroleum and coal products and gas distribution), metal smelting and processing (non-ferrous metals and basic iron and steel) and transport (air, rail, road and water transport). Collectively, these nine industries accounted for almost $62 billion of total sales in 1986-87, and just under 24 per cent of GDP. If indirect linkages are also taken into account then chemical products and other non-metallic mineral products are also affected more than average by the increased prices of fossil fuels.

Table 9.1: **Principal energy using industries, 1986-87**

Industry[a]	*Fossil-fuel costs*[b] *as a share of total cost (%)*	*Direct and indirect requirements*[c] *of coal, oil and gas ($)*	*Total sales ($m)*
Electricity[d]	38.8	17.8	11 458
Petroleum & coal products[b]	37.1	28.8	11 848
Gas distribution	29.1	30.1	1 574
Cement	14.7	10.5	692
Non-ferrous metals	14.1	7.4	7 772
Fishing	13.4	4.6	985
Forestry & logging	11.9	4.3	888
Air transport	11.8	3.9	6 174
Cereal grains	9.9	3.4	3 382
Railway, transport nec	9.8	3.4	3 939
Water transport	9.2	3.7	2 056
Basic chemicals	7.7	5.7	5 222
Meat cattle	7.1	2.8	2 821
Pulp, paper, paperboard	7.0	4.4	2 677
Agriculture nec	6.6	2.5	4 017
Repairs nec	6.6	2.3	2 130
Sheep	6.0	2.3	3 479
Road transport	5.9	2.0	10 009
Milk cattle & pigs	5.6	2.2	1 690
Clay products, refractories	5.5	4.9	1 218
Basic iron and steel	5.5	5.7	7 145
Personal services	5.4	1.7	2 233
Total sales for all industries			2 199 156
Average for all industries	4.7	-	-

[a] ABS input-output industry classification. [b] Usage of coal, oil and gas; petroleum and coal products; and electricity as a proportion of total costs. [c] This shows the direct and indirect requirements of inputs from the coal, oil and gas industry to supply $100 of output to final demand. [d] Includes intraindustry usage of their own energy by these industries.
Source: ABS, Cat. No. 5209.0, December 1990.

The tax on emissions of carbon dioxide is projected to affect these downstream using industries most. The output of the electricity industry is projected to fall by around 8 per cent, while other transport (air and sea) is projected to decline by 4 per cent, as shown in Table 9.2. Construction activity falls by 3 per cent, since this industry is affected both by the overall decline in investment activity and the increased cost of cement and other inputs.

Table 9.2: **Economic effects of tax on carbon dioxide emissions**

Variable	
Macro-economic effects[a]	
Real GDP	-2.1
Real consumption	-1.6
Real investment	-3.4
Exports (volume)	-3.4
Imports (volume)	-3.0
CPI	0.5
Trade balance/GDP	..
Direct taxes	-6.1
Employment	-0.5
Capital stock	-3.4
Real pre-tax wages	-3.6
Terms of trade	0.3
Greenhouse gas emissions[a]	
Carbon dioxide	-44.0
Methane	-7.6
Reduction in GWP[b]	-33.0
Taxes on GHG emissions ($1988/tonne)	
Carbon dioxide	$21.75
Methane -	
Estimated revenues from emissions taxes ($1988 billion)	$4.7

Variable	
Industry outputs[a]	
Agriculture	-0.7
Black coal	-26.2
Brown coal	-62.3
Oil	-9.5
Gas	-19.3
Petroleum products	-11.4
Other mining	-9.4
Manufacturing	-2.2
Electricity	-7.6
Other utilities	-2.7
Construction	-3.1
Services	-1.8
Road transport	-1.8
Rail transport	-1.7
Other transport	-4.0
Nominal effects of tax on prices to households[a]	
Petroleum products	20.7
Electricity	16.2
Gas distribution	2.6
Effects of tax on household demand for domestic production of\[a]	
Petroleum products	-11.0
Electricity	-8.8
Gas distribution	-2.9

.. Less than + or - 0.05.
[a] Percentage change in variable. [b] Global warming potential (GWP) is the potential of the combined gases to contribute to global warming. For greater detail refer to Appendix C.
Source: Revised ORANI-Greenhouse projections.

Substitution effects

In the long run, introduction of a fossil fuel tax would induce substitution in production processes away from energy and into capital and labour. In the course of this inquiry the Commission was advised of many possibilities, which are discussed in greater detail in Appendix F. For example, consumers would be able to reduce household energy usage by installing insulation in their houses. Cars could be made more fuel efficient through the adoption of measures to reduce aerodynamic drag, idling time, vehicle weight and so on. This form of substitution is likely to be more prevalent in the electricity generation, transport, manufacturing and residential sectors, because of their expenditure on energy and the opportunities available to incorporate energy saving devices. By contrast, some participants such as CRA and Comalco saw little scope to substitute away from energy towards capital and labour in their particular industrial processes.

It is also expected that there would be substitution away from fuels that are highly taxed to those with a lower carbon content and thus more lightly taxed. The model allows energy using industries as well as households to substitute among fossil fuel energy sources and electricity. Given the relatively high carbon content of coal and the relatively low carbon content of gas, energy using industries would have an incentive to substitute away from coal and towards gas. Petroleum products and electricity have intermediate carbon content, this content being indirect in the case of electricity and reflecting the use of brown coal in energy generation in Victoria. Whether energy using industries would substitute towards or away from these intermediate carbon content fuel sources would depend on the relative importance of these fuels in their cost structure as well as on their technological substitution possibilities.

The model therefore allows gas to provide an increasing share of energy into activities such as electricity generation, at the expense of brown and black coal. This is consistent with the work of ABARE using their MENSA linear programming model (sub. D132). However, gas is used in a wider variety of uses than electricity generation and the overall prospects for the gas industry depend in turn on the prospects of all its downstream using industries, as well as on household usage. Unlike MENSA, the Commission's modelling takes comprehensive account of the way energy demands from these sources would change in response to energy prices in order to provide projections for energy industries. The Commission's output results are consistent with strong substitution away from brown and black coal by most users. The projected overall decline in gas is greater than the projected decline in electricity. Although gas becomes a relatively attractive energy source within each using industry, the gas industry is also relatively more dependent than the electricity industry on sales to downstream users such as the alumina industry which are particularly adversely affected by rising energy prices. The model assumptions concerning interfuel substitution are explored in greater detail in Appendix G.[1]

Effects on national output and prices

The model suggests that Australia's GDP would decline by 2.1 per cent (or $8 billion in current values) as a result of the introduction of a carbon dioxide tax. On account of the price increases, consumers would have lower real incomes and would consume less. However, these effects would be offset somewhat as the revenues from the emissions tax would allow lower income tax rates, partly restoring consumer's post-tax real incomes and spending. Subsequently, and depending on the flexibility of the labour market, displaced workers would have opportunities to take up employment in new locations, albeit at lower levels of real wages. As adjustment took place, the initial losses in production would be tempered, though some permanent loss would remain. Since ORANI is a comparative static model, the time profile of these losses is unknown, but experience in other countries in the face of changes in real energy prices suggests the initial adjustment costs could be substantial.

If carbon dioxide emissions are reduced by 44 per cent, methane emissions could be expected to fall by around 7.6 per cent, because of the projected decline in some methane producing activities such as gas production and distribution.

Following the introduction of the carbon dioxide tax, a number of induced effects could either reinforce or offset the direct effects. The key induced effects would be on Government revenue, inflation, wages and unemployment.

A tax of $21.75 (in 1988 dollars) per tonne of carbon dioxide is estimated to raise general Government revenue by around $4.7 billion, or 4.0 per cent. In turn, general Government revenue is equivalent to about 35 per cent of GDP. What is of particular importance is the purpose to which

1 The treatment of interfuel substitution differs slightly from that in the draft report in that petroleum rather than crude oil is the fuel source that substitutes with black coal, brown coal, gas and electricity.

the additional revenue from the new tax is put. In its analytical work the Commission has assumed that direct taxes (income and company taxes) are reduced to hold the real government borrowing requirement constant. The emissions tax would allow direct taxes to be reduced by around 6.1 per cent. Lower company tax rates, together with lower real labour costs, would help insulate those industries with low fossil fuel usage that trade on the world markets, for example, agricultural produce.

The Commission's modelling work suggests, however, that the effect on consumer prices would be relatively small, as the effects of a contraction in economic activity offset the price increases associated with the introduction of the tax. The prices of some particular commodities would still increase significantly. After the economy has adjusted, the tax on carbon dioxide emissions is projected to increase the retail price of petroleum products to households by 20.7 per cent, electricity by 16.2 per cent and gas by 2.6 per cent (Table 9.2).

Effects of targeting different gases

Carbon dioxide is of course not the only greenhouse gas. It is of interest to know whether Australia would benefit from targeting other greenhouse gas emissions, instead of or in addition to carbon dioxide. Several participants stressed the need to apply action across a broader range of greenhouse gases and the Government has sought advice on the costs and benefits of controlling all non-CFC greenhouse gases.

Little is known about emissions of nitrous oxides, which makes it difficult to devise a policy to constrain such emissions and to estimate the effects of such a policy. However, some estimates have been made of the sources of methane emissions (Appendix G). The Commission has attempted to evaluate the costs of a tax levied on methane emissions. As with the tax on carbon dioxide, it is levied on consumption of goods that produce methane, the main ones being gas (through leakage), petroleum products, cattle, sheep and pigs.

If action were taken to constrain emissions of methane, it is unlikely to be done in isolation from emissions of carbon dioxide. Therefore the Commission has analysed the impact of reducing both carbon dioxide and methane emissions. Emissions of the two gases were weighted according to their combined ‘global warming potential’, which takes into account the relative importance of each gas to the greenhouse effect. The weights used are the relative contributions of each gas over a 20 year period, in which the global warming potential of a unit of methane is 63 times that of carbon dioxide (Appendix C). The target in each case was a 44 per cent reduction in the combined global warming potential of these two gases. This target is slightly more stringent than a 44 per cent reduction in the emissions of carbon dioxide alone, since this would reduce combined global warming potential by only 33 per cent (Table 9.2).

Two methods of reducing the global warming potential were considered:

- targeting carbon dioxide alone; and

- cutting both carbon dioxide and methane by 44 per cent.

It is infeasible to consider reducing the combined global warming potential of the two gases by 44 per cent by targeting only methane, since eliminating methane emissions entirely would be insufficient to meet this target.

The results presented in Table 9.3 confirm firstly that even in a unilateral context, the cost of reducing emissions of a single gas rises more than proportionately with the size of the emissions reduction. When the required reduction in carbon dioxide emissions increases from 44 to 58 per cent, the real GDP cost almost doubles, rising from 2.1 to 3.9 per cent (Tables 9.2 and 9.3).

The results also raise some significant issues with respect to the mix of gases. They suggest that a uniform target applied across a range of gases may be far from a least-cost solution to achieving a given reduction in combined global warming potential. In particular, methane emission reductions are far more costly for Australia than carbon dioxide emission reductions of the same size. This is because the amounts of methane emitted per dollar of methane emitting activity are very much lower than the amounts of carbon dioxide emitted per dollar of carbon dioxide emitting activity. Thus a one tonne reduction in methane emissions requires a larger contraction in the value of output of methane emitting activities than a one tonne reduction in carbon dioxide emissions requires of carbon dioxide emitting activities.

Table 9.3: **Effects of alternative taxation schemes to reduce combined emissions by 20 per cent**

Variable	*Taxing only carbon dioxide*	*Taxing both gases*
Macroeconomic activity		
Real GDP	-3.9	-7.3
Real wages	-6.7	-24.2
Greenhouse gas emissions		
Carbon dioxide	-58.1	-44.0
Methane	-11.4	-44.0
Reduction in GWP[a]	-44.0	-44.0
Taxes on greenhouse gas emissions ($1988/tonne)		
Carbon dioxide	$44.16	$8.6
Methane	-	$20 047
Selected outputs		
Black coal	-40.0	25.5
Brown coal	-74.0	-15.7
Oil	-17.0	-22.8
Gas	-32.4	-48.8
Petroleum products	-20.4	-38.3
Wheat	-2.2	12.0
Meat cattle	-0.7	-42.8
Wool scouring	-5.1	-63.9

[a] Global warming potential (GWP) is the combined potential of carbon dioxide and methane to contribute to global warming. For greater detail refer to Appendix C.
Source: Revised ORANI-Greenhouse model projections.

For example, a one tonne reduction in methane from petroleum products would require a reduction of almost $15 000 in petroleum products use, compared with a reduction of less than $100 in petroleum products use to reduce carbon dioxide emissions by one tonne.[2] As a second example, a one tonne reduction in methane from beef cattle would require a contraction of over $3000 in beef cattle output, while a one tonne reduction in carbon dioxide from brown coal would require a less than $10 contraction in brown coal use.[3] While these cost ratios vary between pairs of methane and

2 Based on a weighted average price for petroleum products of 6.4 cents per litre or $4 555 000 per PJ, methane emissions of 318 tonnes per PJ and carbon dioxide emissions of 68 600 tonnes per PJ.

3 Based on a price of $7.64 per tonne or $759 000 per PJ and carbon dioxide emissions of 94 400 tonnes per PJ for brown coal, and a weighted average price of $163 per beast and methane emissions of 0.046 tonnes per beast for beef cattle.

carbon dioxide emitting activities, they are higher than the 63:1 benefit ratio that a one tonne reduction in each gas would contribute to reducing global warming potential. In other words, reducing methane is more costly than reducing carbon dioxide because the increased benefits per tonne of gas are more than outweighed by the increased costs to the Australian economy.

In a scenario in which emissions of both gases are reduced by 44 per cent, the necessary *percentage* reduction in methane emissions could not be achieved solely by the 44 per cent contraction in Australian consumption of fuels such as gas and petroleum products that also emit carbon dioxide, since these products account for only about 25 per cent of total methane emissions. Part of the required contraction in methane emissions would therefore need to be met by contractions in methane emitting agricultural activities. Since the required contraction in the value of their output is large -- and since these activities contribute significantly to Australia's exports and income -- the real GDP cost of restraining both methane and carbon dioxide would be almost twice as large as achieving the same reduction in global warming potential by taxing only carbon dioxide.

On the other hand, taxing the emissions of both methane and carbon dioxide produces a markedly different pattern of pressures on individual industries. Petroleum products and natural gas, fuels which emit both carbon dioxide and methane, are more adversely affected when both greenhouse gases are taxed. The beef cattle and wool scouring industries are also adversely affected by the tax on methane, although some of the pressure on agricultural output is relieved by substitution in production away from sheep towards wheat. Finally, when petroleum products and natural gas are taxed for emitting both carbon dioxide and methane, the relative prospects for brown and black coal improve markedly.

Adjustment costs

The projected outcomes of unilateral action reflect a number of key assumptions about the flexibility of the economy to adjust to cost increases resulting from the alternative taxes on greenhouse gas emissions. There are five important channels of flexibility: technology, the Government's fiscal stance, factor markets, consumer preferences and timing. Each of these factors will affect the severity of adjustment costs as the economy moves to reduce greenhouse gas emissions.

In the course of the inquiry the Commission was advised of the potential importance of these adjustment costs. For example, CRA was concerned that there was a:

> significant underestimation of the socioeconomic costs associated with the implementation of such policies and the subsequent process of adjustment. (Sub. D135, p. 1)

The Australian Coal Association and Shell Australia were concerned about the regional implications and the potentially large effects on small but vulnerable industries:

The Commission ought to be able to speculate, for example, on what might be involved if most of the coal industry in the Hunter Valley were to be closed down .... The analysis of costs and benefits would seem to be decidedly incomplete if local and regional impacts of that magnitude were not outlined. (Australian Coal Association, Sub. D130, p. 8)

Discussions of structural adjustment are most concerned with changes in the size of individual industries far smaller than those being contemplated in the greenhouse context. This should lead to an obligation for those proposing change to consider the adjustment costs that would be involved. (Shell Australia, Sub. D149, p. 1)

Technical change can reduce costs

The ORANI simulations assume that the technology is available for industrial users of primary energy (black and brown coal, petroleum and natural gas) to switch from one type of fuel to another as their relative prices change. An elasticity of substitution of 1.2 has been assumed. This means that if the relative price of one type of fuel increases by 1 per cent (for instance caused by a tax on greenhouse gas emissions) then users will increase the quantity share of the lower priced fuel input by 1.2 per cent. If the true elasticity is lower than 1.2, then users will be less able to switch to the lower priced fuel and hence their costs will rise more with deleterious effects on both the user and the overall economy.

Similarly, it is assumed that users of energy can substitute capital equipment for energy in their production process, with an assumed elasticity of 0.5. Again if the substitution possibilities are not as great as this, the economy will be less able to adjust to higher energy prices resulting from a tax on greenhouse gas emissions.

Based on historical experience, the assumed values for the substitution elasticities are quite high, but they may be more representative of what might occur over the decades to come, especially given the size of possible price increases.

In the ORANI simulations no explicit account has been taken of the possibility of technological change affecting the substitution and production possibilities modelled as described above. If technology is developed to increase the efficiency with which energy is used by industry, then greenhouse gas emissions could be significantly reduced. For example, technical change that costlessly reduced energy requirements per unit of output for all industries by 16 per cent (equivalent to 1 per cent a year over 15 years) could reduce carbon dioxide emissions by around 15 per cent and methane emissions by around 3 per cent. Emissions would not fall by quite as much as the improvement in energy efficiency because the efficiency improvement would increase the productive capacity of the economy (less inputs are needed per unit output) leading to an increase in overall economic activity and a consequent partial offsetting increase in emissions. The increase in efficiency should of course be offset by any costs in developing and installing the new technology that generates the reductions in energy requirements, and which have not been taken into account in the above estimates.

One specific example of how technical progress could amend the Commission's projections is in the use of brown coal. The projected impact of a 44 per cent reduction in carbon dioxide emissions was a 62 per cent reduction in the output of the brown coal industry. This strong decline in brown coal production would impose substantial regional costs, especially in Victoria. The results also presume the availability of a national power grid to facilitate the provision of electricity generated from gas or black coal to Victoria. But one inquiry participant claims the availability of new brown coal technology that would improve the energy efficiency of brown coal so it was comparable with black coal (sub. D103). Such a development could dramatically reduce the cost to the Victorian brown coal industry of measures to reduce carbon dioxide emissions.

What happens to tax revenue?

If greenhouse gas emissions were controlled through taxes on emissions, large amounts of revenue would be raised. How the Government used the increased revenue would have an important bearing on the overall economic outcome. Offsetting the new revenue source by reductions in other taxes would minimise the overall impact of the new tax. In the ORANI simulations, it is assumed that the revenue raised by the new tax is offset by a reduction in direct taxes (income tax and company tax), so that the Government's real borrowing requirement is held constant. The borrowing requirement is affected not just by the emissions tax itself but also by changes in revenue and outlays stemming from the changes to the economy induced by the constraint on greenhouse gas emissions. The overall decline in activity reduces revenue from other taxes and increases outlays on personal benefits payments. The ORANI simulations reduce income taxes so as to offset the emissions tax revenue, net of other revenue losses and expenditure changes associated with the overall decline in activity. They do not, however, take into account that some part of the revenue from the new tax may need to go towards the costs of collecting the new tax.

This would reduce the fall in direct taxes.

Constraining greenhouse gas emissions by non-tax measures would not enable the Government to allow full or partial offsetting of other tax imposts and could prove more costly in terms of the overall impact on the economy. In an alternative ORANI simulation, the Commission examined the implications were carbon tax revenue not available to reduce other taxes. The Government borrowing requirement was still constrained to be constant in real terms. Income tax changes were therefore still required to offset the declines in commodity tax revenue and increases in personal benefits payments induced by the overall decline in activity. Since carbon dioxide emitting activities currently provide a significant share of Government commodity tax revenue, the revenue losses from this source were relatively severe so that in the absence of offsetting carbon tax revenue, an increase in income tax rates was required to keep the real Government borrowing requirement constant. The real GDP cost of reducing carbon dioxide emissions in this situation was slightly higher, at 2.4 per cent, and the declines in activity in at least some industries were also correspondingly greater. For example, black coal output was projected to fall by 28.1 per cent, and gas output by 20.9 per cent.

Although an explicit carbon tax could potentially raise a large amount of revenue, the question of whether it is redistributed back to households in the form of income tax cuts does not seem to greatly affect the projected economic costs of reducing carbon dioxide emissions.

A less flexible economy means higher costs

If the economy is not flexible in terms of being able to reallocate labour and capital between industries, then it becomes more difficult for the economy to adjust to a constraint such as a reduction in greenhouse gas emissions. Several factors would contribute towards making the economy less flexible over a shorter time horizon than a longer one. Over a shorter time horizon it would be more difficult to reallocate capital between industries, because new investment takes time to install and many industries would have limited incentives to scrap old capital stocks prematurely unless there were specific regulations forcing them to do so. Over a shorter time horizon rigidities in the labour market may make it difficult to institute major changes in real wage levels or wage relativities that would help to provide signals for the reallocation of labour to new activities. Indeed, the United Mineworkers' Federation of Australia confirmed that in the absence of major labour market and community adjustment programs, the level of trade union and community resistance to large scale employment and community restructuring could be expected to be substantial (sub. D118). Finally, over a shorter time horizon industries would tend to have fewer technological substitution possibilities.

Under these conditions of fixed capital stocks, fixed real and relative wages and lower substitution possibilities,[4] the ORANI model projects that a 44 per cent reduction in carbon dioxide emissions

4 The elasticities governing substitution between labour and other primary and energy factors of production, between energy and other primary factors, between types of energy, between modes of transport, and between capital and land were all set to 40 per cent of their long run values. The size of the reduction in substitution elasticities is based on the estimated relativities between Australia's short run and long run capital/labour substitution elasticities.

would require a much higher carbon tax, at $94 per tonne of carbon dioxide, while the real cost would be higher than in a more flexible economy, amounting to 4.6 per cent of GDP rather than 2.1 per cent. Much of the adjustment would be felt in employment levels, with employment falling by 4.3 per cent, and in industry profitability, with aggregate real profits falling by almost 24 per cent. Even with industry capital stocks fixed, a 44 per cent reduction in carbon dioxide emissions would still require substantial reductions in Australia's fossil fuel production. Indeed, given the significant inflationary pressures created by a $94 tax per tonne of carbon dioxide in an inflexible environment, the black coal industry is projected to lose significant export as well as domestic sales, with black coal output projected to fall by 67 per cent. Other export industries are similarly much more adversely affected.

It is obvious that were action taken to reduce greenhouse gas emissions sooner rather than later, emissions would no longer need to be reduced by a full 44 per cent in order to reduce them to 80 per cent of their 1988 levels. The 44 per cent target is the reduction required were emissions to grow on a business-as-usual basis until the year 2005. Nevertheless, the projected impacts of a 44 per cent reduction in a short time frame are useful for demonstrating the importance of flexibility in helping to alleviate the adverse economic consequences of greenhouse gas emissions reduction.

Consumer preferences matter

Constraints on greenhouse gas emissions would push up prices of goods and services. Such price rises would depend largely on the energy intensity of inputs. These direct price changes may then be amplified or offset by economy-wide induced effects.

One way in which users would adjust is to switch to lower priced goods and services. In the Commission's ORANI model, overseas demand for Australia's major exports is quite sensitive to changes in relative prices. Within the domestic economy, users are responsive to relative price changes between domestically sourced and imported goods for some categories of imports. The model allows industrial users to switch energy sources and transport modes as relative prices change, and households can also change demands for different goods and services as their relative prices change. However, the assumed price responsiveness of household demand is quite low. In the case of intermediate inputs to production, for inputs other than energy and transport, no substitution is allowed for in the model (except between imported and domestically sourced categories of the same inputs).

The net effect is probably that the model underestimates the true extent to which household and industrial users of goods and services would adjust their demands in response to a tax on greenhouse gas emissions. To the extent that switches in demand are underestimated, the impact on the overall economy is likely to be overestimated.

The timing of reductions is also important

Assuming that the Government were to proceed to reduce emissions to 80 per cent of their 1988 levels by the year 2005, a major question would be whether or not to act early to reduce greenhouse gas emissions.

Announcing policy measures early would give a clear signal to industry in planning its investment and production decisions. Actually implementing them early could also imply a lower percentage reduction being required to meet an absolute emissions target of the Toronto-type. The total costs of adjustment may therefore be lower as a result, but the present value of such costs, using traditional discount rates which place a much higher value on current costs than costs in 10 years time, could well be much higher. Acting sooner may mean lower taxes on greenhouse gas emissions (if that instrument is used by the Government). However, if it would take some time to develop the necessary technology to increase energy efficiency and enable substitution across fuels and between energy and capital, then it may be prudent to wait for the technology to emerge. That raises the obvious question as to what incentive there would be to develop technology if constraints on greenhouse emissions were not imposed.

Over time the economy is expected to grow, with consequential increases in greenhouse gas emissions. Thus a fixed target for the level of emissions, ie 80 per cent of its level in 1988, will become more difficult to achieve. Higher tax rates will be needed to induce the economy to reduce emission levels. By 2005 it is projected that emission levels might be 44 per cent greater than in 1988. Also the shorter the time available for industry to adjust the higher the rate will have to be to force the necessary rate of adjustment. It would probably be completely impracticable to make the adjustments to the target levels for 2005 (or the interim target for the year 2000) in a short period just prior to 2005. Meeting the interim planning target for the year 2000 implies reducing emissions from their projected levels in the year 2000 by 26 per cent.

Comparing results with other studies

Considerable efforts have been made and continue to be made by a number of different groups to estimate the economic impacts on Australia from actions to reduce emissions of greenhouse gases. All studies have focused on unilateral action by Australia and therefore exclude the trade and income effects of action by other countries. At the time of finalising this report many of the studies had not yet been completed and published. However, the Commission has been kept advised of progress and given access to at least some preliminary results for each study. Progress reports on these studies were given at the Commission's workshop on greenhouse gas modelling in October 1991 (Appendix H).

A notable feature of more recent work has been a convergence of assessments of the likely magnitudes of effects, despite large differences in focus and analytical approaches.

The estimated effects depend on which activities are constrained to reduce emissions and by how much, what measures are used to constrain emissions and their timing, what allowance is made for the adoption of new technologies, what provision is made for additional investment requirements, whether demand is allowed to change as costs increase, and whether more general economy-wide feedbacks are taken into account, as well as specific features of different models.

Reconciling ORANI and WEDGE

In its draft report, the Commission also modelled the effects of unilateral action to constrain carbon dioxide emissions by Australia using the WEDGE model. Further investigation suggests that such a simulation is not sufficiently realistic because of the modelling constraint that aggregate capital stocks are fixed. If Australia alone took action, there would in fact be some outflow of capital due to the general loss of competitiveness in Australia and also because energy-intensive industries would seek to move offshore. However, there is some broad similarity in terms of overall activity level changes and required taxes on carbon dioxide between the WEDGE results for multilateral action to reduce emissions of carbon dioxide from combustion of energy by 40 per cent and the ORANI results from unilateral action to reduce corresponding emissions by 44 per cent. They project falls in GDP of around 1.5 per cent and 2 per cent respectively. The required tax according to the ORANI model is $22 compared with a tax of $40 or $US34 per tonne of carbon dioxide with the WEDGE model.

The lower GDP loss in the WEDGE model reflects the assumption that capital stocks are fixed, precluding the possibility of capital outflow. However, the incentives for capital outflow are lower in a multilateral than unilateral context. The higher carbon tax in the WEDGE model reflects the slightly lesser substitution possibilities. For example, WEDGE does not allow for intermodal substitution in transport use. The main message to come from comparing the ORANI and WEDGE model results is that Australia is affected far more by domestic action to reduce emissions than by international action, assuming no sanctions.

A number of studies have already been publicly released. While the nature of these studies varies considerably, it of interest to compare the Commission's work with that already published. (Some of the studies are considered in greater detail in Appendix G.) The methodology used varies considerably between studies, as do the assumptions made, particularly regarding the role of new technology and the costs of implementing that technology. This is further compounded by differences in the size of emission reductions and time periods, and the use of different policy instruments. As a result, the estimates and conclusions differ considerably.

Some of the early studies were reviewed by Greene (1991) for DASETT. The studies are summarised in Boxÿ9.1. They were undertaken in 1989 and 1990, and most focused on engineering possibilities to reduce emissions. Some studies estimated that adoption of new technologies would yield net economic benefits. The CRA study was a notable exception. These benefits raise the obvious question of why the new technologies are not adopted without the need for action by governments. But more importantly they also demonstrate the technological capabilities for producing and using energy at lower greenhouse gas emission levels.

Box 9.1: Summary of greenhouse studies: carbon dioxide emissions and costs/benefits

		Carbon dioxide outcome, 2005		
Study	*Mt CO_2*	*vs 2005*[b]	*vs 1988*[a]	*Costs/Benefits*
Business-as-usual[b]	402	equal	46%	above
Walker	344	14% below	25% above	Economic/ Low Cost
AMEC [c]	"	"	"	"
Wilkenfeld[d] - a	321	210% below	16% above	Economic: 3 year payback
- b	281	30% below	2% above	Economic
Greene	227	44% below	18% below	Benefits of $6500 M pa
NIEIR (Victoria)[e]	n/a	39% below	20% below	Benefits of $900 M pa
Greene/NIEIR[f]	227	44% below	20% below	Benefits of $6220 M pa
ABARE	314	22% below	14% above	Economic
CRA			20% below	Total costs $1860-3170 M

[a] 1988 Carbon dioxide emissions = 276 Mt. Includes wood and bagasse. [b] Reference/Business-as-usual forecast 402 Mt, ABARE, 1991. Greene/NIEIR business-as-usual forecast is 394 Mt. [c] Identical to Walker. [d] Two scenarios, the second with less stringent economic criteria. Reductions stated to be against business-as-usual forecast. [e] Independent business-as-usual forecasts completed. Two energy efficiency scenarios analysed. [f] Four scenarios examined: 10%, 20%, 30%, 45% reductions.
Source: Greene 1991.

CRA study

The first study was commissioned by CRA (1989). The study focused on reducing emissions of carbon dioxide by 20 per cent in the road transport and electricity generation sectors. These two sectors account for around 65 per cent of direct emissions of carbon dioxide in Australia. The reductions were to be achieved by a combination of higher energy prices to suppress demand and new technology to reduce energy requirements. The analysis was undertaken using the ORANI-F model. The estimated present value of GDP forgone by action to reduce emissions over the period 1989 to 2005 was around $32 billion, assuming a 5 per cent discount rate. This is broadly comparable with one half the Commission's estimate of GDP forgone by action to reduce emissions of carbon dioxide associated with all energy usage by 44 per cent. The differences in estimates probably reflect two factors. The CRA study took into account the significant costs of adopting new technologies in the two sectors, which would raise the overall cost of action to reduce emissions, whereas the Commission's analysis allows more flexibility in switching between fuels and between energy in general and capital, which would tend to reduce the estimated costs of action.

Tasman Institute

The Tasman Institute (sub. 55) used a simple methodology to consider the effects of a tax of $19.60 per tonne of carbon dioxide in 1988 dollars. Their estimate of the welfare loss, between 1990 and 2005, was of the order of $25 billion for an immediate 20 per cent reduction and $8.6 billion for a strict adherence to the interim Toronto target (assuming a 4 per cent discount rate). The welfare losses estimated by Tasman only represent the initial impact of the carbon tax. They neglect any general equilibrium effects. Hence, the true costs could be substantially higher than the Tasman Institute indicates.

In a subsequent paper (Moran and Chisholm 1991), the Tasman Institute extended their analysis to consider the need for further reductions in greenhouse gas emissions beyond 2005. They projected ABARE estimates of Australia's demand for energy out to the year 2050, assuming that a reduced ratio of energy to GDP was maintained and allowing for population growth. Next they drew on estimates from Nordhaus (1990b) of the rate of carbon tax required to reduce carbon emissions. The tax is not introduced until the year 2001, but by the year 2050 they estimate that a tax of $499 per tonne would be required to keep emission levels down to their 1988 base levels. However, at this rate other energy forms would be viable and hence they suggest an upper limit to the tax of $330 per tonne of carbon. The total welfare cost of such taxes through to 2020 is estimated at $64 billion, using a 3 per cent discount rate, which they equate with an annual loss in GDP terms of 0.55 per cent per annum in the decade to 2010 and 1.1 per cent per annum in the following decade. However, they note that not all of the welfare loss will translate into a loss in measured GDP. Only to the extent that reductions in carbon emissions involves lower production of marketed goods and services would measured GDP decline. The work of the Tasman Institute highlights the need to look beyond 2005 if there is serious concern about the greenhouse effect. Action will still be needed beyond that time to constrain the growth in emissions.

ABARE's MENSA model

Some of the most detailed analysis has been undertaken by ABARE (sub. D132), who used the MENSA model to estimate least cost combinations of fuels in order to meet Australia's future energy requirements subject to constraints on carbon dioxide emissions. The most likely scenario appears to be the projection in which neither nuclear or baseload solar thermal power enter the picture. Excluding the former would reflect community concerns about waste disposal and the low probability of it being politically viable. The latter is excluded because of the highly experimental nature of the technology and uncertainty surrounding the costs involved.

To reflect the fact that emissions should not be permitted to grow once again after the Toronto target date has passed, ABARE assumed that carbon dioxide emissions are to be maintained at their 2005 level until 2020.

The introduction of a carbon emissions tax will gradually make the ‘dirtier’ technologies less cost effective. Under the base demand scenario, increasingly stringent emissions reduction targets are achieved through interfuel substitution and energy conservation particularly in the post-2000 periods. The latest ABARE study suggests that Toronto target is achievable by Australia but that considerable changes to the pattern of energy supply and demand are required. The most striking result is that no black or brown coal is used to generate electricity by 2015. It would still be used in the commercial and transport sectors but this is because there is limited scope for substitution away from coal and coke for those applications.

These adjustments are made at additional system costs each year that increase to around $6ÿbillion (1990 dollars) between 1997 and 2007 and exceed $4 billion in the years that follow. The additional system costs in 2005 represent about 1.1 per cent of ABARE's projected GDP.

ABARE assumes that the Government levies an emissions tax to force the required change. Some energy technologies become more attractive; others are phased out. The tax is levied initially at $52 per tonne of carbon dioxide[5] in 1997.

This estimate probably overstates the tax actually required. The MENSA model, like the Tasman Institute's estimates, abstracts from general equilibrium effects. That is, a tax of $52 a tonne of carbon dioxide would be necessary in the absence of a decline in the demand for energy. Some fall in energy consumption would be expected to follow from the imposition of such a tax.

The same characteristic of MENSA can also explain the difference between the GDP effects estimated by ABARE and the Commission. The extra percentage point of GDP loss in ORANI may reflect general equilibrium effects associated with reduced activity once substitution possibilities have been exhausted.

The COPS model

The Centre of Policy Studies (COPS: Adams et al. 1991) modelled a set of projections relating to the partial replacement of coal with natural gas in electricity generation by 2005, a 50 per cent reduction in the world producer price of black coal between 1990 and 2005 and an annual 1 per cent electricity saving technical change in all industries. These results were intended to provide elasticities rather than projections. The results would have to be scaled or calibrated with other

5 Converted from $192 per tonne of contained carbon.

estimates of projected technical change or substitution of gas for coal in electricity generation -- for example from MENSA model results -- to generate projections of likely effects.

Drawing on results from the MENSA model, COPS estimate that greater use of natural gas in electricity generation would require additional capital investment and raise electricity prices by around 7 per cent a year. The economy-wide impact of this would be a real reduction in GDP of 0.3 per cent a year, or some 3 per cent over a decade. If balance of trade problems were to be avoided this fall would have to be largely absorbed by real wages. The substitution of gas for coal would not meet the Toronto target for reducing greenhouse gas emissions, but might form one part of a package of changes to the energy production and distribution system.

Technical efficiency improvements would reduce emissions through lower output of electricity and have a small beneficial impact on GDP.

As these scenarios lead to greater exports of black coal, COPS also considered what would happen if overseas demand for our coal fell. They simulated the effects of a 50 per cent reduction in coal export prices over 15 years, as being representative of the impact of a global consensus to reduce carbon dioxide emissions. While real GDP does not change significantly from the base case, the economy is worse off through cutbacks in imports and lower investment spending. Exports of coal are projected to fall significantly. The main conclusion drawn from this simulation is that Australia's economy is more influenced by domestic action to reduce emissions, but prospects for the Australian coal industry depend more on overseas actions.

NIEIR

The work by NIEIR (National Institute of Economic and Industry Research) and Energy Policy and Analysis Pty Ltd for the Commission for the Future is not yet finalised. However, preliminary results (Brain et al. 1991) presented at the Commission's workshop in October 1991 indicated that compliance with the Toronto target would not appreciably affect real GDP but would instead reduce real consumption by 2 per cent per annum. An additional $53 billion (1990 dollars) in capital expenditure would be needed to achieve the necessary efficiency improvements. The present value of the discounted costs of action was estimated to be around $20 billion. This study contrasts with earlier work by the NIEIR (1990) for the Victorian Solar Energy Council which projected benefits of $900 million per annum from action to curtail emissions. The reason for the differences in results was the adoption of more conservative assumptions concerning alternative technological possibilities and their associated costings.

Implications of action at the State level

The analysis to date has assumed that Australia acts as one country with uniform policies across all States, rather than the States and Territories acting independently. The issues involved in comparing the two approaches are very similar to those concerned with global emissions reductions discussed in Chapters 2 and 5.

If each State independently tried to reduce emissions by 20 per cent, the national costs would be higher than if Australia as a whole reduced emissions by 20 per cent, even though in the latter case individual States may not reduce emissions by the same amount. For example, electricity generation in Tasmania emits virtually no carbon dioxide and the costs associated with reducing that State's emissions would be much higher than for the more emission intensive mainland States. In such a case, the economic costs would be lower if emissions associated with electricity generation were reduced by more in the mainland States.

Just as the effective taxing of secondary exports can induce a shift away from high value-added processing towards primary exports, similar effects could occur if the tax rate was not the same across States. If one State increased electricity prices significantly and another did not, industries that use electricity relatively intensively would have an incentive to relocate between States. The Australian total of carbon dioxide emissions may not change. For new industries, these factors could well influence their ultimate location.

The global model analysis suggests that tradeable permits could be an efficient way of reducing emissions due to the greater flexibility involved. For Australia, the economic costs could be lower if such a system of tradeable permits existed rather than a regional or activity-specific reduction target.

The costs involved could be reduced if the States coordinated their action. Commodities such as electricity should be produced in whichever State can do so at the lowest cost (taking any environmental damage into account). For example, it would be more efficient in terms of reducing emissions to generate electricity from gas or black coal in preference to brown coal. Greater interstate trade in electricity would also help to alleviate any additional expenditure on capital equipment through the use of current excess capacity in certain States.

The optimal allocation of emission reduction levels would vary between States depending on the nature of the activities concerned and their relative efficiency.

9.3 Weighing up the costs and benefits of unilateral action

The climatic benefits of any unilateral action by Australia to reduce greenhouse gas emissions would be negligible. The best outcome would be if it encouraged other nations to take similar action.

There would be costs of taking action unilaterally both in terms of lower rates of increase of GDP and of real incomes, although the costs would be lower than if the rest of the world also decreased emissions.

The magnitude of the costs of unilateral action would depend very much on the policy adopted by the Government to constrain emissions and on the extent to which that stimulated the development of new technologies to reduce the emission intensity of production and consumption in Australia.
The Commission's analysis has focused on one instrument to reduce emissions, namely a tax on products which emit greenhouse gases in the course of their consumption. A tax on emissions of carbon dioxide through the conversion of fossil fuels into energy seems likely to be the most practical way of reducing emissions without imposing very high costs on the economy. Nevertheless, the results can also be taken as indicative of the likely impact of non-tax regulatory controls, since these would also have a taxing effect on emitting activities.

If such a tax were imposed with offsetting reductions in other taxes, the costs to the economy would be significantly lower in a flexible and adaptable environment, once all the adjustments had occurred, than in an inflexible environment. Even so, the costs would be substantially higher than average for some industries and their workforces.

It would be considerably more costly to constrain emissions of methane than emissions of carbon dioxide, and administratively less practicable. However, action to constrain emissions of carbon dioxide would have some effect on the level of methane emissions.

The impact of unilateral action to reduce emissions depends crucially on two factors -- technology and factor market flexibility. The availability of technology to reduce emissions per unit of economic activity is already embedded in projections of future emission rates to the year 2005, and in the Commission's assumptions about the capacity of the economy to substitute between different sources of fuels and between energy and capital. However, significantly more technological change is required if the costs of constraining emissions are to be minimised. Many technological possibilities may well become economically viable if the costs of emitting greenhouse gases are increased through the use of taxes or other policy instruments.

New technology induced by changing price signals would not obviate the need for flexibility in factor markets. If factor markets are not allowed to adjust in response to changing circumstances, the costs to Australia of reducing greenhouse gas emissions could more than double.

10 OPPORTUNITIES FOR AUSTRALIAN INDUSTRY

The reference requires the Commission to report on new opportunities which could arise for Australian industry as a result of an international consensus to reduce emissions of greenhouse gases. This could be interpreted as requiring the Commission to indicate which activities might expand, or which new ones might be undertaken, under such a consensus. This is no easy task, as a myriad of factors, external and domestic, both related and unrelated to reductions, would affect the outcome.

10.1 Factors influencing opportunities

As noted in earlier chapters, implementation of an international consensus to reduce emissions of greenhouse gases would undoubtedly result in large changes in the patterns and volumes of international trade. Australia, as a relatively large trader of energy products (predominantly coal), unprocessed minerals and agricultural commodities, could be significantly affected by such changes in trade. In some areas, it could lose; in others it could gain from expansion or from new opportunities. As DASETT said:

> if Australia is in a position to exploit ... new opportunities as they emerge, the costs to Australia of an international consensus ... will be lower. (Sub. D154, p. 8)

However, a particular new opportunity will not necessarily be restricted to Australia. As part of an international consensus, other countries would also need to reduce emissions levels. This will lead to new opportunities for industry in those countries as well. Domestic factors which differ between countries, such as resource endowments, economic flexibility, management skills and wage levels, might mean that in particular areas other countries may be able to take better advantage of a given opportunity than Australia.

New opportunities are often spoken about in terms of opportunities for manufacturing industry, rather than opportunities for industries in other sectors of the economy. But, in the past, most Australian exports have generally been from resource based industries in the agriculture and mining sectors, rather than from transformed manufactures. Although the introduction of policies to reduce greenhouse gas emissions would affect the structure and competitiveness of different economies in different ways, it is not possible to prejudge the extent to which the export opportunities of Australian manufacturing activities would improve. Factors such as our small domestic market could continue to restrain manufacturing opportunities for Australia.

This possibility was recognised by the United Mineworkers' Federation of Australia, which said:

> Our potential to participate in new industrial opportunities is limited by the current size and poor condition of our manufacturing and R&D sectors. The lack of a substantial domestic market and large industrial base means that it is very difficult to undertake major technological innovations and develop them to the demonstration and commercialisation stage. Given the economies of scale relevant to many industries, it is clear that Australia can often only support one or a few producers in such industries. Investment is therefore both very `lumpy' and high risk. Either something is done well and on a large scale, or it is not done at all. (Sub. 53, p. 24)

In similar vein, CRA Ltd considered that:

> even if Australia gets into some of the ‘new’ technologies initially, such manufacturers typically move offshore as they develop. This is because Australia generally does not have a comparative advantage in maintaining high technology industries. We only have a small market, we have a limited high technology support base and typically the high technology inputs are more readily available in the bigger markets. (Sub. 135, pp. 9-10)

Further, the effects upon the Australian economy which would result from large changes in patterns of trade and in the domestic economy are difficult to predict. Because economic changes feed back through an economy in many complex ways, unexpected outcomes can sometimes happen. Activities expected to gain sometimes lose, and those expected to lose sometimes gain. Australia's industry policy experience provides ample testimony to the difficulty of ‘picking winners’.

Some understanding of the possible effects of emissions reductions could in principle be gained through the use of economic models. The modelling conducted by the Commission, and as reported in Chapters 5 and 9, suggests that most sectors of the Australian economy would be adversely affected from implementing policies to reduce greenhouse gas emissions (future climate effects aside).

However, these sectoral results through their level of aggregation hide the gains which could arise to particular activities from worldwide reduction of greenhouse gas emissions. Further, available general equilibrium models do not adequately account for several factors which influence economic outcomes of emissions reductions. For instance, the ORANI model database does not incorporate emerging technologies such as renewable energy, energy efficient appliances, and changes in iron and steel technology. Such technologies therefore cannot be shown by the model results to respond to policies reducing greenhouse gas emissions, and overall reductions costs could be overestimated. Nor does the database incorporate ‘no regrets’ policies. On the other hand, the model cannot capture many adjustment costs and economic rigidities which apply in reality and, on this basis, would tend to underestimate overall costs.

Work undertaken by ABARE with the MENSA model simulates possible changes in usage of different energy types which could arise from reductions (on a unilateral basis) in greenhouse gas emissions to meet the Government's interim planning target. ABARE's results indicate that usage of coal would contract, with demand taken up by various combinations of natural gas, renewables, and nuclear energy depending on the assumptions used. Liquid fuels would continue to take up a substantial proportion of demand.

Although presently available models may give some idea of the magnitude of the likely aggregate costs to Australia of reductions in greenhouse gas emissions as part of an international consensus, and indicate some possible switches in energy fuel types, they do not provide any real guidance about specific opportunities for Australian industry.

10.2 Possible opportunities

A distinction should be made between opportunities arising in the normal course of technical progress and economic development, and those new opportunities which could derive specifically from government measures to reduce greenhouse gas emissions. Renewable energy solutions, for example, have been sought at least since the oil shock of the early 1970s -- a greenhouse gas emissions reductions policy should add to the interest in that technology. However, in examining opportunities, it would be difficult to distinguish between technological progress already under way and that arising additionally due to emissions reductions and the Commission has not attempted to do so.

Bearing in mind the caveats of the preceding section, it is possible in broad terms to list examples of industries, in Australia and overseas, which could be advantaged by an international consensus. These include industries which produce relatively little greenhouse gases, or use relatively little input from industries which do; industries which produce products or provide services which act as sinks for greenhouse gases; industries which produce devices to save energy; industries which use energy more efficiently; industries which generate electricity more efficiently or with lower greenhouse gas emissions; industries which can capitalise upon changes in lifestyle induced by emissions reductions policies; industries which produce or use natural resources which are ‘cleaner’ than others; and industries researching solutions to greenhouse gas problems.

Some specific examples of possible new opportunities for Australian industry commented upon by participants are listed below:

- examples relating to *energy efficiency*: production of more efficient lighting and refrigeration equipment, high efficiency electric motors, development of fuel efficient engines, continuing improvements in the efficiency of electricity generation from coal, cogeneration of electricity, adding value to resources in Australia before their export, production of b-doubles for road transport, and provision of energy advisory services;

- development and use of *new/different technology*: capsules to reduce methane emissions from cattle, production of ethanol to replace petrol, development of `ultra clean' coal, technology for ‘drying’ brown coal, displacement of coal electricity generation with gas, hydro, nuclear or renewable energy technology;

- arising from *changing lifestyles*: development of new urban forms to reduce energy use, opportunities for public transport; and

- *capturing emissions and sinks*: relining gas pipes to prevent leakage, capturing natural gas from landfills, expansion of forestry operations.

It is not possible for the Commission to determine which among these possibilities hold the most promise for Australian companies. What can be said in general terms is that companies in Australia may have some advantage in those areas where Australia has relatively abundant supplies of the necessary resources (uranium, gas); has somewhat of a head start (solar water heating, photovoltaics); and/or has well developed R&D capability (agriculture).

Not all possible opportunities for Australia necessarily relate to the Australian market. There could be good opportunities, for example, in exporting technological skills for efficient generation of electricity. The NSW Department of Minerals and Energy commented that:

> Many conventional technologies currently in use in NSW are considerably more efficient/advanced than those in use in the third world for instance, and application of these known technologies in such areas could have significant greenhouse benefits. Such technologies could include pulverised coal power generation, fluidised bed combustion, gas reticulation networks (using for example AGL's ‘goldline’) and could offer significant opportunities for local manufacturers to export. (Sub. 100, Attachments, Volume 1, p. 24)

Opportunities need not all relate to ‘high tech’ either. For instance, the Tasmanian Government considered that:

> with the emphasis place on the design and manufacture of new, emission ‘free’ wood stoves, a not inconsiderable opportunity exists for Australian manufacturers both in the home and export markets. (Sub. D139, p. 3)

Appendix F presents a series of short case studies, drawing on information from participants about possible ways for Australia to reduce greenhouse gas emissions, including possible new opportunities for Australian industry.

10.3 Some illustrations

Renewable energy

ABARE's work with the MENSA model suggests that pursuit of the Toronto target by Australia could lead to increased use of renewable energy for electricity generation, particularly if nuclear power is ruled out. Three potentially important forms of renewable energy are wind power, solar thermal and solar photovoltaic. At present, wind power is considerably more economic than solar for generating electricity; and solar thermal is more economic than photovoltaic (see Appendix F). To illustrate some of the opportunities for, and difficulties faced, by renewables, this section uses solar photovoltaic technology as an example.

For many years, renewable energy has been considered to have promise as a ‘sunrise’ industry for Australia. Indeed, Australia has been at the forefront in development of renewables such as solar thermal technology, including hot water heating, and of photovoltaic cells. One of the main factors spurring this progress has been the geography of the country, with its relatively abundant sunlight and its remote areas. Undoubtedly, policies to reduce greenhouse gas emissions will increase the attractiveness of renewable energies such as solar. Such energy sources cause no emissions of greenhouse gases (although the manufacture of solar systems of course does).

Kuhn (1991, section 7) considered that:

> Australia is at the leading edge of photovoltaic device research. A group at UNSW [University of New South Wales] led by Prof Martin Green is internationally recognised, having broken numerous world records for conversion efficiency with silicon material. Many of the ideas and innovations from UNSW have been transferred through licence agreements to both local and overseas companies.

These comments were supported by the NSW Department of Minerals and Energy (sub. 100, Attachments, Volume 1, p. 23) which added that ‘given the encouraging recent developments at the University of NSW, photovoltaic solar cells represent a major business opportunity’. In contrast, DASETT commented that:

> Australia has been a leader in research and development of renewable energy technologies and various energy efficient technologies, especially wind, solar thermal, photovoltaic and biomass. However, it is allowing itself to slip behind in the technology race in some of these fields. (Sub. 82, section 6)

The Australian Coal Association considered that:

> [Australia's] comparative advantage, if any, in the field of solar energy is likely to be increasingly and strongly challenged. (Sub. 36, p. 37)

Some obvious technical problems constrain the development and widespread use of solar energy, although there are many market niches where it can be cost-effective. For example, some form of energy storage or supplementary power would be needed to provide energy during periods of darkness. Lead-acid batteries, currently the most suitable form of storage for solar generated power, need full recharging periodically if they are to have a long life. This may require access to mains power or to a diesel generator, for example. Similarly, wind power requires backup.

But solar photovoltaic systems are well-proven, and their cost has declined markedly since their introduction. Kuhn (1991) commented that:

> Researchers are continuing to improve the conversion efficiency with improved cell structures but the dramatic decline in cost from around $150/W in 1974 to $10/W in 1985 has slowed in recent years and is now about $6/W.

Dr David Mills considered that while costs of photovoltaic installations are currently falling about 12 per cent a year, they are `too expensive for general use' (sub. 25, p. 8). As noted by the State Energy Commission of Western Australia, solar power is significantly less economic at present than large scale fossil fuelled power generation (sub. 72, p. 14). According to ECNSW (1991) solar photovoltaics technology is more than ten times the price of conventional coal electricity generation, on a kilowatt/hour basis. Further, solar power not only would need to compete against peak load power presently generated largely from coal, but also against off-peak power. This is presently supplied at relatively low rates by the utilities. Solar water heating, at present, is uncompetitive with conventional water storage systems using off-peak electric power. The costs of electricity generated from wind and solar thermal also currently exceed that generated from coal (and, in most cases, from nuclear). Many renewable technologies are still in the development stage and have not yet reached commercial scale production. As they do, costs could be expected to fall.

Some participants considered that present electricity prices were artificially low, because utilities used low-cost government guaranteed funds (not available to purchasers of renewables), and were not required to make commercial returns on their capital. Removing these barriers would add to the attractiveness of solar energy. In its recent report on Energy Generation and Distribution (IC 1991a), however, the Commission concluded that pursuit of microeconomic reform could result in a *reduction* in electricity prices in the longer term, mainly arising through improved productivity. If this occurred, the competitive position of renewable energy would be worsened.

Set against this would be the boost to renewable technology which would arise from implementation of policies to reduce Australian greenhouse gas emissions. For example, a carbon tax would feed through into the price of electricity, and could give a substantial spur to renewable energy technology. Further, measures to incorporate external environmental costs into electricity prices could also favour renewable energy sources.

An additional complication, in trying to assess prospects for a solar energy industry in Australia, is that other countries will presumably be active in this area as well. It is by no means certain that Australian industry would obtain the lion's share of whatever Australian market developed for these renewable technologies.

In summary, many factors, domestic and international, influence the extent to which new opportunities would arise for Australian renewable energy technologies from a reduction in greenhouse gas emissions. The overall outcome is clearly hard to predict.

Uranium and nuclear energy

Generating power from nuclear energy avoids emissions of greenhouse gases (except of course those arising as a result of the construction of nuclear power plants). Although not currently as expensive as most renewable energy technologies on a cents per kilowatt hour basis, nuclear power remains at least two and a half times as expensive as coal generated power (ECNSW 1991).

As just noted, the Industry Commission's recent report on Energy Generation and Distribution, concluded that microeconomic reform in the electricity and distribution sector could act to reduce electricity prices in the longer term. If this occurred, the relative attractiveness of nuclear energy in the domestic market would be reduced. On the other hand, as with renewable energy, measures to reduce greenhouse gas emissions would increase its competitiveness. ABARE results indicate that, if its use were to be permitted in Australia, nuclear generation of electricity could achieve substantial market share in response to a greenhouse gas emissions reductions policy.

Although there is growing pressure for environmental reasons to cut back on its use overseas, some countries make substantial use of nuclear power. Worldwide, according to CRA Ltd, nuclear energy accounts for some 17 per cent of electric power. Nuclear energy would become a more attractive option with any cutbacks being required in carbon dioxide emissions. All things equal, this would increase export demand for Australian uranium. As the State Energy Commission of Western Australia noted:

> Within the energy sector of the world economy, nuclear fuel (uranium or plutonium) is the most widely used non-CO_2 emitting fuel. On purely technical grounds, nuclear fuelled electricity generation would probably feature in a least financial cost national CO_2 emission reduction strategy. (Sub. 72, p. 14)

However, the present uranium policy of the Commonwealth Government would impede growth in uranium exports. In noting that there are already some 450 nuclear power stations operating worldwide, CRA Ltd commented that:

> If these did not exist and their output were supplied by coal-fired plants, there would be an extra 2 billion tonnes of CO_2 released each year, which would add one third to electricity's CO_2 contribution to the greenhouse gas increment. While Australia itself is unlikely to use nuclear electricity for some considerable time, we have a role as suppliers of uranium for fuel, and that role should arguably increase. This would require Australian Government approval and a change to the ALP's ‘3 mines’ policy. (Sub. 38, p. 7)

Australia accounts for about 30 per cent of known reserves of uranium worldwide (Rutland 1990, p. 36). In 1989, production of uranium in Australia totalled about 3800 tonnes. This was about 11 per cent of world production.

Other participants, including Western Mining Corporation, the Australian Coal Association, London Economics and the Australian Mining Industry Council also commented on the positive role nuclear power could play in reducing greenhouse gas emissions.

A few participants expressed opposition to the greater use of nuclear energy. Greenpeace Australia commented that nuclear power:

> has got too many negatives associated with it and ... those negatives, whether it is nuclear proliferation, melt-downs, ... just do not give it a clean bill of health ... we do not have at the national level a policy for development of nuclear power and we would recommend the government stick to that. (Transcript p. 204)

Ms D. Margetts put forward the view that:

> Nuclear power is uneconomical because of the huge costs and problems of decommissioning and the storage of nuclear waste. Possible social costs are unacceptable to the majority of Australians. (Sub. D147, p. 7)

This illustrates that action taken for one set of environmental reasons (in this case, reduction of greenhouse gas emissions) can often pose other environmental problems (disposal of radioactive waste). The associated costs should ideally be factored into the energy equation. Undoubtedly, however, policies to reduce greenhouse gas emissions would favour the nuclear industry worldwide. Whether this presents new opportunities for Australian industry will depend on future government policy towards uranium mining and export, and towards nuclear power generation in Australia.

Value-adding in Australia

Transportation of basic minerals such as coal and iron ore, and of unprocessed agricultural products such as wool and wheat, emits considerable amounts of carbon dioxide. One way of reducing those emissions is to transform those basic resources into processed products before transporting them to overseas destinations. This could have considerable relevance in Australia's case, given the large share of relatively bulky unprocessed products in Australia's exports. Governments have made statements encouraging greater processing of those products in Australia before export.

As BHP Steel Ltd said:

> if the problem is considered globally as it should be, it may well be better for Australia to make more rather than less steel as its production methods are modern and its raw materials of good quality. Furthermore, the transportation energy would be more effectively used by transporting 100 000 tonne of finished product rather than transporting 100 000 tonne of raw material which may result in only 70 000 tonne of finished product. (Sub. 27, p. 8)

Dr B. O'Brien also commented on the greenhouse gases reductions that could be achieved:

> A case can be made that increased refining, value-added processing and manufacturing industries might be better located, from greenhouse viewpoints, in Australia. A simple calculation shows that transport of iron ore to Japan contributes about 2% of Australia's annual emissions of carbon dioxide, which would be `saved' by local processing. That may seem a small amount, and it is, but it must be viewed in the context of policies which view 20% as a major national issue. (Sub. 19, p. 19)

Although more value-added processing in Australia before export could reduce global emissions of greenhouse gases, it would increase Australia's own emissions. If an international consensus imposed a fixed upper limit of emissions on individual countries such as Australia, then such increased value-adding in Australia might be ruled out. As Pasminco Metals Ltd observed:

> Australia could not expand its GDP if it involved an increase in greenhouse gas emissions. This would stop expansion of energy intensive processing of Australian minerals, contrary to the Government's policy of value-added processing prior to export. This would also be contrary to the Government's economic and social objectives. (Sub. 68, p. 7)

Whether new opportunities for value-adding in Australia eventuate or, indeed, whether opportunities decline, will thus depend crucially on the nature of any international consensus. The nature and extent of those opportunities would differ widely between a tax/permit consensus which allowed different levels of reduction between countries, and one which set regulated targets country-by-country. With the tax/permit consensus, emissions could be optimised from a global point of view -- this could encourage value-adding in a country such as Australia which currently exports unprocessed goods to foreign places. In contrast, set targets would reduce the extent of value-adding opportunities.

10.4 Making the most of new opportunities

As illustrated by these three examples, many factors are likely to influence the 'success' of a new opportunity. These include how other countries respond to new opportunities, the ability of the economy to respond to changing opportunities, government policies in areas such as uranium, and the form of an international consensus. So what should governments do to encourage Australian industry to take advantage of the opportunities which will arise from an international consensus?

An important issue is whether opportunities would be improved if Australia took unilateral reductions action in advance of an international consensus being implemented. Some participants considered that there could be advantages for Australia in doing so. The Australian Conservation Foundation commented that:

> Contrary to the arguments raised by many industry groups and economic commentators, increased input costs for Australian industry, if strategically directed, could in fact upgrade the competitive advantage of Australia's industry, rather than degrade ... Australia, therefore, needs to be moving faster than its competitors in improving its relative energy and resource use efficiency. To lag behind would leave us open to having to import technologies to achieve emission reductions rather than produce them domestically. (Sub. 46, p. 14)

On the other hand, CRA Ltd expressed concern that:

> as an industrialised nation, with an economy in trouble and very dependent on our ability to develop and process our mineral resources, Australia could be badly damaged by policies which restrict the development of energy intensive industries and placed them at an economic disadvantage compared to their overseas competitors. (Sub. 38, opening remarks, p. 3)

Modelling results set out in Chapter 9 illustrate that unilateral emission reductions by Australia in advance of other countries could be costly. But, as noted above, the model is limited in its ability to take account of new and developing technologies, and can disguise cost-effective opportunities available now. Obviously, opportunities should be taken advantage of as they become cost-effective to those individuals, firms or industries undertaking them. But the question then becomes whether Australia should implement reductions measures, which are not presently cost-effective, in advance of an international consensus. This is a complicated issue which essentially depends on whether the benefits of doing so outweigh the costs. On the benefits side, Australian companies may gain a strategic advantage in being able to develop new opportunities before other countries can do so. This would assist Australia to develop export markets. However, this favourable effect could be offset if industries in those countries, prompted either by entrepreneurial foresight or government action, also developed those opportunities early. On the costs side, early unilateral action could be expensive. Costs would be further increased if the early action were to impose such penalties on particular industries that they moved offshore. In this regard, the Tasmanian Government commented that:

> The Australian policy response must take account of policy implementation elsewhere. It is already becoming apparent that some nations will not act until such time as any adverse impacts become readily apparent ... Under such circumstances, any early Australian policy responses may lead to adverse economic impacts such as offshore migration of energy intensive industry. (Sub. 32, p. 1)

Some participants considered Australia should subsidise particular activities or industries to take full advantage of emerging opportunities. The Australian Conservation Foundation, for example, called for significant additional funding to be given to energy efficiency and renewable energy research, development and demonstration as well as funding for 'early commercialisation of near-economic renewable technologies' (sub. D137, p. 6).

The Tasman Institute commented critically about subsidies offered by governments in the past:

> The results have been singularly disappointing and governments should avoid the temptation of trying to outperform market forces, which are based on profit opportunities, in any new arena of potential that might unfold. Intervening not only wastes public resources but serves to distract management into seeking public funding rather than grasping the technological and market opportunities. (Sub. 55, p. 35)

Another justification for a subsidy is related to matching assistance by overseas governments to their industries. Pasminco Metals Pty Ltd considered that `if Australian industry is to survive, subsidies must be available to Australian companies to counter those granted in overseas competitor countries to compensate for pollution taxes on greenhouse gas emissions' (sub. 68, p. 13).

Subsidising particular industries while they developed, or to match assistance accorded overseas would be of assistance to those industries, and could assist Australia to develop new opportunities. Set against this, however, would be the cost imposed upon those other industries and community groups faced with paying the cost of the subsidy. Further, there would be the problem of deciding which of the many available new opportunities should be subsidised. As already explained, identifying new opportunities is no easy task -- nominating which of those are likely to succeed, and should be subsidised, is even more difficult.

Rather than attempting to `pick winners' by subsidising particular activities, it would be better to allocate money to R&D. Several participants supported government funding for research. For instance, the Australian Coal Association commented that:

> It is critical to progress R&D ... expeditiously, since better knowledge of the costs and risks involved is likely to be very prudent insurance against the real risk of policy mistakes. There is a case ... for a significant part of this research to be subsidised, since it is intended to provide benefits for the whole community. (Sub. 36, p. 24)

There are, indeed, some good arguments for government funding of research into greenhouse issues. As noted in Chapter 6, funding for research to reduce uncertainty about an enhanced greenhouse problem provides a form of insurance. If, as a result of research, improved information suggests that climate change will not arise, the costs of needlessly undertaking a full emissions reductions program will have been avoided; alternatively, if such research confirmed a serious problem existed, emissions reductions could be increased.

Already, significant funding is extended for research on greenhouse issues. As an illustration, in 1990-91, over $12 million was available to the CSIRO's climate change research program (CSIRO 1991, p. 23). Of this, over $5 million came from non-CSIRO sources, including about $2.7 million from DASETT. Research, both scientific and economic, is also currently undertaken by other public bodies such as the Bureau of Meteorology, the universities, ABARE and State Governments. Private firms can take advantage of the tax concession for R&D. The Commission has not endeavoured to estimate total funding for greenhouse-related research in Australia but, clearly, it would amount to a substantial sum.

In addition, considerable funding is provided directly or indirectly by governments for the provision of information to the community about greenhouse issues. Unless members of the community are well informed, they will not be able to develop appropriate adaptation and mitigation strategies. Provision of relevant information might provide a relatively cheap way of encouraging appropriate responses to the greenhouse problem. This issue is discussed further in Chapter 11.

While for the reasons discussed above it is difficult to justify selective assistance, there is a need to remove handicaps preventing the full development of new opportunities. This, indeed, is the objective of microeconomic reform. Such reform, in itself, may not always lead to reductions in greenhouse gas emissions. For example, lower energy prices consequent on microeconomic reform in the electricity supply industry could increase electricity use and emissions of carbon dioxide. However, microeconomic reform should continue to be pursued, as the greater resulting income levels within the community will make the cost of emissions reduction policies more affordable, and the more flexible economy resulting from reform will offer lower cost options for making reductions in emissions.

11 SOME POLICY IMPLICATIONS

The reference asks about the costs and benefits to Australia of a global consensus to reduce greenhouse gas emissions. The Commission has had less success in quantifying costs and, especially, benefits than in identifying them and the influences governing their extent. Nevertheless, it has learnt a lot in the process which is relevant to what Government should be doing about an enhanced greenhouse effect -- in the words of the reference, so that Australia can 'best prepare itself.

There are two areas of 'preparation' or strategy for Australia: the international and the domestic. This chapter focuses on each of these in turn, drawing on analysis and information in the preceding chapters.

11.1 International strategies

An enhanced greenhouse effect is a global phenomenon. For action to reduce it to be effective, a global solution would be required. Any particular global outcome, however, could be pursued in different ways, having different impacts on the interests of individual countries, including Australia. It is obviously important that Australia pursues strategies in international negotiations which best serve our interests -- interpreting that term in the broadest sense.

The global consensus

The Commission has heard different views from participants in the inquiry about:

- whether there is an enhanced greenhouse effect;
- whether global action is necessary at this stage;
- and, as a corollary, what position Australia should take in international negotiations.

The Commission has reported the state of scientific knowledge about the first point. It has noted the emerging scientific consensus that unabated anthropogenic emissions are likely to lead to some amount of global warming, but it has also reported the uncertainty about the extent of any such global warming, and the even greater uncertainty about what it would mean for living conditions on earth.

As discussed in Chapter 6, given the pervasive uncertainties, the evidence is not such as to permit an `objective' decision about whether global action on emissions reduction is needed -- let alone the appropriate amount. Available studies have been helpful in showing the elements of the calculation, but they have also served to demonstrate the shakiness of the foundations on which any such calculations must be based. The scientific, technical and economic information is not such that it can indicate what the ‘correct’ decisions are. In the end, such decisions -- which amount to choosing insurance -- must depend essentially on judgment. These judgments should not, however, be arbitrary: they should be as well informed as possible and, given the responsibilities involved, taken in politically representative forums.

At this stage, the ‘global community’ has not reached such a collective judgment. The Toronto meeting produced the target of 20 per cent below 1988 levels by 2005. But, as noted in Chapter 7, that forum was not sufficiently representative to conclude that this number is the accepted appropriate amount of global insurance. As some participants have observed, it was also conducted at a time when some scientific predictions were more alarming than they are now (for example, sea level rise and the timing of any global warming). While Australia, the EC and some other Governments have largely accepted the Toronto position, most major emitters have not. The UNCED meeting in Brazil next year will be the first politically representative forum to attempt to reach a collective view. As noted, the lead-up negotiations are already departing from the Toronto framework.

The Australian Government's stated policy is that it ‘will not proceed with measures which have net adverse economic impacts ... in the absence of similar action by major greenhouse gas producing countries’. It is not entirely clear whether this should be interpreted to the effect that Australia *will* proceed with measures having such effects if major emitting countries do likewise. In any case, it raises the question of what the different net economic effects for Australia would be (climate aside) between participating or not participating in a consensus.

Australia would incur considerably less cost by not participating, as this would avoid the compounding effect of national measures on economic activity, but it could not be a ‘free-rider’ in the sense of obtaining all potential benefits for no cost. A proportion of the costs to Australia would derive from the actions of other countries impacting on Australia's trade. If to these adverse effects -- reflecting lower world incomes and changes in relative world prices -- were added trade sanctions by the consensus participants, which by definition would include Australia's major markets, then the cost advantage from staying out would be reduced. The experience of other international treaties suggests that such sanctions would be likely in the event of an agreement which included the major world economic powers.

This all abstracts, of course, from other strategic or political considerations which might influence such a decision, as well as the general question about benefits from a global consensus.

If Australia is to participate in an international consensus, however, it is clearly in our interests to influence the kind of agreement that eventuates.

What sort of consensus?

A Toronto-type agreement, as already endorsed in principle by the Australian Government, could be implemented in various ways. There are several elements involved which can have an important differential impact on Australia. These include the gases covered by the agreement, the instruments to be applied to reduce emissions and the monitoring and enforcement regime adopted.

Gases

Australia produces man-made emissions of carbon dioxide, methane and nitrous oxide. Given that much of Australia's wealth and trade rest on energy resources which are relatively heavy emitters of carbon dioxide, in theory it would appear in Australia's economic interests to argue that any overall emissions target should give credit for reductions in emissions of methane and nitrous oxide. This is consistent with the interim target that Australia has set for itself. In pursuing a broader greenhouse gas coverage, however, we would want to be able to trade-off one gas for another. In other words, any target should relate to greenhouse gases in aggregate, rather than individually.

The Commission has used its modelling work to get some sense of what the economic advantages to Australia of a broader gas commitment might be. The unilateral analysis suggests that, for a given reduction in global warming potential, the costs of reducing emissions of methane would be substantially greater than for carbon dioxide. Taken together with the technical infeasibility of including nitrous oxide, this suggests that Australia would not have much to lose in accepting an agreement on carbon dioxide alone.

Instruments

There is a range of ways of implementing a given global reduction in emissions among participating countries. As discussed, these can have a significant bearing on the aggregate level and distribution of costs among participating countries. There appears, however, to have been little thought given to this in the international negotiations thus far. Australia may have scope to influence the debate.

As a general proposition, if Australia is to participate in an agreement involving global targets, it would be best to secure an emissions reduction mechanism which takes into account the different costs of countries, and activities within countries, in reducing greenhouse emissions. Otherwise national and global costs of securing a global emissions target would be higher than necessary.

In principle, an efficient way of meeting a global target would be by a uniform global tax on greenhouse gas emissions. As discussed previously, however, there are some difficulties with such an approach, including the problem of finding the right tax rate to achieve the target reduction (inevitably requiring trial and error); the institutional arrangements for collecting the tax, including selection of the tax base and enforcement arrangements; and the question of how the (very large) tax revenues would be redistributed.

An inefficient mechanism would be the assigning of fixed quotas for emission reductions by all countries, for reasons already discussed. However the experience of other treaties (including the Montreal Protocol) is that this approach is the most commonly adopted, because of apparent simplicity and dependability. The distribution of the global costs of this approach would depend on how the quotas are allocated. Some rules would be worse for Australia than others. With its relatively small population and high per capita emissions, Australia could expect to be disadvantaged by a per capita quota for example.

A fixed quota approach would be even more costly if it required countries to meet their external commitment by regulatory controls domestically -- preventing them from choosing their own least-cost ways of attaining their national quotas. Australia would need to insist on national choice of domestic instruments.

A means of implementing a global target, which could in principle combine the efficiency properties of a global tax with the relative dependability of quotas, is a system of internationally tradeable emission permits. As discussed elsewhere, to be a viable system, the rights to trade would in practice need to be vested in governments rather than individual emitters (enterprises, households) around the world, and this would lower the potential efficiency gains. In these circumstances the choice of national instruments could be critical. Nevertheless, the Commission considers that the Government should urge consideration of this approach if negotiations reached that point, and in the meantime should support further analysis and investigation of its potential in the OECD and other forums.

Then there is the question of how best to respond to inevitable demands for differential treatment among countries. Hardship claims may be made by countries other than developing ones (like those with more fossil-fuel dependent economies -- Australia itself would be a candidate) but it seems clear that any agreement would need provisions to assist developing countries if they were to participate. The choice is between some combination of delayed commitments and subsidised participation. Both involve costs to the other participants. Depending on the degree of (early) commitment required, the costs could be a substantial addition to those which the donors already bear. It would clearly be important to do our sums before entering into a commitment of that kind.

More generally, the Government should argue that a decision about international mechanisms for implementing a global target not be taken before careful empirical analysis of alternatives.

Monitoring and enforcement

As noted in Chapter 3, there is a potential free-rider problem in seeking international commitments to reduce greenhouse emissions. It would be in the interests of countries genuinely committed to reductions to insist on stringent monitoring and enforcement provisions. Monitoring and enforcement costs could vary depending upon the gases covered by a consensus and the range of instruments used to achieve it.

Should we act without a ‘consensus’?

To have a chance of reducing an enhanced greenhouse effect, global greenhouse emissions would need to be reduced. That means that an agreement would need to comprise major emitters now and in the future. An agreement that did not encompass some major emitters, or even potential emitters, would place a larger burden (cost) on those within the agreement to achieve any given global outcome. What this might entail was discussed in previous chapters.

The efficacy of a subgroup agreement in reducing global emissions would depend critically on the emission record of other countries. On current projections of energy use, even a 40 per cent reduction in carbon dioxide emissions by the OECD, for example, would be made up for by other countries within a short time. What is more, with the potential for `dirty' industries migrating to countries without carbon taxes, there could end up being higher global emissions than if no action had been taken at all.

This suggests that if reducing greenhouse gas emissions is the main objective, ‘going for global’ is the best strategy to pursue. This need not mean 100 per cent membership. But an agreement would at least need to include the United States, Brazil, China, USSR and India, among other countries, to be effective in reducing global emissions. At this stage, those particular countries -- together accounting for around two-thirds of global carbon dioxide emissions -- are either opposed to global targets, or to taking any action on their own part (or both).

In the event that a consensus is not possible, there is some prospect of a subgroup of countries seeking to have an agreement -- to which Australia might have to respond. The Commission had hoped that it would be possible to set out some rules of thumb about what subgroups would be likely to be more advantageous (or less disadvantageous) to Australia than others, but the relevant considerations seem too complex for that. The only rule of thumb seems to be that there is no rule of thumb.

All we know with any certainty is that as a subgroup's share of global emissions declines, any potential climate benefits would diminish commensurately (or participants' costs of meeting a given global target would rise).

From the cost side, each case would also need to be looked at on its merits, taking into account the size of countries, their trade patterns and relative competitiveness, and a range of ‘strategic’ questions, including the possibility of them imposing trade sanctions on outsiders. In responding to any subgroup offer, therefore, the Government would need to insist that it have time to do its homework before deciding whether to accept or refuse.

What the Commission's modelling in Chapter 8 does suggest is that the costs Australia would incur in making emissions reductions are such that it could be significantly more costly for Australia to join a coalition than to remain outside (trade sanctions aside).

What about unilateral?

The Government has already said that it will not unilaterally take action involving net costs (presumably leaving aside any climate benefits). The Commission supports this approach. It seems clear that unilateral action by Australia would have a negligible direct effect on global emissions and hence negligible effect on any global warming. The Commission is also not convinced on the basis of the information available to it, that the interim target could be achieved by means which involve no net costs. On the basis of the results presented in Chapters 5, 8 and 9, the costs of unilateral action on Toronto-type targets would appear to be of the same order of magnitude as those arising from participation in an international consensus. In so far as unilateral action would necessarily achieve, at best, negligible climate benefits, the costs involved would represent a poor investment for Australia.

This is not to dismiss the possibility, raised by some participants, that unilateral action by Australia could influence others to take similar action. However, the experience in other areas suggests that the most powerful influence on the attitudes of most countries will continue to be their individual perceptions of the costs and benefits of taking action. Where these have in the past been influenced by other countries, this has often been attributable to the use of inducements (like economic sanctions).

A more 'flexible' consensus

The foregoing has presumed that a consensus would take the form of a collective target-type agreement, but as noted in Chapter 7, international negotiations have recently been giving increasing attention to an individual best endeavours or 'pledge and review' alternative. This has obvious attractions in maximising flexibility and overcoming resistance to participation, but some have expressed concern that it would jeopardise the attainment of a global outcome such as the Toronto target.

Such an arrangement clearly has limitations in getting comparable substantial reductions in emissions by all countries, but the alternative may be a smaller agreement -- having a global impact that is no larger -- or no agreement other than on `motherhood' principles. As discussed previously, pledge and review (or something comparable) may be a suitable compromise between the 'act now' and 'wait until we know more' positions.

As to what Australia's pledge should be within such a consensus, that would need to take into account the pledges of the major greenhouse gas producing countries, as Government policy presently does in relation to a Toronto-type commitment. If Australia were to persist with a 20 per cent reduction commitment while some majors made only token pledges, then the outcome would resemble the unilateral or plurilateral, as discussed previously, and similar considerations would apply. Without a comparable target by the other countries, Australia would largely be wasting scarce resources by making a larger commitment. Indeed an attraction of entering a pledge and review consensus is that Australia could make the commitment that it felt was warranted, without being caught by an 'all or nothing' global decision rule, with the adverse economic consequences that a decision either way could imply.

Becoming better informed

Disparate views about whether action is needed reflect considerable uncertainties about the nature, extent and impact of the build-up of greenhouse gas concentrations in the air.

Like us, other countries are trying to come to terms with whether costly current actions to reduce emissions would be a good investment, in terms of future climate-related benefits. Until more is known about greenhouse, particularly its regional impacts, decisions can only be made on subjective grounds and reasonable governments are bound to differ. Just as taking some global insurance is one rational international response to the uncertainties, so too may be a 'wait until we know more' strategy, depending on the participants' (subjective) views about the trade-offs. There are major greenhouse producing countries in both camps at present.

It is essential therefore that international negotiations be supplemented by continuing research aimed at clarifying the nature and extent of the greenhouse phenomenon -- both in its scientific and socioeconomic dimensions -- so that decisions at the national and international levels can be as well informed as possible. Australia has already played an important role, notably in the IPCC, and its contribution should continue to be supported by government.

11.2 Domestic strategies

The potential benefits to Australia from averting climate change largely depend on the extent to which other countries reduce greenhouse gas emissions; Australia's own actions can have only a negligible direct effect. Australia has more control, however, over the costs of its participation in an international agreement, and it is desirable that an attempt be made to keep these to a minimum, for any given emissions objective.

It is convenient to think of domestic strategies in two contexts: implementing a commitment once an international agreement is reached, and what we should be doing in the meantime. It is acknowledged, however, that this distinction may in practice be somewhat artificial, since what Australia does before any consensus could have implications for what needs to be done in a consensus.

Implementing an international commitment

Consideration of the various means of implementing an international commitment presumes that Australia has the choice (that we are not faced, for example, with an internationally administered global tax). Since Australia could always replicate domestically the instrument choice of an internationally imposed regime, it is clearly better that we do have the ability to seek cost minimisation, by suitable domestic instrument choice as argued previously.

That being said, it is not possible to conclude that any particular instrument will be superior in all circumstances, for reasons discussed in previous chapters. To some extent it is a matter of `horses for courses'. Nevertheless, it is possible to make the generalisation that on efficiency grounds, instruments that harness market forces are preferable to those that don't, subject to reasonable monitoring and enforcement costs.

On the basis of its review of the principles involved as well as available experience, the Commission considers that in the domestic sphere, as internationally, a tradeable permits approach has much to commend it in principle -- against efficiency and dependability criteria. But the experience so far is limited and there are some questions about how it would work out in practice. An important test case may be CFCs, where such a tradeable permits regime has been implemented. Australia has also had substantial experience with the marketing of import quotas. A more detailed investigation would seem warranted.

In similar vein, while a carbon tax also has important potential as a market instrument, not enough is known about the operation of carbon taxes in practice and further, more focused work, is necessary in relation to the incidence of such taxes, how they can be manipulated to achieve a target rate of emissions, any non-greenhouse gas benefits that they may bring, and how they would impact on the general taxation regime. A further issue is how to implement a carbon tax without stifling potential innovation in the use of carbon dioxide emissions.

Interim strategies

As noted, the Government has said that it will not take unilateral action having net costs. This raises the issue of the scope for ways of achieving cost free reductions in greenhouse gases -- so called ‘free lunches’ or ‘no-regrets’ options. The Commission's modelling work suggests that meeting Toronto-type targets would involve costs. The models used assume costless adjustment, and so could be expected to underestimate the true costs. On the other hand, they do not incorporate the full range of technological change which might occur, especially if fossil fuel prices are raised by policy action. There are three areas which emerge from the Commission's investigations as potential sources of cost mitigation in reducing greenhouse emissions: technological improvements, better information, and microeconomic reform.

Technological improvements

It seems clear from other studies and from information supplied by participants (Appendix F) that there are many changes in production and consumption methods and alternative technologies which would, in aggregate, substantially reduce greenhouse emissions. On the evidence available to it, however, the Commission does not consider that most such changes could be implemented without net cost. The potential for incurring cost would in any case be heightened under government regulations requiring the introduction of different technologies, especially if they did not allow phasing in so that existing capital could be used over its depreciable life.

In some cases, there may indeed be net benefits but the Commission is not in a position to judge the merits of individual cases, other than by focusing on possible reasons for them not being adopted.

Impediments to the development and adoption of cost reducing technology raised by participants include lack of information and regulatory or other policy-related measures.

Before considering what might be done in these areas, however, it should be said that it would not be advisable for the Government to attempt to subsidise particular technologies. If anything, the potential for wastage of resources are even greater here, given the uncertainties, than in assisting more traditional activities with established markets. If there is concern to promote new technologies, increased general support for R & D in this area might be more appropriate (as noted in Chapter 10).

Information

Information is not costless, but it is something which can often be cost-effectively supplied or facilitated by Government. It is possible that some greenhouse gas reducing devices or methods are not being adopted simply because households and industry have inadequate information.

The Commission was given many examples of how households could reduce their energy consumption. Suggestions as to how that could be achieved ranged from insulating walls and ceilings of houses to using energy efficient appliances. An attempt to address such perceived information deficiencies was made recently by the Commonwealth Government and the Australian Consumers' Association with the production and distribution to every Australian household of 'The Energy Guide', a booklet containing information on energy efficiency. It is questionable whether households are likely to change their energy consumption patterns or lifestyles solely for the purpose of reducing their individual contribution to the greenhouse effect. They are more likely to show interest in reducing their consumption of energy, and to seek the relevant information, if energy prices increase.

For those enterprises in which energy is recognised as a major input to the production process, information on energy efficient practices and technologies will generally be known to firms. If energy is not recognised as a major input, for example when used mainly for air-conditioning and lighting, there is some evidence that lack of information, or apathy, is inhibiting the realisation of potential energy efficiencies. Enersonics Pty Ltd gave evidence to this effect (sub. 26). But services provided by that and other companies are advertised and available on a commercial basis and there is no reason to expect that such services could be better delivered by government.

Enterprises in a competitive environment could normally be expected to do their best to search for and adopt cost-minimising technology. They also have the incentive to identify market needs and trends as early as possible. But they do need a view of likely future price movements. These depend in part on government policy and greenhouse policy in particular. This suggests an important role for government is keeping industry (and the community generally) abreast of policy developments, including in international negotiating forums.

Then there is the question of government supporting *investment in knowledge.* Australia is a minor contributor to global emissions, but it could be greatly affected by an enhanced greenhouse effect and by international responses to it. There is a need to know more about the possible impact of any global warming on our region in particular: knowledge at the moment is minimal. No other country has the same incentive to do this research about impacts on Australia.

Another priority area is in enhancement of globally integrated economic models in which Australia is separately specified. The Commission found existing models less than satisfactory. It has therefore been obliged to build a special purpose model of its own, WEDGE. As noted, this model is still in the development stage. At present there is no other model available for analysis of costs and benefits to Australia from international action to reduce greenhouse gas emissions.

Microeconomic reform

A number of participants referred to policy measures and institutional arrangements which lead to inefficient energy use and excessive greenhouse gas emissions. However, it is not clear that correcting such distortions will lead to less greenhouse gases in the longer term. While the impact effect from removing an implicit subsidy to energy use is to reduce the use of energy, the resulting improved productivity and income growth may eventually outweigh it.

A specific concern, already raised, is the manner in which fossil fuel is currently priced and taxed. Although the taxation of fossil fuels has recently been substantially simplified, the question remains as to whether existing policies reflect non-greenhouse gas social costs of the production and use of that source of energy. As shown in Appendix B, there is still a wide variety of State and Commonwealth taxes and charges on fossil fuel.

Looking more broadly, the greenhouse issue provides two good reasons for continuing the vigorous pursuit of microeconomic reform:

- *Keeping adjustment costs down*. The more flexible the Australian economy the more readily it could adapt to new constraints, with less capital wastage and transitional unemployment. The modelling work reported by the Commission abstracts from the cost of adjusting to a carbon taxation regime. But, as indicated in Chapter 9, those costs may be large.

- *'Paying for' the costs.* While microeconomic reform will not necessarily lead to reductions in greenhouse gas emissions, it is expected to produce higher income levels. These should make the costs of any emissions reductions more affordable.

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