INDUSTRY COMMISSION

Costs and Benefits of Reducing Greenhouse Gas Emissions

Volume II: Appendixes

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APPENDIX A: INQUIRY PROCEDURES

Following receipt of the reference on 6 December 1990 (the terms of reference are given at the beginning of the report), the Commission advertised the commencement of the inquiry in the press and despatched an initial circular to parties considered to have an interest in the inquiry.

A second circular, despatched in January 1991, called for submissions and announced the timing and venues of the initial round of public hearings. With that circular, participants and other interested parties were sent an issues paper. A brochure outlining the Commission's inquiry procedures was sent upon request.

Because of an overlap between this reference and the terms of reference for the Commission's recent inquiry into Energy Generation and Distribution, the Treasurer amended the latter's terms of reference. A copy of correspondence from the Treasurer on this matter is set out in Attachment A1. On 20 March 1991 the Commission requested the Treasurer to extend the reporting date from 30 September to 15 November (see Attachment A2). Approval was received on 18 April 1991 (see Attachment A3).

Initial public hearings were held in Canberra, Brisbane, Sydney, Adelaide and Melbourne during March 1991. Thirty-three participants attended. Further circulars were despatched in April and June giving participants the opportunity to obtain and comment on other submissions.

In August, a draft report was finalised and despatched to participants and made available to other interested parties on request. At that time, a circular calling for submissions on the draft and notifying participants of the venues for hearings was also sent out. The draft report hearings during late September-early October 1991 were held in Brisbane, Melbourne, Sydney, Hobart and Canberra with forty-one participants attending.

A total of 164 submissions were received, 100 before the draft report was finalised. Inquiry participants are listed in Attachment A4.

The Commission held a briefing for Commonwealth Departments after the draft report was sent out. It was attended by representatives of:

- Department of Prime Minister and Cabinet;
- Department of Finance;
- Department of the Arts, Sport, the Environment, Tourism and Territories;
- Department of Treasury;

- Department of Foreign Affairs and Trade; and
- Department of Industry, Technology and Commerce.

The Commission and/or staff met informally with the following organisations or individuals to seek background information and views about inquiry issues:

- Australian Bureau of Agricultural and Resource Economics;
- BHP Pty Ltd;
- Bureau of Meteorology Research Centre;
- CRA Limited;
- CSIRO Division of Atmospheric Research;
- CSIRO Division of Mineral Products;
- Department of the Arts, Sport, the Environment, Tourism and Territories;
- Department of Foreign Affairs and Trade;
- Ecologically Sustainable Development Working Groups Chairmen and Secretariat;
- Electricity Commission of New South Wales;
- Greenpeace Australia;
- Dr David James;
- London Economics;
- New Zealand Ministry for the Environment;
- Prof. J.B. Opschoor, Chairman, Netherlands Advisory Council for Research on Nature and Environment;
- Tasman Institute; and
- Telecom Australia, Energy Technology Section.

Members of the Commission and/or staff also attended the following Seminars and Conferences:

- Australian Institute of Energy Conference on Energy Efficiency for the Residential Sector on 1 July 1991;
- Business Council of Australia launch of the `Energy Prospects' Report on 23 May 1991;
- Climate Change Impacts and Adaptation Workshop, Macquarie University NSW, May 1991;
- Department of the Arts, Sport, the Environment, Tourism and Territories sponsored Conference on Economic Analysis for Responding to Greenhouse Climate Change on 12 April 1991;

- Energy Use and Energy Production Working Groups on Ecologically Sustainable Development -- Workshop on Efficiency and Renewable Energy on 16-18 April 1991;

- The 1991 Australian Bureau of Agricultural and Resource Economics Outlook Conference: Climate Change and the Agricultural and Resources Sectors on 31 January 1991;

- The 20th Conference of Economists, at the University of Tasmania, Hobart from 30 September to 3 October 1991, at which Commissioner Dr Tor Hundloe and Associate Commissioner Mr Michael Common presented invited papers; and

- Greenhouse Action for the Nineties, a conference on opportunities for limiting greenhouse gas emissions, on 21-23 July 1991.

Associate Commissioner, Mr Common, attended the Annual Meeting of the European Association of Environmental and Resource Economists in Stockholm from 10-14 June 1991. While overseas he spoke with a number of UK academics on greenhouse-related issues, and visited the OECD. In Geneva he also met the Deputy Secretary General of United Nations Commission on Environment and Development and sat in on a session of the International Negotiating Committee for a Framework Convention on Climate Change.

A Workshop on Modelling the Impact of Greenhouse Abatement Strategies was organised by the Commission and held in Canberra on 21 October 1991. All inquiry participants and interested parties were notified of the workshop. Further details are given in Appendix H.

Attachment A1: **Letter from the Treasurer amending the Energy Generation and Distribution Inquiry terms of reference**

TREASURER
PARLIAMENT HOUSE
CANBERRA 2600

~ 5 DEC 1990

Mr A.S. Cole
Chairman
Industry Commission
Benjamin Offices
Chan Street
BELCONNEN ACT 2600

Dear Mr Cole

The Government is forwarding a reference to the Commission on greenhouse gas emissions. There is an overlap between this new inquiry and the Commission's current reference on energy generation and distribution where, among other matters, it is to report on the relative efficiency and cost effectiveness of options to reduce the environmental impact of burning fossil fuels.

I see considerable merit in your suggestion that the Commission consolidate its work on this issue in the new reference on greehouse gas emissions. Accordingly, I am prepared to exercise my powers under section 7(2) of the Industry Commission Act and amend the terms of reference on energy generation and distribution dated 20 May 1990 by deleting clause 3(i).

Yours sincerely

P.J. KEATING

Attachment A2: **Letter from the Acting Chairman of the Industry Commission to the Treasurer requesting an extension of the reporting date**

INDUSTRY
COMMISSION

The Honourable P J Keating, MP
Treasurer
Parliament House
CANBERRA ACT 2600

Dear Treasurer

I am writing to seek an extension in the reporting date for our inquiry into the implications of reducing greenhouse gas emissions.

The greenhouse inquiry is currently scheduled to report by the end of September 1991 and in total was to have taken some ten and a half months to complete. While this is a short period for an inquiry of this nature, it appeared to be achievable at the time the reference was sent to us. Since then two key participants in the inquiry have left. The departure of Tony Cole, who was the presiding Commissioner, has necessitated the appointment of a new presiding Commissioner who will inevitably take some time to get up to speed on this important issue. Secondly, the key staff member on the modelling side has departed.

These two departures have forced us to re-evaluate the end-September reporting date, and we have reached the judgement that an extension to mid-November would be the minimum necessary to complete our report satisfactorily.

We have consulted with Dr S Harris and Mr D Throsby, who chair the two Sustainable Development Working parties most closely associated with our inquiry. While they would prefer us to complete our report within the current timetable, the availability of a comprehensive draft report and an ongoing close working relationship between the parties means that they would not object to an extension of time. Consultations have also been held with the Department of the Arts, Sport, the Environment, Tourism and Territories, which would also not object to an extension.

Should you agree to our request, I have attached a draft letter indicating that the reporting date has been extended to 15 November 1991.

Yours sincerely

A C Harris
Acting Chairman

20 March 1991

CHAIRMAN

Benjamin Offices Chan Street,
Belconnen ACT
PO Box 80, Belconnen ACT 2616
Telephone 06 264 3029
Facsimile 06 253 1662
Telex AA 62263

Attachment A3: **Letter from the Treasurer approving an extension of the reporting date**

TREASURER

PARLIAMENT HOUSE
CANBERRA 2600

Mr A C Harris
Acting Chairman
Industry Commission
PO Box 80
BELCONNEN ACT 2616

Dear Mr Harris

I refer to your letter of 20 March 1991 concerning the Industry Commission's inquiry into the implications of reducing greenhouse gas emissions.

In the circumstances, I approve an extension of the reporting date for the inquiry until 15 November 1991.

Yours sincerely

P J KEATING

Attachment A4: **List of inquiry participants**

	Submission No.
Aerosol Association of Australia Inc.*	12
Aluminium Development Council	D125
Australian Air Transport Association	65
Australian and New Zealand Association for the Advancement of Science	D104
Australian and New Zealand Environment Council	85, 94
Australian Automobile Association #	14, D136
Australian Bureau of Agricultural and Resource Economics *#	20, D132
Australian Cane Growers' Council *	5
Australian City Transit Association Inc.	79
Australian Coal Association *#	36, D130, D155
Australian Conservation Foundation *#	46, D137
Australian Consumers Association	D126
Australian Council of Professions *	33, D120
Australian Council on Smoking and Health	69
Australian Fertilizer Manufacturers' Committee	63, D105
Australian Gas Association *	37, 73, D138
Australian Gas Light Company #	64, D121
Australian Institute of Agricultural Sciences *#	15, 80, D109
Australian Institute of Petroleum *	30, D129
Australian Mining Industry Council *	16
Australian National Railways Commission	86
Australian Petroleum Exploration Association Ltd #	48, 96, D112
Australian Road Transport Federation *	24, 51
Australian Supermarket Institute Ltd	28
BHP Environmental Affairs #	50, D134
BHP Steel Group *	27, 83
Bostock, Mr T E	D160
BP Australia	D158
Brian J O'Brien & Associates Pty Ltd *	19, 90
Bureau of Meteorology #	77, D106
Bureau of Rural Resources	D150
Bureau of Transport and Communications Economics	84
Business Council of Australia	42, 91, D127
Canberra Ash Inc. *	6
Centre for the Environment and Sustainable Development *	29
Chamber of Mines and Energy	56
Chamber of Mines, Metals & Extractive Industries (NSW)	8
Chemical Confederation of Australia	67
Coast and Wetlands Society Inc. *	10
Council of ACT Motor Clubs Inc.	95
CRA Ltd *#	38, D135, D159
CSIRO D101	
CSIRO Division of Atmospheric Research	60, 61, 92, D151, D161
CSIRO Division of Oceanography #	-
CSIRO Plant Industry Division *	17
CSR Distilleries Group	22
CSR Ltd	70

	Submission No.
Daly, Mr John L #	98, D107
Department of the Arts, Sport, the Environment, Tourism and Territories	82, D154
Electricity Supply Association of Australia *	35
Electricity Supply Association of Australia and Energy Research and Development Corporation	D128
Energy Action Group *#	44, D119
Energy Research Centre	D148
Enersonics Pty Ltd	26
Federal Chamber of Automotive Industries	62, D143
Forest Industries Federation (WA) Inc.	40
Friends of the Earth Cessnock	D141
Friends of the Earth #	43, D116
General Motors_Holden Automotive Ltd	58, D146
George Wilkenfeld and Associates Pty Ltd *	9
Greenhouse Action Australia *	31
Greenhouse Association of South Australia Inc. *	2, D108, D145
Greenpeace Australia *#	23, D117, D157
Henderson-Sellers, Prof Ann	D122
ICI Australia Ltd *	45
Incitec Ltd *	18, 41
Institute for Science and Technology Policy	D124
Institution of Engineers, Australia	D156
Jabiru Town Council	3
Kay Bee Developments Pty Ltd *	4
Kimberly_Clark Australia Pty Ltd #	D114
Laird, Dr P.G. # (Oral evidence presented by Ms Gabriella Adorni-Braccesi)	39, D113
London Economics	89
Losee, Mr Scott	54
Margetts, Ms Diane	D147
May, Prof Peter	59
Meekatharra Minerals Ltd	97
Migmaplas *	13
Mills, Dr David	25, D123
MIM Holdings Ltd *#	21, D133
Motor Trades Association of Australia #	7, D131
Multi_Marketing Enterprises International *#	11, 99, D110
National Association of Forest Industries Ltd	87, D144
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Paltridge, Prof Garth #	-
Pasminco Metals Pty Ltd	68, D111
Plastics Industry Association	88
Potter, Prof O.E. #	D103
Rheem Australia	D102
Rural Industries Research and Development Corporation	47, D152
Shell Australia Ltd	52, D149

	Submission No.
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State Energy Commission of Western Australia	72
Sugar Research Institute	57
Tasman Institute	55, D140
Tasmanian Government *	32, D139
Total Environment Centre	76
Town and Country Planning Association *#	34, D115
United Mineworkers' Federation of Australia #	53, D118
Victorian Chambers of Commerce and Industry Inc.	81
Victorian Employers' Chamber of Commerce and Industry	D142
Victorian Government	74, 93, D162
Western Mining Corporation Ltd *	49
Williams, Dr J.E.	66, D153
Worksafe Australia	1

- Indicates the participant presented evidence at the March 1991 public hearings.

# Indicates the participant presented evidence at the September-October 1991 public hearings.

D Denotes submissions received after the finalisation of the Draft Report.

_ Indicates oral evidence only

APPENDIX B: GOVERNMENT RESPONSES TO POSSIBLE CLIMATE CHANGE

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Concern over the enhanced greenhouse effect has motivated governments of many countries and at all levels to respond. This appendix firstly describes Australia's participation in recent international discussions and negotiations. It then examines domestic initiatives, at Commonwealth and State levels. The fourth section of the appendix examines the Australian constitutional environment affecting the use of policy instruments to reduce greenhouse gas emissions. The appendix concludes with a review of current fossil fuel taxation in Australia.

The enhanced greenhouse effect has relevance for numerous different policy areas and a prolific number of policy statements have been issued by Australian Governments. The Commission has attempted to report on the most current major statements and initiatives.

B1 Australia's participation in international discussions and negotiations

B1.1 The Villach Conference, 9-15 October 1985

The Conference, entitled an International Assessment of the role of Carbon Dioxide and of other Greenhouse Gases in Climate Variations and associated Impacts, was sponsored by the United Nations Environment Programme (UNEP), the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU). Scientists from 29 countries attended the conference:

> to assess the role of increased carbon dioxide and other radiatively active constituents of the atmosphere (collectively known as greenhouse gases and aerosols) on climate changes and associated impacts. (Villach Conference 1985, p. 1)

The Conference concluded that:

- increasing concentrations of greenhouse gases are expected to cause a significant warming of the global climate in the next century. Global mean temperature is predicted to rise by between 1.5 and 4.5^{0}C, leading to a potential sea level rise of 20 to 140 cm, within the space of several decades;

- climate change and sea level rises are closely linked with other major environmental issues. Measures to abate one problem will help abate one or more of the others; and

- while some warming of the climate appears inevitable, the rate and degree of future warming could be profoundly affected by government policies on energy conservation, use of fossil fuels, and the emission of some greenhouse gases.

The Conference qualified its conclusions saying:

> Major uncertainties remain in predictions of changes in global and regional precipitation and temperature patterns. Ecosystem responses are also imperfectly known. Nevertheless, the understanding of the greenhouse question is sufficiently developed that scientists and policy-makers should begin an active collaboration to explore the effectiveness of alternative policies and adjustments. (Villach Conference 1985, p. 3)

The Conference recommended that governments and other agencies should increase funding of research into the world's climate, and its interaction with the atmosphere, the oceans and ecosystems; examine possible measures to help prevent, or help people to adapt to, climate change; and increase public education about greenhouse gases, climate change and the sea level.

The UNEP, WMO and ICSU were encouraged to establish a task force on greenhouse gases, to ensure the Conference's recommendations were followed up and, to initiate, if necessary, consideration of a global convention addressing the issue.

B1.2 The Toronto Conference, 27-30 June 1988

At the invitation of the Canadian Government, more than 300 scientists and policy makers from 46 countries, United Nations organisations, other international bodies and non-government organisations (NGOs) attended the conference into `The Changing Atmosphere and Implications for Global Security' in Toronto, Ottawa:

> to consider the threats posed by the changing global atmosphere and how they might be addressed. (Toronto Conference 1988, p. 1)

The Conference called on governments to ratify the Montreal Protocol on substances that deplete the ozone layer (see Appendix E). Additionally, it suggested revising that protocol in 1990 to ensure emissions of fully halogenated CFCs were nearly completely eliminated by the year 2000. It recommended governments set energy policies to reduce emissions of carbon dioxide and other trace gases, and called on governments to reduce carbon dioxide emissions to a level of approximately 20 per cent below 1988 levels by the year 2005, as a global goal.

The Conference urged governments, people and organisations:

> to take specific actions to reduce the impending crisis caused by pollution of the atmosphere. (Toronto Conference 1988, p. 1)

Some of the actions suggested by the Conference included:

- setting targets for energy efficiency improvements that are directly related to reducing greenhouse gas emissions, and initiating management systems to encourage, review and approve major new projects for energy efficiency;

- vigorously applying existing technologies to reduce emissions of acidifying substances, precursors of tropospheric ozone, and other non-carbon dioxide greenhouse gases;

- labelling products to allow consumers to judge the extent and nature of atmospheric contamination arising from the production and use of different products;

- initiating the development of a comprehensive global convention as a framework for protocols on the protection of the atmosphere;

- establishing a world atmosphere fund;

- supporting the work of the Intergovernmental Panel on Climate Change (see below);

- devoting increasing resources to research and monitoring efforts within existing programs, to research, development and transfer of information on renewable energy, and for more intensive technological transfer and technical cooperation;

- reducing deforestation/increasing afforestation; and

- funding environmental education programs in primary and secondary schools and universities.

B1.3 The Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) was jointly established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1988 in order to:

- assess the scientific information related to the various components of the climate change issue, such as emissions of major greenhouse gases, and the resulting modification of the Earth's radiation balance, to enable the environmental and socioeconomic consequences of climate change to be evaluated; and

- formulate realistic response strategies for the management of the climate change issue.

In November 1988, the IPCC established three working groups:

- Working Group I to assess available scientific information on climate change;

- Working Group II to assess environmental and socioeconomic impacts of climate change; and
- Working Group III to formulate response strategies.

The IPCC also established a Special Committee on the Participation of Developing Countries to promote, as quickly as possible, the full participation of developing countries in its activities.

Working Group I (Scientific Assessment) (WG I) examined how human activity may be changing the Earth's climate through enhancing the greenhouse effect. About 170 scientists from 25 countries contributed to WG I's report through international workshops and written contributions. Another 200 scientists reviewed WG I's draft report. Scientists from the CSIRO, the Bureau of Meteorology and Australian universities contributed, either as secondary authors or as reviewers of the draft report.

WG I concluded that:

- emissions from human activities are increasing atmospheric concentrations of some gases, which, in turn, are enhancing the greenhouse effect;

- atmospheric concentrations of some gases adjust only slowly to changes in emissions, and continuing emissions at current rates will increase atmospheric concentrations of those gases for centuries ahead; and

- the long-lived gases would require reductions in emissions from human activities of over 60 per cent to stabilise their concentrations at today's levels.

WG I predicted a rate of increase of global mean temperature during the next century of 0.3^0C per decade, under a business-as-usual scenario. Assuming controls on emissions are increased progressively, the rate of increase might be slowed to 0.2^0C or 0.1^0C per decade. Similarly, it predicted sea level rises of between 3 and 10 cm per decade. By 2030, the global mean sea level might rise by 20 cm, and might reach 65 cm by the end of the next century.

WG I said its predictions were limited by a lack of understanding of greenhouse gas sources and sinks; of clouds and oceans, and how they influence climate change; and of polar ice sheets, and their impact on sea level rises. Through more research, the development of better climate models, and improvements in observations of climate-related variables on a global basis, WG I hoped the accuracy of future predictions would be improved. The Working Group continued its work with a follow-up meeting in London on 8-11 June 1991, and the First Session of the Task Force on Greenhouse Gases, at Shepperton Moat House in the UK the next month.

Appendix C of this report summarises what is understood about the science of the greenhouse effect. Chapter 2 briefly covers the same ground.

Working Group II (Impacts Assessment) (WG II) examined the potential impacts of climate change on: agriculture and forestry; natural terrestrial ecosystems; hydrology and water resources; human settlement and socioeconomic activities; oceans and coastal zones; and the cryosphere. Over 200 people from around the world contributed to the report, which was edited by WJ McG Tegart, GW Sheldon and DC Griffiths and published in Australia.

WG II concluded that:

- on a regional level, there could be significant changes in agriculture and livestock productivity, but whether agricultural production would increase or decrease globally is uncertain. Patterns of agricultural trade could also be affected. Food production is likely to be maintained at existing levels, but at what cost is undetermined;

- climate zones are anticipated to radically shift over the next 50 years, having a significant impact on natural terrestrial ecosystems. These shifts would be determined principally by the rate of projected climate change;

- regional impacts on human settlement are uncertain, but climate changes could initiate large migrations of people, and create social instability in some areas. Major health impacts are possible, especially in urban areas. Vector-borne and viral diseases are expected to spread to higher latitudes, putting large populations at risk;

- most changes to the energy, transport and industrial sectors in developed countries may be determined by policy measures adopted in response to climate change. In developing countries, these sectors would be affected by climate-related changes in the availability and price of energy, food, water and fibre;

- changes to oceans and coastal zones are expected to be accelerated by global warming. The costs are expected to be high, as are the costs associated with attempts to delay or prevent their occurrence;

- the area and volume of seasonal snow cover, near-surface layers of permafrost and some ice masses, are expected to decrease, affecting regional water resources, regional transportation and recreational facilities. Permafrost could suffer significant degradation, leading to increases in terrain instability, erosion and landslides.

WG III also highlighted the problem of a lack of information about the possible effects of climate change, and encouraged governments and others to continue funding climate research. Chapter 4 of the Commission's report considers possible climate impacts in some more detail. The Working Group planned a follow-up meeting for the 12-13 August 1991.

Working Group III (Response Strategies) (WG III) identified and examined the range of options currently available to policy makers to limit future climate change, and to adapt to possible climate changes. It examined measures designed to limit net GHG emissions from the energy, industry, agriculture, and forestry sectors. The group also reviewed two categories of adaptation options: coastal zone management -- to protect coastal regions against sea level rises, and reduce vulnerability to storms; and resource use and management -- to address the potential impacts of climate change on food security, water availability, natural and managed ecosystems, land, and biodiversity.

WG III considered five mechanisms for implementing strategies to address the issue of climate change: public education and information; technology development and technology transfer; economic mechanisms; financial mechanisms; and legal and institutional mechanisms (including possible features of a framework convention on climate change). Forty-three countries and eight international organisations attended a special workshop held by WG III to discuss these mechanisms.

WG III identified a number of measures which may help address the problem of climate change. Measures to limit emissions in the short term included:

- improving energy efficiency;
- using cleaner energy sources and technologies;
- improving forest management, and where feasible, expanding forest areas;
- phasing out CFCs under the Montreal Protocol;
- improving livestock waste management, altering the use of fertilisers, and making other changes to agricultural land use, without affecting food security; and
- improving the management of land fill and waste water treatment operations.

Short term measures to help *adapt to climate change* included: developing emergency and disaster policies and programs; developing comprehensive coastal zone management plans to reduce potential damage to populations, coastal developments and ecosystems; and continuing research into halting desertification and enhancing the ability of crops to adapt to changes in climate and salinity.

In the longer term, WG III suggested governments should:

- accelerate and coordinate research programs to reduce scientific uncertainty about climate change and adaptation strategies;
- develop new technologies in energy, industry and agriculture;
- review planning in the fields of energy, industry, transportation, urban areas, coastal zones, and resource use and management;
- encourage beneficial behavioural and structural (for example, transportation and housing infrastructure) changes; and
- expand the global ocean observing and monitoring systems.

WG III concluded by saying:

> The measures [quoted above] require a high degree of international cooperation, with due respect for the sovereignty of states. The international negotiation of a framework convention should start as quickly as possible after the completion of the IPCC First Assessment Report ... The Convention should, at a minimum, contain general principles and obligations. It should be framed in such a way as to gain adherence of the largest possible number, and most suitably balanced range of countries, while permitting timely action to be taken. (IPCC 1991, p. xxviii)

WG III subgroups on Energy/Industry, Forestry and Coastal Zones met in Geneva on 5-8 June 1991 and planned to meet there again on 5-8 August.

The Special Committee on the Participation of Developing Countries made a number of recommendations to help developing countries take part in IPCC activities. These included:

- providing uninterrupted travel assistance to developing countries to allow them to attend IPCC functions, and to participate in follow-up actions;
- establishing mechanisms to help developing countries coordinate nationally all their activities related to climate change;
- helping developing countries to identify what information they need to have to develop emission abatement strategies and adaptation plans; and
- helping developing countries integrate considerations of climate change into their development policies.

The IPCC released its First Assessment Report in 1990. It consisted of an overview, the policy makers' summaries of the Working Groups and the Special Committee on the Participation of Developing Countries, and the reports of the three Working Groups. The overview presented the IPCC's conclusions, proposed lines of possible actions, and outlined what additional work needs to be done to provide a more complete understanding of the potential problems associated with climate change.

The Report was discussed at the 45th General Assembly of the UN, where the IPCC's main findings were accepted.

The IPCC was given a mandate from the WMO and the UNEP to continue, and is involved in the work of the Intergovernmental Negotiating Committee as it endeavours to prepare a framework convention on climate change. The work for the IPCC mostly involves responding to requests for technical and scientific assistance from the Committee. An updated IPCC Scientific Assessment is expected to be published in the first half of 1992.

B1.4 The Second World Climate Conference, 29 October-7 November 1990

The Conference was convened in Geneva under the sponsorship of the WMO, the UNEP, the United Nations Educational, Scientific and Cultural Organisation (UNESCO), the Food and Agriculture Organisation (FAO) and the ICSU. It included a scientific and technical session, from 29 October to 3 November, and a ministerial session from 6-7 November. The scientific session was attended by 747 participants from 116 countries, including 16 participants from Australia. The ministerial session was attended by 908 participants, including 730 delegates from 137 countries. Australia sent a delegation of 13, including Minister for the Arts, Sport, the Environment, Tourism and Territories, the Hon. Ros Kelly.

The Conference had two main purposes: to review the first decade of operation of the World Climate Programme and to set directions for its future development; and to review the First Assessment Report of the IPCC, as a lead-in to the negotiations on a framework convention on climate change.

The scientific discussions reviewed various components of the World Climate Programme and the conclusions of the three IPCC Working Groups. Five specialist panel sessions were held, and 12 task groups were established to make specific recommendations on areas such as water, agriculture and food, environment and development, and energy. The Conference issued a Statement, endorsing the general scientific conclusions of the IPCC, and adopted many of the recommendations made by the Conference task groups.

The ministerial session produced a statement of commitment to cooperative action on the climate change issue agreed to by most of the countries attending the Conference.

B1.5 Asian Pacific Seminar on Climate Change, 23-26 January 1991

This seminar held in Nagoya, Japan was organised and largely funded by Japan. It involved about 70 participants from 19 Asian Pacific countries and 10 international organisations, along with a number of Japanese observers. The Australian delegation consisted of Dr W Tegart (Australian Science and Technology Council), Dr A Pittock (CSIRO) and Dr J Zillman (Bureau of Meteorology).

The seminar aimed to assist the exchange of information and to generate awareness on the climate change issue. The participants agreed that there is significant scope for regional cooperation, particularly working with the various existing international programs. However, the main importance of the meeting was the apparent Japanese commitment to leadership on environmental issues in the region.

It was agreed that a further seminar should be organised for regional information exchange and coordination in advance of the United Nations Conference on Environment and Development to be held in June 1992.

B1.6 Intergovernmental Negotiating Committee for a Framework Convention on Climate Change

The Intergovernmental Negotiating Committee (INC) was established to prepare a framework convention on climate change before the United Nations Conference on Environment and Development commences in Brazil in June 1992. The need for a framework convention was first suggested at the Toronto Conference in 1988.

The Committee held its first session in Chantilly, Virginia from 4-14 February 1991. The session was hosted by the United States Government and was attended by representatives from 101 national delegations. A variety of UN, government (including the EC) and non-governmental organisations (including Greenpeace International) also attended as observers. Australia sent a delegation of 12 to the session: 10 representatives of the Commonwealth Government, 1 representative of Australian industry, and 1 representative of Australian environment/conservation groups.

The second session of the INC was held in Geneva from 19-28 June. Again Australia sent a large delegation, including NGO representatives. At these meetings, Australia has argued for an international convention binding all countries to feasible and sustainable greenhouse gas emission reductions.

According to information available to the Commission, the first meeting of the INC 'bogged down' and was somewhat unproductive. However, greater progress was made at the second meeting.

A third session was held in Nairobi from 9-20 September 1991. The 'Pledge and Review' concept (see Chapter 7) was discussed in an informal plenary session. It seems that while the term is no longer in vogue the concept remains popular. The INC now has a loose form for the framework convention. Although there has been no negotiations on commitments, the mechanisms working group achieved progress at the third session.

The Committee hopes to agree on the definitions of principles at the fourth session to be held in Geneva from 9-20 December 1991. A fifth session will take place in February 1992 with another likely before the Brazil 1992 conference.

The Committee has established two working groups to help it in its task. *Working Group I (Commitments)* is examining the commitments countries should be expected to make under a framework convention, in relation to:

- limiting and reducing net emissions of carbon dioxide and other GHG emissions; protecting and enhancing GHG sinks and reservoirs; and supporting measures to counter the adverse effects of climate change; and

- providing adequate financial resources to developing countries to enable them to fulfil their obligations under such a framework convention, and to facilitate the transfer of technology expeditiously on a fair and most favourable basis.

The Commitments Group is to take special account of the needs of developing countries, especially the problems of small island developing countries, and those with low-lying coastal areas and/or with areas threatened by erosion, flooding, desertification and high urban atmospheric pollution.

Working Group II (Mechanisms) is examining the legal and institutional mechanisms which could be used to establish a framework convention. It has not been asked to examine what policy instruments countries could adopt.

A framework convention could cover: emissions; sinks; transfer of technology; the provision of financial resources and funding mechanisms for developing countries; international scientific and technological cooperation; and measures to counter the effects and possible adverse impacts of climate change.[1] However, as noted in Chapter 7 of the report, the negotiations are difficult and the final form of a framework convention is far from certain a this stage.

B1.7 United Nations Conference on Environment and Development, June 1992

The United Nations is planning a Conference on Environment and Development (UNCED) in Brazil June 1992. The Conference will cover economic and social issues at global, national and regional levels. It will concentrate on major cross-sectoral or inter-sectoral problems leading to a deterioration in the global environment, taking into account the links between trade and the environment, the protection of marine resources and the rights of indigenous peoples.

The Conference will be a Heads of Government meeting of UN member states. It is also open to non-government organisations with consultative status in the UN's Economic and Social Committee. Other organisations without this status can apply directly to the UN for accreditation to UNCED.

The Secretary General of UNCED has identified five possible results of the 1992 Conference:

- an *Earth Charter*, containing the principles nations should follow when pursuing ecologically sustainable development;
- *Agenda 21* -- a record of the current global environment, an action plan for solving problems, and an assessment of the tools currently available to implement the plan;
- new legal agreements on climate change and biodiversity (DFAT (1991) believes the framework convention on climate change should be ready for adoption, but that the prospects for an agreement on biodiversity are not as good);
- a convention on forests, as proposed by the Houston G-7 summit (although a non-binding statement of principles may be more likely); and
- proposals on the international legal and institutional structures required to achieve sustainable development, and the funding and technology transfer mechanisms needed to enable developing countries to quickly achieve the goals set.

DFAT said:

> Australia is now focussing on some key aspects [in preparing for the conference]: a strategy for oceans and coasts such as coral reefs and mangroves; the content of the Earth Charter and Agenda 21; suitable methods for funding and technology transfer; and the legal and institutional responses to problems identified by the UNCED. (DFAT 1991, p. 2)

According to DFAT (1991), Australia may propose a number of principles for the Earth Charter, which could be modified later if necessary.

1 See Environment policy and Law, No. 21/2, 1991, pp. 50, 51.

A public discussion draft of the *Australian National Report,* to be presented when finalised to the Conference Preparatory Committee, was released on 31 July 1991. It was prepared by DASETT after consultation with Federal Government departments and agencies, and non-governmental organisations. The Report provides background information on Australia's natural environment and social institutions. It outlines the key environmental and developmental issues facing sectors of Australia's economy, and details past and present relevant Government policies and programs, and commitment to international cooperation.

B2 Commonwealth Government initiatives

In October 1990, the Commonwealth Government adopted an interim planning target to stabilise emissions of greenhouse gases (excluding chlorofluorocarbons and halons) at 1988 levels by the year 2000, and to further reduce these emissions by 20 per cent by the year 2005. However, the Government stated that it would not adopt measures which have net adverse economic impacts nationally or on Australia's trade competitiveness, or in the absence of similar action by major greenhouse gas producing countries. Further, the Minister for the Arts, Sport, the Environment, Tourism and Territories, and the Minister for Primary Industries and Energy (1990) stated that the Government would encourage the immediate adoption of emission reduction options such as increased energy efficiency and conservation and new technology. The more complex options would be addressed in consultation with the Ecologically Sustainable Working Groups and with further cost_benefit studies as required.

B2.1 Prime Minister's Special Working Group on Greenhouse Gas Emissions

Following the July 1989 statement on the environment entitled ‘Our Country, Our Future’ by the Prime Minister, the Hon. Robert Hawke, the Commonwealth Government established several groups and committees dealing with aspects of climate change. The Prime Minister's Special Working Group on Greenhouse Gas Emissions was formed to evaluate options for reducing emissions in Australia. Its discussion paper (Prime Minister's Working Group on Greenhouse Gas Emissions 1989) suggested short term response options requiring minimal Government intervention at reasonable economic cost, such as: continued phasing out of chlorofluorocarbons (CFCs); increased energy efficiency and energy use management; and reforestation programs. However, it put the view that major industrial restructuring, infrastructure modification and changes to living practices coupled with a sustained long term research and development effort to develop the necessary technologies would be necessary to achieve large reductions in the long term. These views were subject to a caveat that such measures should only be implemented when understanding of the extent of global warming and its likely regional impacts is greatly advanced.

B2.2 Interdepartmental committees

The International Environment Interdepartmental Committee is responsible for coordinating a wide range of environmental issues but especially the international aspects of climate change. Its Climate Change Subcommittee comprises members drawn from relevant Commonwealth departments and its main task is developing Australia's contribution to the work of the IPCC. The Greenhouse Interdepartmental Committee was also established in early 1989 to coordinate Commonwealth action on greenhouse issues. The National Greenhouse Advisory Committee provides expert scientific advice to Government on greenhouse gas issues and coordinates the government's research grants scheme.

B2.3 Australian and New Zealand Environment Council

The Australian and New Zealand Environment Council (ANZEC) has been involved with greenhouse gas emissions issues for the past decade. Council members include Commonwealth Environment and Science Ministers, State and Territory Environment Ministers, and the New Zealand Environment Minister. In 1989 it appointed a Greenhouse Task Force to prepare a discussion paper (ANZEC 1990). A phased adaptive approach was recommended which takes into account the costs and benefits of both action and inaction. The approach is responsive to scientific uncertainty and takes into account the actions of other countries and various sectors of the Australian community.

The Council's Task Force determined that immediate action must be taken to address greenhouse gas emissions and that an effective national strategy would include the following critical elements (ANZEC 1990):

- improved information on greenhouse-induced changes through coordinated research, especially on a regional basis;

- limitation of national greenhouse gas emissions by developing specific goals for control, adopting initial global targets, implementing a National Ozone Protection Strategy and reviewing economic and fiscal practices affecting the generation of greenhouse gas emissions;

- pressure for acceptance of options identified as high priority which can be implemented immediately, are cost effective and involve minimal disruption to society;
- development of mechanisms to improve Australia's capacity to cope with changes;

- assurance that adequate information on the greenhouse effect and its potential impacts are readily available to all Australians; and,

- assurance that Australia has a direct and influential input to international decisions on climate change, including the development of international conventions and protocols.

ANZEC submitted the report, `Towards a National Greenhouse Strategy for Australia' to Ministers attending the July 1991 Special Premiers' Conference (SPC).

B2.4 National Greenhouse Response Strategy

In October 1990, a strategy to achieve a reduction of greenhouse gas emissions was announced along with the Commonwealth's interim planning target.

The National Greenhouse Response Strategy was to involve (Barson & Furbank 1990):

- introducing a range of initiatives that can be implemented immediately to reduce energy demand and emissions using known and available energy efficient technologies and energy management techniques; and

- placing greenhouse on the agenda of the SPC for urgent consideration by the States and Territories.

The Greenhouse Interdepartmental Committee, chaired by the Department of Prime Minister and Cabinet, is coordinating development of the National Greenhouse Response Strategy. The Committee intends to set up a Steering Committee under the auspices of SPC. The Steering Committee, under direction of the Heads of Government and ministerial councils, would develop a framework strategy and present it to the SPC at a future meeting.

B2.5 Australian Minerals and Energy Council

The Australian Minerals and Energy Council is the principal forum for bringing together State, Territory and Commonwealth energy ministers and officials. Its report, entitled Energy and the Greenhouse Effect, details an extensive range of energy-related measures both in place and planned by Australian governments, as well as suggesting a range of new initiatives to improve previous achievements. It considers the issues of relevance to the energy sector, but does not attempt to define a rigid long term blueprint, nor does it directly address the issue of national targets.

B2.6 Research grants

The CSIRO Institute of Natural Resources and Environment (INRE) coordinates a Climate Change Research Program which draws on the range of expertise in the fields of atmospheric chemistry, climate and climate change within the organisation. Funding for the INRE Climate Change Research Program for 1990-91 totalled $12.2 million (CSIRO 1991, p. 23). The Program includes research already established and funded through the normal CSIRO appropriations amounting to $4.31 million in 1990-91 (CSIRO 1991, p. 25).

New research has been made possible by special Commonwealth funding made available via the Department of the Arts, Sport, the Environment, Tourism and the Territories and aims to improve Australia's capability for prediction of regional climate change. In 1990-91, DASETT funded research amounted to $3.95 million, $1.23 million of which was carried over from the previous year's allocation (CSIRO 1991, p. 23-24).

This research overlaps with agreements between CSIRO and Victoria, New South Wales, Western Australia and the Northern Territory Governments for the provision of advice on specific impacts of climate change on a regional scale. There also exist formal links between CSIRO and the Bureau of Meteorology and a number of universities and institutions. The Bureau monitors climate and has a smaller greenhouse-related research program.

In December 1991, successful applicants under the Greenhouse Research Grants Scheme were announced. The funds were allocated by the Department of the Arts, Sport, the Environment, Tourism and the Territories on the basis of recommendations by the National Greenhouse Advisory Committee. Among the allocations was $25 000 to the Bureau of Meteorology Research Centre for development of a high-quality historical climate data base for Australia, $395 000 to various divisions of the CSIRO for work on climate and climate change modelling and $880 000 to various university research programs (Barson & Furbank 1991).

B2.7 Senate Standing Committee on Industry, Science and Technology

On 1 January 1991 the Senate Standing Committee on Industry, Science and Technology released its report ‘Rescue the Future: Reducing the impact of the greenhouse effect’.

The Committee was asked to report on strategies for the most efficient generation, transmission, distribution and use of electricity and gas, to ensure Australia meets or exceeds a minimum reduction of 20% in emission of greenhouse gases by 2005. In particular, the Committee considered possibilities for national coordination and rationalisation of current generation and distribution activities, and the appropriate authority to coordinate and control the generation, transmission and distribution of electricity and gas.

Some specific recommendations found in the ‘Rescue the Future’ report include:

- a Special Premiers' Conference should be convened to determine a coordinated approach to reducing greenhouse gas emissions;

- there should be further research undertaken to more accurately predict the consequences of global warming;

- a 10-year energy plan should be developed for ratification at the Special Premiers' Conference, which should include greater interstate load sharing;
- CSIRO and energy utilities should establish demonstration projects;
- AMEC should present awards for innovation in energy efficiency;
- the Federal Government should provide incentive and assistance measures for industry to implement energy conservation measures; and
- the State Governments should set market penetration targets for solar hot water heating and introduce minimum appliance efficiency standards within two years.

The Senate Standing Committee is currently conducting an inquiry into strategies for the most efficient generation, transmission, distribution and use of electricity and gas, to ensure Australia meets or exceeds the Commonwealth target. The Committee is considering:

- issues raised by the national coordination of gas and electricity use;
- the possible need for rationalisation of current State and private sector generation and distribution authority activities; and
- whether for environmental, social or economic reasons the generation, transmission and distribution of electricity and gas should be coordinated and controlled by one national authority, by State Authorities, the private sector or a combination of these alternatives.

B2.8 Ecologically Sustainable Development Strategy

A Commonwealth Government discussion paper on ecologically sustainable development (ESD) was published in June 1990 (Department of Prime Minister and Cabinet 1990). The paper defined ESD as using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased. It emphasised the integration of economic and environmental goals by the appropriate valuation of environmental assets, maintaining intra- and intergenerational equity, dealing cautiously with risk and irreversibility and recognising the global dimension of environmental problems.

Ecologically Sustainable Development Working Groups were then established as part of the process of developing a national strategy. They were to report on the implementation of ESD principles in nine key areas: agriculture, fishing, forestry, energy production and use, manufacturing, mining, tourism and transport. Represented on these groups were industry, conservationists, unions, other community groups, CSIRO, ANZEC and the Commonwealth and State Governments.

The Working Groups also were to address cross-sectoral, and the implications of inter-sectoral, issues (including global environment change) on their sectors. The task was to:

> provide advice to Government on future policy directions, and to develop practical proposals for implementing them, in the context of the government's general budgetary constraints and existing policies and programs which impinge on the subject areas (ESD Working Groups 1991, Preface p. vi).

The Working Groups have been conducting their work in parallel with the Industry Commission. Both organisations have kept each other informed about their progress. The Groups released their draft reports in August-September and were due to submit their final reports to the Prime Minister by the end of October.

B2.9 The proposed National Environment Protection Agency

In March 1990 the Prime Minister announced the Government's intention to establish an Environment Protection Agency (EPA) to improve the Commonwealth's capacity to find long term solutions to environmental issues. The new environment protection arrangements are to be implemented in two stages: Firstly, the Commonwealth EPA will be created, and secondly, new Ministerial arrangements with the States and Territories will be established (DASETT 1991).

The agency will initially be established as part of DASETT during the 1991-92 financial year. It will not reach full operational capacity until the following year, and is intended to ultimately become an independent statutory authority (DASETT 1991).

The EPA's proposed powers and functions already fall within Commonwealth responsibility. Its role is seen as complementary to the primary enforcement agencies in the States and Territories.

The emphasis of the Agency is likely to be on research programs, establishment of national standards and better processes for assessments and approvals, and encouragement and assistance to develop ‘satisfactory’ industry and consumer behaviour. The position paper (DASETT 1991) lists the agency's intended powers and functions as:

- to undertake, encourage and arrange research leading to better understanding of natural systems;
- to develop and maintain indicators on the condition of the environment;
- to report on the state of the environment;
- to publicise environmental protection issues and make available information on them;
- to develop or participate in the development of national and international environment quality standards, policies and programs;

- to administer legislation and processes for the assessment of policies, programs and projects affecting the environment;

- to foster the development of technology, processes and management practices conducive to maintaining or improving environmental quality;

- to undertake legal, economic, social and other analyses of environment protection issues, including their relative priorities, to advise governments and to achieve and effectively administer national quality standards;

- to participate in regional and local planning and in arrangements with the States and Territories to ensure a national coordinated approach to environment quality issues, environmental impact assessment and project approval processes; and

- in accordance with Government requirements, to represent the Commonwealth and Australia in dealings with the States, Territories, other countries and international organisations in all aspects of environment quality standards and international obligations (such as the proposed Framework Convention on Climate Change).

DASETT proposes that the Commonwealth EPA will be divided into six general program areas: environment quality, industry and technology, monitoring, auditing reporting and databases, legal and economic analysis, environment assessment, and education and information.
The second stage in establishing the Commonwealth EPA is to instigate new arrangements with the States and Territories.

The position paper on the proposed Commonwealth Environment Protection Agency (DASETT 1991) suggested three options for such arrangements: first, an agreement to implement standards agreed to by the Australian and New Zealand Environment Council; second, a reliance on Commonwealth powers to implement national standards, whether decided in collaboration with the States and Territories or based on Commonwealth decisions; and the third and most practical option, a Commonwealth-State-Territory Ministerial body with a standard-setting role. The Ministerial body would be supported by complementary legislation or a referral of powers by the States to the Commonwealth for the purpose of creating standards. It would be chaired by the Commonwealth and secretariat support would be provided by the Commonwealth EPA.

These issues are unlikely to be settled until 1992.

B3 State and Territory Government initiatives

The primary responsibility for protecting the environment rests with the State and Territory Governments. All have released discussion and/or strategy papers and set up committees to canvass the problems of, and possible responses to, rising concerns about greenhouse gas emissions.

B3.1 New South Wales

The New South Wales Government adopted the Toronto Accord resolutions (to reduce the 1988 level of *carbon dioxide* emissions by 20 per cent by the year 2005) as an interim target in July 1989 [emphasis added]. The Government then set up two high level committees: the NSW Cabinet Committee on Climate Change and the Interdepartmental Committee on Climate Change, and actively participated in a number of Commonwealth-State consultative forums. The Cabinet Committee released ‘The Greenhouse Strategy for NSW' in June 1990 (New South Wales Government 1990a). The discussion paper details actions already being undertaken, or where there is a firm commitment to do so, and proposals the Government is considering.

It presents the Government's four priority areas:

- development of administrative arrangements to ensure a coordinated and cost-effective response and regular reviews;
- collection of information on climate change and its potential impacts on NSW;
- evaluation and implementation of interim reduction strategies; and
- evaluation of adaptive strategies.

A detailed submission was presented to the Industry Commission prepared by the Treasury and the Cabinet Office. The NSW Government detailed its views on the development of greenhouse strategies. That is:

- an international consensus and concerted international action is required if the greenhouse problem is to be effectively addressed;
- the NSW Government will only adopt measures that do not impose net costs upon the community;
- in general, market-based policy instruments have significant efficiency advantages over regulatory regimes;
- there is scope for emission reductions within the broader strategy of microeconomic reform;
- research is needed to provide the data required to determine the full costs and benefits of reduction strategies; and

- in light of this information gap, greenhouse policies should be implemented with caution, such as via staged reduction strategies.

The Government is currently developing a `State Energy Resources Policy and Strategy'. This work will consider issues relevant to the greenhouse problem in the context of security of energy supplies, the efficiency of energy production, distribution and utilisation, the potential for alternative fuel sources and environmental issues.

The NSW Government stated that:

> Specifically, NSW will delay adopting greenhouse gas reduction strategies which impose net costs on the State until the scientific uncertainties surrounding the Greenhouse Effect are adequately resolved and until a binding international agreement on greenhouse gas reduction is in place which will ensure the State's efforts contribute to a significant reduction in greenhouse gas emissions globally (Sub. 100, p. 16).

The Government's submission has as attachments submissions made by seven NSW Government agencies: Department of Minerals and Energy; Electricity Commission of NSW; Department of Transport; Department of Planning; The Water Board; NSW Agriculture and Fisheries; and the Waste Management Authority.

Department of Minerals and Energy

The NSW Department of Minerals and Energy submitted its `Review of Energy Conservation and Management Policies and Programmes' to the Government in November 1990. The report detailed energy efficiency initiatives and programs for sectors of the NSW economy.

The Department has established a primary greenhouse database. It also currently administers a number of energy efficiency, renewable energy and energy substitution programs such as: Energy Labelling, Government Energy Efficiency Program, Energy Efficient Housing, research, development and demonstration, and the provision of information (AMEC 1990).

Electricity Commission of NSW

The Electricity Commission of NSW (ECNSW) has developed a strategy aimed at meeting the Toronto target that it believes is technically plausible and consistent with NSW Government policy, although not necessarily the least-cost energy strategy nor the most efficient way of meeting a target at any level (New South Wales Government 1990b). In fact,

> From the ECNSW's viewpoint, energy decisions based on arbitrary targets and greenhouse effect models using highly uncertain data could lead to incorrect courses of action and penalise energy options and the related economic development (Sub.100, p. 7).

The ECNSW described its approach as one of `prudent preparedness' involving:

- implementing economic and greenhouse effective actions;

- investigating likely economic solutions which are also greenhouse effective;
- developing demand side options;
- initiating research and development programs for greenhouse effective technologies; and
- developing education programs relating to greenhouse.

The Proposed New South Wales Environment Protection Agency

On 15 December 1990 the Premier and the Minister for the Environment announced the decision to support the formation of an EPA, provided an outline of key functions and substantially increased staffing and funding. An update was provided in the information paper, 'Establishing the Environment Protection Authority for New South Wales' published by the NSW Ministry for the Environment in January 1991.

It was originally intended that the new organisation would be formally established by July 1991. However, due to intervening State elections the draft legislation required to support the Environment Protection Authority proposal is still before the NSW Parliament.

The legislation is in two parts. The first part provides for the administrative set-up of the EPA and the second allows for the integration of existing environmental legislation in an attempt to ensure consistency and to accommodate the possible use of economic instruments.

The NSW EPA will be responsible for policy and program development for environment protection and pollution prevention. It will promulgate goals, objectives and standards for air quality, water quality, control of chemical contamination and site rehabilitation, the waste cycle and noise control in concert with those developed at national level. (NSW Ministry for the Environment 1991)

The rationale behind establishing a State EPA for NSW was considered by Niland (1991):

- to ensure improved service to the community, industry and government is achieving a balanced approach toward environmental protection and economic development of the State;
- to promote a streamlined and rationalised environmental protection framework that provides certainty to the community, industry and Government; and
- to consolidate the current disparate system of environmental control over chemicals, toxic substances and hazardous substances.

An interesting feature of the NSW EPA is its recognition as an opportunity to consider and apply market-based approaches by the NSW Government. The EPA will move cautiously towards pricing policies which reflect the magnitude of the environmental impact, which are consistent with user-pays and polluter-pays principles and which positively influence behaviour towards environmental protection (State Pollution Control Commission 1991).

The EPA is to establish an Environmental Economics Unit to ensure that economic factors are considered in licensing and standard-setting processes. The Agency will consult with other State and Federal agencies, industry and the community while developing economic instruments. The need for a multidisciplinary approach to undertake cost-benefit analyses and environmental modelling and to collect inventories of pollution and sociological data has been recognised. The agency aims to benefit from overseas experience whilst recognising the differences in Australian industry structure, our federal structure and geography and intends to start with pilot or demonstration programs.

B3.2 Victoria

The Victorian Government is committed to achieving a significant reduction in greenhouse gas emissions by the year 2005, aiming for the Toronto goal of a 20 per cent reduction on 1988 levels of *carbon dioxide* emissions by 2005 as an interim target for planning purposes, and subject to review in 1991 [emphasis added]. The Government is also committed to matching any international agreements for action on the greenhouse effect.

Along with the State Electricity Commission of Victoria (SECV) it has published a number of strategies since early 1989. The first major Government document was entitled ‘The Greenhouse Challenge’ (Victorian Ministry for Planning and the Environment 1989). It proposed a five part greenhouse strategy: research, emission reduction, education, planning and national coordination. A Greenhouse Unit has been established to coordinate further development and implementation of the strategy and to supervise, promote and develop policy responses.

`The Greenhouse Challenge' was followed up by a second report by the Ministry for Conservation and the Environment (1990) entitled ‘Greenhouse -- Meeting the Challenge’ which contained a summary of progress for the previous year. During 1989-90 the Victorian Government:

- continued to support CSIRO greenhouse research;
- commenced monitoring projects on elements of the environment;
- implemented the policy on CFCs and halons;
- introduced regulations on manufacture and sale of aerosol products, halon fire extinguishers, and extruded polystyrene, and introduced waste management measures for ozone depleting substances;

- promoted energy conservation by householders through the `Keep Vic Fit' campaign;
- set up a task force to examine ways of easing traffic congestion and greenhouse gases in inner Melbourne;
- began the `Tree Victoria' project;
- established a Greenhouse Community Grants Program;
- released an education kit called 'Greenlinks' in June 1990; and
- undertook impact studies into environmentally sensitive projects.

Climate monitoring

In June of 1989 the Victorian Government announced a program to track trends in climate and sea level changes, and to promote information on the progressive effects of such changes. The Greenhouse Unit, then a part of the Department of Conservation and Energy supplied the core funding.

The program includes the following:

- Port of Melbourne Authority with the Division of Survey and Mapping began to progressively install a network of 32 tide gauges around the Victorian coast;
- in addition, the Authority conducted a preliminary study of `Assessment of Coastal Vulnerability for Victoria';
- the Melbourne and Metropolitan Board of Works is mapping the effects of a 30 centimetre sea level rise on the flood plains in Port Phillip Bay, the results of which will not be available until 1992;
- three automatic weather stations of a standard suitable for inclusion in the Bureau of Meteorology network, are being installed in the Victorian Alpine region;
- the Wildlife Management Branch of the Department of Conservation and the Environment is undertaking an examination of the potential distributional changes for a number of Victoria's rare or threatened fauna under a number of different climate change scenarios using the BIOCLIM model; and,
- the program also includes a project using remote sensing data from Landsat to map forest cover clearing rates in the western part of Victoria over 1987 to 1990. Estimates of carbon dioxide emitted as a result of this clearing will be made.

The NIEIR study for the Victorian Solar Energy Council

This study examines a range of energy options that represent alternative least cost energy paths for Victoria, under the economic projection that the economy will experience steady and balanced growth over the entire period under each scenario. In 2005, the annual energy cost savings from the efficient renewable energy scenario as compared to the reference case were estimated to be $3.1

billion, and in the case of the Toronto target scenario, $4.7 billion. The attainment of this scenario was said to require acceleration of the introduction of technologies that improve energy efficiency (NIEIR 1990). See Chapter 9 and Appendix G.

Department of Industry, Technology and Resources

The Department of Industry, Technology and Resources (DITR) released a green paper in early 1990 which proposed a broad range of programs and activities. It stated that Victoria is committed to encouraging renewable energy and energy conservation, through the identification of potential energy alternatives, regulations for new housing, extending appliance energy labelling programs, focusing energy information services and working toward new national standards for vehicle fuel efficiency.

In September of that year a report commissioned by DITR concluded that current data available from energy suppliers was generally inadequate for energy planning analysis (Energetic et al. 1990). The Department undertook to develop data of greenhouse gas emissions by energy sector to enable an assessment of the impact of energy conservation and renewable energy on current emission levels.

The Government has introduced a requirement for wall and ceiling insulation to be included in all new houses built since March 1991. The Renewable Energy Authority Victoria (REAV) was established to replace the Victorian Solar Energy Council in July 1990 with responsibilities for energy conservation and renewable energy and released its first five-year plan in December 1990.
In June 1991, the Department (now known as the Department for Manufacturing and Industry Development) released `Victoria's Energy Efficiency Strategy'. It is intended to provide a policy framework for the promotion of energy conservation and renewable energy over the next five years.

Under the Strategy, energy conservation and renewable energy will be developed by the SECV and The Gas & Fuel Corporation of Victoria (GFCV) as outcomes of their `integrated least-cost resource planning'. The SECV and GFCV will implement demand management plans which reflect the technical potential and economic practicalities of developing demand-side resources. The REAV will have an important role in developing energy conservation and renewable energy programs working in cooperation with the energy utilities.

The strategy has a number of goals (Victorian Department of Manufacturing and Industry Development 1991):

- to ensure Victoria's energy needs are satisfied at the least cost while promoting economic development, protecting the environment and improving social justice;

- to reduce dependence on fossil fuels and the impact of energy supply and use on the environment; and

- to achieve sustainable progress toward meeting targets for Greenhouse emission reduction.

The Strategy also sets out a set of criteria for planning and selecting programs, identifies key areas of strategic importance and describes the roles of the energy authorities and Government agencies in implementing the strategy.

One particular initiative was brought to the Commission's attention:

> the Government has adopted, on an interim basis, a policy to account for externalities. This gives a 10 per cent cost advantage for planning purposes to energy conservation and renewable energy options, pending the outcome of a major study to be completed before the end of 1992. (Sub. 162, p. 1)

State Electricity Commission of Victoria

At the conclusion of an 18-month joint study, the SECV and the Department of Industry and Economic Planning released two demand management information papers signifying savings through conservation and cogeneration[2]. The SECV also launched its Three Year Demand Management Action Plan, which was based on the least cost (to society) planning philosophy. Programs already in place include: a Cogeneration and Renewable Energy Incentives Package, Remote Area Power Supply Program, Appliance Labelling, Dairy Energy Savings Program, and Industrial and Commercial Energy Audits (Industry Commission 1990).

The SECV has also published a discussion paper detailing its response to the rising concern about greenhouse emissions. The Commission intends to (SECV 1990b):

- encourage and promote energy efficiency, cogeneration and renewable energy;

- ensure new power stations are designed to optimise thermal efficiency and a reduction in carbon dioxide;

- investigate economics of reduced carbon dioxide emissions by decreasing the use of brown coal;

- increase the efficiency of the existing system;

- investigate revegetation programs;

- inform the public of the issues;

- monitor/support scientific understanding; and

- ensure energy end-use in Victoria takes into account the need to minimise carbon dioxide emissions from primary fuels.

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2 Cogeneration is the generation of electricity and heat or steam for other useful purposes from a single combustion source. The potential for cogeneration exists where significant amounts of waste thermal energy are produced as a part of some other industrial process. (See Appendix F, Section F4)

In its submission to the Industry Commission's recent inquiry into the Energy Industry, the SECV detailed a Strategic Research Program which concentrates on technologies for the economic generation of electricity from the more thermally efficient brown coal. The SECV also undertook to respond to future regulatory standards. (SECV 1990a)

An innovative project undertaken by the SECV and reported in the Climate Change Newsletter (Barson & Furbank 1990) was the purchase of 30ÿ000 new generation compact fluorescent `Philips' lamps, which were then placed with retailers at a reduced price of $20. The bulk of the lamps were sold out in a few days.

B3.3 Queensland

Queensland's initial response to concerns about greenhouse emissions has been to concentrate on public education. The Government's discussion paper (Queensland Government 1989) offered in-principle support for some general greenhouse strategies. That paper was prepared by the previous Government. Two publications have been released by the current Government. In November 1990 `Towards a Queensland Conservation Strategy: Facing the issues' was released by the Department of Environment and Heritage. This paper mentioned the greenhouse problem briefly in terms of ecologically sustainable development concept. In February 1991 a discussion paper into Queensland Energy Policy was released. It outlined the general principle that the Queensland energy sector should operate '... in a manner which is economically efficient, environmentally responsible and socially acceptable' (Queensland Government 1991a, p. 14). It also makes the point that the successful reduction of carbon dioxide emissions depends on community acceptance of the lifestyle impacts of policies.

The Commission understands that the Queensland Government has begun to formulate a greenhouse policy. Responsibility for the policy has been allocated to the Office of Cabinet.

The Industries Energy Management Sub-program run by the Department of Resources operates an information and advisory service to assist industries and Government departments to utilise energy more efficiently. The Department is also investigating the feasibility of establishing an ethanol fuel industry, researching remote area power systems for isolated rural properties, hybrid energy systems and promoting natural gas.

B3.4 Western Australia

The Western Australian Government issued a 'Greenhouse -- Meeting the Challenge' policy statement in December 1988. In 1989, the Government made an election commitment to adopt the Toronto Accord as an interim target.

Western Australian Greenhouse Coordination Council

The Western Australian Greenhouse Coordination Council was set up to develop a strategy for the state to mitigate concerns about greenhouse gas emissions. The proposed plan (Western Australian Greenhouse Coordination Council ND) had two components:

- to set up a representative body (an ongoing Greenhouse Coordination Council) to coordinate the implementation and adoption of programs and to develop new programs as necessary; and
- to develop a set of initial substantive programs.

As a result, in 1989 a Cabinet Sub-committee developed an Energy Conservation Strategy (Government of Western Australia 1990).

Its main features were:

- community and industry energy conservation;
- demand-side management of electricity and gas;
- transport energy conservation;
- government energy conservation scheme; and
- implementation and consultation.

To identify potential policy options and ensure proper targeting, the Western Australian Greenhouse Coordination Council has instituted a series of energy audits for the State. The report (Western Australian Greenhouse Coordination Council 1991) stated that the use of fossil fuels accounts for 48 per cent of the greenhouse impact and options to decrease carbon dioxide emissions from this source were identified. Programs for the conservation of fossil fuel have already been set up by the Review Committee on Power Options for WA, the Renewable Energy Branch of SECWA, the Energy Conservation Committee, and the Renewable Energy Advisory Council.

The report concluded that:

> Overall the audit shows that it is possible to achieve a 20 per cent decrease in greenhouse gases by phasing out CFCs and halons and reducing the amount of methane from landfills. Lowering carbon dioxide emissions from fossil fuel usage would result in an even greater reduction. (Western Australian Greenhouse Coordination Council 1991, p. 6)

State Energy Commission of Western Australia (SECWA)

The Commission believes that small reductions in projected emissions can be achieved at small cost, and perhaps some gain, but thereafter increasing use must be made of more costly technologies which will cause the cost of target compliance to escalate rapidly. It holds the view that the economic impact of reduction strategies will most likely be minimised if Government policy avoids encouraging early retirement of buildings, plant and consumer products and continues research into the climatic implications of increasing greenhouse gas emissions. The SECWA concludes that given the uncertainty surrounding the effects at present, it would be prudent for the Commonwealth Government to encourage investment in energy efficiency initiatives and discourage investment in uneconomic initiatives for the purpose of greenhouse gas emission reduction. (Sub. 72)

B3.5 South Australia

Overall policies are being developed by the South Australian Government in accordance with the Australian Minerals and Energy Council and State interdepartmental policies. The South Australian Office of Energy Planning is the coordinating body for the State's energy policy.

In its submission to the inquiry, the South Australian Government listed initiatives aimed at facilitating the reduction in greenhouse gas emissions. These included:

- energy conservation and fuel efficiency measures, such as the Government Energy Management Program, the Energy Information Centre -- a service for the community advising on the most economic and energy efficient means of heating and cooling etc. -- and the Greenhouse Information Centre;

- energy labelling schemes, such as the mandatory labelling of refrigerators and freezers (introduced in June 1990), for air-conditioners, dishwashers, clothes driers and clothes washers (introduced in February 1991) and the ‘Five Star Design Rating’ to encourage energy efficient housing; and

- investigations into alternative energy sources, such as the wind generation demonstration at Coober Pedy and the demonstrations of cogeneration implemented at the Queen Victoria Hospital and the Parks Community Centre, as well as programs like remote area power systems, landfill gas recovery, ‘clean coal’ technologies and transport fuel research.

In January 1990, the Premier commissioned a review into the long term development of Metropolitan Adelaide to the year 2020. Environmental and energy concerns and specifically land use and transport planning have shown themselves to be major issues to the public.

Committee on Climate Change

The South Australian Government established an interdepartmental committee on climate change on 14 August 1989 to prepare a strategy addressing the greenhouse issue. The Committee's first report, `Implications of Climate Change for South Australia', was released in August 1990 and described the possible impacts of climate change.

The second report by the Committee was released on 5 June 1991. Entitled ‘The Greenhouse Strategy for South Australia, this comprehensive report examined possible options to:

- limit greenhouse gas emissions;
- expand the known carbon sinks; and
- adapt to, or mitigate against, the effects of climate change on the community and the environment.

The limitation strategy is divided into short to medium term measures, which will require substantial government commitment to maximise potential, and medium to long term measures. In the short term, recommendations include: the promotion of energy audits; supply-side and demand-side measures by energy authorities; energy reduction targets for government operations; continued control of vegetation clearance, expansion of plantation forestry, agro-forestry, woodlots and tree planting; waste minimisation and greater recovery of natural gas.

In the medium to long term, the Committee recommended the immediate implementation of: urban consolidation, telecommuting and ridesharing to reduce travel; improved urban planning and building design to reduce energy use; integrated land use and transport strategic planning and a greater provision of cycle and pedestrian routes. Long term options requiring detailed evaluation included the early replacement of existing electricity generation plant to utilise advanced technologies; the introduction of significant capacity from renewable energy sources; and substantial improvements in energy efficiency in the residential, industrial, commercial and transport sectors.

Strategies to adapt to the effects of climate change included: assisting agriculture for structural adjustment, financing and diversification, and research into new crops; for pastoralism, improving water conservation, management and control of pest plants and animals and legislative protection for expanded rangelands; incorporating modifications to infrastructure during maintenance or replacement; and monitoring of impacts on tourism and leisure patterns with strategies modified accordingly.

To encourage national and international coordination on the greenhouse issue, the South Australian Climate Change Committee recommended (South Australian Government, Department of Environment and Planning 1991):

- establishing a broadly based Climate Change Committee to be serviced by the Department of Environment and Planning;
- in the medium term, establishing a Climate Change Office;
- that the Government should contract the CSIRO Division of Atmospheric Research to identify and evaluate regional climate change within the State at a cost of $100 000 annually for three years;

- that the Government establish a Greenhouse Grants Scheme of $100 000 per annum to provide for a community-based research information and education scheme; and
- that the Multi-Function Polis Adelaide: Environmental Management Project could provide a centre of expertise on climate change, a base for research and development and offer advice for governments, industry and the community both within and outside Australia.

The Department of Environment and Planning

In November 1990, the South Australian Cabinet endorsed the Toronto Accord as an interim target and supported the Commonwealth initiatives. The Cabinet also required the Offices of Energy Planning and Transport Policy and Planning report on energy management initiatives to decrease emissions using known and available energy efficient technologies and energy management techniques that can be implemented immediately. According to the South Australian Minister for Environment and Planning, the Government favours voluntary measures now, when there will be little effect on the South Australian lifestyle, instead of waiting until the costs of adaptation may be higher. The Minister stated further that the Government already requires use of recycled materials by its departments and is 'leading the way in Australia' in phasing out CFCs (Hon. Susan Lenehan, News Release, 20 November 1990).

The Department of Mines and Energy

In February 1989, the Minister for Mines and Energy released an information paper entitled, 'Greenhouse Effect and Energy Policy in South Australia'. A Green Paper released by the Department of Mines and Energy in 1991 (Government of South Australia 1991) sought to commit the State Government to building a wind turbine generator at Coober Pedy, commissioned in 1991 and to the introduction of energy labelling regulations for a range of domestic electrical appliances. The paper also discusses a range of energy supply and demand issues for the State. It is intended that an Energy Plan for the State will be released later in 1991.

The Electricity Trust of South Australia and The South Australian Gas Co.

The Electricity Trust of South Australia is implementing a demand-side management program to include demonstration projects, technology promotion and community involvement in a wide range of energy end-use activities. The South Australian Gas Co. (SAGASCO) is working with a private company to recover landfill gas from the Wingfield tip in Adelaide. The gas is blended with propane to raise its heating value to that of natural gas and is fed into the reticulation system.

SAGASCO in an attempt to have cogeneration accepted as a viable option for reducing operating costs, is offering a package in conjunction with the Detroit Engine and Turbine Co. It offers a package which includes feasibility studies, finance, operation and maintenance (Sub. 75, p. 4).

B3.6 Tasmania

Tasmania accounts for only 2 per cent of Australia's energy consumption, with 98 per cent of the State's electricity being supplied through hydro-electric projects. The Tasmanian Government estimates that mainland power supply authorities are responsible for approximately 45 per cent of fossil fuel sourced emissions compared with only 1 per cent from Tasmania (Govt of Tasmania, 1989).

The State Government estimates that the proportion of Tasmania's energy usage of ‘Greenhouse free’ or ‘neutral’ energy forms has risen from 39 per cent of total usage ten years ago to 46 per cent at present, compared to 4 per cent for the nation overall.

Despite this, Tasmania has implemented actions such as (Government of Tasmania 1989):

- encouraging the replacement of petroleum products used for non-transport applications by renewable energy sources;
- industrial and commercial cogeneration and energy conservation measures through use of alternative fuels such as woodchips, waste wood and LPG;
- investing in the use of battery powered vehicles and in conservation opportunities in agriculture; and
- the *Chloroflurocarbons and Other Ozone Depleting Substances Act 1988* which prohibits the manufacture, distribution and sale of such substances.

In addition the Hydro-Electric Commission runs the Energy Efficiency Initiatives Program for Tasmania involving energy efficiency education, and the State Government has run the Government Energy Management Program for the last seven years (AMEC 1990).

Tasmania is the site of an experiment in the propagation of sound through water. The aim is to make a `big noise in the ocean somewhere near Heard Island' (Transcript, p. 570) which will then be intercepted, and the time taken to cover the distance measured, all around the world. As the speed of sound is affected by the water's temperature, this information should be a good reflection of any change in global warming.

In its submissions to this inquiry, the Tasmanian Government opposed the possibility of a separate 20 per cent target for each State and Territory, and suggested that the appropriate jurisdiction could be addressed by the Special Premiers' Conference Working Group on the Environment. The Government also expressed its support for the development of cooperative research programs on both international and national scales.

B3.7 Northern Territory

The Conservation Commission of the Northern Territory was established in September 1988 with representatives from government, environmental and conservation groups, and research organisations. In a report (Conservation Commission of the Northern Territory 1989) the Conservation Commission described the Territory's development of combined cycle electricity generation (with a combined cycle power station operational in Darwin) and the development of renewable energy resources, especially the replacement of diesel in remote areas. The Government Energy Management Program has provided lighting and air conditioning efficiency improvements. The Commission also arranged for publication of `Greenhouse 88 Planning for Climate Change -- Issues for the Top End' which was derived from the national television conference ‘Greenhouse’ organised by the Commission for the Future and the CSIRO. It also sponsored a major environmental conference called `Environment 90' held in March 1990 in Darwin where discussion included greenhouse issues.

The report describes plans for the CSIRO to undertake regional climate study over four years in collaboration with the Northern Territory Government. It also details a greenhouse activity survey to identify proposed and current greenhouse related research and investigation programs being considered by various organisations. The research organisations are required to categorise their activities into three areas:

Phase 1. Identification of significant regional changes in climate;

Phase 2. The assessment of probable environmental effects and extremes of climate change; and

Phase 3. Possible responses to identified extremes.

The Northern Territory has also developed a registry for greenhouse information, especially for material of relevance to the tropics and the Territory. The Territory Greenhouse Strategy will supplement the National Strategy. The Northern Territory has endorsed the National Ozone Protection Strategy. It will concentrate on two major directions in responding to climate change:

1. Limitation and prevention -- aimed at securing decreases in the production and release of greenhouse gases; and

2. Adaption -- aimed at mitigating, even capitalising on, the changes that occur.

B3.8 Australian Capital Territory

The ACT Strategy to tackle concerns about greenhouse gas emissions aims `to participate in the Australian goal of reducing emissions of carbon dioxide by 20 per cent by the year 2005 (Toronto Goal) and to phase out the use of CFCs in advance of 1995 (Montreal Accord)' [emphasis added]. The booklet released by the ACT Government proposes policy commitments and specific action in the short and longer term. Short term measures include:

- reducing emissions of greenhouse gases;
- conserving energy;
- promoting recycling;
- developing reafforestation; and
- promoting sensitive agricultural and land management practices.

However, in the longer term, the emphasis will turn to research and monitoring to predict the impact of climatic change and develop adaptive planning and land management techniques. Other elements of the long term plan are community education and participation, national and state coordination and implementation, evaluation and reporting. An implementation schedule will be released after the Assembly Standing Committee on Conservation, Heritage and Environment tables its report on an Integrated Energy Resources and Environment Policy for the ACT. It will detail the agency primarily responsible for the plan, timing and reporting mechanisms, the timeframe for implementation and the method of evaluation.

B4 Legal impediments to government action

Various policy instruments are available to effect reductions in Australia of greenhouse gas emissions. Which ones can be utilised in practice will be influenced by the various legal powers of the Commonwealth, State and Local Governments.

External affairs power

The Montreal Protocol on Ozone Depleting Substances had effect in Australia via *the Ozone Protection Act 1989 (C'lth).* The Act introduced a national system of comprehensive federal regulations, licences, levies and tradeable quotas for the production, import and export of ozone depleting substances (see Appendix D).

The Commonwealth Act directly regulates activities within the States. However, Section 4 of the *Ozone Protection Act 1989 (C'lth)* concedes that:

> It is the intention of Parliament that this Act is not to affect the operation of a law of a State or Territory that makes provision with respect to the protection of ozone in the atmosphere and is capable of operating concurrently with this Act.

Most State Governments also have legislation regulating ozone depleting substances: both Tasmania and Queensland had adopted controls prior to the Commonwealth legislation, and Victoria South Australia, Western Australia, New South Wales and the Northern Territory have subsequently introduced specific controls. The approaches taken in these various State enactments are diverse.

According to Fowler (1991) it is possible that at least certain provisions within some of the State Acts would not enjoy the protection of Section 4 of the *Ozone Protection Act 1989 (C'lth).* Such provisions are likely to be invalid under Section 109 of the Constitution which states that State laws on the same subject matter can only operate to the extent that they are consistent with the Commonwealth legislation.

The Commonwealth relied on its external affairs powers under Section 51(xxix) of the Constitution to enforce the *Ozone Protection Act 1989.* However, as an international agreement on climate change is not yet in force, whether the Commonwealth could use these powers to enforce reductions in the emissions of greenhouse gas is uncertain.

Fowler (1991) believes the *Ozone Protection Act 1989 (C'lth)* is nevertheless a powerful precedent for direct federal action in other areas of environment protection. Legislation to meet obligations under an international convention on climate change could impose national energy efficiency standards or introduce measures to promote the development of alternative energy technologies.

The external affairs power does, however, have its limits. Justice Brennan in the Tasmanian Dam case in 1983, stated that where duties are imposed by a convention, legislation must be ‘conducive to the performance of the obligations imposed by the Convention’ (158 CLR at 232).

Power to levy excise

The Commonwealth has the power to tax environmentally harmful activities or to allow deductions for sound environmental practices under Section 51(ii). A Commonwealth law to impose pollution charges to discourage the discharge of wastes into the environment would be a valid exercise of Commonwealth legislative power under this particular head. (Fowler 1991)

The question then remains, which specific instruments can the States impose on emitters of greenhouse gases and which can only be implemented by the Commonwealth?

Under Section 90 of the Australian Constitution, the Commonwealth Parliament has the absolute power to ‘... impose duties of customs and of excise’. State and hence Local Governments are prohibited from imposing an instrument to reduce greenhouse gas emissions if it can be defined as an excise. This raises some potential limitations on the levying of State pollution taxes.

In the case into the Victorian pipeline operation fee, the High Court took the broad view of an excise. Justice Mason in Hematite Petroleum Pty Ltd v Victoria (1983) stated that the term:

> embraces all taxes upon, or in respect of, a step in the production, manufacture, sale or distribution of goods. (151 CLR 599 at 632)

This view was later qualified in the High Court case, Harper v. Minister for Sea Fisheries (1989), where it was found that a State-imposed royalty payment for the right to exploit a resource in the public domain was not an excise (88 ALR 38). Fowler (1991) argues by analogy that a State tax on air pollution constitutes a charge for the right to exploit the air as a common good and therefore is also not an excise.

If this argument can be extended to greenhouse gas emissions, State Governments may be free to impose:

- *environmental damage charges* which require payment for emitting greenhouse gases equal to the value of damage to the environment;
- *emission charges*, such as a tax levied per unit of carbon dioxide emissions, which are collected in return for permission to release emissions;
- *environment protection charges* which are equal to the profit made by breaking an environmental standard, and could apply in addition to other penalties; and
- *tradeable emission rights.*

An input tax applied to fossil fuels according to their carbon content may appear to be an excise according to the Hematite definition. However, if they are distinguished as a rental charge for use of the atmosphere such a tax may also be available to the States.

The majority of instruments to reduce greenhouse gas emissions can be implemented by any level of Australian government. Nevertheless, State legislation to reduce greenhouse gas emissions would be constrained to function alongside Commonwealth legislation on greenhouse. In addition, the Commonwealth has substantial constitutional powers to form legislation, especially in regard to external affairs.

B5 Carbon taxes and how they could fit into our present tax system

Chapters 5, 8 and 9 present estimates of the possible costs of reducing greenhouse gas emissions. The estimates are derived from the WEDGE and ORANI models. These also present estimates of the magnitude of carbon taxes (but expressed in those chapters as carbon dioxide taxes) required to bring about a reduction in greenhouse gas emissions equivalent to the Commonwealth target. The carbon tax revenue in the WEDGE model, a worldwide model with several regions separately specified, is applied to reduce income tax in order to retain a fixed ratio between the government budget deficit and net domestic product; whereas, in ORANI the revenue is used to reduce other taxes to maintain a constant ratio between the public sector borrowing requirement and net domestic product.

In designing carbon taxes to apply in practice, either multilaterally or nationally, it is clearly necessary to have a good understanding of existing fossil fuel taxation. As Shell Australia stated:

> Existing tax rates on different energy sources differ considerably ... in Australia there are heavy excises on some petroleum products, while gas prices in some States incorporate public authority charges and coal prices are affected by excess rail freight charges. Given that one reason for introducing a carbon tax is to encourage substitution between alternative fuel sources, it makes sense to assess the impact of current taxation arrangements before introducing new measures (Sub. 149, p. 4-5)

A further issue is whether there would be merit in rationalising existing fossil fuel taxation measures before adding the additional taxes required to bring about the reductions in emissions. Other important issues concern, in a national context, the distribution of revenue between the various levels of government; legal powers of implementation of taxes; and monitoring and enforcement.

This section does not seek to address these obviously involved and difficult issues, but presents some relevant background information. It presents: information about existing fossil fuel taxation in Australia; relates the carbon dioxide tax estimate to a carbon tax; relates it to the existing level of taxation; and presents estimates of revenue.

Since ORANI has a more detailed specification of fuel demand systems, the remainder of this appendix concentrates on the ORANI carbon tax estimate.

B5.1 The taxation of Australia's fossil fuels

A review of current fossil fuel taxation

The Commonwealth and States impose a wide range of royalties, levies, pipeline and licence fees on resource industries operating in their jurisdictions. These charges are inconsistent, reflecting the lack of coordination between the States or between the Commonwealth and the States as they have evolved. The current state of taxation of fossil fuel in Australia is set out in Table B1.

Federal taxation

The taxation of oil and gas production by the Commonwealth is in transition. The main tax instrument remains the excise levied on coal and petroleum products. Although replaced by the Petroleum Resource Rent Tax (PRRT), petroleum excise remains a significant source of revenue for the Federal Government (refer Box B3).

Table B1: **Fossil fuel taxation in Australia**

	Commonwealth	Victoria	New South Wales	Queensland	Tasmania
COAL	Excise tax: -25c per tonne Coal Export Duty: -$-3.5 per tonne of high quality Australian coking coal (a)	Royalties: (1988 data) -SECV owned brown coal at 1.5c per tonne -Privately owned brown coal at 4c per tonne -Privately owned black coal at 6c per tonne	Standard Royalty -$1.70 per tonne of saleable black coal Super royalty: -50c per tonne extra for open cut mines (1998 data) Additional 'Royalty': (b) -Excess coal freight charges of $3.40 per tonne	Royalties: (1988 data) -Export open-cut royalties at 5% of ex-mine value -Export underground royalty at 4% of ex-mine value -Domestically sold royalty at 5c per tonne Additional 'Royalty': (b) -Excess coal freight charges of $7.30 per tonne	Royalty: (1988 data) -25c per tonne of saleable coal
PETROEUM PRODUCTION:					
-Offshore	Petroleum Resource Rent Tax: (c) -40% of taxable profit Excise tax: (d) -levied as a percentage of VOLWARE price C'lth Royalty: (e) -10% of well-head revenue shared	nil (f)	nil	nil	nil
-Onshore	Excise tax (as above) C'lth Royalty: (I) -10-12.5% of well-head value, revenue shared	State Royalty: -10 to 12.5% of well-head value	State Royalty: -10% of well-head value -11-12.5% secondary	State Royalty: -10% of well-head value	State Royalty: -10% of well-head value
PETROLEUM PRODUCTS:					
Motor Spirit	Excise tax (k) -25.767c per litre	Petroleum Franchise Fees: -Petroleum wholesaler pays a $50 fee for annual licence or $10 per month plus 11% of the value of motor spirit sold -Petrol retailer does not pay if all purchases are from licensed wholesalers. otherwise 11% of the value of motor spirit purchased (l)	Business Franchise License: (m) -Petrol wholesaler pays $10 per month plus 15.5% of declared value (42c/litre) of motor spirit -Petrol retailer does not Pay if all purchases are from licensed wholesalers, otherwise $10 per month	nil	Petroleum Products Business Franchise Licence Fees: -Petrol wholesalers pay a monthly licence fee of $50 plus 12.68% of determined value of motor spirit of 48.48c per litre -Petrol retailer pays an annual licence fee of $50

Table B1: **Fossil fuel taxation in Australia (contd)**

	Commonwealth	Victoria	New South Wales	Queensland	Tasmania
PETROLEUM PRODUCTS (contd):					
Automotive Diesel oil	Excise tax (k) -25.767c per litre	Petroleum Franchise Fees: -Petrol wholesaler pays $50 fee for annual licence or $10 Per month plus 11% of value Of sold diesel fuel for on road Use -Petrol retailer does not pay if purchased from licensed wholesalers, otherwise 11% of the value of diesel fuel purchased	Business Franchise Licences: (m) -Petrol wholesaler pay $10 per month plus 15.5% of declared value (25.5c/litre) of diesel fuel sold for on-road purposes only -Petrol retailer does not pay if all purchases are from licensed wholesalers, otherwise $10 per month	nil	Petroleum Products Business Franchise Licence Fees: -Petrol wholesalers pay a monthly licence fee of $50 plus 12.68% of the value of diesel fuel at the determined value of 48.22c per litre (o) -Petrol retailer pays an annual licence fee of $50
Aviation Gas	Excise tax (k) -27.074c per litre	nil	nil	nil	nil
Fuel Oil Heating Oil Kerosenes LP.G.	Excise tax on fuel oil, heating oil, and kerosene (k) -5.345c per litre	nil	nil	nil	Franchise Licence Fee for Heating oil and LP.G. (p) -Wholesaler pays monthly fee of $50 plus 12.68% of the det. Value of 50.83c per litre -Retailer pays an annual licence fee of $50
ENERGY CONSUMPTION:					
Natural gas (Transmission and Reticulation)	nil	Gas and Fuel Corporation of Victoria: Rent payment of 33% of sales revenue to Consolidated Fund -Public Authority dividend	The Pipeline Authority: -Reticulation, licence and mains authorisation fees of 1.75% of sales	AGL Petroleum Licence Fee: -Licence fee of $50 p.a. plus $9.50 per 100 GJ of gas sold	Franchise Licence Fees for Launceston Town gas: (p) -Wholesaler pays monthly fees of $50 plus 12.68% of the det. Value of $410 per tonne -Retailer pays $50 p.a.
Electricity	nil	State Electricity Commission Of Victoria: -Public Authority dividend	Electricity Commission of New South Wales: -State Government Charge on sales to all users of electricity -Public Authority Dividend	nil	HEC to Tasmania: -Statutory Levy of 5% of retail sales revenue each quarter excl. exempt sales -Electricity Consumption Levy on bulk consumers at 56.76c per kW of contract demand

Table B1: **Fossil fuel taxation in Australia (contd)**

	South Australia	Western Australia	A.C.T.	Northern Territory
COAL	Royalty: (1988 data) -2.5% value of production	Royalties: (1988 data) -1.00 per tonne -5c per tonne for use by Government -7.5% for exports	nil	Royalties: (1988 data) profit less depreciation over $50 000 for projects started after 1.7.82 and which chose to change from the 10% ad valorem royalty
PETROLRUM PRODUCTION:				
-- Offshore	nil	North Rankin field on the North West Shelf: (g) 0C'lth royalty levied at 12.5% of well-head value, and 605 of revenue of WA Govt. Special Payments: (h) -C'lth has agreed to pay extra funds up to its share of the C'lth Offshore Royalty from 1985 to 2000	nil	nil
--Onshore	State Royalty -10% of well-head value	State Royalty: -10% of well-head value Resource Rent Royalty: (l) -applied to Barrow Is. on same basis as C'lth RRT and revenue shared with C'th 75:25 Western Australia	nil	State Royalty: -10% of well-head value
PETROLEUM PRODUCTS:				
Motor Spirit	Business Franchise (Petrol) Licence Fee: -Petroleum wholesalers pay $50 per month plus share of determined valued of 45c per litre, equivalent to Zone 1: 5.50 c per litre Zone 2: 4.24c per litre Zone 3: 3.03c per litre (n)	Fuel Franchise Levy: -5.67c per litre	Petroleum Franchise Licence Fees: -Petrol wholesaler pays $10 per month plus 6.53c per litre -Petrol retailer pays $50 per year	Petroleum Franchise Licence Fees: -$10 per month plus 6c per litre

Table B1: **Fossil fuel taxation in Australia (contd)**

	South Australia	Western Australia	A.C.T.	Northern Territory
PETROLEUM PRODUCTS (contd):				
Automotive Diesel oil (gross)	Business Franchise (Petrol) Licence Fee: -Petroleum wholesalers pay $50 per month plus hare of determined value of 45c per litre, equivalent to Zone 1: 6.71c oer litre Zone 2: 5.50c per litre Zone 3: 4.24c per litre (n) -Petroleum resellers pay $100 per annum	Fuel Franchise Levy: -7.45c per litre	Petroleum Franchise Licence Fees: -Petrol wholesaler pays $10 per month plus 6.57c per litre	Petroleum Franchise Licence Fees: -$10 per month ply 6c per litre
Aviation Gas	nil	nil	nil	nil
Fuel & Heating Oil, Kerosenes & LP.G.	nil	nil	nil	nil
ENERGY CUNSOMPTION:				
Natural gas (Transmission and Reticulation)	The Pipeline Authority of South Australia: Contribution to Consolidated Revenue was $1.1 m in 1989-90 revenue	State Energy Commission of Western Australia Statutory Contribution of 3% of specific metered sales of gas	The Pipeline Authority Gas levy of 1.75% of sales	NT Gas Pty Ltd high pressure pipeline licence fee of $80 per km Distributors fees of $15 000 and a share of profits Reticulation licence (Alice Springs) totalled 3.2% of 1989-90 revenue
Electricity	Electricity Trust of South Australia: -5% levy on sales revenue -Charge by South Australian Government Finance Authority on a non-Repayable capital contribution	State Energy Commission of Western Australia: -Statutory Contribution of 3% on specific metered dales of electricity	ACTEW (Australian Capital Territory Electricity and Ware): -Business Enterprise Dividend	Power and Water Authority: -Received Government subsidies

Table B1: **Fossil fuel taxation in Australia (contd)**

[a] The export duty applies to coal with 85% or more carbon content, from open-cut mines of less than 60 metres in depth, opened before 1980. Effectively only mines in central Queensland are relevant.

[b] As estimated by Easton and quoted IC 1991, p. 262.

[c] Although the enabling legislation came into force on 15 January 1988, the excise duty on crude oil and LPG was collected until PRRT legislation became effective from 1 July 1991. PRRT applies to offshore areas other than the North West Shelf which is subject to excise and royalty arrangements.

[d] Since January 1988, the Federal Government changed the basis of excise assessment to the VOLWARE (volume weighted average fob prices of all sales made from an area) price from the Import Parity Price. The first 30 million barrels of crude oil produced from each new offshore project in the north West Shelf is exempt from excise. The excise rates vary according to the vintage of the area refer below).

[e] The Commonwealth Offshore Royalty is levied on the North West Shelf only. The Commonwealth retains 40% of the proceeds of the basic royalty rate of 10% of well-head value.

[f] The Commonwealth Treasurer announced in the 1990-91 Budget that the PRRT would be extended to Bass Strait oil and gas developments from 1 July 1990. This replaced the previous Commonwealth petroleum excise and royalty regime.

[g] The revenue are shared with the Western Australian Government for the financial consequences of the shortfall in domestic markets after signing take-or-pay contract for the supply of gas.

[i] The Commonwealth Onshore Royalty is levied on production under Commonwealth exploration permits issued prior to 1983 (effectively only the Varanus, South Pepper and Saladin fields in Western Australia).

[j] The *Petroleum Revenue Act 1985* permits the waiving of the Commonwealth's crude oil excise where the State Government introduces a resource rent royalty on onshore petroleum developments and enters into a revenue-sharing agreement with the Commonwealth.

[k] Excise rates apply from 8 August 1991. The rates of duty for the main excisable commodities (with the exception of crude oil, LPG and coal) are adjusted each August and February in line with half-yearly CPI movements.

[l] The ad valorem fee on motor spirit was increased from 7.8% to 11.0% on 1 November 1990. The additional 3.2% is paid into a Special Purpose Trust Account to be used to facilitate the payment of refunds to unsecured depositors with the Farrow Group of building societies. (Government of Victoria 1991, p. 24.).

[m] Exemptions from the Business Franchise Licence apply to primary producers and the railways, as well as to off-road use.

[n] The rates of South Australian Petrol Tax are applied differently according to the distance of the retail outlet from the GPO. Zone 1 is less than 50km from the Adelaide GPO, Zone 2 is 50 to 100 km away and Zone 3 incorporates the rest of South Australia.

[o] the exemption which previously exempt from the diesel franchise fee may apply for a rebate when the weight average base wholesale price for diesel exceeds 67.06c per litre. The maximum rebate is 6.11c per litre.

[p] Franchise fee arrangements extended to include sales of heating oil, LPG and Launceston town gas from 1 January 1991.

Sources:
Information from the Australian Coal Association, The Australian Institute of Petroleum, State budget Papers 1989-90 to 1991-92, Treasuries of the ACT, South Australian, Western Australian and Northern Territory Governments. Commonwealth of Australia 1991, *Budget Statements 1991-92: 1991-92 Budget Paper No. 1.* p. 415, AGPS, Canberra. DPIE 1990, *Background Report on Petroleum Production Taxation,* AGPS, Canberra. Electricity Supply Industries of Australia and the International Energy Agency Statistics 1991, *Energy Prices and Taxes: Fourth Quarter 1990,* OECD, Paris. Government of Victoria 1991, Budget Paper No. 4, L.V. North Government Printer, Melbourne. IC 1991, *Rail Transport Volume 1:* Report No. 13, AGPS Canberra.

The Commonwealth PRRT scheme was introduced in the 1990-91 Federal Budget. It applies to offshore 'greenfields' petroleum projects operating under licences issued after 1 July 1984. The tax is imposed at a rate of 40 per cent of taxable profit after exploration and development costs (DPIE 1990). Where no PRRT liability exists, companies can carry forward each year the value of exploration and development costs at a rate equal to the long-term bond rate plus 15 percentage points (DPIE 1990).

PRRT applies to offshore areas other than the North West Shelf production licence areas and associated exploration permit areas. North West Shelf production remains subject to Commonwealth offshore excise and royalty arrangements. The revenue from these levies is shared with the Western Australian Government (see below).

The Commonwealth PRRT scheme was extended to Bass Strait oil and gas production from 1 July 1990. The Commonwealth undertook to provide Victoria with an amount equivalent to what that state would have received under the previous revenue sharing arrangements for 1990-91 and 1991-92 (Government of Victoria 1991).

In general, onshore mineral rights are vested in the State Governments. However, the Commonwealth levies an Onshore Royalty on production under Commonwealth exploration permits issued prior to 1983. This revenue is shared between the Commonwealth and the States according to the '1967 Agreement'. The Agreement applies to offshore and onshore Commonwealth royalties calculated as a percentage of the well-head production value of petroleum (determined by agreement between the licence holder and the designated authority). Four per cent of the royalties go to the Commonwealth and the remainder to the States. Any other revenue from the offshore petroleum developments, such as rents, permit or licences fees, belongs to the States.
The existing arrangements will have the effect of exempting from excise all petroleum produced, whether from onshore or offshore areas.

All onshore fields and the offshore fields of the North West Shelf remain liable to pay Commonwealth crude oil excise. However, the first 30 million barrels of crude oil produced from an onshore field or a new offshore project is exempt from excise. To July 1990, only Bass Strait production had attained levels which attract excise. This production now comes under the Commonwealth PRRT scheme and is exempt. In addition, excise on Barrow Island production has been waived as part of the Resource Rent Royalty scheme. (DPIE 1990)

Commonwealth crude oil excise rates vary according to the vintage of the area: one applies to 'old' oil, one to 'new' oil and another to 'intermediate oil'. Rates are generally higher for old oil, less for intermediate, and lower again for new oil. In 1988 the Federal Government changed the assessment base of the excise rate to the VOLWARE price (refer Table B1). (DPIE 1990)

Petroleum pricing arrangements

Despite the Federal Government's deregulation of the Australian crude oil market, the Prices Surveillance Authority (PSA) remains involved in the wholesale pricing of both petrol and distillate.

However, the PSA is no longer setting an industry price. A new regulation and monitoring scheme began on 1 February 1990.

Oil companies are now required to notify the PSA of price increases and provided the price remains at or below an intervention level PSA endorsement is immediate. It is based on the calculation of an import parity product basket for petrol from Singapore and includes prevailing product excise duty and the relevant State or Territory business franchise fees. From 23 September 1991 the intervention price for distillate has been based on a product basket containing Singapore gas oil and kerosene prices.

State taxation

State Governments are prohibited from imposing an instrument that can be defined as an excise. The States have eluded this restriction by defining charges on fossil fuels as fees for mineral exploration on public property (rents), the price of rights to explore for and to produce government minerals (royalty) or fees on petroleum retailers to cover road maintenance (refer Box B1).

Box B1: **The Victorian Business Franchise Fee -- history**

The *Victorian Business Franchise (Petroleum Products) Act 1979* was enacted after the abolition in Victoria of the road maintenance charge.

Following a High Court decision in 1983, which invalidated the pipeline licence fee, the franchise fees were increased. Major amendments to the franchise legislation were made in 1988 following further High Court decisions.

A licence is no longer compulsory for wholesalers of petroleum products. However, retailers who purchase supplies from unlicensed wholesalers become liable for the ad valorem fee which would otherwise be paid by the wholesaler.

The rate for motor spirit was increased again from 1 November 1990 to accommodate payment to unsecured depositors of the Farrow Group of Building Societies.

Source: Government of Victoria 1991, pp. 23-24.

Royalties are the dominant method of taxation for the States. An ad valorem royalty is a charge based on a percentage of the gross value of production. All State Governments except Queensland impose an additional tax on motor spirit and diesel fuel in the form of franchise fees. The tax requires wholesalers to pay a fixed plus variable fee based on percentage of the value of sales.

Examples of direct State Government participation in mineral exploration and production in Australia are few: The State Electricity Commission of Victoria and the Electricity Commission of New South Wales mine for coal, and the Gas & Fuel Corporation of Victoria and South Australian Oil and Gas Corporation Pty Ltd produce petroleum. (Crommelin 1985) These State authorities are required to pay a lesser royalty than private producers as a rule.

Utilities responsible for the transmission and distribution of natural gas and electricity are generally required to pay rents to Consolidated Revenue and dividends to their owners -- the State Governments.

Queensland Rail has a monopoly on the haulage of black coal from mine to wharf and uses this monopoly to extract mineral rents from coal producers. Queensland Rail explained this in its submission to the IC Rail Inquiry, saying:

> Coal and mineral rail freight rates are more than simply a charge for carrying out a transport service, they are also a means of deriving an additional royalty from the development of the State's coal and mineral resources. (Queensland Government 1991b, p. 27)

These ‘excess’ rail freight rates are de facto specific royalties except that the freight rates automatically escalate with certain railway costs while a normal specific levy remains fixed until deliberately changed. (Willett 1985)

B5.2 Industry Commission estimates of carbon taxes

In Chapter 9 of the report, the Commission estimated a carbon tax (expressed as a carbon dioxide tax) using the ORANI model. The ORANI simulation estimated the tax required to reduce greenhouse gas emissions unilaterally by 44 per cent. Using information on the Australian economy, the modellers assumed that:

- the tax was applied to domestic consumption of fossil fuels, including imports;
- primary exports of fossil fuels were exempted but secondary exports were not;
  was revenue neutral); and that
- the carbon tax calculated was that required in addition to the fossil fuel taxes levied in 1980-81 (the date of the main database) to reduce greenhouse gas emissions by 44 per cent.

The model estimated that a tax of $21.75 per tonne of carbon dioxide (in 1988 dollars) would be required to reduce carbon dioxide emissions by 44 per cent. This is equivalent to a tax of approximately $80 per tonne of carbon. This rate has been converted into equivalent taxes on selected fossil fuels using ABARE (1991) data. The estimates are presented in Table B2.

Table B2: **ORANI estimates of carbon tax**

	Brown coal	Black coal (avg)	Petrol products average	Natural gas
Carbon dioxide tax (1988) $A/t of CO_2	$21.75	$21.75	$21.75	$21.75
GJ per tonne fossil fuel	10	22	46	54
Kt of CO_2/PJ	94	89	69	53
Energy supply 1988 (PJ)	449	1,081	1392	619
Carbon tax (per tonne of fossil fuel)	$20.12	$43.39	$68.62	$62.35

Source: Industry Commission estimates using data from ABARE 1991.

B5.3 Introducing a carbon tax

Relating carbon taxes to existing levels of taxation

Assuming the value of black coking coal is roughly $50 to $60 per tonne, the estimated ORANI carbon tax is certainly far higher than the imposts on fossil fuel presently required by Australian governments. Taking the example of exported Queensland coal: as the back-of-the-envelope calculations in Box B2 demonstrate, the present Federal and Queensland Government taxes impose a penalty less than half the ORANI estimated carbon tax of $43.39 per tonne of black coal.

Box B2: **Consider the taxation of Queensland high quality coking coal for export**

Coal export duty	3.50
Commonwealth excise tax	0.25
Federal taxation ($ per tonne)	3.7
plus	
Excess coal freight charges	7.30
Queensland royalties (export open-cut) assuming a value per tonne of $50	2.50
Total taxation ($ per tonne)	$13.55

Source: Table B1.

The story however, is completely different when we turn to the more heavily taxed petroleum products.

As illustrated in Table B4, the carbon tax per litre of motor spirit implied by ORANI is minor compared to the present taxation of petroleum. It is far less than the Federal excise rate of 25.767c per litre, even without consideration of the significant level of State taxation in the form of royalties and various franchise fees.

Revenue effects of introducing carbon taxes

Box B3 summarises 1990-91 Commonwealth Government revenue from the taxation of fossil fuels. The ORANI carbon tax on just the four forms of fossil fuel included in ORANI would generate extra revenue of approximately (1988) $Aÿ4 billion (refer Chapter 9). This is about 4 per cent of 1990-91 Commonwealth revenue of $Aÿ97ÿ937 million (Commonwealth of Australia 1991, p. 4.3).

Table B3: **Carbon taxes in terms of cents per litre of motor spirit**

	ORANI estimate
Carbon dioxide tax (1988) $A/t of CO_2	$21.75
GJ per tonne	46.4
Kt of CO_2/PJ	74.9
Energy supply 1988 (PJ)	776.6
Carbon tax per tonne	$75.59
Carbon tax per litre of motor spirit	$0.056

Source: Industry Commission estimates using data from ABARE 1991 and Wilkenfeld (Sub. 9).

Box B3: **A summary of Commonwealth revenue from fossil fuel taxation in Australia**

1990-91 Budget Revenue outcomes ($m)

Coal exports:		
	Customs duty	47
Petroleum:		
	Resource rent tax	293
	Excise tax	6601[a]
	Royalties	337[b]
Crude oil & LPG:		
	Excise Tax	1354
Total revenue:		8632

[a] net of refunds/drawbacks
[b] Petroleum royalties include the Commonwealth's share of the income from the WA resource rent royalty and the Commonwealth offshore and onshore royalties. Royalty payments for petroleum recovered in 1990-91 from Bass Strait have been credited against the producers' PRRT liability for the corresponding period.

Source: Commonwealth of Australia 1991, Budget Statements 1991-92, 1991-92 Budget Paper No. 1, AGPS, Canberra, p. 4.15.

REFERENCES

ABARE (Australian Bureau of Agricultural and Resource Economics) 1991, *Projections of Energy Demand and Supply: Australia 1990-91 to 2004-05*, AGPS, Canberra.

ACT Government Service ND, *Developing an ACT Strategy to Respond to the Greenhouse Effect*, Canberra.

AMEC (Australian Minerals and Energy Council) 1990, *Energy and the Greenhouse Effect*, June, AGPS, Canberra.

ANZEC (Australian and New Zealand Environment Council) 1990, *Towards a National Greenhouse Strategy for Australia*, August, AGPS, Canberra.

Barson, M. & Furbank, A. 1990, Climate Change Newsletter -- A Newsletter produced for Commonwealth Department of Primary Industries and Energy's Climate Change Core Group by the Bureau of Rural Resources, Volume 2, Number 4, November.

Barson, M. & Furbank, A. 1991, *Climate Change Newsletter* -- A Newsletter produced for Commonwealth Department of Primary Industries and Energy's Climate Change Core Group by the Bureau of Rural Resources, Volume 3, Number 1, February.

Commonwealth of Australia 1991, *Budget Statements 1991-92: Budget Paper No. 1*, AGPS, Canberra.

Conservation Commission of the Northern Territory 1989, *Report of the Northern Territory Advisory Committee on the Greenhouse Effect for 1989.*

Crommelin, M. 1985, *The mineral exploration and production regime within the federal system* in Drysdale P. and H. Shibata (eds) Federalism and Resource Development: The Australian Case, George Allen & Unwin in association with The Australia-Japan Research Centre, Canberra.

CSIRO 1991, CSIRO *Climate Change Research Program Annual Report 1990-1991*, Pearman G.I. and C.D. Mitchell (eds.), CSIRO Institute of Natural Resources and Environment.

DASETT (Department of the Arts, Sport, the Environment, Tourism and Territories) 1991, *Proposed Commonwealth Environment Protection Agency - Position Paper for Public Comment*, July.

Department of Prime Minister and Cabinet 1990, *Ecologically Sustainable Development: A Commonwealth Discussion Paper*, June, AGPS, Canberra

DFAT (Department of Foreign Affairs and Trade) 1991, *Environment, Australia's International Agenda*, No. 1, June, DFAT, Canberra.

DPIE (Department of Primary Industries and Energy) 1990, *Background Report on Petroleum Production Taxation*, AGPS, Canberra.

Energetic Pty Ltd with George Wilkenfeld Associates and Enersonics Pty Ltd. 1990, *Quantification of Victoria Energy-Related Greenhouse Gas Emissions*, A Report for the Department of Industry and Economic Planning, September.

ESD (Ecologically Sustainable Development) Working Groups 1991, *Draft Report -- Manufacturing, August*, AGPS, Canberra.

Fowler, R.J. 1991, *Proposal for a Federal Environment Protection Agency* A report prepared for The Australian Conservation Foundation and Greenpeace Australia Ltd, January, Adelaide.

Government of South Australia 1991, Future Directions for the *Energy Sector in South Australia -- Green Paper*, January.

Government of Tasmania 1989, *Submission No. 112 to The Senate Standing Committee* on Industry, Science and Technology Inquiry into The Contribution that Australian Industry, Science and Technology can make to Reducing The Impact of the Greenhouse Effect.

Government of Victoria 1991, *Budget Revenues 1991-92: Budget Paper No. 4*, L.V. North Government Printer, Melbourne.

Government of Western Australia 1990, *Energy Conservation Strategy for Western Australia -- A Discussion Booklet* by the Energy policy and Planning Bureau, May.

Hawke, R.J.L. 1989, *Our Country, Our Future,* Speech by the Prime Minister Opening of the Atmospheric Research Building, CSIRO Division of Atmospheric Research, July.

Industry Commission 1991, *Rail Transport Volume 1: Report*, Report No. 13, AGPS, Canberra.

Industry Commission 1990, *First draft of the Energy Inquiry Environmental issues paper*, July, Unpublished, Canberra.

International Energy Agency Statistics 1991, *Energy Prices and Taxes: Fourth Quarter 1990,* Organisation for Economic Co-operation and Development, Paris.

IPCC (Intergovernmental Panel on Climate Change) 1991, *Climate Change, The IPCC Response Strategies*, Island Press, Washington.

Minister for the Arts, Sport, the Environment, Tourism and Territories and the Minister for Primary Industries and Energy 1990, *Joint Statement*, 11 October.

New South Wales Government 1990a, *A Greenhouse Strategy for NSW -- Discussion Paper*, June.

New South Wales Government 1990b, *Submission No. 44* to the Industry Commission Inquiry into Energy Generation and Distribution, Appendix E.1.4.: ECNSW Greenhouse Strategy.

NIEIR (National Institute of Economic and Industry Research) 1990, *Efficient Renewable Energy Scenario Study for Victoria -- Executive Summary*, Prepared for the Victorian Solar Energy Council, Melbourne, 25 May.

Niland J. 1991, *Establishing the Environment Protection Authority in a Property Rights Environment*, A paper prepared for the Conference on `The New Environmentalism: Applying Economic Solutions in the Real World' sponsored by the New South Wales Cabinet Office, Sydney on 18-19 March.

NSW Ministry for the Environment 1991, *Establishing the Environment Protection Authority for New South Wales - Information Paper*, January.

Prime Minister's Working Group on Greenhouse Gas Emissions 1989, *Reducing Greenhouse Emissions -- Discussion Paper*, December.

Queensland Government 1989, *The Greenhouse Effect -- Implications for Queensland*, June.

Queensland Government 1991a, *Energy Policy Directions for Queensland into the 21st Century*: *A Discussion Paper*, February.

Queensland Government 1991b, *Submission No. 50* to the Industry Commission's Rail Transport Inquiry.

SECV (State Electricity Commission of Victoria) 1990a, *Submission No. 21* to the Industry Commission's Energy Generation and Distribution Inquiry.

SECV (State Electricity Commission of Victoria) 1990b, *The SEC and The Greenhouse Effect -- A discussion paper*, July.

Senate Standing Committee on industry, Science and Technology 1991, Rescue the Future -- Reducing the impact of the greenhouse effect, The Parliament of the Commonwealth of Australia, January, AGPS.

South Australian Government, Department of Environment and Planning 1991, *The Greenhouse Strategy for South Australia*, a report by the South Australian Climate Change Committee, June.

State Pollution Control Commission 1991, *Notes on how the NSW EPA might use Economic Instruments*, New South Wales Government - Dr Pamela Stark.

Toronto Conference 1988, Conference Statement, 27-30 June 1988.

Victorian Department of Manufacturing and Industry Development 1991, *Victoria's Energy Efficiency Strategy: Part I*, June.

Victorian Ministry for Conservation and the Environment 1990, *Greenhouse, Meeting the Challenge --The Victorian Government's Statement of Action*, October.

Victorian Ministry for Planning and the Environment 1989, *The Greenhouse Challenge -- The Victorian Government's Response*, A draft strategy for public comment, June.

Villach Conference 1985, *Conference Statement*, 9-15 October.

Western Australian Government 1988, *Greenhouse --Meeting the Challenge*, December.

Western Australian Greenhouse Coordination Council 1991, *Greenhouse Gas Audit for Western Australia*, Study prepared by Laura Stocker, Institute for Science and Technology policy, Murdoch University, Perth, January.

Western Australian Greenhouse Coordination Council ND, *Addressing the Greenhouse Effect -- A discussion paper.*

Willett, K. 1985, *Mining taxation issues in the Australian federal system* in Drysdale P. and H. Shibata (eds) Federalism and Resource Development: The Australian Case, George Allen & Unwin in association with The Australia-Japan Research Centre, Canberra.

APPENDIX C: THE SCIENCE OF THE GREENHOUSE PROBLEM

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Preamble

This appendix defines the greenhouse problem as the consequences which may flow from the increasing concentration of greenhouse gases brought about by human activities. In preparing this appendix the Commission has drawn heavily on the report of the Intergovernmental Panel on Climate Change (IPCC) Working Group I (WG I). Where possible the Commission has sought to update this report with more recent information, and to summarise other interpretations of the science brought to its attention by way of submissions from participants.

In Section C1 of the appendix the role of the greenhouse gases in the atmosphere as an agent to bring about change in Earth's climate system is reviewed.

Section C2 provides a detailed analysis of the properties of the most important greenhouse gases; water vapour, carbon dioxide, methane and nitrous oxide. In this section it is argued that science provides a high level of knowledge of the radiative heating of the atmosphere which arises from the changing greenhouse gas concentrations but that this is not the same as understanding the warming response of the climate system to the heating.

In Section C2 it is also shown that global monitoring stations have been able to demonstrate that concentrations of certain greenhouse gases are rising because of human activities. These gases are the called the `anthropogenic' greenhouse gases, the principal ones being carbon dioxide, methane and nitrous oxide. While it is clear that a reasonable amount is known about the processes which create and break down these gases, details of their regional and global budgets are incomplete.

In Section C3 the record of the Earth's climate is briefly reviewed with a view to providing an understanding of its natural variability and the processes which lead to change. The modern records of near surface, air temperature, sea surface temperature and sea level are reviewed for evidence of change which could be conclusively related to the increasing greenhouse gas concentrations. It is concluded that such unequivocal evidence of an anthropogenically caused greenhouse effect does not yet exist.

In Section C4 the results from the use of mathematical models in simulating various aspects of the Earth's climate system are reviewed. Recognising that uncertainty exists concerning the precise nature of the feedback systems in the land, ocean and atmosphere systems, and that uncertainty exists concerning future levels of greenhouse gas emissions, a scenario approach to analysing the effects of the changing concentrations of anthropogenic greenhouse gases is examined. From global and national scenarios the possible climatic consequences of a greenhouse problem are presented.

C1 Climate and the greenhouse effect

Climate is a statistical description of the atmosphere, averaged over a significantly longer period than the lifetime of discrete weather systems. The observed climate is the product of the interactions between the physical, chemical and biological processes occurring within the earth-atmosphere system. Figure C1 shows schematically some of the processes occurring within the five major components of the earth/ocean/atmosphere system:

It is a fundamental law of physics that all systems remain in a steady state unless forced to change. Variability of the climate system is driven by external forcings which do not depend on the state of the climate system (eg solar radiation), and internal forcings involving exchanges of mass, momentum and heat energy between components of the earth-atmosphere system. In the context of the greenhouse problem, an internal forcing of crucial importance is that caused by human activities, the so-called ‘anthropogenic forcing’. Table C1 provides some estimates of the periodicities and time scales, of various internal and external forcings.

Table C1: **Mechanisms and time scales of climate change**

External forcings	Periodicity (year)
Eccentricity of Earth's orbit	100 000
Obliquity of Earth's axis	42 000
Precession of equinoxes	21 000
Rotation of the Earth around the Sun	1
Internal forcings	Time scale
Volcanoes	random
Anthropogenic	generally increasing(?)
Land-sea configuration	1 000 000 to 10 000 000
Ocean conditions	1 month to 1 000 years
Land ice	1 000 year
Sea ice	1 month to years
Snow	1 month to years

As will be seen from the analysis of the role of greenhouse gases in the atmosphere, they lead to a heating of the atmosphere, this is called a `thermal forcing' of the climate system. The rate of global warming in response to some thermal forcing is determined by the adjustment times of the system components and the interactions between the components. The interactions between the components are complex and not fully understood creating some uncertainty as to the response of the system to thermal forcing. The adjustment time scales of the components to thermal forcing are estimated to be:

- the atmosphere--adjusts on a time scale of days;
- the ocean -- adjusts on a time scale of decades to centuries;

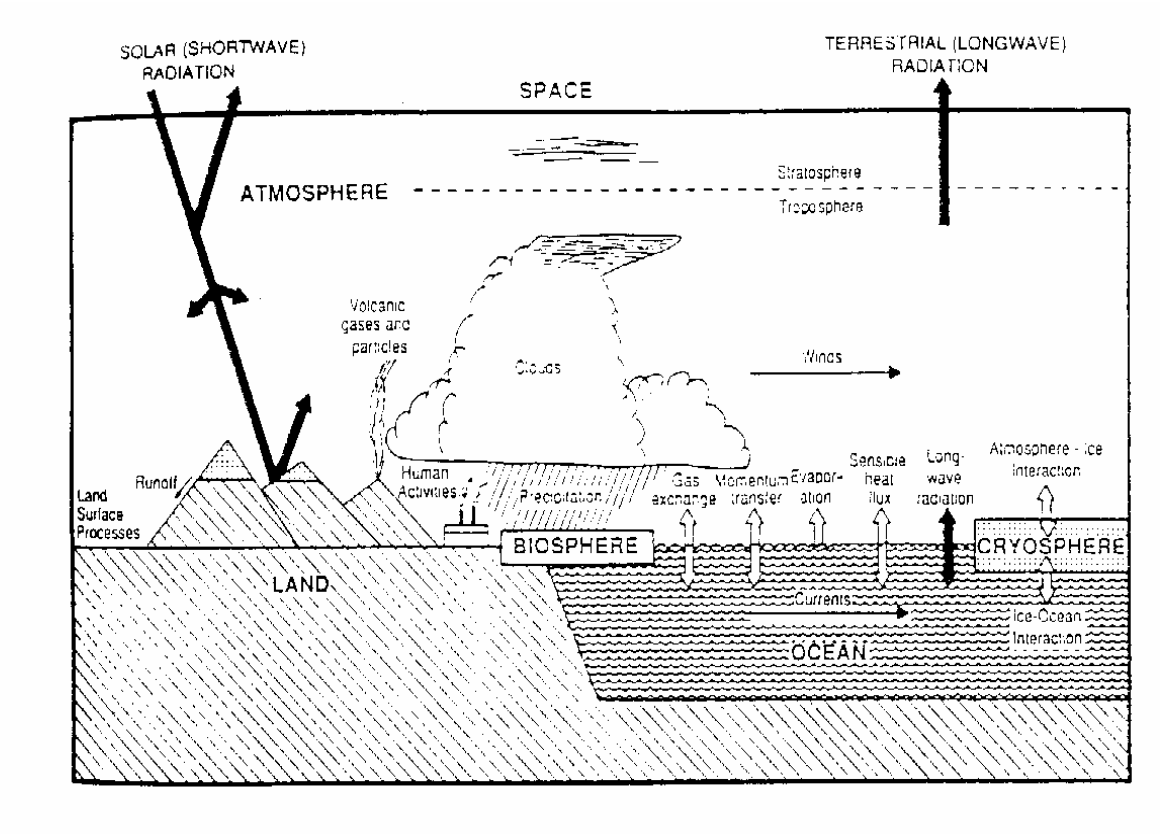
- the land surface -- has components which adjust on all time scales;

- the cryosphere -- adjusts on a time scale of months to centuries;

- the biosphere -- (vegetation and phytoplankton are significant factors) adjusts on a time scale of a season to decades.

It is important to recognise that any forced change of the temperature of the atmosphere will be 'buffered' by feedbacks between it and the more slowly changing components of the system. The two parameters which determine the response of the system are its sensitivity (or absolute response) to the forcing and the time lag between the forcing being applied and the absolute response being observed.

Figure C1: **A schematic representation of the components of the global climate system**



Source: Zillman et al. 1989.

The Earth's climate is driven by solar short wave radiation from the Sun (sunlight). The amount of solar radiation intercepted by a flat disc, perpendicular to the incoming Sun's rays, at the mean distance of the Earth from the Sun is approximately 1380 watts per metre squared (wm^{-2}). This is the so-called ‘solar constant’. As this solar radiation passes through the atmosphere around 31 per cent is reflected back to space by clouds, atmospheric particulates and the Earth's surface, leaving 952 wm^{-2} to be absorbed at the surface. Assuming the energy of the earth-atmosphere system is constant, then an equal amount of energy in the form of infra-red (or long wave) radiation is emitted back to space. For the earth-atmosphere system to achieve a reasonably constant, ‘equilibrium’ temperature (as is observed), the incoming solar radiation must be balanced by losses of energy, in the form of radiation, to space. From this balance requirement, and using the Stefan-Boltzman relationship, it is possible to compute an equilibrium temperature for the Earth of $-18^{O}C1$ (or $255^{O}K$)

The observed global, mean surface temperature of the Earth is around $15^{O}C$ (or $288^{O}K$). The difference in temperature between that calculated by assuming the Earth radiates at its surface temperature, and that observed, is brought about by the gases and clouds in the atmosphere trapping outgoing long wave radiation and re-emitting it back towards the Earth’s surface. This is a natural ‘greenhouse effect’. There is no doubt that the natural greenhouse effect is responsible for the relatively mild climate enjoyed by the Earth at present. As will be shown in Section C2 of this appendix, the level, or atmospheric concentration, of some greenhouse gases (most notably carbon dioxide, methane and nitrous oxide) are increasing because of human activities. This Inquiry is concerned with impacts flowing from a possible anthropogenic enhancement to the natural greenhouse effect. In this report the enhancement of the greenhouse effect by human activities is referred to as the ‘greenhouse problem’.

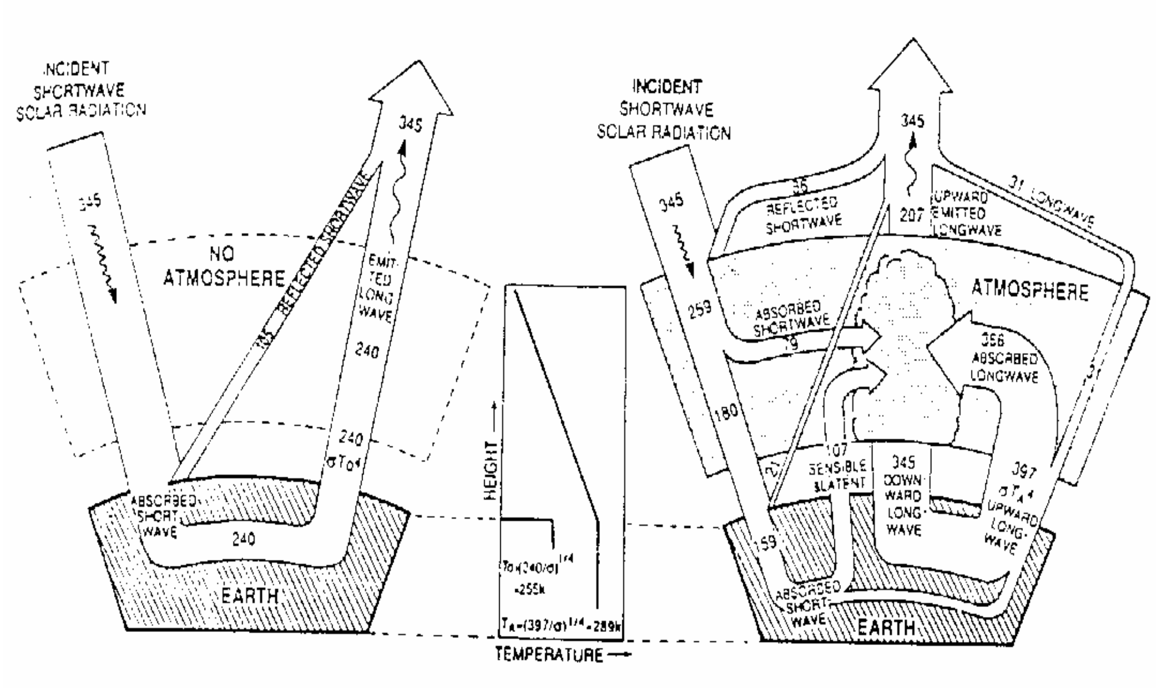
With the solar constant around 1380 wm^{-2}, the annual, globally averaged flux of radiation incident at the top of the atmosphere is 345 wm^{-2}. Figure C2 summarises the greenhouse effect by contrasting the no-atmosphere radiation budget with that for the atmosphere as it is currently believed to be. This schematic indicates that in the absence of the atmosphere (Figure C2, left), the long wave radiation emitted by the Earth's surface at temperature $-18^{0}C$ or ($255^{0}K$) and reflected short wave radiation balances the incoming short wave radiation. In the presence of the atmosphere (Figure C2, right), the situation is more complex: incoming short wave radiation is absorbed by clouds and outgoing long wave radiation is intercepted by clouds and atmospheric gases and re-radiated towards the surface, raising the average temperature to $15^{0}C$.

C2 Greenhouse gases and climate change

In Section C1 of this appendix the physical principles underlying the radiative effects of the greenhouse gases were outlined. This section provides a review of the role played by greenhouse gases in the Earth's climate. The physics and chemistry of the anthropogenic greenhouse gases;

carbon dioxide, methane, nitrous oxide, and the non-anthropogenic greenhouse gas; water vapour, are described. The sources, and the processes which break down the gases (i.e. their ‘sinks’) are identified, both nationally and internationally and where possible a budget for the gas is constructed.

Figure C2: **The Earth's radiation budget: in the absence of the atmosphere** (left), **and with an atmosphere** (right)



Source: Zillman et al. 1989.

C2.1 The radiative properties of greenhouse gases

A gas molecule absorbs energy at specific wavelengths determined by its molecular structure. The major sources of radiation for gas molecules in the Earth's atmosphere are the Sun, which radiates with a black-body temperature of around 6000^0C and the Earth, with a black-body temperature of approximately -18^0C. The major greenhouse gases which absorb radiation from these sources are water vapour and carbon dioxide, with the gases nitrous oxide, methane, ozone and chlorofluorocarbons making smaller contributions.

The absorption of energy by greenhouse gases is termed the ‘radiative heating’ of the atmosphere. The physics of this heating process is well understood and there is no debate within the scientific community concerning the nature of the processes involved. With increasing concentrations of greenhouse gases there will be increased radiative heating of the atmosphere. The greenhouse issue is, how much of this increased radiative heating is manifested as warming of the Earth's climate system? In order to further illustrate the difference between heating and warming the concepts have been described, by way of an analogy, in the box below.

Box C1: **The difference between heating and warming**

Consider two houses which are identical in all regards except that one is fully insulated and the other is not. When the occupants return home, at the same time on a cold winters night each turns on the heater to the highest setting.

The rate of heating will be the same for each house, but the insulated house will warm more quickly and reach a higher equilibrium temperature (i.e. be warmer) than the uninsulated house.

To heat a house, or the Earth, is to supply energy to that entity. Warming is the consequence of retaining some of that energy so that an increase in temperature can be observed.

With the greenhouse problem there is great certainty that increasing greenhouse gas concentrations will lead to increased radiative heating of the atmosphere. There is however uncertainty concerning whether the net effect of all the compensating feedbacks initiated by this heating will lead to substantial, or insignificant, warming.

Any strategy to minimise the cost of meeting a greenhouse gas emission target must correctly identify the relative contribution each of the greenhouse gases makes to planetary warming. Table C2 below lists the important greenhouse gases, their pre-industrial revolution concentrations, current concentrations (1989), the radiative heating (globally) of the current volume of the gas and the lifetime of a molecule of the gas. There are a number of ways of expressing the relative contributions of the gases involving different assumptions and different reference points. Table C2 provides estimates of instantaneous radiative heating of the gases, the simplest way to look at their greenhouse contributions. It is also possible to evaluate the contribution to the atmosphere's change in the rate of absorption of infra-red radiation since the industrial revolution, expressed in absolute terms (units of wm^{-2}) or as a percentage of the total change in the effect. Because the gases have different atmospheric lifetimes, and because the focus of the problem is directed towards what may happen in the future it is not always sufficient to compute the instantaneous, or past radiative heating contributions of a particular gas.

Under the terms of reference of this inquiry, consideration must be given to the costs and benefits to Australian industry of reducing the concentration of the anthropogenic gases not covered by the Montreal protocol. Thus, a detailed analysis of the effects of the chlorofluorocarbons is not given here though they do have a significant atmospheric heating potential. It would also appear that the role of water vapour is outside the scope of the Inquiry as changes in the concentration of water vapour are not a first order effect of human activities. The dominant role of water vapour in the greenhouse process, and the uncertainties associated with its proper role in mathematical general circulation models indicate that its behaviour should be discussed.

Table C2: **The concentrations of the major greenhouse gases in 1850 and 1989, their instantaneous contribution to heating of the atmosphere through radiative processes, and their estimated atmospheric lifetimes**

	Concentration		*Radiative heating*	*Lifetime*
Gas	*1850*	*1989*		
	ppmv	*ppmv*	*wm-2*	*year*
Water vapour	3000	3000	~100	0.02
Carbon dioxide	285	350	~ 50	120a
Methane	0.75	1.70	1.7	10
Nitrous oxide	0.29	.310	1.3	150
CFC - 11	-	.00025	.06	75
CFC - 12	-	.00045	.12	110
Ozone	0.015	0.025	1.3	0.2

a This estimate was derived from modelling work of Siegenthaler (1983).
Source: Zillman et al. 1989 and Pearman 1989.

Of direct concern to the Inquiry is the effect of releasing further volumes of these gases into the atmosphere. This leads to the need to determine the change in contribution to radiative forcing of the atmosphere for future releases of the gas. For some gases with very low concentrations (eg tropospheric ozone), the radiative forcing response is essentially linear. For other gases the change in radiative forcing per unit increase in gas is non-linear (eg radiative forcing due to increasing carbon dioxide concentration increases logarithmically).

Table C3 below gives the functional form of the radiative forcing for the three major greenhouse gases and ozone. Because of the overlapping (in wavelength) contributions of radiative forcing by nitrous oxide and methane a correction function must be calculated to allow for the effect of their relative concentrations.

Having calculated the effect of changing the concentration of gas in the atmosphere from some reference concentration point, it is usual to express this effect relative to the change caused by carbon dioxide. Table C4 gives the instantaneous radiative forcing of the greenhouse gases methane and nitrous oxide expressed in per molecule and per unit mass terms. Since any regulation is likely to focus on the mass of gas emitted it seems most useful to express forcing in per unit mass terms.

Table C3: **Functional form of change in radiative forcing due to change in concentration for the more important anthropogenic greenhouse gases**

Gas	*Radiative forcing function* *ΔF in units of wm^{-2}*
Carbon dioxide	$\Delta F = 6.3 \ln (C / C_o)$
Methane	$\Delta F = 0.036 (\sqrt{M} - \sqrt{M_o}) - \{f(M, N_o) - f(M_o, N_o)\}$
Nitrous oxide	$\Delta F = 0.14 (\sqrt{N} - \sqrt{N_o}) - \{f(M_o, N) - f(M_o, N_o)\}$

$f(M,N) = 0.47 \ln\{1 + 2.01 \times 10^{-5} (MN)^{0.75} + 5.31 \times 10^{-15} M(MN)^{1.52}\}$

Where: C is the concentration of CO_2 in ppmv;
M is the concentration of CH_4 in ppbv;
N is the concentration of N_2O in ppbv;
the subscript (o) denotes the concentration of the gas in the reference state from which the change in radiative forcing is being calculated;
f is the so-called "overlap" term.

Source: IPCC 1990a.

Table C4: **The change in radiative forcing (ΔF) for a change in concentration (Δc) of the major greenhouse gases, normalised by the change for carbon dioxide**

Gas	*ΔF for Δc per molecule relative to CO_2*	*ΔF for Δc per unit mass relative to CO_2*
Carbon dioxide	1	1
Methane	21	58
Nitrous oxide	206	206

Source: IPCC 1990a.Δ

Table C2 shows that the different gases have different lifetimes. To allow for these different atmospheric residence times when evaluating the potential of a gas to contribute to global warming it is necessary to integrate the product of the instantaneous radiative forcing and the concentration over the interval of interest normalised by the same calculation for carbon dioxide. That is, the Global Warming Potential, of a gas is given by (IPCC 1990a):

$$GWP = \frac{\int_o^n a_i c_i \, dt}{\int_o^n a_{co2} c_{co2} \, dt}$$

where: n is the number of years in interval of interest

a is the instantaneous radiative forcing of gas (i)

c is the concentration of gas (i)

co2 is the reference gas, carbon dioxide.

To determine the GWP of a gas over an interval it is necessary to specify the background concentration level of that gas, the rate of dissipation of that gas and whether it is transformed into other greenhouse gases as it dissipates (eg in the atmospheric decomposition of methane carbon dioxide is a possible intermediate product) over the time interval of interest. The same information is required for carbon dioxide. Table C5 shows the results of such calculations assuming that 1 kg of the three major greenhouse gases is released into the atmosphere. Integration intervals of 20, 100 and 500 years are used.

In the discussion of the results presented in Table C5 the IPCC (WG 1, 1990) notes that these results must be considered as preliminary only, because there are uncertainties in the atmospheric chemistry of all gases, including carbon dioxide. These uncertainties mean that the detailed behaviour of a pulse of a gas in the atmosphere (including the variation of concentration with time) is not yet completely known.

Table C5: **Global Warming Potential of the major anthropogenic greenhouse gases normalised by that for carbon dioxide**

Gas	*Estimated lifetime (yr)*	*GWP integration interval (years)*		
		20	*100*	*500*
Carbon dioxide	120a	1	1	1
Methane	10	63	21	9
Nitrous oxide	150	270	290	190

a The choice of a lifetime for carbon dioxide depends on the assumed rate of oceanic sequestering of the gas. This estimate was derived from modelling work of Siegenthaler (1983).
Source: IPCC 1990a.

C2.2 The role of water vapour

While water vapour is a greenhouse gas it is generally not considered to be an anthropogenic greenhouse gas. The source of atmospheric water vapour is primarily evaporation from ocean, lake, river and plant surfaces. This evaporation serves to cool these surfaces. The sink for water vapour is to these, and land surfaces, after condensation and precipitation. The process of condensation leads to heating of the atmosphere (balancing the evaporative cooling at the water vapour source). The typical lifetime of a water molecule as atmospheric water vapour is of the order of a week (Betts 1990).

The concentration of water vapour in the atmosphere is highly variable. In the lowest layers of the tropical atmosphere concentrations around 15 000 ppmv are observed, whereas at the tropopause above the tropics concentrations may be as low as 2 or 3 ppmv.

The synoptic analysis of water vapour on a global scale is undertaken using data from sensors carried aloft by weather balloons (rawinsondes) or from satellites. Rawinsondes provide information on the detailed vertical structure for the column of air through which the balloon ascends. Such ascents occur once or twice a day at around 1200 sites globally. These sites are concentrated over the landmasses and are predominantly in the northern hemisphere (there are 170 sites in the southern hemisphere). Satellites provide higher horizontal resolution water vapour observations, but are only able to provide such data for relatively thick layers of the atmosphere. Satellite derived water vapour measurements are obtained by measuring upwelling energy from the atmosphere at carefully chosen wavelengths, and then solving the radiative transfer equation to determine the water vapour concentration for the radiating layer. This procedure of solving for layer water vapour concentration introduces some uncertainty (or error) into the observation.

The global daily analysis of water vapour, dependent as it is on a very uneven database, has major uncertainties associated with it. Monthly values for atmospheric layers of water vapour can be analysed to derive radiative budgets.

Because water vapour is such a powerful greenhouse gas its behaviour in any assessment of climate in ‘greenhouse’ studies must be considered carefully. The Clausius-Clapeyron equation indicates that water vapour concentration will rise with increasing temperature, a prediction confirmed by observation. This being so, water vapour is generally expected to provide a positive feedback effect from the concomitant increase in water vapour concentration with increasing temperature. Increasing the atmosphere's water vapour concentration may also lead to increased cloudiness. If the resulting clouds are cumulonimbus (thunderstorms) they may increase the upper level cloudiness of the atmosphere. Increased upper cloudiness may serve as a radiation blanket, leading to further earth-atmosphere warming.

It is also possible that cloud induced negative feedbacks may be established. An increase in the number of highly reflective low-level clouds will increase the amount of solar shortwave radiation reflected back to space, thereby cooling the atmosphere. In addition to this Lindzen (1990) proposed two negative feedbacks in the enhanced evaporation-condensation cycle of greenhouse at work in a warming atmosphere. He proposes that the more intense thunderstorm activity of a warmer world could:

- lead to a net drying of the uppermost layers of the atmosphere, thus decreasing the heat 'blanket' effect of the upper atmosphere; and

- deposit heat at a higher level than is currently observed, thereby increasing the rate at which heat is radiated to space.

Those theories of Lindzen, which are not proven, point to the importance and complexity of the role of water vapour in the greenhouse effect. They also illustrate that there remain considerable scientific uncertainties associated with the detailed understanding of the behaviour of water vapour and clouds.

C2.3 The role of carbon dioxide

Atmospheric carbon takes the form of carbon dioxide, however in the other four reservoirs of carbon (the soil, ocean, vegetation and fossil fuel reserves) it may take the form of pure carbon or be a part of some other molecule. Any policy to manage the volume of atmospheric carbon dioxide must be built upon an understanding of the nature of the carbon reservoirs and of the processes which lead to exchanges between them. Table C6 lists the major reservoirs of carbon and estimates by Pearman (1988), Lashof and Tirpak (1990) and the IPCC (1990a) of the amount of carbon sequestered in each reservoir (in metric Giga (109) tonnes). The difference between these estimates provides an indication of the uncertainty attached to the values.

Table C6: **Major reservoirs of carbon**
(Gt)

Reservoir		*Estimated mass of carbon*		
		Pearman (1989)	*Lashof and Tirpak (1990)*	*IPCC (1990a)*
Atmosphere		725	770	750
Vegetation		620	800	550
Oceans		37000	39000	39000
Soil		1300	2300	1500
Fossil fuel reserves		7500	5000	ng
Oceanic sediments	- organic	ng	12000000	ng
	- limestone	ng	50000000	ng

ng - not given.

An estimate of the annual exchanges of carbon between the various reservoirs is given by IPCC (1990a) and shown in Table C7. The primary sinks of anthropogenically emitted carbon are uptake by the oceans and biota. The slow mixing of the oceans and the buffering effect of the oceanic carbonate systems means that the ocean is relatively slow in adjusting to increasing levels of atmospheric carbon dioxide. A second oceanic sink of carbon is the sedimentation of dying organic matter (phytoplankton) in the oceans. The size (and therefore importance) of this sink is unknown and is the subject of considerable research. Table C7 also indicates that annually 197 Gt of carbon enter the atmosphere and 194 Gt is removed. The anthropogenic contribution (including that from deforestation) is around 4 per cent of the carbon entering the atmosphere, a very small fraction of the global sources.

Figure C3 shows a plot of the observed increase with time of the measured carbon dioxide content of the air at the Mauna Loa (Hawaii, USA) measurement site. Similar traces have been obtained from a global network of monitoring stations however the Mauna Loa site, having been the first to commence these observations, provides the longest record. These records indicate unequivocally that the atmospheric carbon dioxide content is increasing at approximately 0.5 per cent per annum. The strong seasonal cycle in Figure C3 is believed to be a result of the uptake by the northern hemisphere mid-latitude forests in their growing season and the general upward trend is believed to be caused by anthropogenic sources of carbon dioxide exceeding the capacity of the sinks to absorb this additional flow of the gas. In summary then, while the data from Table C7 show that anthropogenic sources are only 4 per cent of the annual emissions, Figure C3 shows that the atmospheric carbon dioxide content is steadily increasing, indicating that the Earth's carbon balance is a delicate one.

Table C7: **Global sources of carbon**
(Gt/yr)

Source	*Amount*
Fossil fuel burning	+5a
Deforestation	+2
Soil – Atmosphere	+50
Biota - Atmosphere	+50
Atmosphere - Biota	-102
Atmosphere - Ocean	-92
Ocean - Atmosphere	+90
TOTAL	+3

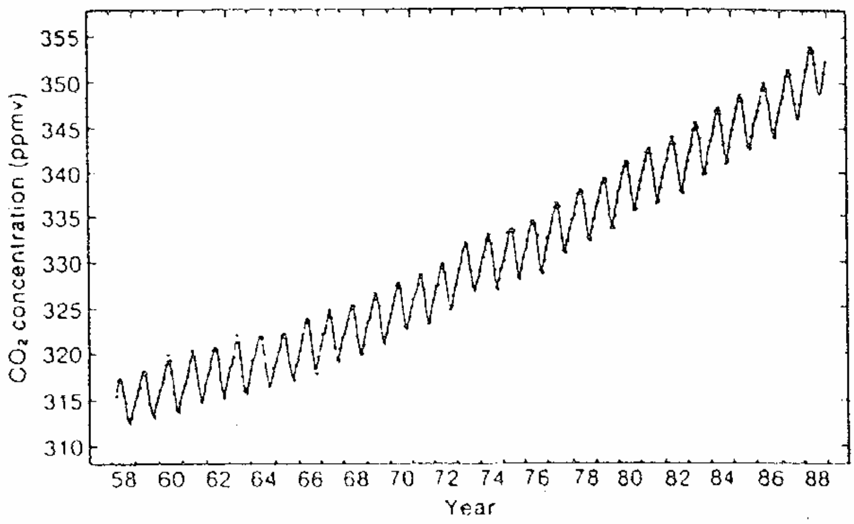
a An exchange which increases the atmospheric carbon content is denoted with a positive sign. Values for exchanges are representative of those quoted in the literature in the mid-1980s.
Source: Derived from Figure 1.1 in IPCC 1990a.

C2.4 Carbon dioxide emission by nation

Anthropogenic carbon dioxide emissions arise through the combustion of fuels in the production of energy and through the burning of forests in land clearing operations.

Table C8 provides data showing the per capita energy consumption, per capita carbon emission, total carbon and carbon dioxide emissions and percentage of the total emissions for a number of countries for 1987. This list, compiled from a Department of Foreign Affairs and Trade report (DFAT 1990) does not contain information for all countries emitting carbon, but does cover the major nations and is generally representative of all sectors of the globe excepting Africa. The Commission believes that at the present time a more comprehensive data set is not generally available. The OECD and the IEA are working together to develop a comprehensive global inventory of greenhouse gas emissions and sinks, as the work of the experts involved in this process progresses the global picture regarding carbon dioxide sources and sinks should become clearer.

Figure C3: **Monthly average carbon dioxide concentration in parts per million of dry air observed at Mauna Loa, Hawaii, USA**



Source: Keeling et al. 1989.

It must be noted that the carbon dioxide emission total given in Table C8 is not precisely that for the globe (as some nations are not included here). It closely approximates estimates for the global emission and will be taken as such. These estimates may differ to those from other sources (see for example Table 2.5). When differences in estimates of emission levels have been encountered in data obtained from reputable sources the Commission has generally been unable to determine which data are correct (or indeed if any are). Such differences between estimates of global and national emissions highlight the uncertainties in assessing greenhouse gas emission levels generally. The large number of countries for which DFAT was able to make estimates, and the fact that a consistent methodology was used to obtain these estimates, makes these data useful for comparative purposes.

Inspection of Table C8 reveals that four countries were individually responsible for more than 5 per cent of global carbon emissions in 1987: USA (23 per cent), Brazil (18 per cent) USSR (10 per cent), and China (10 per cent). These data show that Australia is responsible for around 1.4 per cent of the global emissions of carbon dioxide. On a per capita basis the three largest emitters were: Brazil (9.1t), GDR (5.4t), and USA (5t) with Australia (4.7t) recording the fourth highest emission rate. The high level of per capita emissions for Brazil arise because the carbon dioxide emitted during combustion of biomass in the Amazon basin has been taken into account. It is possible that inclusion of some very small countries (particularly Gulf states) could change the per capita rankings, however their contribution to the global budget is generally very small.

It is possible to gain an assessment of the reduction in carbon dioxide emission levels needed to meet the Toronto target of a 20 per cent emission cut by the year 2005 by using population projections for that year and the per capita emissions given in Table C8. Whitaker's Almanac (1990) provides population estimates for the year 2000 for a number of geographical regions (Europe, Asia, Latin America, North America, Oceania and Africa). These estimates were extrapolated to the year 2005 and the implied growth rate of each region applied to the populations of the individual countries from Table C8 that were located in the region. Using this methodology the 1987 carbon dioxide emission total of 21 148 Mt was forecast to grow to 28 613 Mt in 2005 assuming no change in per capita emissions. To meet the Toronto emissions target for the year 2005 of 16 918 Mt (that is, a 20 per cent reduction from 21 148 Mt), and given the expected population growth, there will need to be a global per capita reduction in emissions of 40.9 per cent.

Noting that the IPCC WG I Report (1990) argues that a 60 per cent reduction in long lived gases (including carbon dioxide) is needed to stabilise concentrations at today's levels, this implies a carbon dioxide emission target for this group of countries of 8460 Mt for 2005. With the expected population growth the per capita reduction in emissions from 1988 levels to meet this target would be 70 per cent.

Table C8: **Estimated carbon dioxide emissions by nation for 1987**

Country	*Per capita energy consumption*	*Per capita carbon emission*	*Total carbon*	*Total carbon dioxide*	*% of global carbon dioxide emission*
	GJ	*T*	*MT*	*MT*	*%*
United States	280	5.0	1155.6	4237.0	20.04
Canada	291	4.3	109.0	399.8	1.89
Austria	118	2.0	15.1	55.4	0.26
Belgium	163	2.7	26.6	97.6	0.46
Denmark	157	3.3	16.9	62.0	0.29
Finland	167	3.0	14.7	53.8	0.25
France	109	1.7	93.2	341.8	1.62
FRG	165	3.0	183.1	671.4	3.17
GDR	231	5.4	89.9	329.5	1.56
Greece	72	1.6	16.0	59.5	0.28
Ireland	101	2.1	7.2	26.5	0.13
Italy	105	1.8	102.8	377.1	1.79
Netherlands	213	2.5	36.1	132.5	0.63
Norway	345	2.9	12.0	44.1	0.21
Portugal	39	0.8	8.1	29.7	0.14
Spain	62	1.2	46.6	170.8	0.81
Sweden	147	1.9	15.8	58.1	0.27
Switzerland	111	1.7	11.04	0.3	0.19
United Kingdom	150	2.8	156.2	572.7	2.71
Poland	141	3.4	125.0	458.2	2.17
USSR	194	2.7	578.9	2122.6	10.04
Australia	240	4.7	77.6	284.5	1.42
New Zealand	113	1.8	6.0	21.8	0.10
Japan	110	2.1	254.2	932.1	4.41
Argentine	56	1.0	27.9	102.2	0.48
Brazil	22	9.1	1083.8	3974.0	18.79
Mexico	50	1.4	110.3	404.5	1.91
China	22	0.6	604.9	2218.0	10.49
Republic of Korea	52	1.1	46.2	169.4	0.80
India	8	0.4	274.1	1004.9	4.75
Indonesia	8	1.5	247.5	907.5	4.29
Malaysia	38	3.1	48.9	179.3	0.85
Singapore	140	3.0	7.6	27.8	0.13
Thailand	14	2.1	108.8	398.9	1.89
Saudi Arabia	185	3.7	45.9	168.2	0.80
			5767	21148	100.00

Source: DFAT 1990. Data for Australia from ABARE 1991.

C2.5 Australia's carbon dioxide emissions

It is possible to envisage a number of scenarios for the development of the Australian economy over the period 1992 - 2005 which will lead to quite different rates of energy usage by the various sectors of the economy. A recent report (ABARE 1991) documents past energy usage and provides estimates of rates of consumption for the various energy types for financial years through to the year 2004-05. The Toronto emission targets appear to refer to calendar years rather than financial years, indicating the need to convert the ABARE past and projected consumption figures to a calendar year basis. Table C9 shows the results of this energy demand analysis, with calendar year data being obtained by averaging the data for the two financial years overlapping the calendar year. Data for 2005 were obtained by extrapolating linearly the trends from the previous year.

Table C9: **Total energy consumption by fuel for Australia for calendar years through to 2005**

(PJ)

	Energy consumption				
Calendar year	*Black coal*	*Brown coal*	*Renewable*	*Crude oil*	*Natural gas*
1987	1026.8	414.5	219.1	1341.5	599.5
1988	1080.9	449.9	226.3	1400.0	619.2
1989	1139.3	464.4	232.0	1442.0	658.0
1990	1183.1	472.1	237.2	1477.1	692.0
1991	1224.6	492.2	247.7	1516.4	709.2
1992	1265.7	491.2	256.6	1550.5	737.8
1993	1315.7	494.1	261.3	1573.7	770.3
1994	1372.7	510.7	263.5	1590.1	793.2
1995	1401.6	525.7	266.0	1622.1	810.2
1996	1412.0	535.1	269.3	1652.6	836.5
1997	1439.5	544.9	272.8	1678.5	855.6
1998	1478.5	554.7	276.6	1708.3	860.7
1999	1516.8	564.7	280.5	1739.3	866.9
2000	1556.8	562.8	284.6	1766.3	881.3
2001	1583.5	545.7	288.5	1789.7	922.7
2002	1608.2	529.8	292.2	1813.0	967.1
2003	1638.9	515.3	296.0	1839.4	1003.6
2004	1669.9	501.4	300.1	1866.4	1042.1
2005	1684.9	494.4	302.2	1879.9	1061.4

Source: ABARE 1991.

The mass of carbon dioxide emitted through using the volumes of energy listed in Table C9 may be calculated by using standard carbon dioxide emission coefficients for the various fuels. Estimates of the emission coefficients, which give the amount of energy released when the various fossil fuels are burnt, vary considerably depending upon the source of the data. Table C10 shows in summary form some of these estimates. It is believed that the differences between the estimates arise because of the different qualities of fuel being used by the various testing laboratories.

Using the emission coefficients of Wilkenfeld (Sub. 9) the actual and forecast carbon dioxide emission levels for the carbon based fuels used in Australia have been computed (Table C11). Carbon dioxide emissions for renewables such as bagasse and wood have not been calculated. For bagasse it is possible that in the long run the amount of carbon dioxide emitted through the burning of sugar cane as bagasse is re-absorbed by the crop of the following season. For wood products the assumption of a carbon dioxide equilibrium may not be a good one however definitive data concerning the carbon dioxide balance of the Australian forest industries are not available. Renewable energy sources such as solar and hydro-electricity do not give rise to carbon dioxide emissions.

Table C10: **Estimates of emission coefficients, by fuel type**
(kt/PJ)

	Energetics	*Walker* [a]	*CRA*	*AIP*	*Steinberg* [b]	*Wilkenfeld*		*Methane* [e]
Fuel type						*Primary form* [c]	*End use* [d]	
Black coal	-	92	92	104.1	87.0	89.3	90.7	0.10
Brown coal	106.4	95	95	112.7	-	94.4	95.2	-
Renewables								
(Wood & bagasse)	96.0[f]	-	80	78.9	-	96.3 [f]	96.3 [f]	-
Petroleum products	76.4	77	73	73.2	68.2	68.6	74.9	0.03
Natural gas	54.2	55	59	54.9	49.1	52.7	60.7	0.21

a Converted from Mt C to Mt CO_2 by multiplying by 44/12. b Converted from $lbCO_2$/1000BTU by multiplying by 426.54. c Primary form denotes the amount of CO_2 released from burning the fuel in its primary form. d Final form includes primary form emissions plus those released in extracting, processing and transporting the fuel. e Commission estimates based on CSIRO (Sub. 61) and ABARE (1991). These coefficients can vary by as much as a factor of 3 either way. f Wood only.
Units: kt - kilotonne, PJ - petajoule (1015 joules), MtC - million tonnes carbon, Mt CO_2 - million tonnes carbon dioxide,
$lbCO_2$- pounds of carbon dioxide, BTU - British thermal units.
Sources: Energetics 1990, Walker 1990, CSIRO (Sub. 61), CRA 1989, AIP 1989, Steinberg 1984 and Wilkenfeld (Sub. 9).

C2.6 Carbon dioxide sinks

Through the process of photosynthesis all plant life extracts carbon dioxide from the atmosphere and stores carbon in its tissues. This trapping of carbon in plant matter is referred to as sequestration. Trees trap carbon as wood and release it back to the atmosphere when the wood rots or burns. Forest products are a form of carbon storage; as paper products the storage can be relatively short-term, as furniture or structural timber the storage can be for decades or centuries.

Organic matter in soil is another form of sequestered carbon. This carbon can be returned to the atmosphere when soil is tilled. Current estimates are that in 1990 4 Mt of carbon (15 Mt of carbon dioxide) was released to the atmosphere by soil cultivation and cropping in Australia, whereas soil organic matter increased by about 8.1 Mt of carbon (30 Mt of carbon dioxide) in that year due to pasture improvement (AIAS, Sub. 80).

The consideration of sources and sinks of carbon dioxide together makes it possible to prepare a national budget for carbon dioxide emissions. Table C12 provides an estimate of such a budget. Perhaps the most striking feature of this budget is the very high sequestration rate of carbon dioxide attributed to carbon dioxide fertilisation of vegetation.

The oceans provide a major sink for atmospheric carbon. The oceans absorb carbon dioxide directly from the atmosphere and also gain carbon from the sedimentation of organic matter. As the ocean warms the solubility of carbon dioxide decreases and the carbonate equilibrium shifts towards carbonic acid. These effects combine to increase the partial pressure of carbon dioxide in the ocean by about 4 to 5 per cent for a fixed alkalinity and total carbon content. Because the total carbon content would only have to decrease by about one tenth this amount to restore the carbon dioxide partial pressure to its previous level, the impact of this feedback is to increase atmospheric carbon dioxide by about 1 per cent per ^{o}C temperature rise.

Table C11: **Carbon dioxide emission levels**
(Mt)

Year	*Black coal*	*Brown coal*	*Crude oil*	*Nat'l gas*	*Total*
1988	96.5	42.5	96.0	32.6	267.7
1989	101.7	43.8	98.9	34.7	279.1
1990	105.6	44.6	101.3	36.5	288.0
1991	109.4	46.4	104.0	37.4	297.2
1992	113.1	46.4	106.4	38.9	304.7
1993	117.5	46.6	108.0	40.6	312.7
1994	122.6	48.2	109.1	41.8	321.7
1995	125.2	49.7	111.3	42.7	328.8
1996	126.1	50.5	113.4	44.1	334.1
1997	128.6	51.4	115.2	45.1	340.3
1998	132.1	52.4	117.2	45.4	347.0
1999	135.5	53.3	119.3	45.7	353.8
2000	139.0	53.1	121.1	46.4	359.8
2001	141.5	51.5	122.8	48.6	364.4
2002	143.6	50.0	124.4	51.0	369.0
2003	146.4	48.6	126.2	52.9	374.0
2004	149.1	47.3	128.0	54.9	379.3

Source: Derived from Tables C9 and C10.

Any strategy to remove carbon from the atmosphere will be, by necessity, based around sequestration of the element in timber reserves, as a stable solid stored underground or in the ocean. Edmonds et al., (1986) provide a review of possible mechanisms for `stripping' carbon from industrial processes which emit carbon dioxide, while Barson and Gifford examine the impact of tree planting on Australia's atmospheric carbon budget.

Table C12: Net anthropogenic carbon dioxide emissions and sinks for Australia: 1990 (MT CO_2)

$C0_2$ emission sources		*Annual sequestration or fixation of carbon to land systems*	
Fossil fuels	287	Soil cultivation and cropping	-15
Wood and bagasse	16	Soil Organic matter/improved pastures	30
Cement manufacture	4	Shrub encroachment	5
		Net deforestation and land disturbance	-10
		Wildfire suppression	23
		CO_2 fertiliser effect	110
Subtotal	307	Subtotal	143
Net $C0_2$ emissions	164		

Source: AIAS (Sub. 80).

Control of carbon dioxide at the point of emission

Removal and recovery of carbon dioxide from gas streams can be accomplished by absorption in liquid solvents or solids which may be chemically reactive or non-reactive. Edmonds et al. (1986) demonstrate that around 20 per cent less energy is expended in the absorption process using liquids compared to solids though the principles of the techniques are essentially similar.

Liquids which may be used in the stripping process include:

- water;
- aqueous sodium carbonate;
- aqueous potassium carbonate;
- sodium hydroxide;
- amines;
- other non-reactive solvents; and
- chemically active solvents such as NH3, alkazid.

Edmonds et al. (1986) present the results of a study using monoethanolamine as a carbon dioxide solvent with disposal of the waste product in the ocean. They note that one 500 MW non-fossil fuel power station is required to separate all the carbon dioxide from the gas stream of a 1000 MW coal fired power station operating at 38 per cent efficiency.

Solids which may be used in the stripping process include:

- naturally occurring sorbents (eg clay, zeolites);
- waste shale oil;
- sorbents (silica, molecular sieves); and
- coal, char, carbon.

A calculation by Edmonds et al. (1986) assuming the use of molecular sieves and disposal of the waste in abandoned mines indicates that a non-fossil fuel power plant of 710 MW capacity would be required to strip the carbon dioxide from the output gas stream of a 1000 MW power station.

From these studies it may be conclude that if stripping of carbon dioxide was to be used as a preliminary step in sinking atmospheric carbon to the Earth or oceans a substantial non-fossil fuel source of energy would be needed to drive the system. Noting the efficiency of the stripping process it must be concluded that the efficiency of electricity generation within coal fired power stations must be raised substantially and the effectiveness of the absorbents needs to be improved before the process could be considered viable.

Use of forests as an enhanced carbon dioxide sink

Sequestration of carbon in trees can affect a nation's carbon dioxide budget in a number of ways depending upon forest management techniques and the use of the forest products:

i) an increase/decrease in the size of the forest areas will produce a one-off decrease/increase in the anthropogenic stock of atmospheric carbon dioxide spread over the period the forest takes to reach maturity;

ii) replacing a non-renewable energy source (eg electricity sourced from a coal fired power station) with wood (from a long-run, steady-state plantation) reduces the (flow) emissions of carbon dioxide in an on-going fashion;

iii) replacing, in an ongoing fashion, high input energy building materials (eg metal components) with wood (from a long-run, steady-state plantation) extends the sequestration period of wood (decreases atmospheric carbon dioxide stocks) and has an ongoing impact in reducing emissions because of the substitution of low for high energy materials.

Currently Australian forests contain a standing reserve of about 19 Gt of carbon. Timber harvesting in 1989 removed an estimated 4.9 Mt from the forest carbon stocks (2.6 Mt hardwoods, 1.3 Mt softwoods) (RAC 1991). The RAC (1991) notes that it is not clear whether Australia's forests are in carbon balance or gaining or losing carbon while evidence submitted to this inquiry by the AIAS (Sub. 80) suggests that Australia's forests and scrublands are still a net source of carbon dioxide though the rate of release of the gas has been decreasing in recent times.

An assessment of the impact of a tree planting program on the Australian atmospheric carbon dioxide budget is provided by Barson and Gifford (1990). In their analysis Barson and Gifford (1990) consider only that effect which tree planting has on carbon dioxide stocks through the extraction of carbon from the atmosphere (see dot point i) above). They do not provide a detailed analysis which explicitly considers the potential for wood to displace high energy content materials, however by their consideration of different rates of return of sequestered carbon to the atmosphere they do implicitly consider the effect of alternative uses of the wood from the plantations.

Barson and Gifford (1990) consider three scenarios:

i) Planting 40 000 ha/yr of trees each year for 40 years. The trees are then progressively harvested as they reach an age of 40 years. Under this scenario, assuming half the sequestered carbon has re-entered the atmosphere ten years after harvesting, a peak carbon absorption rate of 11 Mt/yr is reached 40 years after commencement of the program and the amount of carbon removed from the atmosphere asymptotes to 180 Mt.

ii) Maintaining the planting program given in scenario i) for 100 years. The asymptotic standing biomass under this scenario is 390 Mt.

iii) Planting 10 000 ha/yr for 10 years with soft woods for paper pulp production. After 10 years 100 000 acres are maintained under this soft wood production management strategy. Under this scenario, assuming that half the sequestered carbon will have re-entered the atmosphere by 2 years after harvesting, 4.2 Mt of carbon will be sequestered in these forests.

For a tree planting program to be effective in decreasing the atmospheric carbon stocks it is necessary that previously cleared agricultural land be used. Barson and Gifford (1990) estimate that scenario i) would require the utilisation of 3.3 per cent of Australia's agricultural land as plantations. The success of such a program would also be dependent on the economics of the industry. To maximise the decrease in atmospheric carbon sawn timber rather than pulp woods should be the end product. Barson and Gifford (1990) point out that demand for sawn timber would need to increase by 2 to 3 times current levels to absorb the scenario i) production.

The impact of a tree plantation scheme to reduce atmospheric carbon levels is relatively small. The scenario i) scheme would absorb around 10 to 15 per cent of Australia's 1988 gross anthropogenic emissions at its time of maximum absorption under the accounting process outlined. If high energy building materials were displaced by the wood the carbon reductions could be higher. The scheme may provide other benefits in terms of stabilisation of ground water levels in selected areas thereby reducing salinity problems. A tree planting scheme could also provide for a reduction in net emissions during a time when alternative greenhouse gas emission reduction technologies were being developed, however as Gifford (1991) notes:

> it is more efficient to leave carbon in the ground, where it is more compact as coal .... than storing it above ground as trees.

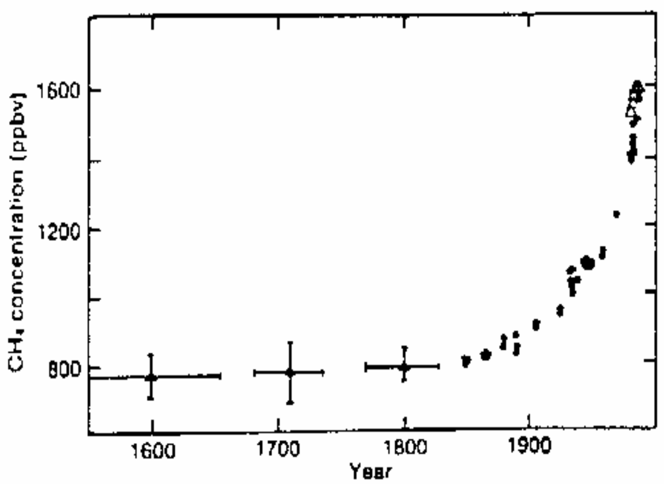
Gifford is thus suggesting that if atmospheric stocks of carbon are to be drawn down in the long-run, then emission reduction methods should be put in place which will ensure that carbon remains in its most efficient storage form; as coal. As a corollary to this it may be inferred that the viability of tree planting as a sink for atmospheric carbon may ultimately be determined by considerations other than the impact such a program would have on the atmospheric greenhouse gas budget.

C2.7 Global sources of methane

Methane is produced in the anaerobic decay and combustion of organic matter. Sources of methane include rice paddies, ruminants, biomass burning, gas and coal fields and landfills.

The amount of methane in the atmosphere has been increasing for a considerable time. Long term observations during the past three decades indicate an average yearly increase by about 1.1 per cent (Crutzen 1988). Furthermore, analyses of air trapped in ice cores have shown that the atmospheric methane content before 1650 was around half the present concentration. Figure C4 shows atmospheric methane variations for the past four centuries. The most striking feature of this figure is the relatively rapid increase in the concentration of methane after 1800.

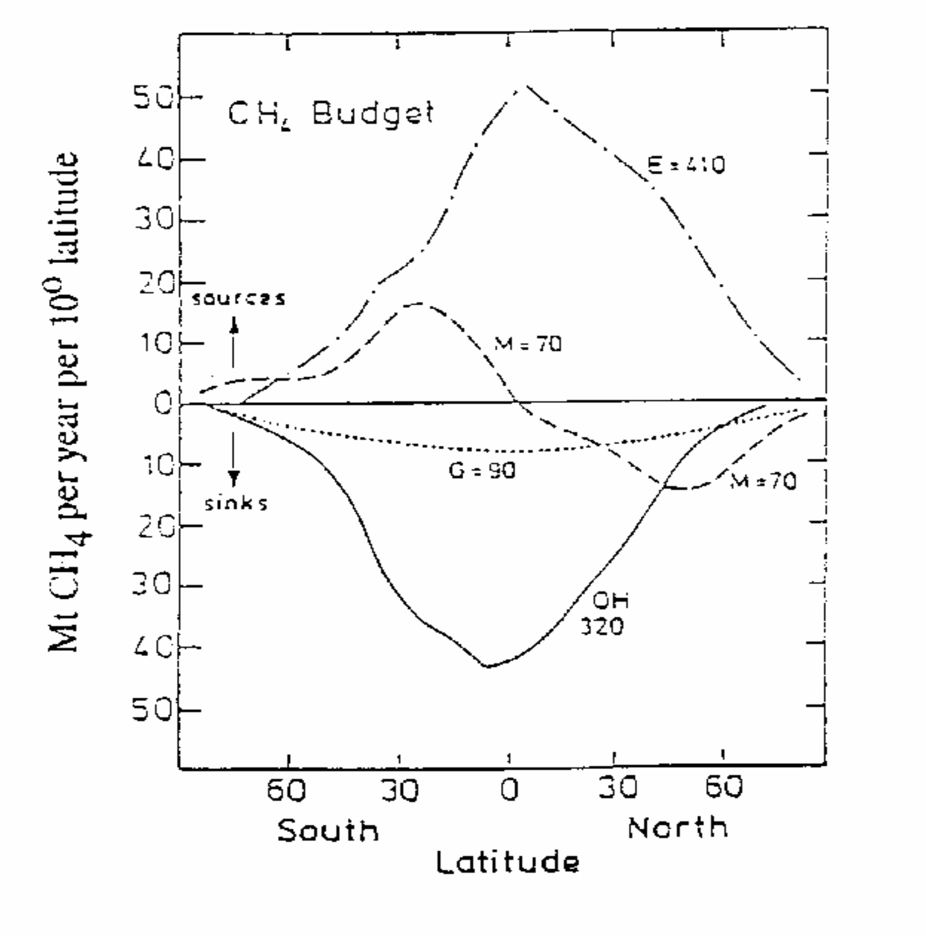
Figure C4: **Atmospheric methane variations over the past four centuries determined by the dating of air trapped in ice cores**



Source: Data from Etheridge et al. 1988, Pearman and Fraser 1990. IPCC 1990a.

Figure C5 shows the latitudinal distribution of methane sources and sinks. The major source of methane is equatorial in origin with a secondary source located near 40°N. There is a net transport of methane to the southern hemisphere with destruction of the species being largely dependent on the presence of the hydroxyl (OH) radical.

Figure C5: **Calculated and estimated sources and sinks of methane** (Mt per year)



OH = destruction by OH (320 x 1012g); M = transport from northern to southern hemisphere (70 x 1012g); G = annual growth (90 x 1012g); E = total source (410 x 1012g).

Source: Crutzen 1988.

Table C13 provides estimates of the methane emissions by country. On a per capita basis New Zealand and Canada have the highest emissions, presumably due to releases from natural gas fields and animal production. Canada, USA, China and India are the major contributors to the global emissions of methane (together they account for 68 per cent of estimated emissions).

Table C13: **Estimated gross anthropogenic methane emissions by country in 1987**

Country	*Per capita*	*Total*	*Share of global*
	t	*Mt*	*%*
USA	0.17	39.29	12.97
Canada	4.30	109.05	36.00
Austria	2.00	15.10	4.98
Belgium	0.04	0.39	0.13
Denmark	0.05	0.26	0.08
Finland	0.04	0.20	0.06
France	0.08	4.39	1.45
FDR	0.04	2.44	0.81
GDR	0.04	0.67	0.22
Greece	0.03	0.30	0.10
Ireland	0.12	0.41	0.14
Italy	0.03	1.71	0.57
Netherlands	0.19	2.75	0.91
Norway	0.16	0.66	0.22
Portugal	0.03	0.30	0.10
Spain	0.03	1.16	0.38
Sweden	0.03	0.25	0.08
Switzerland	0.04	0.26	0.09
United Kingdom	0.08	4.46	1.47
Poland	0.06	2.21	0.73
USSR	0.07	15.01	4.95
Australia	0.27	4.25 a	1.40
New Zealand	0.43	1.42	0.47
Japan	0.03	3.63	1.20
Argentina	0.12	3.34	.10
Brazil	0.06	7.15	2.35
Mexico	0.08	6.30	2.08
China	0.03	30.25	9.98
Korea	0.02	0.85	0.28
India	0.04	27.41	9.05
Indonesia	0.04	6.60	2.18
Malaysia	0.03	0.47	0.16
Singapore	0.00	0.00	0.00
Thailand	0.10	5.18	1.71
Saudi Arabia	0.39	4.84	1.60
		302.94 b	100.00

[a] CSIRO (Sub. 61), (shown in Table 13) estimate Australia's methane production to be 3.3 Mt/yr in the late 1980s. [b] This incomplete global estimate of gross anthropogenic emissions may be compared with the global emissions value (anthropogenic and natural sources) of 410 Mt shown in Figure C5, and the considerably higher estimate used by the IPCC (see for example Fig. C7(b)).
Source: DFAT 1990.

C2.8 Australia's methane sources and sinks

Table C14 provides estimates of the mass of methane produced and destroyed annually in Australia by the major sources and sinks. The uncertainty associated with the terms of this budget is illustrated by the range between the upper and lower estimates for the budget terms and by the qualification that the budget is representative generally of a year in the late 1980s.

The dominant Australian, anthropogenic sources of methane are domestic animals and landfills, with emissions from natural gas production and mining also important source terms. Biomass burning is a significant source of methane, it is estimated that 60 per cent of the annual average area of Australia burnt by bushfires is lit by humans, however perhaps as much as half of this area would have been ignited by natural means had it not been deliberately fired. It is also possible that since white settlement of Australia the incidence of bushfires has been reduced from that occurring under aboriginal land practices.

Table C14: **Annual methane surface exchange budgets for Australia**
(Mt)

Source	*CSIRO ESTIMATES (Late 1980s)* *Lower estimate*	*Best estimate*	*Upper estimate*	*AIAS ESTIMATES (1990)*
NATURAL				
Biomass burning	0.37	**1.10**	3.30	**1.20**
Dryland (uptake)	-0.83	**-2.50**	-7.50	**-2.66**
Natural wetlands	0.04	**0.20**	1.00	**0.21**
Kangaroos	0.0007	**0.002**	0.006	**ng**
Termites	0.23	**0.70**	2.10	**0.70**
TOTAL NATURAL	-0.19	**-0.50**	-1.09	**-0.55**
ANTHROPOGENIC				
Domestic animals	1.30	**2.00**	3.00	**2.06**
Landfills	0.40	**0.80**	1.60	**0.80**
Natural gas	0.05	**.10**	0.2	
Mining	0.10	**0.30**	0.90	**0.40** [a]
Motor vehicles	0.027	**0.05**	0.075	**0.05**
Rice	0.013	**0.04**	0.12	**0.06**
TOTAL ANTHROPOGENIC	1.89	**3.30**	5.90	**3.37**
TOTAL	1.70	**2.70**	4.81	**2.82**

ng - not given. [a] This figure (0.40 Mt) combines methane emissions from natural gas leaks and mining.
Source: CSIRO (Sub. 61) and AIAS (Sub. 80).

There are two identified sinks for tropospheric methane; oxidation within the atmosphere by reactions initiated by the presence of the hydroxyl radical, and oxidation by methanotrophs (bacteria) within the soil. The chemical path by which the oxidation of methane proceeds has a number of steps, with two possible alternatives according to the chemical composition of the environment. In each case the presence of the hydroxyl radical is essential for the process. Crutzen (1988) notes that the two possibilities for the oxidation of methane depend upon whether the environment of the reaction is rich or poor in oxides of nitrogen. The oxidation of methane commences with the following step:

$$CH_4 + OH \rightarrow CH_3 + H_2O$$

In an NO rich environment the following net reaction occurs:

$$CH_4 + 4O_2 \rightarrow CH_2O + H_2O + 2O_3$$

In an NO poor environment the net reaction is:

$$CH_4 + O_2 \rightarrow + CH_2O + H_2O$$

The hydroxyl radical is formed through the absorption of ultra-violet radiation by ozone (O3) in the following fashion:

$$O_3 + h\nu \rightarrow O(1_D) + O_2 \quad (<310 \text{ nm})$$

$$O(1_D) + H_2O \rightarrow 2OH$$

From this it may be concluded that the concentration of the hydroxyl radical in the lower troposphere is directly related to the concentration of tropospheric ozone. Typically the concentration of tropospheric ozone is in the range $20 * 10^{-9}$ to $100 * 10^{-9}$ parts by volume (ie 20 to 100 ppbv). The concentration of the hydroxyl radical has been inferred by Crutzen (1988) to be around $3 * 10^{-14}$ parts by volume.

Only about one quarter of the tropospheric hydroxyl radicals react with methane, the remainder react with carbon monoxide. The first step in this reaction process is:

$$CO + HO \rightarrow H + CO_2$$

In an NO rich environment the net reaction which occurs is:

$$CO + 20_2 \rightarrow CO_2 + O_3$$

While in an NO poor environment the net reaction which follows is:

$$CO + O3 \rightarrow CO2 + O2$$

Clearly the circumstances which will maximise the rate of oxidation are those for which the atmospheric concentrations of the hydroxyl radical are highest. It is not clear what the impact of the increasing concentrations of pollutants will be on the availability of the hydroxyl radical for reactions such as these.

This literature survey has failed to identify any studies which examine the possibility of anthropogenically enhancing the atmospheric concentrations of the hydroxyl radical, or establishing an otherwise chemically favourable atmospheric environment for the oxidation of methane, in the vicinity of known methane sources (rice paddies, ruminants, coal mines etc.).

CSIRO (Sub. 61) indicates that as methane emitting swamps dry, the soil they contain can become methane consuming. The methane uptake in this situation is the result of activity by methane consuming bacteria known as methanotrophs. Oxidation of methane by this process is highly sensitive to moisture levels and affected by the application of nitrogen fertilizers but is thought to be independent of temperature. The observed fluxes reported to be in the range (2 to 250) * 10^{-9} kg of methane per m^2 per hour (Sub. 61). The data presented in Table C14 show this sink to be of considerable significance in the Australian methane budget. As was with the case for the atmospheric sink of methane, there is no reported analysis of how this sink might be anthropogenically enhanced in a cost effective manner.

C2.9 The role of nitrous oxide

While it is possible to accurately monitor the change in atmospheric concentration with time of nitrous oxide it is the gas for which regional budgets are the most unreliable (eg CSIRO Sub. 61 and AIAS Sub. 80). The atmospheric concentration of nitrous oxide is currently increasing at about 2.5 per cent per year due to microbial processes in soil, the burning of biomass and fossil fuels, the use of nitrogen fertilizers in cropping, and by the oceans. Figure C6 shows the nitrous oxide concentration increase determined from air sampling over the past decade (upper chart) and the variation of concentration inferred from ice core records over the past four hundred years.

Galbally (1985) provides a detailed review of the sources and sinks of nitrous oxide. The production of nitrous oxide (N2O) in soil commences with the biological oxidation of fixed nitrogen:

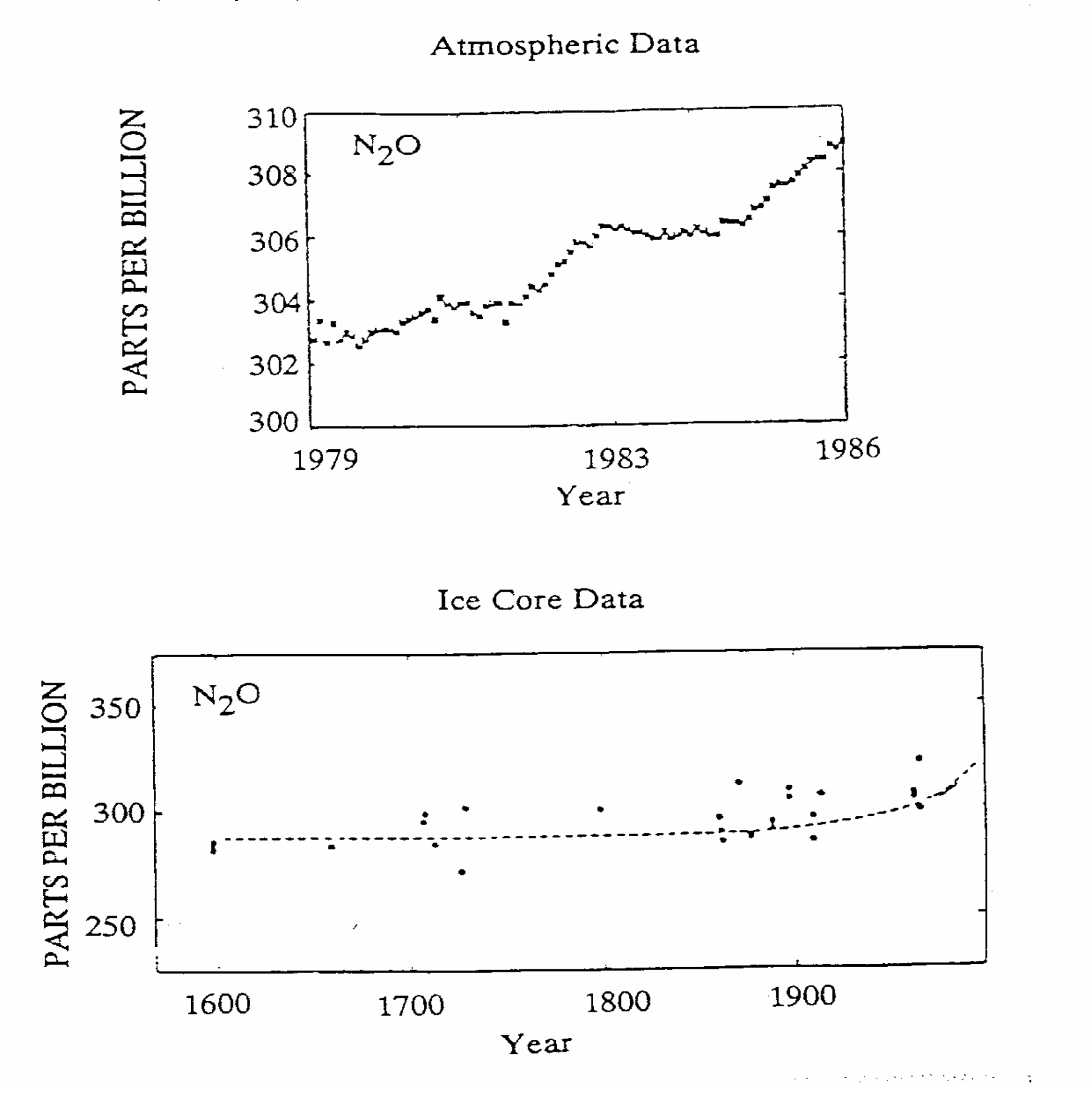
$$NH_4^+ \rightarrow NO_2^- \rightarrow CO_3^-$$

The bacteria which perform this oxidation require only carbon dioxide, water and oxygen to grow. Denitrification then proceeds, once again through the agency of bacteria:

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

Galbally (1985) notes that at least 146 strains of bacteria have been identified which can carry out the complete denitrification process. Denitrification appears to flourish in warm moist soils containing both NO_3- and available carbon, however it should be noted that only a small fraction of nitrogen is lost as nitrous oxide during denitrification.

Figure C6: **Increase in nitrous oxide concentration over past decade (0.25%/yr)** (upper panel), **and change in nitrous oxide concentrations over past four centuries** (lower panel)



Source: Lashoff and Tirpak 1990.

Another source of N_2O is production during the combustion of fuels and biomass. The nitrogen content of different fuels varies considerably, with typical values of 0.4 per cent-1 per cent for dead plant matter and 1 per cent-2 per cent for coal and fuel. During combustion the nitrogen in the fuel is partitioned between products NH_3, NO, N_2O, N_2 and HCN. CSIRO (Sub. 61) indicates that the N_2O/N emission factor for the fuels they consider is 0.7 per cent. The sink for N2O in the atmosphere is via a photochemical reaction occurring in the stratosphere:

$$N_2O + h\nu \rightarrow N_2 + O(1_D) \quad \text{and;}$$

$$N_2 + O(1_D) \rightarrow N_2 + O_2$$

Calculations by Johnston et al. (1979) and Levy et al. (1979) suggest that this sink accounts for 10 $\pm$ 3Tg N/yr (33 $\pm$ 10.Tg N2O/yr)

Nitrous oxide is produced in the ocean (eg Elkins et al. 1978) however accurate estimates of the global flux have not been possible (Galbally 1985). Cohen and Gordon (1979) and Elkins et al. (1978) have estimated oceanic nitrous oxide production from the ratio of N_2O to NO_2^- produced during nitrification and the total NO_3^- production rate. They suggest a global ocean to atmosphere flux of 4 to 10Tg N/yr (13.2 to 32.9 Tg N_2O /yr).

While it is possible to deduce a global budget for nitrous with relatively high uncertainty, estimates budgets for most countries are not available.

C2.10 Australia's nitrous oxide sources and sinks

Table C15 provides an estimate of the annual surface budget for Australia of nitrous oxide. As with Table C14, the uncertainty of the CSIRO budget is illustrated by the range between the upper and lower estimates for the budget terms and by the qualification that the budget is representative generally of a year in the late 1980s. The budget presented by AIAS contains estimates which generally line up with the best estimates of CSIRO.

Using the ratios giving the nitrogen content of various fuels, annual areas of fires and the N2O/N emission factors they calculate the mass of nitrogen emitted as nitrous oxide from combustion in Australia for a typical year in the late 1980s. The natural ecosystems referred to in Table C15 are forests, woodlands, grasslands and wetlands not subject to cultivation.

As noted earlier nitrous oxide in the soil is the product of denitrification and is brought about by the activity of bacteria within soils. The rate of denitrification is temperature dependent, with CSIRO (Sub. 61) reporting a doubling of the rate with each $106^{O}C$ rise in temperature. Lipschultz et al. (1981) indicate that between 0.3 per cent and 10 per cent of NH4+ in an aqueous growth medium is converted to NO and N_2O.

Table C15: **Estimates of the annual nitrous oxide budget for Australia**
(kt N2O/yr)

Source	*CSIRO ESTIMATES (Late 1980s)* Lower estimate	Best estimate	Upper estimate	*AIAS ESTIMATES (1990)*
NATURAL				
Biomass burning	5	14	42	14
Natural ecosystems	153	766	3830	766
Termites	12	35	105	35
TOTAL NATURAL	170	816	3977	815
ANTHROPOGENIC				
Crops/fertilisers	30	60	120	58
Legume pastures	27	80	240	92
Motor vehicles	2	3	6	3
TOTAL ANTHROPOGENIC	59	143	366	153
TOTAL	229	959	4343	968

Source: CSIRO (Sub. 61 and pers. com.) and AIAS (Sub. 80).

In Australia the nitrogen content of soils have generally been raised through the use of legumes coupled with the application of superphosphate. This is in effect nitrogen fertilization through biological means. CSIRO (Sub. 61) reports high fluxes of nitrous oxide from soils which have been previously used to raise legumes and then tilled over the summer months. High nitrous oxide emission rates were also reported from sunflower crops growing in soils where legumes had previously been planted.

C2.11 Greenhouse gas emission scenarios

In Section C2.1 of this appendix it was noted that there is uncertainty associated with the degree of climate warming to be expected from a specified increase in radiative heating of the atmosphere. There is also considerable uncertainty associated with the forecasting of the future emission rates for the various greenhouse gases. Scientists and policy makers have responded to the uncertainty associated with events in the future by formulating scenarios and performing sensitivity studies on these to identify possible outcomes.

The IPCC WG I (IPCC 1990a) developed four greenhouse gas emission scenarios. In essence they were for:

i) constant emissions at the 1990 rate;

ii) a reduction by 50 per cent, in 1990, of all greenhouse gas emissions;

iii) a 2 per cent per annum reduction of all greenhouse gases, commencing in 1990; and

iv) increasing emissions of all greenhouse gases by 2 per cent per annum until 2010 and then a 2 per cent per annum reduction from this time.

None of these scenarios matches the outcome likely to occur from a global consensus to achieve the Toronto emission target.

The IPCC WG III also formulated four scenarios (these are also described by the IPCC (1990a)). In essence they were for the following emission trends in the three main anthropogenic greenhouse gases:

- 'BaU' -- Business as Usual -- assumes that no steps are taken to limit greenhouse gas 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

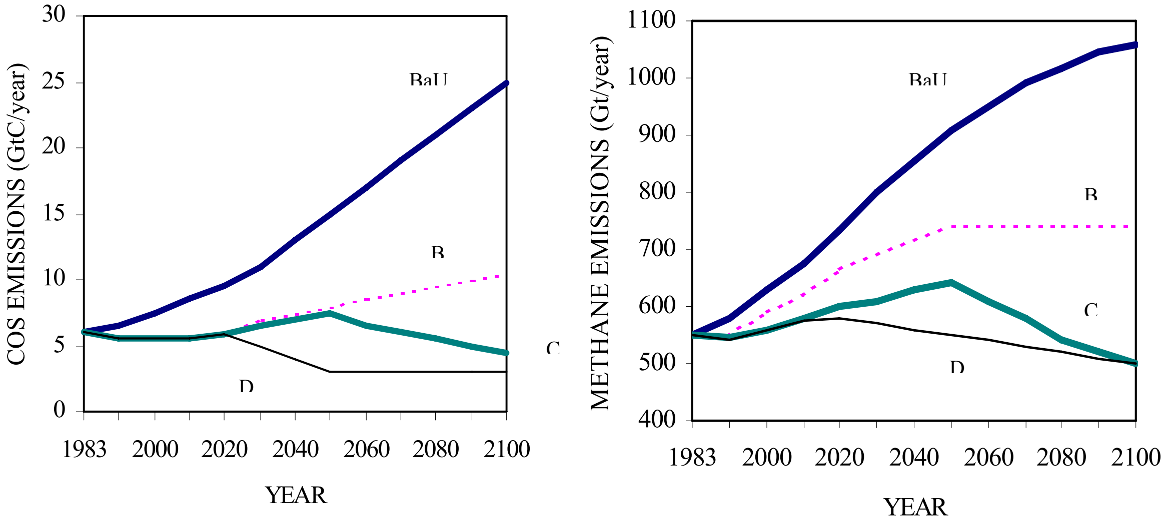
- 'D' -- a stabilisation, or slight decrease in emissions until 2010, with a steady decrease continuing through until 2050 and then maintenance of emissions at a constant level through to 2100.

Once again none of these scenarios precisely matches the outcome expected from a global consensus to pursue the Toronto target, although 'B', 'C' and 'D' are all broadly consistent with its short-term (to the year 2005) thrust.

The IPCC WG III formulated their emission scenarios after developing scenarios of policy strategies for the control of emissions. These policy scenarios have not been described because it would be possible to achieve the emission scenario outcomes 'B', 'C' and 'D', from a variety of different 'policy' scenarios. In a scientific context what is important for this discussion is the relationship between emissions, atmospheric concentrations and radiative heating. Later in this appendix (Section C4.3) the relationship between radiative heating under these scenarios, and atmospheric warming is discussed.

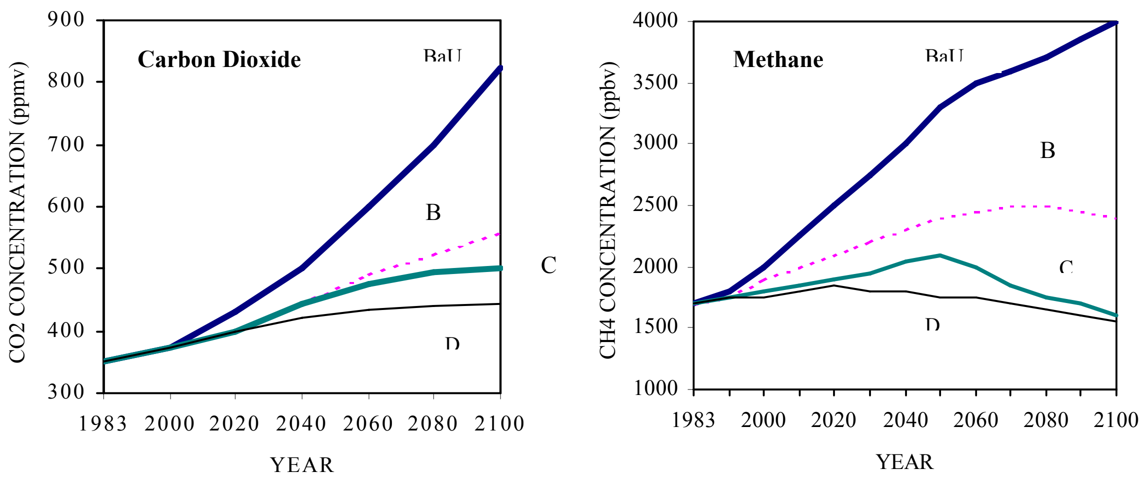
Figure C7 shows the expected rates of emission for carbon dioxide (a) and methane (b) for the four WG III 'policy'scenarios. Figure C8 shows the atmospheric concentrations of carbon dioxide (a) and methane (b) resulting from the emissions under the four scenarios. Figure C9 shows the radiative heating resulting from the changing gas concentrations. One notable feature of these curves is that under scenarios B', 'C' and 'D', emission reductions from the 'BaU' case commence immediately, but there is some time lag before the difference in radiative heating between 'BaU' and the others becomes substantial.

Figure C7: **Emissions of carbon dioxide (a) and methane (b) for the four 'policy' scenarios generated by IPCC WG III**



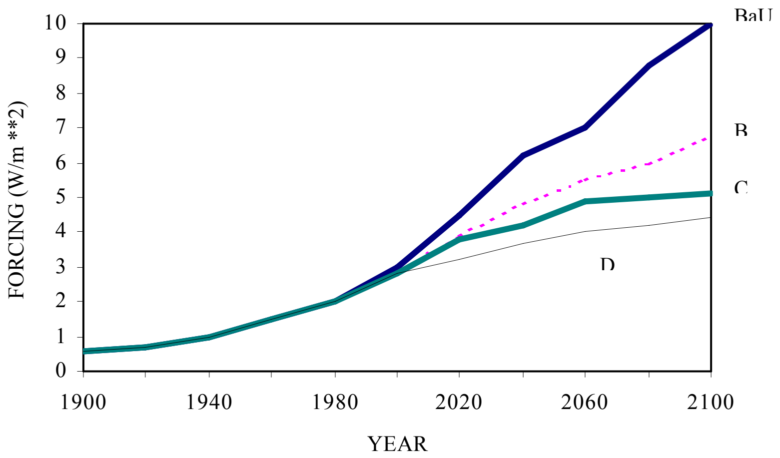
Source: IPCC 1990a.

Figure C8: **Concentrations of carbon dioxide (a) and methane (b) resulting from emissions under the four IPCC WG III 'policy' scenarios**



Source: IPCC 1990a.

Figure C9: **Radiative heating due to increasing greenhouse gas concentrations under the four IPCC WG III 'policy' scenarios**



Source: IPCC 1990a.

C3 Observations of past climate change

The study of climate is concerned with defining how climate has changed in the past, understanding the physical processes which are responsible for this variability, and being able to use this understanding to forecast likely future climate change. In this section the historical record of climate change is examined to provide a background for the analysis of the greenhouse problem.

C3.1 Deductions using palaeo-climate data

It has been possible to formulate a crude record of the Earth's climate through the analysis of a variety of climate sensitive phenomena; pollen remains trapped in geologic samples, lake varves and ocean sediments, insect and animal fossils and remains, and glacier termini. The temperature measurements derived from these `proxy' data are the best records of the Earth's early climate. Temperature records for the last 160 000 years have been deduced from air samples trapped in Antarctic ice cores, and for the last 150 years records are available of observations made using conventional instruments of various types.

Through the analysis of all these types of data it has been possible to deduce the change of the Earth's average surface temperature for the last million years. Figure C10 shows an estimate of the change in surface temperature over this period. The climate record clearly indicates four ice-ages within the last 500 000 years and more recently the little ice-age (around 1650 AD) during which global temperature reached a minimum. The recurring glaciations of the major ice ages are believed to be due to reductions in the solar energy received by the extra-tropical northern hemisphere brought about by variations in the distance between the Earth and the Sun, and by slow changes in the tilt of the Earth (the so-called ‘Milankovitch Cycles’). The more rapid changes in climate on time scales of centuries are not well understood. For example, the cooling associated with the Younger Dryas period (commencing abruptly around 10 500 BP and lasting for approximately 700 years) has been studied extensively, and while a number of plausible mechanisms for the cause of the cooling have been advanced, there is as yet no single, generally accepted cause.

Throughout these major variations in the Earth's temperature the atmospheric concentrations of the greenhouse gases carbon dioxide and methane have closely followed these temperatures. That is, as the global temperature has risen and fallen so too have the atmospheric carbon dioxide and methane concentrations. From these observations it is clear that these gas concentration changes must be linked to the large scale changes in the dynamic, physical, chemical and biological processes of the earth-atmosphere system. Given the uncertainty in identifying all mechanisms associated with climate change it is not possible to describe fully the causal relationships at work in the major shifts in climate observed in the past.

In summary then, the importance of these palaeo-climate records is that they provide evidence of the:

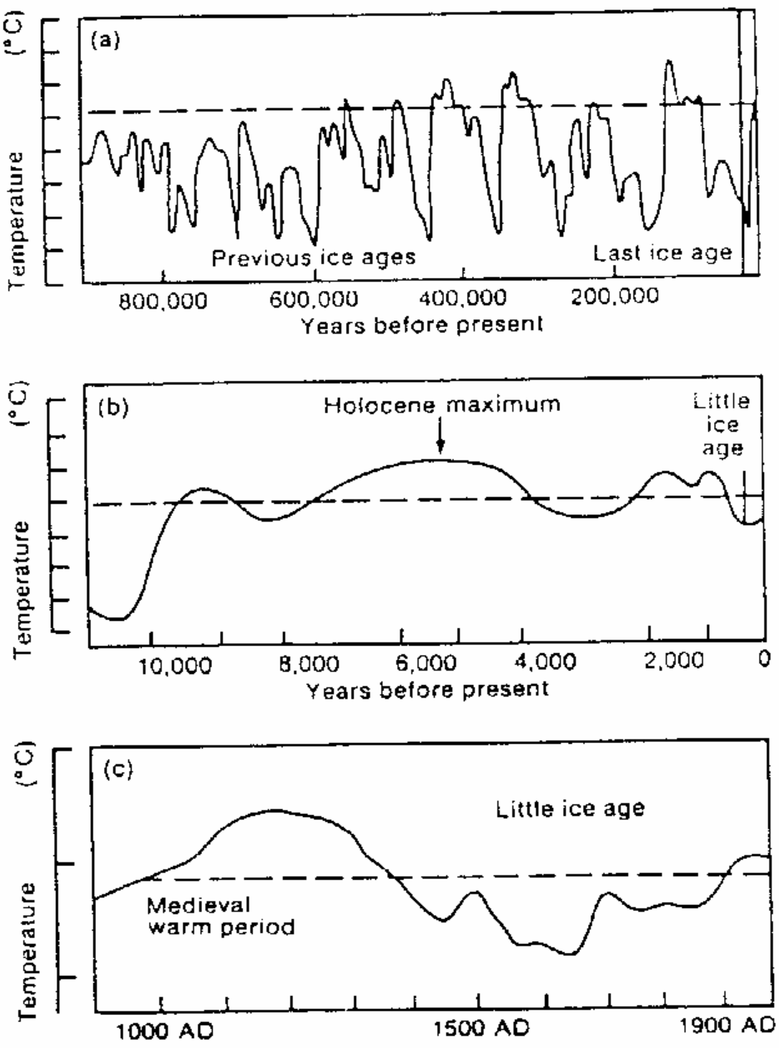
- temperature variability of the Earth's climate in the past when it is known to have been operating within a stable range;
- typical rates of temperature change during times of climate change; and
- inter-relationship between changing atmospheric concentrations of greenhouse gases and changing climate.

C3.2 The modern climate record

The release of the anthropogenic greenhouse gases carbon dioxide, methane and nitrous oxide has only occurred at significant levels since the industrial revolution (see Figures C3 and C4). This period corresponds to that of the modern instrumental record for which global observations of various meteorological and oceanographic parameters are available, and so a considerable amount of research effort has been devoted to the task of identifying trends consistent with the greenhouse warming hypothesis in these records. As noted in Chapter 2 of this report, one motivation for undertaking this analysis is to attempt to quantitatively determine the climate system's sensitivity to increasing greenhouse gas concentrations. If this was achieved, such a determination could be used to validate the performance of numerical models in simulating climate change due to an enhance greenhouse effect.

Observations of near surface air temperatures from land stations and ships, water temperatures at the ocean's upper surface and sea level have all been analysed on a global basis for trends. In addition to these data sets, other studies have focussed on changes in regional precipitation and evaporation rates, the movements of snowlines and glacier termination points and changes to mid-tropospheric temperatures. The IPCC (1990a) provides a detailed summary of the results.

Figure C10: **Schematic diagrams of global temperature variations on three timescales: (a) the last million years, (b) the last ten thousand years, and (c) the last thousand years. The dotted line nominally represents conditions near the beginning of the twentieth century, each gradation on the temperature scale is 1^{O}C.**



Source: IPCC 1990a.

Near surface air temperature

Observations of near surface air temperature from ships and land stations have been collected for the past 150 years and have been archived in computer databases. Figure C12 shows the northern and southern hemisphere land air temperature from a number of studies (Jones et al. 1986 a, b; Jones 1988; Hansen & Lebedeff 1987, 1988; and Vinnikov et al., 1987, 1990). The high degree of similarity between the three studies arises because essentially the same data are used by each group. Differences arise because of slight differences in the database and because different methods have been employed to correct for known deficiencies and biases in the data. From each record it can be seen that the pattern of temperature change differs between the hemispheres, however there is a warming trend evident through each record. This trend is around $0.5^{O}C/100$ year when calculated for the interval 1881 to 1989. The magnitude of the temperature change is dependent upon the interval chosen.

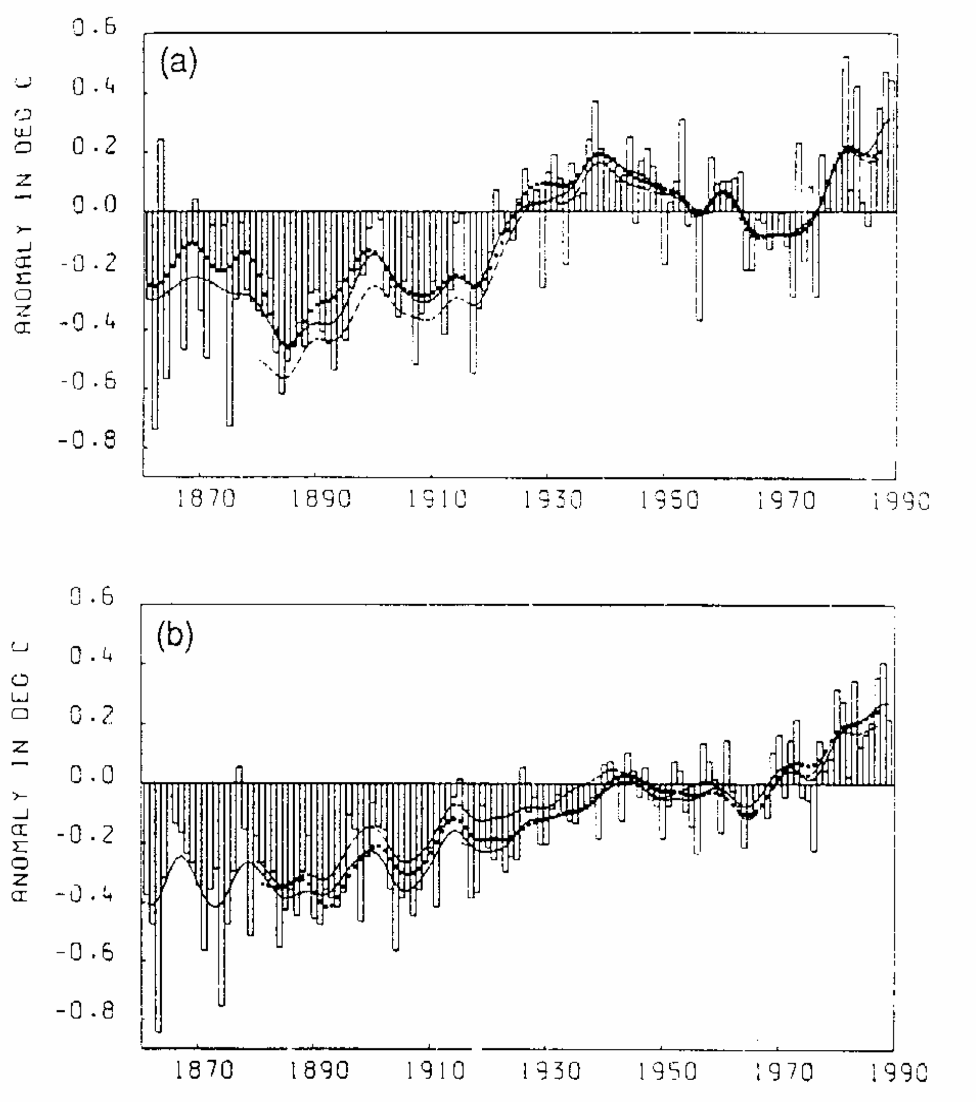
Reservations have also been expressed concerning the quality of the near surface, air temperature observations. Problems which affect the observational data record include:

- the spatial coverage of the data is uneven and varies greatly over time;
- records from individual stations are not stable because of changes to observing practices, I nstrument locations and exposures, and observing schedules;
- the environment around stations has changed, particularly with increasing urbanisation.

A number of analyses have been performed to identify the effect of the varying spatial distribution of the data. Jones et al. (1986 a, 1986b) suggests that the net effect of the spatial variability has little impact after 1900. A recent study by Ardeel et al. (1991) could be interpreted as showing the spatial variability of the observations network to have a greater impact than that described by Jones. The Ardeel study indicates that rapid temperature rise in 1900 - 1920 period may be to some extent an artefact of the changing observation network, as may be the cooling in the 1945 - 1960 period. The results of Ardeel et al. (1991) study do not support the argument that there is no upward trend in the global near-surface air temperature between 1880 and 1990.

Changes in the methods of obtaining observations from stations have unfortunately been commonplace throughout the world. Some changes have been well documented (including their dates of implementation), others not so. The analysis of station data proceeds on the basis that discontinuities will occur in the observational time series because of these changes, and that in many instances a correction to the record can be made. In those instances where the impact of a change is significant and a systematic correction cannot be made, the data are discarded. It is also assumed that the effect of these changes is random across the network, producing at times a positive bias, at other times a negative bias. In the long run the net effect is expected to be near zero.

Figure C11: **Land, near surface air temperatures, expressed as anomalies relative to the mean for 1951-1980**



Annual values from P.D. Jones. Smoothed curves of values from P.D. Jones (1861-1989) (solid lines), Hansen and Lebedeff (1880-1987) (dashed lines), and Vinnikov et al., (1861-1987 NH and 1881-1987 SH) (dots). (a) Northern Hemisphere, (b) Southern Hemisphere.
Source: IPCC 1990a.

Changes in urbanisation represent a major problem in the analysis of long term station records. While changing observational practices and station locations in general impose a set of large random variations in the data, urbanisation provides a systematic warm bias over time which is not representative of global climate change. Hansen and Lebedeff (1987) found that removing all stations from cities with a 1970 population of 100 000 or greater reduced the warming trend by $0.1^{O}C$ over 100 years. They further speculated that a $0.1^{O}C$ per 100 year urbanisation bias remains in the data.

A method of measuring the degree of global warming, independent of conventional observations, has been available since the commissioning, in 1979, of microwave sounding units (MSUs) on the TIROS-N series of satellites. The MSUs can be used to provide measurements of the global mean temperature of the 850 hPa to 300 hPa layer of the atmosphere. For the 1979-1988 period the MSU and conventional measurements are highly correlated, with the MSU measurements showing a warming of $0.04^{O}C$ per decade against that of $0.13^{O}C$ per decade from the conventional observational record (Spencer and Christy 1990). The IPCC (1990) notes that these differences are not statistically significant. Jones and Wigley (1990) provide a more comprehensive discussion of these two data sets.

In summary then, the near surface, land temperature observations cannot be analysed to specify conclusively the magnitude of the warming trend over the past century, however the most plausible interpretation of the data is that there is a trend of rising temperature is present. The natural variability of climate also makes interpretation of the record difficult; if the climate had been going through a cooling phase over the period then the anthropogenic warming may have been twice the observed magnitude of temperature rise, or alternatively, the observed warming may all be a product of natural climate variability with no contribution from the greenhouse effect. Examination of the land, air temperature records alone will not resolve this issue, however consideration of the physics and chemistry of greenhouse gases and the atmosphere in conjunction with other observational records can assist in interpretation of these data.

Sea surface temperatures

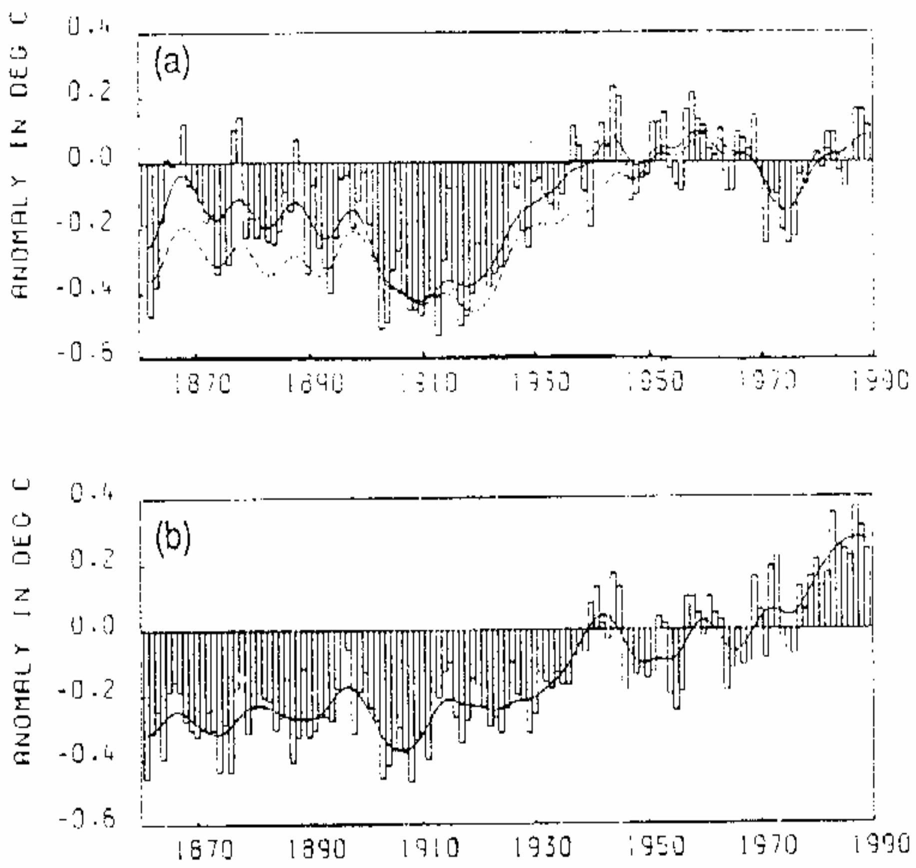
A temperature measure independent of near-surface, land based, air temperature is sea surface temperature (SST). SST measurements have been more numerous over the past century, with the spatial coverage more complete in the northern hemisphere than in the southern. Two data sets have been compiled for analysis of the global SST; the Comprehensive Ocean-Atmosphere Data Set (COADS) in the USA (Woodruff et al., 1987) and the UK Meteorological Office data set (Bottomley et al., 1990). These sets contain around 80 million and 60 million observations respectively, with the UK set being almost completely contained within the COADS set.

The methods used to measure SST have varied over the years. Different types of bucket (canvas, wood, metal, etc.) with differing thermal characteristics have been used to lift water samples on to ships' decks for temperature measuring. More recently (since the 1940s) temperature measurements have occurred at the intake pipe for the ship's engine cooling system.

Careful analysis of the COADS and UK data sets has produced SST anomaly records for the northern and southern hemisphere for the past 130 years. Figure C12 shows the plots of these anomalies. Overall global warming between the late nineteenth century and the latter half of the twentieth century appears to be about 0.4^{O}C.

Comparison of Figure C12 with Figure C11 indicates that there are similarities in the trend of temperatures (from an anomaly of -0.3^{O}C around the turn of the century to +0.2^{O}C in 1990) in all data records. The independence of the SST record from that of near surface, land based air temperature measurements lends confidence to the general conclusion that there has been real warming of the Earth's atmosphere over the period.

Figure C12: **Sea surface temperature anomalies 1861-1989, relative to the 1951-1980 mean**



Annual values (bars) and solid curves from the UK Meteorological Office data. Dashed curves from Farmer et al., 1989. (a) Northern hemisphere. (b) Southern hemisphere.

Source: IPCC 1990a.

There are prospects for more accurate measurements of global sea surface temperature change in the future. Monk (1991) describes an experiment now under way, in which acoustic signals are transmitted through the ocean from Heard Is (in the Southern Ocean) to receivers around the world (including receivers at Bermuda, Vancouver and San Diego). The timing of the receipt of these signals is accurate to 10 milliseconds, accurate enough to enable verification of the forecasts of sea surface temperature change expected by the IPCC under their `business as usual' scenario in about 10 years.

Sea level rise

In a warmer world there are at least three factors which could cause the global sea level to rise:

- thermal expansion of the oceans;
- melting of glaciers;
- melting of Greenland and Antarctic ice sheets.

Thermal expansion

The density of sea water varies inversely with its temperature. Increasing the temperature of water decreases its density, and for constant mass, increases the volume.

The process of ocean warming would have at least two definite timescales: the warming of the upper layer (the thermocline) would occur relatively rapidly, whereas the deeper layers would take hundreds to thousands of years to warm.

Retreat of glaciers and ice sheets

The melting of glaciers and other small ice sheets would provide a net gain in the mass of oceanic water. An ice sheet grows from the accumulation of frozen precipitation and shrinks through melting as the temperature of its environment rises. If global warming were to lead to increased precipitation accompanying increased temperatures it is possible that some glaciers and ice sheets may grow more quickly through accumulation of frozen precipitation than they shrink through ablation and melting.

Observations of sea level rise

For the last century there has been in operation a network of tide gauges whose records, when analysed carefully are able to provide evidence as to whether or not the sea level is changing. There is difficulty in linking these records to global warming because there are a variety of influences not related to global warming which can change relative sea level. They include:

- Earth movements which alter ocean basin volume characteristics;
- eustatic rise and fall of the Earth's crust at the location of the tide gauge;

- a change in atmosphere circulation patterns (surface pressure and wind fields) which leads to an adjustment in ocean surface height across ocean basins.

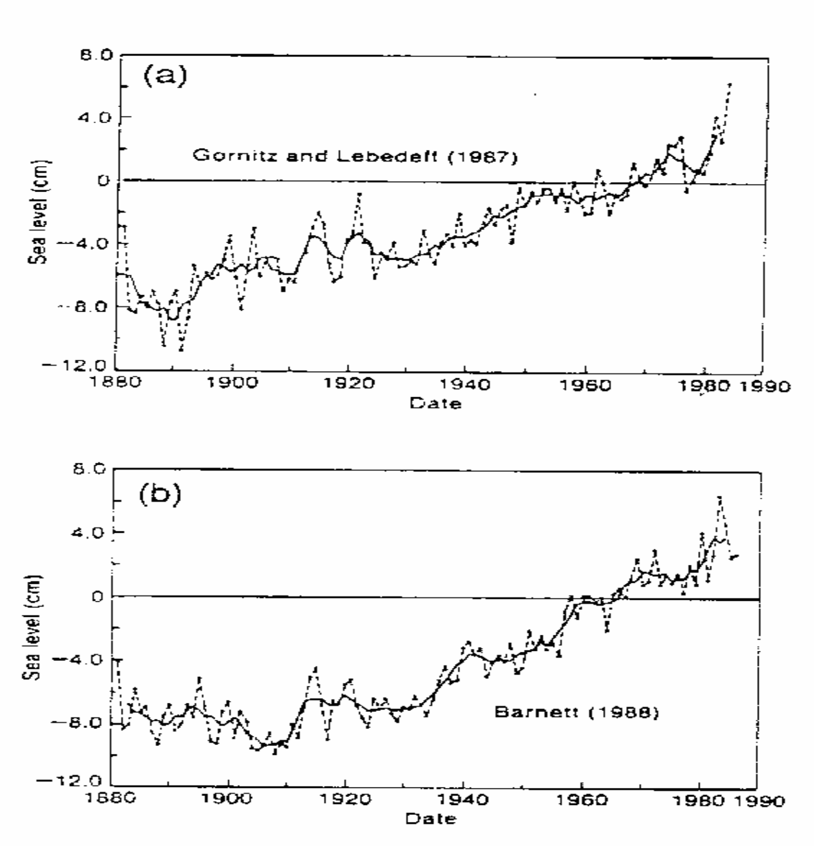
Gornitz and Lebedeff (1987) used data from 130 stations with a minimum record length of 20 years to estimate sea level rise over the period 1880-1982. Barnett (1988) updated this study with 150 stations for the period 1880-1986. Using two different averaging techniques Gornitz and Lebedeff determined sea level rises of 1.2 $\pm$ 0.3mm/yr and 1.0 $\pm$ 0.1mm/yr from their study. Barnett's study has yielded a rise of 1.15mm/yr. Figure C15 shows the results of these studies.

More recently Peltier and Tushingham (1990) have performed a detailed study of sea level rise as deducted from 40 stations with a minimum record length of 51 years. Corrections have been made for eustatic adjustments and the effect of different averaging periods on the trend have been determined. From their study it is apparent that the observational record contains evidence of sea level rise and that the rate from this study is somewhere between 1.6 and 2.3mm/yr.

Noting the uncertainty in the knowledge of coastal and oceanic processes which contribute to tide gauge records there are scientists who argue that rising world sea level is not confirmed by the data to hand and is not an easily confirmable fact (eg Bryant 1988).

Following on from these analyses of tide gauge data, and through making assumptions as to the rates of release of melt-water and increase of sea water volume through thermal expansion, forecasts of sea level rise under global warming scenarios have been made. Table C16 lists some of these sea level rise forecasts indicating the factors considered, the range of forecast and year of validity. From Table C16 it can be seen that thermal expansion of the oceans is expected to be the most significant contributor to sea level rise, but with ice melt of one form or another making a substantial contribution. It should be emphasised that much of the public debate concerning sea level forecasts has often neglected to include information concerning which parameters have been considered in making the forecast, and in doing so has substantially misrepresented attempts by the scientific community to focus attention on what may, or may not become a significant community problem.

Figure C13: **Global sea level rise over the last century**



The baseline is the average sea level for the period 1951-1970. The dashed line is the annual mean, the solid line the five year running mean. (a) Gornitz and Lebedeff 1987. (b) Barnett 1988.
Source: IPCC 1990a.

Table C16 : **Estimates, to a given date, of sea level rise** (cm)

	Contributing factors				*Total rise from the 1980s*		
	Thermal Expansion	*Alpine*	*Greenland*	*Antarctica estimate*	*Best*	*Ranged*	*To (year)*
Gornitz et al. (1982)	20	20 (combined)		40			2050
Revelle (1983)	30	12	13		71a		2080
Hoffman et al. (1983)	280 to 115	28 to 230 (combined)				56 to 345 26 to 39	2100 2025
Polar Research Board (1985)	b	10 to 30	10 to 30	-10 to 100		10 to 60	2100
Hoffman et al.	28 to 83	12 to 37	6 to 27	12 to 220		58 to 367 10 to 21	2100 2025
Robin (1986c)	30 to 60c	20±12c	to ±10c	to -10c	80g	25 to 165g	2080
Thomas (1986)	28 to 83	14 to 35	9 to 45	13 to 80	100	60 to 230	2100
Villach (1987) (Jaegar, 1988)c					30	-2 to 51	2025
Raper et al. (1990)	4 to 18	2 to 19	1 to 4	-2 to 3	21g	5 to 44e	2030
Oerlemans (1989)					20	0 to 40	2025
Van der Veen (1988)f	8 to 16	10 to 25	0 to 10	5 to 0		28 to 66	2085

a Total includes additional 17 cm for trend extrapolation. b Not considered. c For global warming of 3.5^{o}C. d Extreme ranges, not always directly comparable. e Internally consistent synthesis of components. f For a global warming of 2-4^{o}C. g Estimated from global sea level and temperature change for 1880 - 1980 and global warming of 3.5 ± 2.0^{o}C for 1980 - 2080.
Source: IPCC 1990a.

C3.3 Establishing the causal link between changing greenhouse gas concentrations and global warming

It was noted in Section C2.1 of this appendix that the degree of warming which occurs as a response to applied heating is a function not only of the rate of heating, but also of the system's internal dynamics. In Section C3.2 evidence showing global warming has been presented, however the IPCC (1990a) points out that the inter-annual variabilities of the global mean, near surface, air temperature and SST are high, and that the observed trend is within the range of natural climate variability. That is, the empirical data do not unequivocally confirm the link between the observed warming and the observed increase in greenhouse gas concentrations brought about by human activities.

The IPCC (1990a), taking what they claimed was a conservative viewpoint, argued that a further 0.5oC rise in the global mean, near surface, air temperature is required to confirm the link between increasing greenhouse gas concentrations and global warming. Under the 'BaU' scenario (see Figure C17) this temperature rise would be expected to be observed in around 12 to 15 years (depending upon the assumptions made as to the atmosphere's sensitivity to increased radiative heating).

Dr G Pearman (CSIRO) advised the Commission that his view is that using a variety of data, and comparing the vertical distribution of temperature changes with those forecast by mathematical models, the time for confirmation of the causal relationship could be advanced.

C4 Forecasting future climate change: what the general circulation models tell us

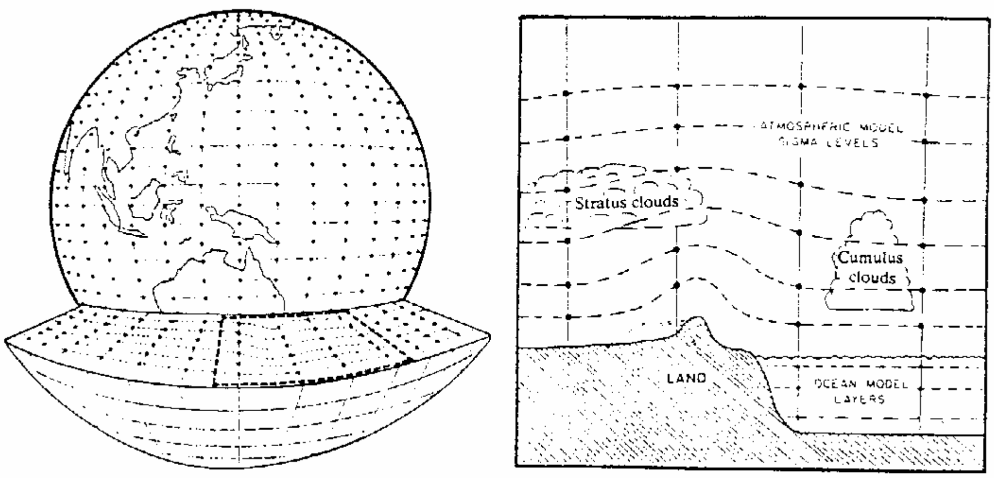
C4.1 Forecasting climate change

As noted in Section C1 of this appendix, if the Earth did not have an atmosphere and its reflectivity to incoming solar radiation remained as it is now, its equilibrium temperature would be around -18^{O}C (255^{O}K). Given the gaseous atmosphere of Earth, but in the absence of convective processes (ie. cloud systems which re-distribute heat in the vertical and horizontal), an equilibrium global, mean, surface temperature of around 72^{O}C (345oK) could be expected (Moller and Manabe, 1961; Lindzen 1990). Thus, the atmosphere contains processes which act as positive feedbacks (eg the radiatively active greenhouse gases) and negative feedbacks (eg clouds) which modify the earth-atmosphere system's warming response to the heating by solar shortwave radiation. Thus to understand the likely warming response of the Earth to a change in heating caused by changing greenhouse gas concentrations, it is necessary to develop a model of the system which somehow reproduces the important feedbacks of the earth-atmosphere system. With such a model it is then possible to introduce the changing greenhouse gas concentrations and observe the consequent change in the model climate. In as much as the model is an accurate depiction of the Earth's climate, useful information of likely future changes will be obtained.

The tool used to reproduce the essential features of the earth-atmosphere climate system is the General Circulation Model (GCM). In a GCM the equations of mass, momentum and energy with appropriate boundary conditions are typically solved using a super computer. The equations are integrated forward together in time using a three-dimensional grid of points through the atmosphere, and on the land and ocean surfaces. The most sophisticated models attempt to take account of processes occurring within the ocean and at the surface. GCMs have been used for about 30 years and over this period have become increasingly sophisticated and complex. Figure C14 shows schematically the horizontal and vertical grid structures of a GCM.

In using a finite grid structure to approximate a continuous atmosphere it becomes necessary to parameterise those processes which are smaller than the resolution of the grid. Because even the most sophisticated models currently have horizontal grid spacings of the order of 300 km to 500 km the effect of many important weather elements which go to make up the Earth's climate are parameterised. For example, the effect of cloud systems on climate must be parameterised rather than treated explicitly. The best formulation of such parameterisation schemes is still a matter of debate in the scientific community, with a variety of different schemes being used in GCMs. While it is an important issue for validation of the GCM to have the cloud feedbacks closely modelling those of nature, what is even more important is that in the change from modelling the observed atmosphere to modelling the atmosphere with an increased concentration of greenhouse gases, the change in feedback is in the correct direction. That is, if clouds in general constitute a negative heating feedback, but on doubling the carbon dioxide concentration of the atmosphere the feedback is less negative then the clouds will contribute to overall warming.

Figure C14: **A schematic view of the horizontal and vertical grid structure of a typical, coarse resolution, GCM**



Source: Zillman et al. 1989.

Closely related to the treatment of clouds is the way in which a GCM models the atmosphere's water vapour field. The Clausius-Clapeyron equation indicates that a warmer atmosphere will hold more water vapour, and because water vapour is a very effective greenhouse gas, this increase of water vapour under a scenario of increasing anthropogenic greenhouse gas concentrations constitutes a positive feedback in a GCM.

A GCM must also be able to accurately forecast snow and ice cover. Snow and ice are highly reflective surfaces. If under a warm climate scenario the area of the Earth's surface covered by snow and ice is reduced, then the alternate surface (vegetation, soil or exposed ocean) will most likely absorb an increased amount of solar, shortwave radiation. Because the rate of accumulation or ablation of frozen surfaces depends on the balance between accumulation and evaporation/run off rates, it is possible that increased precipitation in polar regions under a warm climate scenario could increase ice and snow cover, in such circumstances the Earth would absorb less solar shortwave energy.

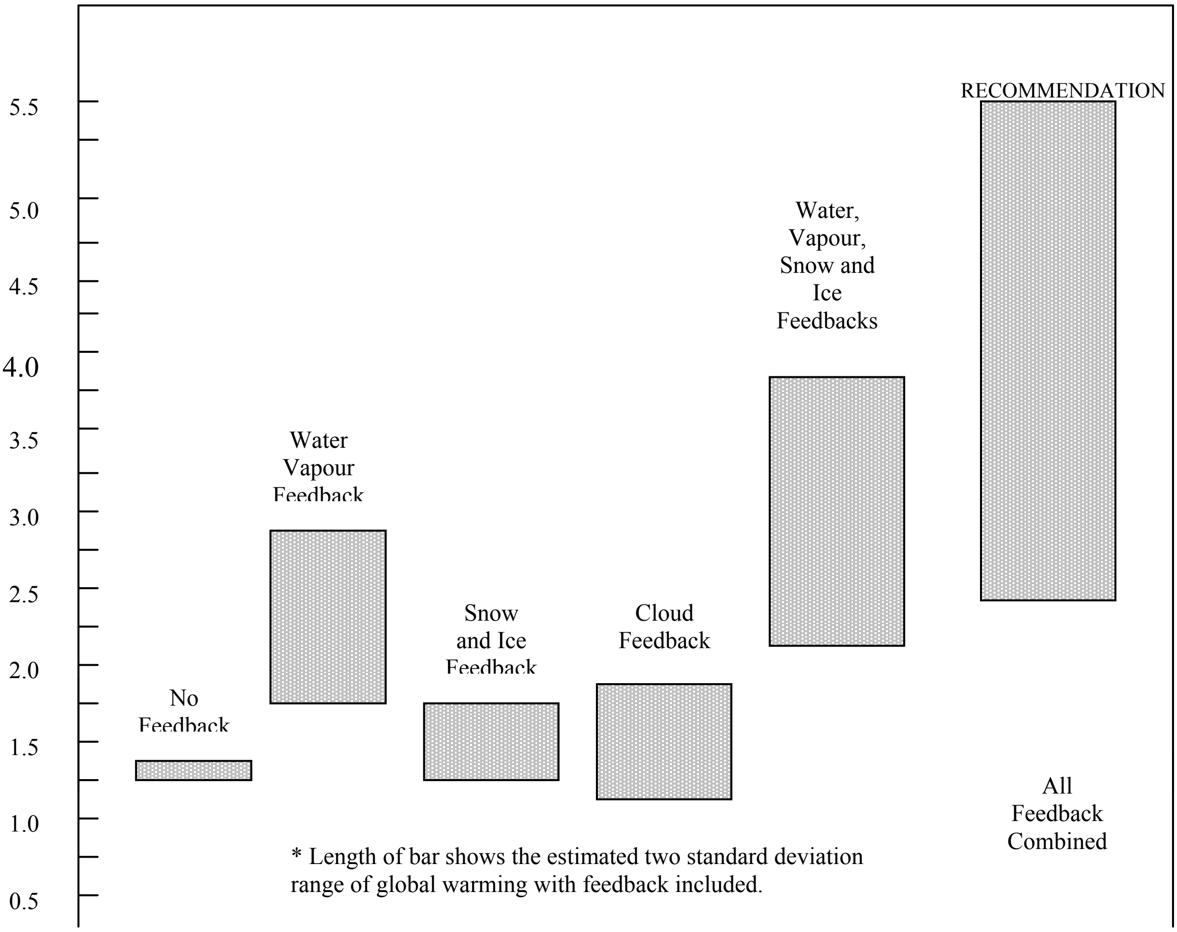
The net effect of the various feedbacks, as deduced from the operation of GCMs has been summarised by Dickinson (1986). When determining the possible amplitude of these feedbacks Dickinson assumed that the global sensitivity to a doubling of carbon dioxide was in the range $1.5^{O}C$ to $5.5^{O}C$. Figure C15 shows the results of this work which indicates that in general increasing water vapour and cloud cover and decreasing snow and ice cover will all provide a positive feedback to global warming. It should be noted that Figure C15 provides an extremely simplistic summary of a variety of complex processes. Substantial research work, through the inter-comparison of a number of GCMs undertaking the same simulations, is being directed towards improving the understanding of these highly non-linear feedback processes (see, for example, Cess et al. 1990).

The accuracy of these parameterisations determines the quality of the model results. The standard ‘test’ of a GCM is how well it can reproduce the Earth's current climate in a long integration.

C4.2 Simulation of the current climate by GCMs

The features of the global climate system to be accurately reproduced by a GCM include the strength and latitude of the upper atmosphere westerly jet streams, the locations and intensities of sub-tropical anticyclones, major trough systems, the major monsoon circulations, surface temperature and rainfall patterns, and the tracks and frequencies of tropical and midlatitude storm systems. The strength of the upper westerly winds is dependent upon the horizontal gradient of temperature in the layers of the atmosphere beneath the jet stream. Because the upper atmosphere jet streams are the integrated effect of the atmospheric pressure and temperature fields in the troposphere they provide a good guide to the overall accuracy of a GCM.

Figure C15: **Equilibrium temperature changes from the doubling of carbon dioxide inferred from a review of the strength of individual feedbacks in various climate models**



Source: Lashof and Tirpak 1990, quoting Dickinson 1986.

Grotch and MacCracken (1991), IPCC (1990a), Mitchell, (1989) and Schlesinger and Mitchell (1987) provide reviews of the results from GCM modelling experiments. In general GCM jet stream systems appear different from observed jet streams in two ways; the summer time southern hemisphere jet is too intense and too far poleward and, excessive westerlies are generated above the summer time jets in both hemispheres of many GCMs simulations causing these jets to become (incorrectly) coupled with the stratospheric westerlies. To some extent these problems are reduced in the higher resolution models giving support to the general rule that the higher the resolution of a model the better its forecast capability.

From a synoptic perspective the task of reproducing the observed sea level pressure field in a GCM simulation is one of correctly locating the sub-tropical anticyclones and polar and equatorial troughs correctly. There is a tendency for GCMs to depict the subtropical ridges in both hemisphere as having higher pressures than are observed, this feature, when combined with an Antarctic trough which is too deep, leads to the over-strength westerlies already described.

The depiction of the oceanic surface temperature in a GCM is controlled by the scheme used to forecast SST. The more sophisticated GCMs use coupled ocean-atmosphere models. Unfortunately these models show a tendency for the SST to drift from observed conditions unless a flux-correction term is added to the formulation. With this term in place, and the SSTs tied closely to observed values, only the near surface, land, air temperatures for locations well removed from coastal influences are highly dependent on the dynamics of the simulation. The IPCC (1990a) notes that in general systematic errors among models in forecasts of surface temperature are difficult to identify. They note that soil moisture is not well handled in many models and may account for some problems and further observe that simulated winter time temperatures over Asia are generally too cold whereas temperatures over Antarctica are too warm.

Precipitation forecasts from GCMs are keenly sought for various greenhouse scenarios. Unfortunately all models, when attempting to reproduce current observations, exhibit some regionally important errors (IPCC 1990a). The highest rainfall zones in the globe are those areas in the tropical belt which are influenced by monsoon circulations. Unfortunately GCMs do not have the horizontal resolution to correctly model the small scale convective process important in producing tropical rainfall, and the parameterisations do not always accurately reproduce the observed climate. In Australia much of the variability of rainfall generally, and more importantly the occurrence of floods and drought, is related to the phase and intensity of the El Nino/Southern Oscillation phenomenon. A part of the dynamics of this phenomenon is the behaviour of the Pacific Ocean currents and temperature field. With the known limitations of the existing generation of GCMs to model the complex ocean-atmosphere interactions it is not possible to confidently build a picture of how the climatology of these events will change with increasing greenhouse gas concentrations.

Ongoing work in numerical weather prediction for short-term forecasting (1 to 5 days) is revealing that numerical models with horizontal grid spacings of less than 100 km are needed to realistically depict tropical cyclones and even finer resolution is needed for the modelling of severe local thunderstorms. As noted previously the current generation of GCMs have relatively coarse grid spacings, and so without some parameterisation of the statistics of the recurrence of these events in terms of parameters resolved by the GCMs the current GCMs will not be able to reproduce the observed climatology.

In summary, the current generation of GCMs reproduces the broad scale (zonal averaged) wind, temperature pressure and rainfall fields relatively accurately. Furthermore the physics of the processes occurring within the atmosphere are well reproduced in these models allowing for the diagnosis of observed climate system interactions. There are however some problems associated with the reproduction of existing regional rainfall patterns (with errors of 20 per cent to 50 per cent) and in the modelling of the El Nino/Southern Oscillation events with regional veracity.

C4.3 GCM forecasts of climate change for a doubling of carbon dioxide

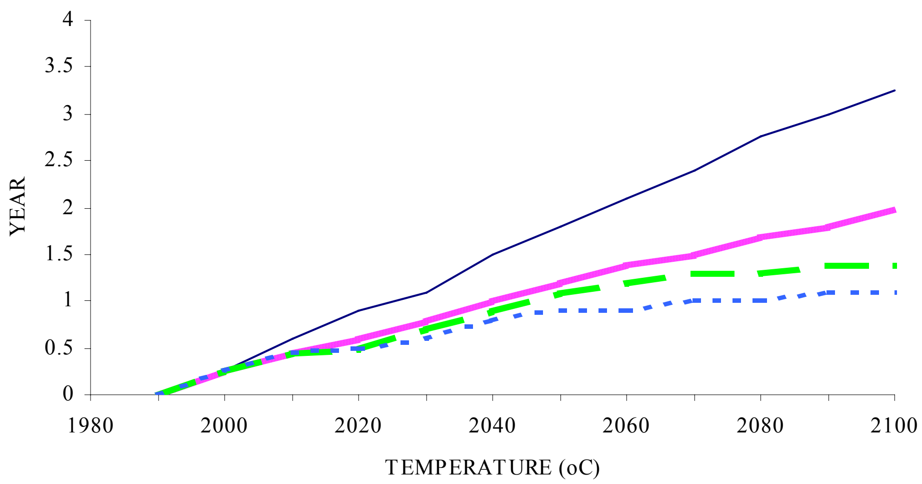
In the atmosphere the concentration of anthropogenic greenhouse gases is constantly changing. Assuming that there is a climate response to this varying forcing, there will be some lag as the components of the earth-atmosphere-ocean systems adjust to a new equilibrium. Because the forcing is constantly changing it is doubtful that a true equilibrium state will be reached. In order to simplify the analysis of the internal dynamics of the earth-atmosphere-ocean system as it responds to a forcing, experiments have been performed using GCMs in which the concentration of atmosphere carbon dioxide is doubled and the climate of the equilibrium state investigated. In these simulations the GCM is integrated forward in time with constant external forcings for long periods (equivalent to 10 to 50 years) and the results presented in terms of difference between the double carbon dioxide simulation and a control simulation.

In the double carbon dioxide, equilibrium experiments the concentrations of other greenhouse gases are kept constant. Because the concentrations of methane, nitrous oxide and tropospheric ozone are known to be increasing the atmosphere will reach a condition where the radiative equivalent of doubling carbon dioxide is reached long before the concentration of carbon dioxide has doubled. For example, under the IPCC WG III ‘Business as Usual’ (BaU) projections the carbon dioxide concentration will double around 2080 (see Figure C8) with a forcing of about 5.7 wm-2. The IPCC projections for increased radiative forcing from all greenhouse gases under the ‘BaU’ projections indicates the increased radiative of 5.7 wm-2 will be arrived at around the year 2025 (see Figure C9), whereas under scenarios ‘B’ and ‘C’ this level of radiative forcing will be reached shortly before 2050 and never for scenario ‘D’.

Should enhanced greenhouse gas radiative heating reach the level consistent with the doubling of carbon dioxide it is expected that there would be a lag in atmosphere response to the forcing. That is, while ‘BaU’ may result in an effective doubling of carbon dioxide by 2025 the warming shown by a GCM equilibrium simulation would not be expected to be observed until some later time. Transient forcing simulations of the climate using a GCM is one method of providing an estimate of the likely thermal lags of the system to radiative forcing.

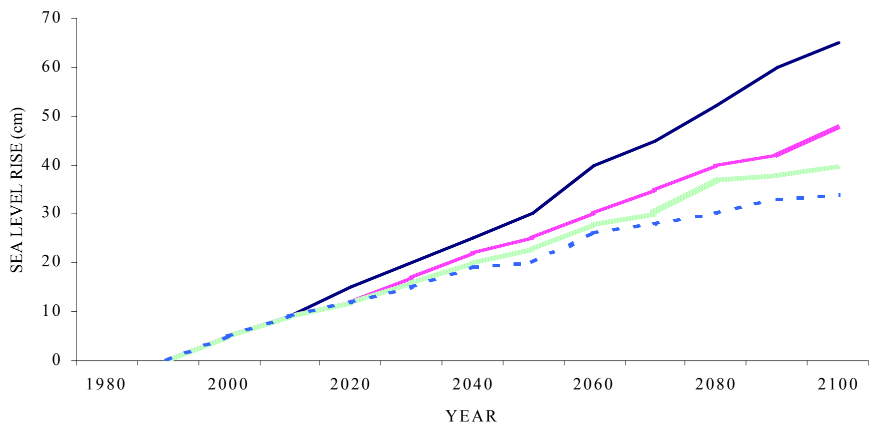
An alternative approach to the transient GCM simulation is to use a simple ‘box-diffusion’ model. In such a one-dimensional model a simplified ocean-atmosphere structure is used to represent the Earth's climate system (the only physical dimension is the vertical structure of the ocean-atmosphere system, the model has time as a second dimension). A value for the sensitivity of the atmosphere to the doubling of the concentration of carbon dioxide is prescribed and the system's response to the increasing radiative heating is simulated. Using a sensitivity of 2.5^{O}C (an estimate at the low end of the climate sensitivity estimates as can be seen from the data presented in Table C17). IPCC (1990a) determined the warming rates for the IPCC WG III 'policy' scenarios. Figure C16 shows the rate of warming deduced from the radiative heating given in Figure C9. For completeness Figure C17 shows the expected rate of sea level rise given the warming scenarios of Figure C16.

Figure C16: **The temperature rise calculated using a 'box-diffusion' upwelling model, with a climate sensitivity of 2.5^{O}C, for the four IPCC WG III 'policy' scenarios**



Source: IPCC 1990a.

Figure C17: **The sea level rise due to the four IPCC WG III 'policy' scenarios**



Source: IPCC 1990a.

There are many groups around the world conducting research into climate change using GCMs. Within Australia the CSIRO Division of Atmospheric Research and the Bureau of Meteorology Research Centre operate the most sophisticated GCMs. Table C16 carries, in summary form the results obtained from 18 experiments using GCMs. The listing describes the characteristics of the models schematically and simplistically portrays their results in terms of the globally averaged equilibrium surface temperature change (vT), and the percentage change in global average precipitation from the doubling of carbon dioxide as compared to a control run with carbon dioxide at current levels.

Table C17: **A summary of some research results using GCMs**

Investigators	*Year*	*No. of layers in vertical*	*Diurnal cycle*	ΔT *global average*	ΔP *global average*
				^{o}C	%
Variable cloud: no ocean heat transport					
1 Schlesinger & Zhao	1989	2	N	2.8	8
2 " "	1989	2	N	4.4	11
3 Noda & Tokioka	1989	5	Y	4.3 a	7a
4 Washington & Meehl	1984	9	N	3.5 b	7b
5 " "	1989	9	N	4.0 b	8b
6 Wetherald & Manabe	1986	9		4.0	9
Variable cloud: prescribed heat transport					
7 Gordon & Hunt	1989	4	Y	4.0	7
8 Hansen et al.	1981	7	Y	3.9	n/a
9 " "	1984	9	Y	4.2	11
10 " "	1984	9	Y	4.8	13
11 Wetherald & Manabe	1989	9	N	4.0	8
12 Wilson & Mitchell	1987	11	Y	5.2	15
13 Mitchell et al.	1989	11	Y	2.7	6c
14 " "	1989	11	Y	3.2	8d
15 " "	1989	11	Y	1.9	3e
High resolution models					
16 Boer et al.	1989	10	Y	3.5	4
17 Wetherald & Manabe	1989	9	N	4.0	8
18 Mitchell et al.	1989	11	Y	3.5	9f
19 McAvaney et al.	1991	9	Y	2.1	3
20 Dix et al.	1991	9	Y	4.8	10
21 Oglesby & Saltzman	1990	12	N	4.0	n/a
22 Wang et al.	1991	12	N	4.2	8.6
23 " "	1991	12	N	5.2	10.9g

a Equilibrium not reached. b Excessive ice. c Cloud water scheme. d Alternative ice formation. e Variable cloud radiative properties. f Gravity wave drag g As in 22 but with CO_2 at 330 ppm and including trace gases..
Source: IPCC 1990a. McAvaney (pers. com.) provided the details necessary for updating the table.

All GCM simulations summarised in Table C17 report temperature rises and all report precipitation increases. There are other areas of substantial agreement between models and areas of inconsistency, these are summarised briefly below.

Areas of agreement:

- all models produce a warming of the Earth's surface and troposphere and a cooling of the stratosphere;
- all models produce an enhanced warming in higher latitudes in late autumn and winter;
- in all models the tropical warming is smaller than the global mean and varies little between season;
- in most models the warming over northern hemisphere mid-latitude continents in summer is greater than the global mean;
- all models produce enhanced precipitation in high latitudes and tropics throughout the year, and in the mid-latitudes in winter; and
- throughout the year there is a weakening of the north-south pressure gradient in the southern hemisphere extra-tropics implying a weakening of the mid-latitude westerlies.

Areas where there is substantial divergence between models include:

- precipitation changes in the dry sub-tropics are generally small and variable between models;
- there are considerable discrepancies regarding changes in precipitation regimes on sub-continental scales; and
- there is substantial variability between models concerning the intensity and location of the Indian and North-Australian monsoons.

C4.4 GCM results: simulation of transient forcing

The GCM simulations which most closely approximate the current atmospheric conditions are those in which the levels of greenhouse gases are allowed to increase steadily with time, and which contain an ocean which can sequester and transport heat. The detailed results of studies by Washington and Meehl (1989), and Stouffer et al. (1989) are available and more recently some preliminary results from Cubasch et al., (1991) have become available. These studies all use coupled ocean_atmosphere models.

Washington and Meehl (1989) use a 1 per cent per year linear increase in carbon dioxide, Stouffer et al., (1989) a 1 per cent per year (compounded) increase in carbon dioxide and Cubasch et al., (1991) model the four IPCC Scenarios (see IPCC, 1990a).

Consistent features of the simulations appear to be:

- all models show a tendency for land areas to warm faster than the oceans;
- oceanic warming is faster in the surface layers than in the deeper ocean (though Cubasch et al. (1991) report an increase in ocean temperature to depths of 1000m in the convective areas, particularly in the North Atlantic ocean);
- the warming at any given time is less than the equilibrium value for that instantaneous forcing; and
- the three models report a warming minimum around Antarctica with Cubasch et al. (1991) reporting a $6^{O}C$ cooling centred at $60^{O}S$ $30^{O}W$.

This last feature appears to be unique to GCMs with a realistic oceanic structure, indicating the importance of understanding ocean dynamics in a thorough analysis of climate change.

The Cubasch et al., (1991) model also forecasts a modest sea level rise (4-5cm) during the 50 year simulation though variations of up to 15cm are observed regionally due to changing wind stress patterns on the ocean surface.

The IPCC (1990a) reported a series of simple experiments used to determine (approximately) the lag of the temperature change in a transient experiment to the change in an equilibrium experiment. The results of these estimates are expressed in terms of the climates net sensitivity to a doubling of carbon dioxide. For example, for an atmospheric model with a temperature sensitivity of $+4^{O}C$ to a doubling of carbon dioxide the transient response is approximately 66 per cent of an equilibrium response with a lag of 11 years. For a sensitivity of $15^{O}C$ the response is 85 per cent of an equilibrium response with a lag of 6 years.

C4.5 Regional scenarios

Information concerning climate change on regional and smaller scales will be required if the correct policy responses are to be made. The work presented in Sections C4.2 and C4.3 of this appendix illustrated that there is considerable variability between regional forecasts from different GCMs (this finding is highlighted by Grotch and MacCracken, 1991). In Section C2.11 it was shown that scenarios can be employed to undertake useful sensitivity studies in the face of considerable uncertainty. The scenario approach has been extended to enable scientists to conduct sensitivity analyses of possible trends in regional climate consistent with global warming.

The IPCC (1990a) developed one scenario for each of five regions of the world. The scenarios (given below) were based on the output from high resolution GCMs, scaled to give a global mean warming of $1.8^{O}C$ by 2030, this is consistent with the best estimate of a $2.5^{O}C$ rise for an effective doubling of carbon dioxide. With a low estimate of $1.5^{O}C$ these values should be reduced by 30 per cent; with a high estimate of 4.5°C they should be increased by 50 per cent. The confidence on these estimates is low. These scenarios were used to identify possible regional impacts of global warming (IPCC 1990b).

IPCC WG I business as usual regional scenarios:

Central North America (35° - 50°N 85° - 105°W)

The warming varies from 2°C to 4°C in winter and 2°C to 3°C in summer. Precipitation increases range from 0 to 15 per cent in winter whereas there are decreases of 5 to 10 per cent in summer. Soil moisture decreases 15 to 20 per cent in summer.

Southern Asia (5° - 30°N 70° -105°E)

The warming varies from 1 to 2oC throughout the year. Precipitation changes little in winter and generally increases by 5 to 15 per cent in summer. Soil moisture decreases in summer by 5 to 10 per cent.

Sahel (10° - 20°N 20°W - 40°E)

The warming ranges from 1 to 3°C. Area mean precipitation increases and area mean soil moisture decreases marginally in summer. However, throughout the region there are both increases and decreases in both parameters.

Southern Europe (35° - 50°N 10°W - 45°E)

The warming is about 2vC in winter and varies from 2 to 3°C in summer. There is some indication of increased precipitation in winter, but summer precipitation decreases by 5 to 15 per cent, and summer soil moisture by 15 to 25 per cent.

Australia (12° - 45°S 110° - 155°E)

The warming ranges from 1 to 2°C in summer and is about 2°C in winter. Summer precipitation increases by around 10 per cent, but the models do not produce consistent changes in soil moisture. The area averages hide large variations at the sub-continent level.

CSIRO regional scenario

A more detailed regional scenario for Australia, which is broadly consistent with that of the IPCC WG I has been developed by CSIRO (1990). This scenario was issued at the Planning Ministers' Greenhouse Seminar in Cairns, June 1990 and labelled:

‘best state-of-the-science advice, June 1990

NOTE: THIS IS NOT A FORECAST

use for sensitivity studies only.’

The scenario for Australia assumes an effective doubling of carbon dioxide by 2030 and that there is a time lag of about 20 years for the consequent warming to fully occur. The scenario was:

TEMP	+1 or 2^{o}C in northern coastal areas +1 to 3^{o}C in southern coastal areas +2 to 4^{o}C inland More in dry season, less in wet.
RAIN	+10 to 20% in summer rainfall region -10% in winter rainfall region (southwest) More intense rainfall events monsoon more intense
EVAPORATION	5 to 15% increase
TROPICAL CYCLONES	Could form and move further south some may be more intense preferred paths may alter Frequency change - affected by ENSO
ENSO	Future behaviour uncertain Probably El Ninos and anti-El Ninos will continue to occur i.e. drought and flood years
SNOW LINE	Up 100m per 1^{O}C
WINDS	Weaker trades Westerlies further south Strong squalls with severe weather fronts
SEA LEVEL	Global average up 20 cm by 2030 3 to 10 cm rise per decade Weather changes will affect magnitude and frequency of severe weather events
EXTREME EVENTS	Magnitude and frequency of extremes generally change more rapidly than means
DIRECT CO2 EFFECTS	Generally beneficial to C_3 plants (eg wheat) but not to C_4 plants (eg sugar cane, sorghum)

CAVEATS: These are generalised best estimates, relative to the 1980s, based on IPCC and CSIRO studies, and are of varying degrees of reliability. There will be important regional and local variations.

REFERENCES

ABARE 1991, *Projections of Energy Demand and Supply - Australia 1990-91 to 2004-05,* Australian Bureau of Agricultural and Resource Economics, AGPS, Canberra, pp 144.

Australian Institute of Petroleum (AIP), 1989, *The Greenhouse Effect - A Position Paper,* AIP, July.

Ardeel, C., Agee, E., and Buja, L., 1991, *Peculiarities of the processed NASA and UK East-Anglia global surface temperature data sets,* Preprints of the second symposium on global change studies, January 14-18, 1991, New Orleans, American Meteorological Society, pp.. J5-J10.

Barnett, T.P., 1988, *Global sea level change*, In: NCPO, Climate variations over the past century and the greenhouse effect. A report based on the First Climate Trends Workshop, 7-9 September 1988, Washington DC National Climate Program Office/NOAA, Rockville, Maryland, USA.

Barson, M.M. and Gifford, R.M. 1990, *Carbon Dioxide Sinks: the Potential Role of Tree Planting in Australia*, In 'Greenhouse and Energy', (ed Swaine D.J.) CSIRO, Australia pp. 433-443.

Betts, A.K. 1990, *Greenhouse Warming and the Tropical Water Budget*, Bull. American Meteorological Society, 71, pp. 1464-1465.

Bjorkstrom, A. 1979, *A Model of* CO_2 *Interaction between Atmosphere*, Oceans and Land Biota, In SCOPE 13 'The Global Carbon Cycle', (eds Bolin, B., Degens, E.T., Kempe, S., and Ketner, P.) John Wiley and Sons, Chichester, pp. 403-457.

Bottomley, M., Folland, C.K., Hsiung, J., Newell, R.E., and Parker, D.E., 1990*, Global Ocean Surface Temperature Atlas (GOSTA*), HMSO, London, pp.. 20-iv and 313 plates.

Bryant, E.A., 1988, *Sea level variability and its impact within the greenhouse scenario,* In: Greenhouse: Planning for climate change, E.J. Brill, Leiden, pp. 135-145.

Cess R.D., Potter G.L., Blanchet, J.P., Boer, A.D., Del Genio, A.D., Deque, M., Dymnikov, V., Galin, V., Gates, W.L., Ghan, S.J., Kiehl, J.T., Lacis, A.A., Le Treut, H., Li, Z-X., Liang, X-Z., McAvaney, B.J., Meleshko, V.P., Mitchell, J.F.B., Morcrette, J-J., Randall, D.A., Rikus, L., Roeckner, E., Royer, J.F., Schlese, U., Sheinin, D.A., Slingo, A., Sokolov, A.P., Taylor, K.E., Washington, W.M., Wetherald, R.T., Yagai, I., and Zhang, M-H., 1990, *Intercomparison and interpretation of climate feedback processes in 19 atmospheric general circulation models,* J of Geophys. Res., 95, No D10, pp 16601 - 16615.

Cicerone, R.J. and Oremland, R.S. 1988, *Biogeochemical Aspects of Atmospheric Methane,* Global Biogeochemical Cycles, in press.

Cline W.R., 1991, *Scientific basis for the greenhouse effect,* The Economic Journal, 101, pp. 904-919.

Cohen, Y. and Gordon, L.I. 1979, *Nitrous Oxide Production in the Ocean,* J. Geophys. Res., 84, pp. 347-353.

CRA Limited, 1989, *Report to CRA Limited: The Feasibility and Implications for Australia of the adoption of the Toronto Proposal for Carbon Dioxide Emission*, CRA, September.

Crutzen, P.J., 1988, *Variability in Atmospheric-Chemical Systems,* In SCOPE 35 `Scales and Global Change', (eds Rosswall, T., Woodmansee, R.G., and Risser, P.G.), John Wiley and Sons, Chichester, pp. 81-108.

Crutzen, P.J., Aselmann, I., and Seiler, W., 1986*, Methane Production by Domestic Animals*, Wild Ruminants, other Herbivorous Fauna, and Humans, Tellus 30B, pp. 271-284.

CSIRO, 1990, *Regional impact of the enhanced greenhouse effect on Victoria,* Annual Research Report, CSIRO, Division of Atmospheric Research, Aspendale, Victoria, pp. 70.

Cubasch, U., Hasselmann, K., Hock, H., Maier-Reimer, E., Mikolajewicz, U., Santer, D.D., and Sausen, R., 1991*, Time-dependent greenhouse warming computations with a coupled ocean-atmosphere model*, Max-Plank-Institut fur Meteorologie, Hamburg, Report No. 67, pp 18.

Department of Foreign Affairs and Trade, 1990, *International Developments on Greenhouse Emissions Targets*, Internal Report, 14 November 1990, pp. 90.

Dickinson, R.E., 1986*, The climate system and modelling of future climate In: The Greenhouse Effect,* Climatic Change and Ecosystems, (Eds., Bolin, B., Doos, B., Jager, J., and Warrick, R.,), Scope 29, John Wiley and Sons, Chichester, pp. 207-270.

Crutzen, P.J., 1988, *Variability in atmospheric - chemical systems,* in Scales and Global Change (Eds. Rosswall T., Woodmansee, R.G., and Risser, P.G.), Scientific Committee on Problems of the Environment (SCOPE), John Wiley and Sons, pp. 355.

Edmonds, J.A., Reilly, J., Trabalka, J.R., Reichle, D.E., Rind, D., Lebedeff, S., Palutikof, J.P., Wigley, T.M.L., Lough, J.M., Blasing, T.J., Solomon, A.M., Seidel, S., Keyes, D., and Steinberg, M., 1986, *Future Atmospheric Carbon Dioxide Scenarios and Limitation Strategies,* Noyes Publications, New Jersey, pp. 620.

Elkins, J.W., Wofsy, S.C., McElroy, M.B., Kolb, C.E., and Kaplan, W.A., 1978, *Aquatic Sources and Sinks for Nitrous Oxide,* Nature, 275, pp. 602-606.

Energetics Pty Ltd, 1990, *Quantification of Victoria's Energy - Related Greenhouse Gas Emissions,* Department of Industry and Economic Planning, Resources Policy and Planning.

Etheridge, D.M., Pearman, G.I., and de Silva, F., 1988, *Atmospheric Trace-Gas Variations as Revealed by Air Trapped in an Ice Core from Law Dome,* Antarctica, Annal. Glaciology, 10, pp. 28-33.

Farmer, G., Widley, T.M.L., Jones, P.D., and Salmon, M., 1989*, Documenting and explaining recent global mean temperature change,* Climatic Research Unit, Norwich, UK.

Friedli, H., Loetscher, H., Oeschger, H., Siegenthaler, U., and Stauffer, B., 1986*, Ice Core Record of the 13C/12C Record of Atmospheric Carbon Dioxide in the Past Two Centuries,* Nature, 324, pp. 237-238.

Galbally, I.E., 1985, *The Emission of Nitrogen to the Remote Atmosphere: Background Paper* in J.N. Galloway et al. (Eds), The Biogeochemical Cycling of Sulphur in Nitrogen in the Remote Atmosphere, D. Reidel, pp. 27-53.

Gifford, R.M., 1991 Evidence presented to the Industry Commission Inquiry into the Costs and Benefits of Reducing Greenhouse Gas Emissions, Canberra, 11 March 1991, pg. 33.

Gornitz, V., Lebedeff, S., and Hansen, J., 1982, *Global sea levels trends in the past century,* Science, 215 pp. 1611-1614.

Gornitz, V., Lebedeff, S., 1987, *Global sea level changes during the past century,* In: Sea level fluctuation and coastal evolution (Eds., Nummedal, D., Pilkey, O.H., and Howard, J.D.) SEPM Special Publication No 41.

Griffiths, J.F., and Driscoll, D.M., 1982, *Survey of Climatology* Charles E. Merrill, Sydney, pp. 358.

Grotch, S.L., and MacCracken, M.C., 1991, *The use of general circulation models to predict regional climate change,* J., of Climate, 4, pp. 286 - 303.

Hansen, J., Lacis, A., Rind, D., Russel, L., Stone, P., Fung, I., Ruedy, J., and Lerner, J., 1984, *Climate sensitivity analysis of feedback mechanisms*, In: Climate processes and climate sensitivity, (Eds., Hansen, J., and Takatiashi, T.), Geophys. Monogr. Ser., AGU, Washington, 29, pp. 130-163.
Hansen, J., and Lebedeff, S., 1987, Global trends of measured surface air temperature, J. Geophys. Res., 92, pp. 13345-13372.

Hansen, J., and Lebedeff, S., 1988, *Global surface temperatures: update through 1987,* Geophys. Res. Letter., 15, pp. 323-326.

Hoffman, J.S., Keyes, D., and Titus, J.G., 1983 *Projecting future sea level rise: Methodology, Estimates to the year 2100 and Research Needs*, US GPO 055-000-0236-3, GPO, Washington (DC).

Hoffman, J.S., Wells, F.B., and Titus, J.G., 1986, *Future global worming and sea level rise,* In: Iceland Coastal and River Symposium, (Ed Sigbjarnason, G.), Reykjavik, National Energy Authority, pp. 245-266.

Intergovernmental Panel on Climate Change (IPCC), 1990a, *Climate change: The IPCC Scientific Assessment* Report prepared by Working Group I of the Inter-Governmental Panel on Climate Change, Eds Houghton, J.T., Jenkins, G.., and Ephraums, J.J., University Press, Cambridge, pp. 365.

IPCC, 1990b, *Climate Change: The IPCC Impacts Assessment* Report prepared by Working Group II of the Inter-Governmental Panel on Climate Change, Eds Tegart W.J.McG., Sheldon G.W., and Griffiths D.C., 1990, , AGPS, pp. 7-33.

IRRI (International Rice Research Institute), 1986, *World Rice Statistics*, 1985, IRRI, Los Banos.

Jaeger, J., 1988, *Developing policies for responding to climatic change: A summary of the discussions and recommendations of the workshops held in Villacte 1987 and Bellagio 1987,* WMO/TD No. 225.

Johnston, H.S., Serang, O., and Podolske, J., 1979*, Instantaneous Global Nitrous Oxide Photochemical Rates,* J. Geophys Res., 84, pp. 5077-5082.

Jones, P.D., Reper, S.C.B., Bradley, R.S., Diaz, H.F., Kelly, P.M., and Widley, T.M.L., 1986a *Northern Hemisphere surface air temperature variations,* 1851-1984, J. Clim. App.l. Met., 25, pp. 161-179.

Jones, P.D., and Wigley, T.M.C., 1990, *Satellite data under scrutiny,* Nature, 344, pp 711.

Keeling, C.D., Bascastow, R.B., Carter, A.F., Piper, S.C., Whorf, T.P., Heimann, M., Mook, W.G., and Roeloffzen, H., 1989. *A Three Dimensional Model of Atmospheric Carbon Dioxide Transport based on Observed Winds: 1. Analysis of observation data in: Aspects of climate variability in the Pacific and Western Americas,* Peterson, D.H., (Ed), Geophysical Monograph, 55, AGU, Washington (USA), pp. 165-236.

Khalil, M.A.K., and Rasmussen, R.A., 1987*, Nitrous Oxide : Trends and Global Mass Balance over the Last 300 Years,* Annals of Glaciology, 10, pp. 73-79.

Lashof, D.A., and Tirpak, D.A., 1990, *Policy Options for Stabilising Global Climate*, U.S. Environmental Protection Agency Office of Policy, Planning and Evaluation, Washington, DC, pp. 807.

Leggett, J., 1990, (Ed) *Global Warming: The Greenpeace Report,* Oxford University Press, Oxford, pp. 554.

Leggett J.K., 1991, *Anxiety and opportunity: The politics of climate science and the scope for a new global energy infrastructure.* In: Cambridge Studies in Global Security, Ed., G. Prins (in press).

Lerner, J.E., Mathews, E., and Fung, I., 1988*, Methane Emission from Animals : A Global High-Resolution Database,* Global Biogeochemical Cycles 2, pp. 139-156.

Levy, I.I., Mahlman, J.D., and Moxim, W.J., 1979, *A Preliminary Report on the Numerical Simulation of the Three-Dimensional Structure and Variability of Atmospheric* N_2O*,* Geophys. Res. Letts., 6, pp. 155-158.

Lindzen, R.S., 1990, *Some coolness concerning global warming*, Bull. Am. Met. Soc., 71, pp. 288-299.

Lipschultz, F., Zafiriou, O.C., Wofsy, S.C., McElroy, M.B., Valois, F.W., and Watson, S.W., 1981, *Production of* NO *and* N_2O *by Soil Nitrifying Bacteria,* Nature, pp. 294-643.

McAvaney, B.J., Colman. R., Fraser, J.F., and Dahni, R.R., 1991*, The response of the BMRC AGCM to a doubling of CO2,* BMRC Technical Memorandum No. 3 (in preparation).

Mitchell, J.F.B., 1989, *The 'Greenhouse Effect' and climate changes,* Rev. of Geophysics, 27, 115-139.

Mitchell, J.F.B., and Warrilow, D.A., 1987, *Summer dryness in northern mid-latitude due to increased CO2,* Nature, 330, pp. 238-240.

Mitchell, J.F.B., Senior, C.A., and Ingram, W. J., 1989, *CO2 and climate: A missing feedback?,* Nature, 341, pp. 132-134.

Moller, F., and Manabe, S., 1961, *Uber das Strahlungsg Leichgewicht der Atmosphere*, Z., Fur Met., 15.

Monk, W., 1991, *Ocean acoustic tomography on a global scale,* Presented at the IUGG 20th General Assembly, Vienna, 11-24 August, IAPSO Programme and Abstract, pp 153.

Neftel, A., Moor, E., Oeschger, H., and Stauffer, B., 1985, *Evidence from Polar Ice Cores for the Increase in Atmospheric Carbon Dioxide in the Past Two Centuries,* Nature, 315, pp. 45-47.

Newell, R., Hsiung,J., and Zhongxiang, W., 1989, *Where's the warming?* MIT Technology Review, p. 80.

Noda, A., and Tokoika, T., 1989, *The effect of doubling* CO_2 *concentration on convective and non-convective precipitation in a general circulation model coupled with a simple mixed layer ocean*, J. Met. Soc. Japan, 67, pg 95-110.

Oerlemanns, J., 1989, *A projection of future sea level,* Climatic Change, 15, pp. 151-174.

Oglesby, R.J., and Saltzman, B., 1990, *Sensitivity of the equilibrium surface temperature of a GCM to systematic changes in atmospheric carbon dioxide,* Geophysical Research Letters, 17(8), pp 1089-1092.

Pearman, G.I., 1988, *Greenhouse, Planning for Climate Change CSIRO* Australia, pp. 725.

Pearman, G.I., 1989, *Prediction of Climatic Change from Best Scientific Models*. in papers presented at the first meeting of the Prime Ministers Science Council, 6 Oct. 1989, AGPS, pp. 3-28.

Pearman, G.I., Etheridge, D., de Silva, F., and Fraser, P.J., 1986, *Evidence of Changing Concentrations of Atmospheric , N_2O and CM4 from Air Bubbles in Antarctic Ice,* Nature, 320, pp. 248-250.

Pearman, G.I., and Fraser, P.J., 1988, *Sources of Increased Methane,* Nature, 332, pp. 489-490.

Peltier, W.R., and Tushingham, A. M., 1990*, The influence of glacial isostatic adjustment on tide gauge measurements of secular sea level,* J. Geophys. Res., (in press).

Polar Research Board (PRB), 1985, *Glaciers, Ice Sheets and Sea Level: Effect of a CO2 induced Climatic Change,* Report of a workshop held in Seattle, Washington, September 13-15, 1984, US. DOE/ER/60235-1.

Rand McNally, 1991, *Rand McNally,* ABC, 1991 World Atlas and Almanac, Rand McNally, pp. 192.

Raper, S.C.B., Warrick, R.A., and Wigley, T.M.L., 1990, *Global sea level rise: past and future,* In: Proceedings of the SCOPE workshop on rising sea level and subsiding coastal areas, Bangkok, 1988, (Ed., Milliman, J.D.), John Wiley and Sons, Chichester, (in press).

Resource Assessment Commission 1991, *Forest and Timber Inquiry*, Draft Report, Vol 2, Appendix I, AGPS, Canberra.

Revelle, R., 1983, *Probable future changes in sea level resulting from increased atmospheric carbon dioxide,* In: NAS Changing Climate, Washington (DC), pp. 433-447.

Robin, G. De Q., 1986, *Changing the sea level, In: The Greenhouse Effect,* Climatic Change and Ecosystems, (Eds., Bolin, B., Doos, B., Jager, J., and Warrick, R.A.), John Wiley and Sons, Chichester, pp. 323-359.

Schimel, D., 1990, *Biogeochemical feedbacks in the Earth system,* In Global Warming: The Greenpeace Report (Ed J. Leggett), Oxford University Press, Oxford, pp. 68 - 82.

Schlesinger, M.E., and Mitchell, J.F.B., 1987*, Climate model simulations of the equilitorium climatic response to increased carbon dioxide,* Rev. of Geophys., 25, pp. 760-798.

Schlesinger, M.E., and Zhao, Z.C., 1989, *Seasonal climatic change introduced by doubled CO_2 as simulated by the OSU atmospheric GCM/mixed-layer ocean model*, J. Climate, 2, pp. 425-495.

Spencer, R.W., and Christy, J.R., 1990*, Precise monitoring of the global temperatures from satellites,* Science, 247, pp 1558-1562.

Steinberg,M., Cheng, H.C., and Horn, F., 1984*, A Systems Study for the Removal, Recovery and Disposal of Carbon Dioxide from Fossil Fuel Power plants in the US*, US Department of Energy, Washington.

Stouffer, R.J., Manabe, S., and Bryan, K, 1989*, On the climate change induced by a gradual increase of atmospheric carbon dioxide,* Nature, 342, pp. 660-662.

United Nations, 1987, *Energy Statistics Yearbook,* United Nations, New York.

Van der Veen, C.J., 1988, *Projecting future sea level*, Surv. In Geophys., 9., pp. 389-418.

Vinnikov, K., Groisman, P., Lugina, K and Goluber, A., 1987*, Variations in Northern Hemisphere and surface air temperature over 1881-1985*, Meteorology and Hydrology, 1, pp. 45-53.

Vinnikov, K., Groisman, P., and Lugina, K., 1990*, The empirical data on modern global climate changes (temperature and precipitation),* J. Clim., (in press).

Walker, I.J., 1990, *Potential to Reduce Emissions of Greenhouse Gases in the Energy Sector*, EPD Discussion Paper No. 1, Energy Programs Division, Department of Primary Industry and Energy, Canberra.

Wang, W-C., Dudek, M.P., Liang, X-Z., and Kiehl J.T., 1991*, Inadequacy of effective CO_2 as a proxy in simulating the greenhouse effect of other radiatively active greenhouse gases*, Nature, 350 (18 April), pp 573-577.

Washington, W.M., and Meehl, G.A., 1984, *Seasonal cycle experiments on the climate sensitivity due to a doubling of CO_2 with an atmospheric GCM Coupled to a simple mixed layer ocean model,* J. Geophys. Res., 89, pp. 9475-9503.

Washington, W.M., and Meehl, G.A., 1989, *Climate sensitivity due to increased CO_2: experiments with a coupled atmosphere and ocean general circulation model,* Climate Dynamics, 4, pp. 1-38.
Wetherald, R.T., and Manabe, S., 1986, *An investigation of cloud cover change in response to thermal forcing,* Climatic Change, 10, pp. 11-42.

Wetherald, R.T., and Manabe, S., 1989, *Cloud feedback processes in a general circulation model*, J. Atmos. Sci., 45, pp. 1397-1415.

Wilkenfeld, G., and Associates, with Energetics Pty Ltd, 1991, *Greenhouse Gas Emissions from the Australian Energy System: the Impact of Energy Efficiency and Substitution,* End of Grant report, Report No. 1379, National Energy Research and Development Program, Canberra.

Wilson, C.A., and Mitchell, J.F.B., 1987*, Simulated climate and CO_2 induced climate change over western Europe,* Climatic Change, 19, pp. 11-42.

Woodruff, S.D., Slutz, R.J., Jeene, R.J., and Steurer, P.M., 1987, *A comprehensive ocean-atmosphere data set,* Bull. Am. Met. Soc., 68, pp. 1239-1250.

Zillman, J.W., Downey, W.K. and Manton, M.J., 1989*, Climate Change and its Possible Impacts in the Southwest Pacific Region,* Scientific Lecture presented at the tenth session of W.M.O. Regional Association V, Singapore, 12-24 November, 1989, pp. 69.

APPENDIX D: THE ECONOMICS OF THE GREENHOUSE PROBLEM

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D1 The economics of environmental pollution

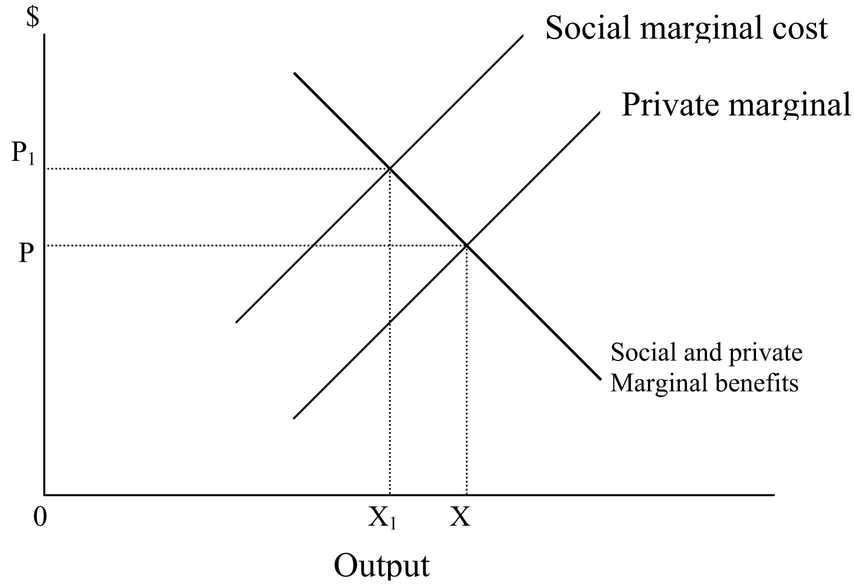
In approaching the issue of possible global climate change due to anthropogenic greenhouse gas emissions, a lot can be learned from the standard analysis of environmental pollution problems. There is a large literature on environmental pollution problems, much of which deals with the choice of instruments for control by a sovereign government of pollution within its geographical boundaries. In recent years, however, it has been recognised that many problems of environmental pollution involve relationships across the boundaries of nation states. The economics literature dealing with such problems is relatively small.

Global climate change would be a trans-boundary pollution problem of an extreme kind. The economics literature relating to policy instruments in relation to an enhanced greenhouse effect is small but growing rapidly. It is necessary to precede discussion of trans-boundary problems with consideration of problems confined within national boundaries, since it is the analysis of such problems which conditions the approach to the trans-boundary case. Additionally, while an enhanced greenhouse problem would have some special features it seems likely that at least some of the lessons which can be learned from the more standard context would be applicable.

D1.1 Optimal pollution levels or arbitrary standards?

In neoclassical environmental economics, the optimal level of pollution is that which would emerge in an ideally functioning market system, where those responsible for pollution would bear all of the relevant costs associated with it -- that is, where private costs equal social costs. In actual market systems polluters do not usually bear all such costs and pollution levels are presumed to be excessive. In a market economy air and water pollution, for example, occur because air and water assets are held in common, and used on a free access basis. Unless private market agents own the affected environmental assets, some costs will be ignored and there will tend to be excessive pollution. The term used in such cases is externality -- see Box D1. This is an example of the class of problems known as market failure.

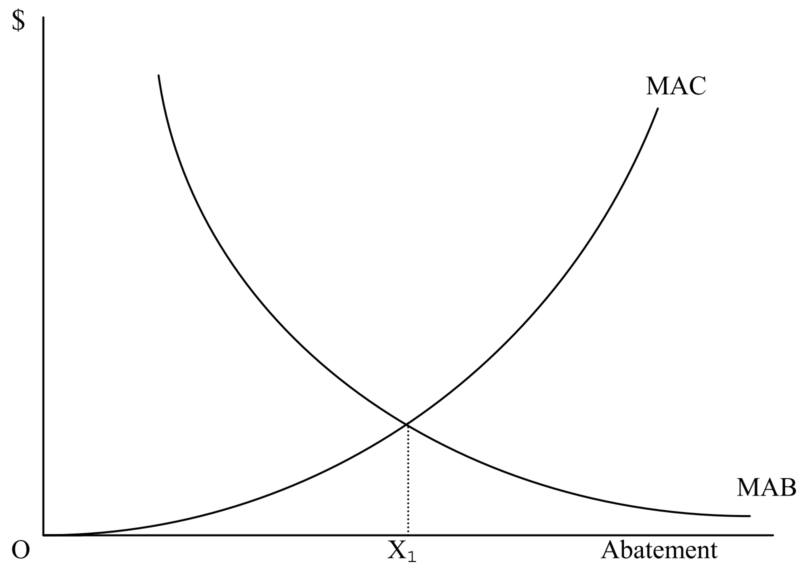
Box D1: **Negative externality and the optimal level of pollution**



The figure relates to decision making by a firm which pollutes in proportion to its output level. As pollution involves real costs to society which are not borne by the firm, social marginal cost is everywhere above private marginal cost. The firm bases its decision on private marginal cost and private, assumed equal to social, marginal benefit and maximises profit by producing output at level OX. The socially optimal levels of output and pollution are given by OX_1, where social marginal cost equals social marginal benefit. There is excessive pollution in amount X_1X at the market optimum. The difference between social and private cost is known as external cost, and the origin of the excessive pollution is said to lie in a negative externality -- the fact that pollution costs are external to private decision making.

An alternative way of representing the optimal level of pollution is in terms of the costs and benefits of pollution abatement. This is illustrated in Figure D1, where MAC is marginal abatement costs and MAB is marginal abatement benefit. As the amount by which the pre-existing level of pollution is reduced, or abated, increases so the costs of a little more abatement increase -- MAC has a positive slope. MAB has a negative slope, on the basis of the assumption that as the level of abatement increases, so the benefits to successive abatement increments decrease. The optimal amount of abatement is OX_1, where MAC = MAB. If abatement were greater than OX_1, MAC would exceed MAB, implying that benefit net of cost would be increased by moving toward X_1. Conversely, if abatement were less than OX_1, MAB would exceed MAC, so that benefit net of cost would be increased by increasing the level of abatement.

Figure D1: **Optimal level of abatement**



The early literature was concerned with identifying the optimal level of pollution, and with the means for internalising externalities so as to correct for market failure and attain optimal pollution levels. However, it turns out to be very difficult to measure external costs (see Section D2 below), and attention in the literature now concentrates on the question of the best means for reducing pollution levels.

It has come to be accepted that the feasible goals are `arbitrary' standards for pollution reduction and that the most useful thing that economists can do is to consider the best means for the attainment of such goals. The main focus of the literature regarded as policy relevant now is the question of the choice of instrument for the attainment of arbitrary standards.

In the economics literature the term ‘arbitrary’ means only that the standard is not known to be that corresponding to optimality as defined by neoclassical economics. An arbitrary standard could emerge, for example, from lengthy scientific analysis. Thus the usual connotations for ‘arbitrary’ should not be imputed and it would perhaps be better if the term had not entered the literature. However, it is important to be clear that the discussion of instrument choice which follows in this section is not conditional on the pollution reduction goal being that which a full blown cost benefit analysis would sanction (ie with the target set to equate marginal social costs and benefits). Nevertheless, it should be noted that much of the discussion here would also apply if an optimal standard was the goal.

There is an extensive discussion of relevant issues in the economics literature -- for example, see Baumol and Oates (1988); Bohm and Russell (1985); Common (1988 and 1990); OECD (1989) and Tietenberg (1990).

D1.2 Instruments for arbitrary standards

Given the objective of attaining some arbitrary standard, what are the available policy instruments?

Four categories of available policy instruments can be distinguished:

- Moral suasion and education to change behaviour. Particular forms could include:
  - government sanctioned appeals to the community to generate public pressure on polluters;
  - education of the community about potential and actual damage;
  - financing research into pollution and the environment;
- Regulation, or direct control, of waste discharge behaviour. This can take two main forms:
  - specification of allowable discharge quantities (either directly, or as percentage reductions);
  - specification of processes and/or equipment.
- Price incentive modification. Four principal options exist here:
  - discharge taxation;
  - subsidisation of discharge reduction;
  - creation of markets in discharge permits;
  - input taxation.
- Public provision of waste treatment facilities.

Various combinations are possible. Regulation of process/equipment could, for example, be combined with subsidisation, and adopted concurrently with a publicity campaign. Again, discharge taxation could be used to finance public provision of treatment facilities for the taxed waste discharges.

This section concentrates on regulation and price incentive instruments.

Criteria for choice

Although the Commission's policy guidelines require it to give primacy to efficiency considerations, decisions about which instruments to adopt can be made against a number of criteria. These include:

- Dependability. This concerns the degree to which the instrument meets the target standard, both in the short and long run.
- Efficiency. An efficient instrument is one which achieves its aim at the lowest possible resource cost.
- Information requirements. Instruments differ in the amount of information available to a regulatory agency which is required for their effective use.
- 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 is not costless and requires 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. The costs generated by the instrument should be distributed equitably.
- Continuing incentive. An instrument might be preferred if it is not only dependable but provides an incentive to reduce emissions further.

Some further comments are made below about some of these criteria, but first a simple model is used to explore dependability and efficiency considerations.

A simple model

The weighting to be given to these various criteria is likely to vary with the circumstances of particular pollution problems. However, when examining the issues involved in instrument choice it is useful to start with a simple economic model.

Suppose there are a number of firms discharging pollution, that there is an environmental protection agency established with all necessary powers, and that the agency decides that total emissions should be reduced by a certain percentage. A number of simplifying assumptions are made:

- all discharging firms are profit maximisers;
- all of the firms act as if all of the prices that they face, including those influenced by the actions of the environmental protection agency, will be unaffected by their own behaviour, as will any regulatory actions taken by the agency;

- that the environmental protection agency has complete information on the relationship for each firm between its profits and its level of waste discharge (ie on the abatement cost function for each firm);
- that the input and output prices facing all of the firms are determined in competitive markets; and
- that the environmental protection agency can costlessly monitor discharges to the extent required, and costlessly enforce compliance.

Given these assumptions, the waste discharge target will be met at least cost (ie most efficiently) when total abatement costs for society overall to achieve that target are minimised. Because of the assumption of perfect information, the agency can compute the level of pollution reductions by each firm which would attain the required total reduction in discharges at the least possible total abatement cost.

As firms generally have differing abatement cost functions, the minimisation of total abatement costs across all firms will require differing amounts of abatement by each firm.

Having done the calculations, there are several ways in which the required reductions could be obtained at the same total level of minimum cost to society:

- regulation -- the agency could simply tell each firm to reduce discharges by the amount that the solution requires of it;
- taxation of emissions -- the cost minimising computation conducted by the agency will indicate the shadow price of the total reduction standard it has adopted. If the agency were to tax each firm's waste discharges at this computed shadow price, the required overall reduction would be realised at the least possible aggregate abatement cost;
- subsidy to reduce emissions -- if each firm were to be paid an amount equal to the computed shadow price for each unit by which it reduced its discharges the overall required reduction would be achieved at least cost; and
- tradeable permits -- these would allow firms to emit waste up to a certain level, and emissions in excess of permits held would be prohibited. As permits are tradeable, the overall reduction in emissions would be obtained at the lowest possible abatement cost irrespective of how the permits are initially allocated among firms. The market clearing price for permits would come to equal to the shadow price that the agency calculated.

In summary, on the assumptions stated, the four different instruments are all dependable and give least cost realisation of the standard. (Each may have different equity effects -- see below). One involves regulation, while three involve price incentive instruments. However, the conclusion that all meet the dependability and least cost (efficiency) criteria no longer holds if some of the assumptions are relaxed.

Imperfect information

If the individual abatement cost functions are not known to the agency, which would be the case in reality, it cannot calculate the least cost abatement regime. Telling each firm to cut back by a common percentage would realise the standard, but not at overall least cost. This regulatory instrument meets the dependability criterion, but not that of efficiency.

Alternatively, the agency could implement an emissions tax, which would tax each firm at the same common rate. The amount each firm would pay in tax would depend upon its level of emissions. Whatever reduction in total discharges this induces would have been attained at the lowest possible cost. But, as the required tax rate would not be known in advance, the total reduction would not necessarily be that required. This tax instrument is thus not dependable, but is efficient. The reason for the least cost property is straightforward. Each profit maximising firm will react to the tax by abating its discharges up to the point where marginal abatement cost equals the tax rate. With all firms facing the same tax rate this means that all will have equal marginal abatement costs, and there is then no reallocation of abatement that could reduce total abatement costs. Similarly, subsidisation, at a uniform rate, of emissions reductions will also be efficient but not dependable.

Dependability (ie meeting the target) could be approached by iterative adjustments of the tax/subsidy rate. However, this could add to monitoring costs and would, at the very least, delay the realisation of required reduction. It would also imply adjustment costs for the firms, in that the necessary iterations in the tax rate could not be declared in advance. Further, if relative input and output prices changed the tax rate could require further adjustment.

In contrast to the other instruments for bringing about emissions reductions, tradeable permits remain both dependable and efficient in the absence of perfect information on each individual firm's abatement cost function. Each firm will, of course, need to have perfect information on its own level of emissions and its own abatement cost function. The quantity of permits it is necessary to create is clearly indicated by the reductions target. And, since a single price for permits will be established in the market for them, marginal abatement costs will be equalised between firms.

Thus, under the assumptions stated, tradeable permits are both efficient and dependable. However if, for some reason (perhaps for equity reasons, see below), permits were to be ruled out, then a choice between the regulation and tax/subsidy instruments would have to weigh up dependability against efficiency. The higher the probability of adverse effects arising from emissions is considered to be, the greater the relative weight presumably given to the dependability criterion, and the greater the relative attraction of regulation. If irreversible adverse effects are considered unlikely, or there is plenty of `lead time', then reaching the chosen target might not be as urgent and the relative attractiveness of the efficient tax/subsidy route is increased.

Monitoring and enforcement

So far, monitoring and enforcement problems have been assumed away. All of the possible instruments require monitoring and enforcement, which involves costs. Are some instruments more costly to monitor and enforce than others?

In regard to monitoring, it would appear that emissions quantity regulation, emissions taxation and emissions permit trading will all involve similar costs. In each case, continuous emissions monitoring at every source would be needed -- as the basis for control in the case of regulation, as the basis for the total liability to the agency in the case of taxation, and as the basis for compliance observation in the case of permit trading. Monitoring costs would vary considerably across pollutant types and problems. In some cases, such as motor vehicle emissions for example, monitoring of emissions as such would clearly involve high costs. In such cases, if there exists a direct physical relationship between inputs to the production (or use) process and the emissions of concern, monitoring inputs as the basis for calculating the emissions would offer cost savings. Alternatively, the inputs themselves could be used as the tax or permit base.

Compliance enforcement requirements differ across instruments. In the cases of emissions quantity regulation and tradeable permits, it is necessary to be able to ensure compliance if dependability is to be ensured, and this implies the existence and operation of a legal sanctions system. In the case of taxation (of emissions or inputs), what is required is a system which guarantees the payment of the assessed tax liabilities.

All instruments involve monitoring and enforcement costs, which will vary also with the pollution problem at issue. Assessment of the relative merits of the various instruments requires empirical analysis of particular cases.

Equity considerations

Different policy instruments can have different effects upon the distribution of costs within society. There are two broad types of costs: abatement costs which are real resource costs to society (ie costs of abatement reduce the resources available for alternative uses); and transfers which merely redistribute income between groups in society.

Each policy instrument involves abatement costs being met initially by individual emissions sources. The extent to which these costs can be shifted depends upon market conditions. Tradeable permits can involve movement of abatement costs between firms. With regard to transfers: regulation involves no transfers; taxation transfers money to the agency; subsidies means the agency transfers funds to firms; under tradeable permits there are transfers between firms, and also possibly to the agency, if the permits are initially charged for.

Analysis of the equity implications of the choice of pollution control instrument is complicated. For example, compare discharge taxation and subsidisation. Consideration needs to include analysis of the final incidence of the taxation, of the use which would be made by the agency of the tax yield, and of the source of the funds which would be used for subsidy payment.

Again, should tradeable permits be given free to firms or auctioned? Issuing permits free would give windfall gains to the owners of the firms. This might suggest that the permits should initially be auctioned. Firms, however, might consider it ‘unfair’ to have to pay for a ‘right’ they already have. Indeed, to the extent that firms consider emissions release a ‘right’ then those ‘rights’ would possibly have been capitalised into the value of the firm's assets. A purchaser of a firm may have already paid for those ‘rights’.

Summing up

The foregoing is necessarily a somewhat superficial review of some of the matters arising in the theoretical economics literature on the choice of instrument for pollution control. It does, however, serve to establish the following points:

- There is a number of criteria which can be used to assess the appropriateness of different policy instruments.
- Trade-offs as between criteria may have to be made.
- There is no uniquely correct choice of instrument which applies in all circumstances.

D1.3 Instruments in practice

Experience

Qualitative analysis indicates that there is no uniquely correct choice from the available policy instruments. It is a matter of case-by-case assessment. Further, for a given pollution problem, judgements can differ as to the best instrument according to the weights given to the different criteria.

The question which then naturally arises is what conclusions can be drawn from experience in the use of the different instruments. The answer to this question is `few', as there is little experience across the full range of instruments to draw upon. In practice, there has been heavy reliance on regulatory control. As Bohm and Russell (1985) put it:

> over the long sweep of history direct regulations (prohibitions, specifications of behaviour, non-marketable permits to discharge) have been the instruments of actual choice for dealing with pollution, whether from geese in village brooks or petroleum refineries on major rivers. Unlike commodity prices and markets, which existed before economists began analysing them, administratively set prices or legislatively created markets do not appear to have sprung up as intuitive responses to externality problems. Quite the reverse; even after sustained intellectual development of these concepts during the period from 1960, we can find few examples of their application.

This statement dates from 1985, but the situation has not materially changed since then. (For a review of more recent developments in the use of market based instruments, see Industry Commission 1991, pp. 95-110.)

Some exceptions to the reliance on regulatory instruments will be noted below, together with such evidence on the cost saving properties of price incentives as has been generated. Some remarks on the possible reasons for the lack of attention to the advice offered by economists will also be made. In the absence of actual data on comparative instrument performance, economists have done a number of empirical exercises in which performance is simulated in a model. An early example is discussed in Kneese (1977), and some later studies are reviewed in Bohm and Russell (1985): Tietenberg (1990) lists some recent studies. These modelling studies generate results which show that tax and permit systems can offer substantial (abatement) cost savings over the regulatory approach. They also reveal some possible problems about realising such savings in practice. Thus, in regard to studies concerned with discharge taxation, Bohm and Russell note results which show a very small cost saving for taxation over regulation even in the best case (locationally differentiated tax rates implying that the agency has all necessary information), and a negative cost saving where a second-best tax system is modelled. They comment:

> While it is true that a tailored charge set can produce large savings, it is not always true that a uniform charge can improve on a simple regulator approach ... The only general rule would seem to be that if we want to explore alternatives in real settings we ought to do so with models first and only after we have an idea of the range of useful options propose policy changes.

Commenting on the simulations they deal with which address tradeable permits, Bohm and Russell state that:

> it appears that the rankings of policy instruments, even in static efficiency terms, will in general depend on the residual in question, the strictness of the ambient standard being contemplated, and the characteristics of the regional economy and environment. We cannot even be certain that the theoretically best ambient permit system will be the lowest cost alternative because of the importance of such small sources as home heating, for which permit requirements and trading seem completely out of the question.

These remarks apply to simulation studies, which necessarily abstract from a number of possible problems attending the working of the alternative instruments. The models incorporate, for example, cost minimising behaviour and an absence of strategic behaviour. In the case of the Fox River, in Wisconsin USA, a simulation study of permit trading was followed by the actual issue of tradeable permits. The Study results gave savings of several millions of dollars. In actuality the cost savings were minimal and only one trade occurred. This appears to have been due to restrictions placed on allowable trades: see Hahn and Hester (1989a).

The extent to which price incentives are used in member countries has been reviewed in a recent OECD report (1989b). It does not attempt to quantify any cost savings arising. It appears to overstate the extent to which price incentives are in use by treating as such situations where charges are used as a means of cost recovery. This is discussed in Hahn (1989) where the experience with tradeable permits in the USA is also considered (see also Hahn and Hester 1989a). Hahn presents what appear to be the only estimates of cost savings associated with price incentives based on actual experience in pollution control practice. This relates to trading in permits for emissions into the atmosphere, and to trading in permits to add lead to gasoline. In both cases tradeability was added to an existing permit structure of control. Hahn estimates the cost savings in the former case to be in the range 960 to 12435 millions of US dollars, plus an amount reported only as `very small'. There is clearly some uncertainty here. The figures relate to the total lifetimes of the several trading programs involved through to 1985. Of the total saving, 525 to 12000 millions is attributed to the netting scheme, which started in 1974, and which, in fact, allows `trades' internal to firms. Hahn estimates the cost savings attributable to lead rights trading to be `hundreds of millions' of dollars over several years.

Hahn and Hester (1989b) systematically analysed the different elements of the US Environmental Protection Agency's emissions trading policy (refer Box D2). They concluded:

> The emissions trading program has yielded a mixed bag of successes and failures. The activity given the most attention -- EPA-approved bubbles -- has been least used. Nevertheless, the cost savings from emissions trading have been impressive, amounting to over a billion dollars. Netting and offsets have been the most successful aspects of the program, having been used by thousands of firms. Banking has been the least used emissions trading activity. In fact, the general failure of active markets in emission reduction credits to develop is the greatest disappointment of emissions trading. Until such markets exist, the full potential of emissions trading to reduce pollution control costs will go unrealised.

Box D2: **EPA emissions trading terminology**

EPA emissions trading involves four different activities that firms can use: offsets, bubbles, banking and netting. Briefly, these activities are:

- Offsets are used when a major new emission source seeks to locate in a non-attainment area. The new emissions may be offset with emission reductions of an equal or greater amount. The required credits may be obtained through internal or external trades.
- A bubble enables a firm to treat an existing plant with multiple emission sources as if it were a single source. Derived from the concept of a bubble enclosing an entire facility with emissions escaping through a single opening, a bubble allows a firm to adjust the mix of controls on individual sources to meet the total emission limit for the facility in a more cost-effective manner.
- Banking enables a firm to hold emission reduction credits as assets for future use or sale. Each State regulatory agency must develop its own administrative procedures in order to have a banking program. Details of these programs differ significantly across markets.
- By using netting, a firm seeking to increase emissions at one source in a plant can avoid classification as a major source by reducing emissions elsewhere within its facility. The reduction in emissions must be enough so that the net increase in emissions is below the level at which a new source would be considered a major source. Since the reduction used for netting need not be as great as the emissions increase that will be caused by the modification, a netting transaction can result in a small increase in emission levels

Source: Hahn and Hester (1989b)

Australian experience

Taxation measures such as a widely applicable carbon tax are not used in Australia at present. One difficulty in applying such a measure would relate to the disparate regime of fossil fuel taxation which presently applies, with differences not only between the different fuels but also between different states and the Commonwealth.

However, environmental fees and charges are fairly widespread. For example, various charges for water relate to quality monitoring, salinity, and chemicals run-off. The NSW Water Board's Trade Waste Policy, revised in early 1990, provides for a progressive increase in charges toward levels where they could be considered legitimate economic instruments. That is, they provide an incentive for firms discharging trade waste into the sewer to examine their processes and find more cost effective ways to reduce, reuse or recover materials from their trade waste. In the transport sector, also, environmental fees and charges are becoming more common.

Another method of providing an incentive for abatement is to provide rewards. The Waste Management Authority of NSW introduced the Council Recycling Rebate Scheme in January 1991 which rewards councils with a rebate for every tonne recycled funded by a levy on waste generators.

NSW's State Pollution Control Commission (SPCC) and Water Board have introduced the use of performance bonds as a form of financial incentive/disincentive. In 1990 the SPCC introduced a formal pollution reduction program attached to BHP's Port Kembla Steelworks licence. The program provides for BHP to complete a $70 million upgrade of its pollution control systems before the end of 1991. In addition, BHP agreed to post a $9 million bond with the Commission to achieve the pollution reductions required within the agreed time frame.

According to information from DASETT in Odgers (1991), some leading firms in Australia have been attracted by the US offsets, bubble and emission trading programs (see Box D2). An offsets program specifies that new emission sources may be located in a particular area only if they offset new emissions by even larger reductions from existing sources. Bubbles are effectively offsets within a plant -- they allow a firm to adjust the levels of control applied to different pollutant sources within a plant so long as the aggregate emission limit is not exceeded.

Victoria's Air Quality Policy makes specific statutory provision for offset arrangements. However, Victorian business has not actively taken up offsets. The sole offset exercised under the Policy was the building of the new Newport power station which was offset against the closing down of three older power stations: Newport A; Newport B and Spencer Street.

A bubble type approach has been adopted by both NSW and Victoria in providing consents for emission standards in large industries such as car manufacturing, oil refining and chemicals, where they are concentrated in particular geographic areas. BHP at Port Kembla and petrochemicals firms at Altona, Victoria have in effect worked netting and emission/discharge tradeoffs, within statutory ambient and solid wastes management standards.

Another economic instrument which should provide an incentive for sustainable use of a common resource is the assignment of property rights to that resource via tradeable permits or quotas. Australia has had some limited experience in this field.

Under the individual transferable quota scheme for Southern Bluefin Tuna, the Australian Government determines the annual total allowable catch. The fishermen then have a guaranteed proportion of the total catch and can concentrate on the most economically efficient method for taking the catch. The scheme provides an incentive to the most efficient fishermen to buy quotas from the less efficient, thereby restructuring the industry.

In 1983, South Australia became the first state to introduce permanent transfers of water entitlements in restricted areas and circumstances. NSW, Victoria, Tasmania, Western Australia and Queensland have also trialled such a scheme. Transferable water entitlements increase landholders' flexibility in response to changing market conditions and input costs (including increased water charges), and trading provides signals to conserve water and to allocate water most productively.

In Australia a tradeable permits regime is currently applied to give effect to the Montreal Protocol on Ozone Depleting Substances via the Ozone Protection Act 1989 (C'lth). The Commonwealth Government relied on its external affairs powers, to constitute the Act which introduced a national system of licences and tradeable quotas controlling the production, import and export of ozone depleting chemicals. In addition, regulations under the Act ban the import or manufacture of many products containing ozone depleting substances.

Part I of the Ozone Protection Act 1989 states that the Commonwealth legislation is not intended to affect the operation of any State or Territory law that makes provision for the protection of ozone provided that law is capable of operating concurrently with the Act. Complementary legislation has been passed by some States: In 1989, the NSW Government passed an Ozone Protection Act enabling the regulation of the handling of ozone-depleting substances, and the Gazetted regulation came into effect on 31 March 1991; and the South Australian Government passed an amendment to the Clean Air Act 1984 to control CFCs and halons.

The licensing scheme under the Commonwealth Ozone Protection Act came into effect on 1 July 1989. All manufacturers, importers and exporters of ozone depleting substances are required to be licensed. According to advice from DASETT, twelve licences were held on 2 October 1991. No licences have been issued for halons, as there is no Australian manufacture, import or export of those chemicals.

Initial quota allocations were based on information reported by industry for 1986, the baseline year nominated by the Protocol. Quotas are re-issued to licence holders annually. Separate quotas apply for manufacture, for export and for import. The export quota allocations have been reduced by 5 per cent each quota period since 1989-90. However, there is no set rule to reduce the quota amount of CFCs allowed for manufacture (encompassing export quota) and import.

In 1989-90, Australian manufacture, export and import of the scheduled substances was less than the volumes permitted by quota (DASETT 1990). According to DASETT, the level of actual activity by licensees continues to be under that permitted by their quota allocations. Due to the declining demand for these chemicals by many user industries and the development and commercial marketing of alternatives and substitutes, the Department does not expect that the quota allocations will constrain production volume of scheduled substances.

The Protocol now provides for complete phasing out of these chemicals by the year 2000 (see below). The Act does not empower the Minister to exceed the reduction program set out in the Montreal Protocol. However, the ANZEC National Strategy, an agreement between business and state and federal governments, sets out the more ambitious target date of 1997. And in some areas this phase-out program has been overtaken by more rapid progress in user industries.

Fees apply to recover the Department's administrative costs. In 1989-90, the fee was $16.09 per ODP (ozone depleting potential[1]) tonne. This was applied to the actual volumes of scheduled substances manufactured and imported during 1989-90. So as to avoid double counting, exports are not separately levied. Provision exists for varying the fee from time to time. The licence fee for 1990-91 was $23.02 per ODP tonne, and remains so for quota year 1991-92 although this may alter before the end of the period.

Under the Act, a quota may be transferred with or without consideration to another licensee. In the year after the scheme came into effect on 1 July 1989, some quota was transferred. In the 1990-91 financial year there was little transfer activity. The Commission sought information about quota transfer activity and transfer prices for licence holders but, due to an incomplete response and for reasons of commercial confidentiality, is not able to provide any additional information about quota transfers.

There were a number of minor breaches under the Act during 1989-90 such as: late quarterly reporting, late payment of licence fees and minor use of quota in excess of the allocation. None of these breaches were considered detrimental to the condition of the ozone layer and no action was taken (DASETT 1990). To ensure compliance with quota allocation limits and assist in detecting any anomalies, industry reporting of quota activity levels is cross referenced with ABS data. The Act makes provision for inspectors to be appointed and prosecutions and fines to be made, however according to written advice from DASETT in October 1991, no compliance measures have been undertaken.

In June 1990, there was a review of the Montreal Protocol in which the parties agreed to 100 per cent phase-out of CFCs and halons by the year 2000 (instead of the previously agreed 50 per cent phase-out by 1998), to include two other ozone depleting substances and to the establishment of a global fund to help developing countries develop ozone safe technologies. Articles in the Ozone Protection Act 1989 provide for it to be upgraded to reflect the revised measures in the Montreal Protocol, and at present amendments are being drafted to enable Australia to adopt the revised Protocol.

1 The ozone depleting potential is calculated by multiplying the actual weight of the substance by its ODP factor, giving a result in ‘ODP tonne’.

Practice and prescription

The published literature reveals a strong preference in favour of price incentive instruments among economists. Economists have effectively prescribed price incentives for the pollution control problem. In practice, the prescription has, to date, been little followed by legislators. Why is this?

Among the possible explanations are the following:

- that legislators, those who advise them, and environmental protection agency staff, are simply ignorant of the relevant theoretical literature in economics;

- that, aware of the theoretical literature, such persons are sceptical about its empirical significance;

- lack of ignorance could coexist with awareness of the correspondence between the standard theoretical assumptions and operative conditions. The assumption of costless monitoring might well, for example be considered suspect, and its rejection lead to a presumption in favour of regulation in terms of process/equipment specification;

- actors in the political and administrative process are unlikely to have the same concern as economists for efficiency. They may well place a high weight on equity and political considerations;

- the view has been expressed, in Frey et al. (1985), that those responsible for administering pollution control systems will favour regulatory approaches on the grounds of self-interest, for example, in job creation;

- finally, it is possible that industry will itself prefer regulation to taxation, because it might cost firms less or be seen as more amenable to negotiation and lobbying.

The question could be turned around, and it could be asked why there has been relatively more progress in the price incentive direction in the USA, and particularly why tradeable permits have been preferred to taxes there. These questions are considered in Hahn (1989) and Nelson (1987). Both note how tradeability was grafted on to a previously existing permit system. Nelson notes the efficiency equivalence of permits and taxation (but see the discussion above regarding dependability), and argues that the former were at the relevant time 'politically more promising means of manipulating market incentives to achieve environmental protection'. His point is that taxation implies collective ownership of the environment, whereas 'the market permit approach establishes a private ownership system', which was 'ideologically more acceptable' in the USA.

Lessons

Among the lessons that can be learned from analysis of and experience with the choice of pollution control instrument for arbitrary standard attainment, the following appear to be the most important:

- There is no unique and generally applicable correct answer to the problem.

- In the economics literature, insufficient attention has been given to using assumptions in analysis that correspond with the relevant stylized facts. This shows particularly in the lack of attention paid to monitoring and enforcement issues.

- Policy makers appear to be much influenced by perceptions of equity across affected parties. This may have led them to dismiss or constrain the use of economic instruments. There is, however, some evidence that they have begun to be more interested in price incentive instruments: see OECD(1989b) and Tietenberg (1990). This may reflect an increasing concern for efficiency.

- The evidence that price incentive instruments offer substantial cost savings derives more from modelling studies than actual experience thus far.

Each of these lessons is relevant to consideration of global warming. There is another important lesson of relevance which does not derive from the literature on instrument choice for arbitrary standard attainment, but from the considerations that lead to an interest in arbitrary standards. This interest arises because of the manifest difficulties which make a full blown cost benefit analysis to determine the optimal level of pollution infeasible. No government has aimed at a pollution target derived from a full blown cost benefit analysis.

In summary, price incentive instruments have not yet been used to any significant extent to control pollution problems, and there has been almost exclusive reliance on regulatory controls. As noted in Chapter 7, several countries are adopting or intend to adopt taxation mechanisms to reduce emissions of greenhouse gases.

D1.4 Trans-boundary pollution

While most of the economics literature on pollution control deals with problems confined within the boundaries of a nation state, there are a small number of contributions dealing with trans-boundary problems other than the enhanced greenhouse effect (on which see Section D3 below).

Mäler (1990) uses simulation modelling to consider the problem of acid-rain in Europe: actual moves to control this problem are described in Appendix E of this report. The principal points emerging from Mäer's work are:

- All the nations taken together would gain from reducing sulphur emissions to an optimal level. Some nations would experience losses which could be offset by side payments.

- Sulphur taxes and tradeable permits have the same efficiency property, both would be least cost instruments, ‘assuming that informational and monitoring problems can be ignored’.
- Taxation raises the revenue for side payments. Tradeable permits can also raise revenue if initially sold, rather than allocated free.
- A tradeable permit system can involve incentives to reduce cheating, as understating emissions will tend to drive down the permit price.
- The optimal outcome does not satisfy the usual version of the polluter pays principle -- it involves some victims paying compensation to the sources of the pollution they suffer.

Morrisette et al. (1990) focus on actual experience with international cooperation to address trans-boundary pollution problems. In regard to CFC control by the Montreal Protocol of 1987 (see also Chapter 7 and Appendix E in this report), they note the following:

- It is directed at the realisation of an arbitrary standard primarily by means of the regulatory ontrol instrument;
- There is provision for delayed standard adoption by developing nations, and for financing technology transfer to them.
- Procedures for monitoring and compliance enforcement were not definitively laid down in the Protocol.

Morrisette et al. also consider policy responses to the acid-rain problem in Europe, noting that;

- The European Community Directive of 1988 specifies national emissions ceilings and reductions from 1980 levels. As between nations, the instrument chosen is regulation. Also, emission levels standards for new plants are specified.
- The Directive does not specify how the nations are to meet their targets.
- Some Community members have adopted national targets more stringent than those placed upon them by the Directive.

In terms of targets and instruments, the situation discussed in previous sub-sections appears to carry over into the trans-boundary pollution context. Economists have canvassed the merits of optimal targets and price incentive instruments. To date, the practice has mainly involved arbitrary standards and regulatory controls.

D2 Valuing environmental damage

One of the reasons why pollution control policies have in practice involved targets which are ‘arbitrary standards’ rather than optimal levels is the difficulty of measuring abatement benefits.

This difficulty arises largely because many of the components of abatement benefit are public goods for which markets do not exist, so that there are no observable prices to use for valuation. This problem also arises in regard to measuring the benefits, in the form of avoided damage, of a program to reduce greenhouse gas emissions. Valuation is not the only problem. The difficulties of estimating the likely biophysical consequences of an emissions reduction program have been discussed at several points in this report: see especially Chapters 2 and 4 and Appendix C.

Table D1 lists a range of techniques for the valuation of effects on environmental quality. This section is concerned with impacts upon consumers of goods and services based upon environmental quality, where markets for such goods and services do not exist. In this context the basic idea involved in impact valuation is to derive surrogate market prices, which reflect the aggregate of individual willingness to pay over the relevant group of individuals. The approach is an extension of the principle of consumer sovereignty. It is discussed at greater length in Pearce et al. (1989) and Mitchell and Carson (1989). Here the intention is to set out the basic issues as they relate particularly to the enhanced greenhouse effect.

D2.1 Categories of value

Economics identifies four classes of benefit flowing to individual consumers based on environmental attributes and quality. Two arise in a world characterised by complete knowledge of the future, two arise only given risk and uncertainty.

In the absence of risk and uncertainty, use and existence values are distinguished. *Use values* relate to willingness to pay for current and future use of the environment and the services based upon it, as in regard to recreation, source of aesthetic appreciation etc. *Existence values* are non-use values in a world of certainty. They involve altruism, and can be subdivided according to the focus of the altruism. Willingness to pay for existence with a view to current use by others is sometimes referred to as *philanthropic value*. Willingness to pay for future use by others is often referred to as *bequest value.* Willingness to pay for preservation independently of any concern for current or future human use is often referred to as *intrinsic value*. Sometimes philanthropic and bequest willingness to pay are jointly treated as willingness to pay for vicarious consumption. Sometimes bequest and intrinsic values are treated jointly as *stewardship value.* There is considerable evidence now available which is consistent with the existence of existence values of the several kinds. The question of what it is that use and existence values attach to is an empirical one.

Table D1: **Classification of cost and benefits valuation techniques for assessing effects on environmental quality**

Valuation techniques	*Examples of application*	
	Producer goods and services	*Consumers goods and services*
Market oriented		
1. Benefit valuation using actual market prices of productive goods and services		
a) Changes in value of output	Loss of value of agricultural crops Caused by seepage of toxic chemicals	
b) Loss of earnings	Value of productive services lost Through increased illness and death caused by air pollution	
2. Cost valuation using actual market prices of environmental protection inputs		
a) Preventive expenditure	Cost of environmental safeguards in project design	Cost of noise insulation; cost of intake water treatment
b) Replacement cost	Cost of replacing structures damaged by acid-rain	Cost of additional painting of houses damaged by air pollution
c) Shadow project	Cost of restoring commercial fresh -water fisheries damaged by discharges	Costs of supplying alternative sport fishing and recreational facilities destroyed by development project
d) Cost effective analysis	Costs of alternative means of disposing Of waste water from a geothermal energy project	
3. Benefit valuation using surrogate markets		
a) Marketed goods as environmental Surrogates	Costs of sewage treatment processes as water proxy for purification by ecosystems	Price paid for visits to private parks and entertainment as proxy for value of visits to wilderness areas
b) Property value approach	Changes in commercial property values as a result of water pollution	Changes in residential property from air pollution

Table D1: Continued

Valuation techniques	*Examples of application* — *Producer goods and services*	*Consumers goods and services*
c) Other land value approaches		Prices paid by government for land reserved for national parks
d) Travel cost		Valuation of recreational benefits of a public park
e) Wage differential approach		Estimation of willingness of workers to trade off wages for improved environmental quality
f) Acceptance of compensation	Compensation for damage to crops	Compensation for adverse health effects eg Minamata disease
Survey oriented (hypothetical valuation)		
1. Direct questioning of willingness to pay		
(a) Bidding games		Estimate of willingness to pay for access to an urban park
2. Direct questioning of choices of quantities		
(a) costless choice method		Hypothetical application to air pollution

Source: Hufschmidt et al.(1983).

Allowing for uncertainty admits two additional classes of value. *Option value* arises from willingness to pay for the guaranteed opportunity to use in the future. It is in the nature of a risk premium in relation to uncertainty about future demand, or supply. Note that what is guaranteed is not future use as such, but that the thing in question -- a wilderness recreation area with unique attribute, for example -- will be available for future use contingent on future willingness to pay for use. *Quasi-option value* arises from willingness to pay to delay an action which if undertaken would foreclose an option at a later date when it is believed that more relevant information will be available. The list of species known to provide useful pharmaceuticals might be expected to grow over time, for example, and there could be willingness to pay to avoid the extinction of a particular species not currently fully researched in this respect. Quasi-option value can be regarded as the value of preserving options given the expectation of growth in knowledge. It can be expected to be especially important where decisions are irreversible.

D2.2 Measurement techniques

Two basic strategies for measuring individual willingness to pay for environmental amenity services can be distinguished (see also Mitchell and Carson (1989) and Young(1990)). *Direct methods* seek to measure by asking individuals what they are willing to pay. Since markets do not exist, such questioning is necessarily hypothetical and this approach is known as *the contingent valuation method* (CVM), responses being contingent on the scenario which creates the hypothetical market. Indirect methods seek to ascertain individual willingness to pay for environmental amenity services by inferences based on observation of actual behaviour in related markets. The main indirect methods are the *travel cost method* (TCM) and the *hedonic pricing method.*

The indirect methods have, in principle, a more limited range of applicability than does CVM. They can, that is, address only willingness to pay in respect of use values. In principle, CVM can, by virtue of its basis in a hypothetical scenario, address use values, existence values and option values. Generally, pollution based environmental damage could involve impacts raising the requirement for the measurement of all classes of value. This is the case with the potential environmental impacts of the enhanced greenhouse effect. Consider, for example, the prospect of species extinction and impacts on lifestyles associated with recreational activity.

CVM is now the most popular technique among economists. A standard work published in 1989 (Mitchell and Carson, 1989) listed about 120 applications from around the world. Some applications have occurred in Australia (see Blamey 1991), and in particular the CVM was used by the Resource Assessment Commission in its Kakadu Conservation Zone inquiry (see Imber et al. 1991). The results obtained in this RAC application generated some controversy.

CVM methodology is an ongoing area of research in economics. Economists disagree as to the reliability of the estimates it yields. A number of potential pitfalls in application of the methodology have been identified (see OECD 1989a, and Pearce et al. 1989). However, many economists working in the area believe that, provided that certain standards are observed in application, the methodology can produce estimates which are sufficiently robust to be used in policy analysis. Cummings et al. (1986) and Mitchell and Carson (1989) discuss the conditions necessary for this to be the case. The most relevant here are:

- respondents should understand the scenario and be familiar with the service that they are asked to express a willingness to pay for;

- respondents should have, or be allowed to obtain, prior experience with respect to alternative levels of the service;

- there should be relatively little uncertainty.

D2.3 Appraisal in relation to the enhanced greenhouse effect

There are several problems in using CVM to appraise projects associated with the enhanced greenhouse effect. Given the differences between the reference conditions for reliable CVM applications and the conditions likely to be satisfied when CVM is applied to enhanced greenhouse related issues, the results obtained by using CVM to evaluate the latter may be unreliable. The uncertainty surrounding regional impacts, which has been stressed throughout this report, would also be difficult to incorporate in a CVM scenario. And asking people to `cost' or `value' these impacts is also difficult, when they are unfamiliar with them.

A more fundamental problem is raised by the argument that for many of the potential impacts of the enhanced greenhouse effect, valuation on the basis of individual's willingness to pay is inappropriate. This argument relates not to reliability, but to relevance. It is that species extinction threats to sustainability, for example, have to be valued socially/politically rather than by means of the willingness to pay of individuals engaging in surrogate market transactions (see, for example, Quiggin 1991). Whatever the merits of this argument, it faces the problem that there does not currently exist a methodology for revealing social values outside of the political process itself.

D3 Enhanced greenhouse as a pollution problem

An enhanced greenhouse effect would be a problem of global pollution, in that emissions affect the atmospheric greenhouse gas concentration equally irrespective of geographical origin, and that any consequent climatic effect is global in scope. This characteristic qualifies the applicability to it of the analysis and experience reviewed in Section D1. Another distinguishing characteristic is that it involves emissions of several different gases to the atmosphere. In what follows, discussion will focus principally upon carbon dioxide emissions. This simplifies the discussion while permitting most of the essential issues to be covered. It also seems likely that policy will address carbon dioxide before the other non-CFC greenhouse gases (CFCs have already been addressed on the basis of their role in ozone depletion).

It is conventional to distinguish three types of policy response to prospective global warming:

- Prevention policies are intended to slow the rate of increase in atmospheric concentrations.
- Mitigation policies are intended to offset the climatic effects of any increase in atmospheric concentrations.
- Adaptation policies are intended to promote adjustment to climatic change and its consequences.

These are not mutually exclusive responses. There is debate over their relative merits. Here only prevention policies are considered, consistent with the terms of reference for the inquiry.

In Section D1 above, the economic analysis of pollution control was introduced by reference to the problem of external cost (see Box D1). In the context of an enhanced greenhouse effect, the external costs involved are the climatic changes, and their impacts, consequent upon anthropogenic emissions of the greenhouse gases. This takes it as established that global warming will occur and have adverse consequences. As noted elsewhere in this report, it is not certain that increasing emissions will have adverse consequences. However, preventative policy response is the subject of this inquiry, and in order to enable analysis to proceed this fundamental uncertainty is now ignored, and it is assumed that emissions do involve external costs. The question of incorporating this uncertainty into the analysis is dealt with in Section D6 below (see also Chapter 5).

An enhanced greenhouse problem so regarded involves market failure due to free access to a global common property resource -- the atmosphere. Analysis of any preventative policy response must address this facet of the problem at the outset. What is at issue is control of use of the atmosphere, which will require agreement among sovereign nation states. Securing such agreement will involve many difficulties. Foremost among these is the so-called ‘free-rider’ problem. This concerns incentives to join and comply with an international agreement to reduce emissions.

Consider the position of a nation state contemplating participation in an international consensus. If it joins and acts to reduce its emissions, it believes that it will incur abatement costs as well as any benefits consequent upon emissions reductions by all states. If it does not join, but all the other nations go ahead and reduce emissions, it will avoid domestic abatement costs, but the effect on global emissions will be small and the perceived reduction in the benefits from avoided global climate change could be negligible. In this situation, there is a strong incentive to free-ride on the abatement efforts of others, since the others cannot prevent non-abating nations from enjoying the benefits consequent upon their efforts. All nations, except for those accounting for a large share of total global emissions, face this incentive structure.

The free rider problem is the basic problem confronting preventative policy response to an enhanced greenhouse effect. The lessons that can be learned from analysis of and experience with domestic pollution control policy have to be set against that and other characteristics of an enhanced greenhouse effect.

D3.1 Problem characteristics

With the caveats just discussed in mind, the ‘problem’ of carbon dioxide pollution of the earth's atmosphere has the following characteristics:

- The problem involves a stock pollutant. What matters is not the flow rate of emissions but the stock of carbon dioxide existing in the atmosphere. Current flow adds to the stock, which also naturally declines. However, the rate of decay is slow.

- The problem is very complex in its physical and biological dimensions. While the basic physics of radiative forcing by carbon dioxide is straightforward, the translation of atmospheric concentration into climate change is such that its study, even in terms of looking at just a few dimensions of climate and on a coarse spatial grid, involves very large computer models. Going from global to regional climate implications is even more complex and much less well understood. Very little is known about the mapping from regional climatic change into impacts on biological systems.

- The problem involves ‘sinks’ for carbon dioxide as well as anthropogenic and natural emissions sources. That is, for any given rate of gross anthropogenic sources, the rate of stock accumulation can vary on account of a changing rate of natural release, and/or on account of a changing rate of sequestration. In regard to the latter, prospects exist for anthropogenic influence as an element of prevention policy additional, or alternative, to emissions reduction. In this context, attention has focussed to date mainly on the role of forests: see for example, Sedjo (1989). The role of sinks adds further complexity to the biophysical dimensions of the problem.

- The problem is also complex in its socio-economic dimensions. This has two aspects:

  a) The dominant source of anthropogenic carbon dioxide emissions is the combustion of fossil fuels and biomass -- the problem resides mainly, that is, in the energy system of the world economy. This is a very complicated system which underpins the current functioning of the world economy.

b) The impacts of climate change on socio-economic systems would be many and various. Complexity arises also because of the adaptations to the impacts which would occur and which would involve changed interactions between particular socio-economic systems as with, for example, trade flows and movements of people.

- The problem necessarily involves massive uncertainties at the physical, biological and socio-economic levels. The prospects for significant reductions in these uncertainties may be questionable.

- There is a non-zero probability of catastrophic outcomes. This is most obviously true at the local level and in regard to sea level rises, but is also true at the global level given that the climate system may involve unknown thresholds for positive feedback.

- Gross carbon dioxide emissions arising in fossil fuel combustion are a case where monitoring can be indirect and accurate at low cost. This is because knowledge of combustion technology, and any `end of pipe' treatment, and of the fuel involved fixes emissions.

- To a first approximation carbon dioxide emissions into the atmosphere mix perfectly and are equally dispersed throughout the entire atmosphere. There are no regional airsheds, and the problem is truly a 'global commons problem'. The implication is that no nation acting alone can significantly influence the future evolution of atmospheric concentrations, or of the impact on it consequent upon given concentrations, at least directly.

It should also be noted that the fact that there are other greenhouse gases increases the complexity of the problem, and enhances uncertainty levels.

It is not the case that all of the characteristics listed above are peculiar to the greenhouse problem. However, taken together they appear to define a unique pollution problem, and the following observations are among the more obvious and immediate. First, intergenerational equity problems are central. Actions are thought to be required now, and to involve costs now, to avoid costs anticipated in the future. The standard treatment of pollution problems in economics, as reviewed above, typically assumes that costs and benefits associated with abatement are contemporary. In the absence of this assumption, the vexed question of discounting is added to those that will be raised when policy is proposed (see Section D4 below).

The global commons nature of the greenhouse problem, gives rise to a number of observations and considerations. Most obviously it implies the need for international consensus and coordination. Equally, it makes clear that this is unlikely to be easily achieved. The free-rider problem is exacerbated by complexity and uncertainty. Some nations may well anticipate that global warming may not be too serious a problem for them, or may indeed improve their circumstances.

International action may be seen as implying some loss of sovereignty, and the degree of loss perceived is likely to vary across feasible instruments for implementing international agreement. Finally, the interposition of national governments makes the intragenerational equity problem particularly acute and relevant to the prospects for consensus. Again, equity outcomes across nation states will vary according to the policy instrument adopted.

Ingham and Ulph (1991) emphasise the stock pollutant characteristic in their discussion of prospective global warming as a pollution problem. They note the relevance of the literature on stock pollutants for the determination of optimal control policy. They also make a point which relates also to instrument choice where arbitrary standards are at issue. It was noted above that in circumstances where the tax setting agency has less than perfect information, emissions (or input) taxation is not dependable. Ingham and Ulph note that where the target relates to a stock rather than a flow, opportunities may arise for subsequent correction of previous under or over taxation. However, the force of this point has to be considered in the light of the inherent uncertainties, and the possible additional costs to industry of adjusting to changing tax rates.

Complexity and uncertainty makes the search for optimality of questionable value. lt is a search that necessarily places intergenerational equity questions centre stage. With few exceptions (see for example Nordhaus (1991), discussed in D5 below, and Ingham and Ulph (1991)), economists have taken it that the relevant problem is the attainment of arbitrary standards, rather than the pursuit of optimal solutions. Further, and in response largely to complexity, it has typically been the case that attention has focussed on arbitrary standards applying to gross emissions of carbon dioxide from fossil fuel combustion.

The problem of the choice of policy instrument and of the arbitrary standard itself, is a problem of decision making in the face of uncertainty. To the extent that economics has addressed this in the pollution control context it has considered the choice of instrument where optimality is at issue and uncertainty attends the nature of the cost and/or benefit functions for abatement: see for example, Baumol and Oates (1988). In the present context, uncertainty together with the non-zero probability of catastrophe could suggest placing considerable weight on the dependability criterion discussed above. It could seem desirable, that is, to select instruments that give some assurance that whatever the arbitrary gross emissions standard is, it will be realised or bettered (see Chapter 5, and Section D6).

With a focus on gross emissions in fossil fuel combustion as a first approach to the problem, in this case, as distinct from many pollution problems, monitoring is not a major problem. It will not be costless, but it is feasible at low cost in relation to the nature of the problem. The problem of enforcement remains.

D3.2 International consensus and instrument choice

In considering the choice of policy instruments for an international consensus to reduce carbon dioxide emissions, the analysis and experience reviewed in Section D1 is drawn upon, in the light of the particular characteristics of the enhanced greenhouse problem. The question of instrument choice is inter-related with the prospects for achieving consensus. Negotiations are unlikely to proceed sequentially from the question of adoption of an agreed target to the question of how to realise it. It is likely that the questions will be addressed simultaneously, and that negotiators will have in mind the second when considering the first.

Following on from the discussion in Section D1, three broad classes of instrument are considered here -- quantity regulation, taxation, and tradeable permits. These are not mutually exclusive and an international consensus might involve elements of each.

Quantity regulation

This would involve each nation being required to cut back on emissions by a given proportional amount from some base year level, or to emit up to a certain absolute amount. The analysis reviewed above indicates that there is a presumption that choice of this class of instrument would not lead to standard attainment at global least cost. It would, that is, be a choice implying inefficiency. That analysis also indicated, however, that, leaving aside enforcement problems, this choice would have the property of dependability -- the global target would be realised. The review of greenhouse problem characteristics suggested that this property could be seen as important in this context.

If national targets were internationally agreed, there remains the question of the means by which a nation would seek to realise its own particular target. This question could itself be decided as part of the international agreement, or left for decision by the individual participating nations. The latter option would involve nations in a smaller perceived sacrifice of national sovereignty than the former. This could be expected to make it the more likely outcome. Under this outcome individual nations could adopt quantity regulation or price incentive systems, and the discussion of section above applies straightforwardly to each nation.

The central question in negotiating this type of international consensus would presumably be the determination of the national targets. It seems likely that perceptions of equity as between nations would dominate consideration of this question. The simple approach of equal proportional cutbacks across all nations would penalise nations already fossil fuel efficient and the less developed nations, it has been argued. An alternative suggestion that has been made is that the initial standard should relate to allowable global emissions which would then be shared equally on a per capita basis. This would be seen as favouring less developed as opposed to developed nations, it seems likely. Obviously, many variants on these simple allocations are conceivable. Grubb (1990) argues that international agreement on national targets would be impossible to reach. Bertram and Toman

(1991) discuss rules for national entitlements from the perspective of the equity implications for reaching an agreement.

Given the restriction to carbon dioxide emissions arising in fossil fuel combustion, monitoring of compliance would be relatively simple and inexpensive via monitoring of fossil fuel combustion. Enforcement of compliance raises more difficult problems. A system of fines for non-compliance would be the obvious approach. They would have to be administered by an international agency, so that some loss of national sovereignty would be involved and this would undoubtedly pose considerable difficulty for many governments. Alternatively, trade sanctions could be used against non-complying nations.

Taxation

This would involve an international agreement to tax carbon dioxide emissions at a common rate. It could take two forms. The first would involve the tax being levied by an international agency, the second would involve it being levied by nation states. In both cases taxation would be globally efficient, ie least cost, but not dependable in hitting the target in one go. The common global tax rate would, that is, realise some emissions reduction at the least possible cost in resource terms but, without some trial and error, it would not guarantee the attainment of the global arbitrary standard for emissions reduction.

Taxation by an international agency would mean revenues accruing to it, and if the tax were set at rates intended to realise significant global emissions reductions these revenues would be substantial: see Grubb (1990) for example. In terms of the prospects for achieving international consensus, this gives rise to problems and possibilities. The problems concern the perceived loss of sovereignty by nation states which would be involved in the creation of an international body with significant spending power outside of their influence. The possibilities concern the related questions of equity and inducement to participate in any international consensus. While taxation is efficient it is not necessarily equitable. Rules could be negotiated according to which the international agency would disburse its revenues which would promote equity. A rule could involve, for example, countries receiving a share of total revenue dependent on population size and per capita national income. This would favour large less developed nations, such as India and China, and might be expected to encourage their participation which would otherwise likely not be seen by them as being in their interest. Of course, such a revenue sharing rule would work against the interests of nations such as the USA, and to that extent discourage their participation.

Taxation of fossil fuels as such could readily be substituted for carbon dioxide emissions taxation, with the rate differing across the fossil fuels according to their carbon content. This input taxation would greatly facilitate and reduce the costs of monitoring. However, it would not, in itself, necessarily encourage the development of emissions reducing technology. Given monitoring, compliance enforcement with taxation is a problem only in so far as nations refuse to pay their tax assessments. This would be tantamount to openly leaving the international consensus, and could presumably be dealt with through trade and/or political sanctions. A problem which has been suggested as likely to arise, see Grubb(1990) and Bertram et al. (1989), is the manipulation of exchange rates in an attempt to reduce the real rate of taxation affecting a nation. Similar problems could arise with regard to domestic tax regimes.

The problems of perceived national sovereignty losses and revenue disbursement could be avoided by a form of consensus which had the common tax rate across nations levied by national governments, which would retain the revenue arising. This would also reduce the scope for redistribution internationally to encourage participation by some key players. An additional consideration arises with this form of international consensus if the advantages of fossil fuel input taxation, as opposed to emissions taxation, are sought. This is that the distributional implications across nations then differ according to whether production or consumption is used as the tax base.

The discussion here has assumed that what is at issue is taxation intended to provide incentives to significantly reduce emissions. Not all taxation in regard to pollution has this intention. Taxation of emissions is frequently in the form of user charges intended to raise revenue to finance administration costs for other control methods, and/or to finance waste treatment facilities. The analogue in the carbon dioxide context would be international taxation at a low rate to provide revenue for a fund to finance research and/or technology transfer to less developed nations. It can be argued that this analogue would face lesser problems of gaining international consensus, and would be the first step in a learning process leading to incentive motivated international agreements on taxation, as well as having some impact on the greenhouse problem directly.

Tradeable permits

The theoretical analysis reviewed in Section D1 above shows that tradeable emissions permits are both efficient and dependable. This carries over, in principle, into the international context and would seem to make them preferable to either quantity regulations or taxation.

The first point to note is that the carry over is assured only if permits are freely tradeable globally between individual emissions sources, so that the world context is the exact analogue of the national. It is not assured if permits are tradeable only between countries, since a country could choose to meet the emissions quantity it holds permits for by quantity regulation within its borders. In this case, dependability at the global level holds, but full efficiency does not. It would seem intuitive that permits tradeable between nation states would offer efficiency advantages over international quantity controls whatever form of control countries adopted within their borders. However, this does not appear to have been demonstrated analytically. In principle, an international consensus could involve a two stage commitment to tradeable permits -- tradeable national permits to be subdivided within nations by tradeable individual permits.

Tradeable permits would be seen, in whatever form, to involve less sacrifice of national sovereignty than would internationally administered taxation. The intragenerational equity implications would depend primarily on the initial allocation of permits. It is difficult to see how this could be negotiated by countries except on the basis that permits attached to countries rather than to individual emissions sources. As with internationally administered taxation, there are problems and possibilities here. The initial allocation would be contentious, but would offer opportunities for addressing existing inequities as between states and for creating incentives for some states to participate. It has been suggested, see Grubb (1990), that initial national allocations based on equal per capita shares of total allowable global emissions would serve the cause of 'international equity'. Bertram et al. (1989) discuss allocation rules principally from an equity perspective.

It was noted that for quantity regulation and taxation regimes, monitoring and administration costs could be reduced by switching the regulation/tax base from emissions as such to fossil fuels. It is not clear that this advantage readily attaches to tradeable permits. Its realisation would depend on permits relating to fossil fuels use rather than emissions. This would require that permits be defined in carbon dioxide equivalent fuel units, with one coal unit exchanging for 1.78 natural gas units for example. With regard to compliance enforcement, the situation here would be essentially the same as with quantity regulation. Monitoring, administration, transactions and enforcement costs would be expected to be greater with permits allocated to individual emissions sources than with permits allocated to nations.

This discussion of the three alternative policy instruments has focussed primarily on efficiency, dependability, equity, and monitoring and enforcement criteria. On this criteria set it is clear that the choice of instrument for arbitrary standard attainment is a complex matter to which there is no simple answer. The weights to be attached to the various criteria are basically a matter of judgement. Grubb (1990) and Bertram et al. (1989) judge tradeable permits to be the most promising option, on the basis of a review of essentially the considerations advanced here. Both implicitly give rather little weight to the efficiency criterion. This marks a significant departure from the situation in the preponderance of economics contributions on instrument choice to date. Ingham and Ulph (1991) favour tradeable permits over taxes for international consensus implementation for two reasons. First, they argue that distributional and participation incentive desiderata can be addressed more directly and reliably via the initial (free) permit allocation than via tax revenue disbursement. Second, they claim that 'it is harder to check that a carbon tax has been fully implemented'.

It is clear that there are many interacting factors involved in the way that an international consensus to reduce carbon dioxide emissions would work, and bearing upon the prospects for the achievement of such a consensus. While qualitative analysis can indicate some of the matters that need to be considered, quantitative analysis is necessary to determine what the outcome of interactions will be. This is especially the case if, as is required by the terms of reference for this inquiry, the problem involves assessing the impact on a particular nation. Chapter 5 of this report reviews some previous modelling studies which have considered the costs associated with some instrument regimes, and presents some preliminary results based on the Commission's own modelling work. Details of the models used by the Commission are given in Appendix G.

The need for quantitative modelling is made clear by a reconsideration of the free rider problem suggested by the discussion of instruments. As the problem is typically formulated (see the introduction to this section), the only costs to be considered by a potential free rider are the domestic abatement costs arising from participation. It is, in fact, clear that there can also be costs associated with non-participation. These would arise from the effect on the trade position of a non-participant arising from the instrument regime adopted by participants. In the case of Australia, an international carbon dioxide or fossil fuel tax would impact on Australian exports irrespective of whether it was a participant. The question of the relative magnitudes of the trade effects and the domestic compliance costs for Australia is addressed in Chapter 5 of this report.

D4 Discounting

Discounting is a contentious matter. In part, problems arise because the question of discounting arises in two rather different contexts in economics.

As the term is usually used, 'cost benefit analysis' refers to the appraisal of projects from a social as opposed to a commercial perspective. The project is evaluated, that is, on a basis which corrects for market failures where market prices do not properly reflect social costs (see Box D1 above). Cost benefit analysis involves discounting so as to select projects which are consistent with the goal of efficiency.

The other discounting context involves the allocation of total consumption as between different points in time. This is the subject matter of 'optimal growth theory', which bears upon questions of intergenerational equity.

Both of these areas of economics are relevant to this inquiry. Cost benefit analysis is needed to analyse the merits of particular projects suggested as having greenhouse gas emissions reducing potential, such as, for example, investments in more fuel efficient equipment of various kinds. The apparatus of optimal growth theory is needed to analyse the issues involved in the proposition that total investment now needs to be increased, reducing consumption now, in order to reduce emissions to levels which will avoid consumption losses in the future.

As this suggests, the demarcation between the realms of cost benefit analysis and optimal growth theory is not always clear-cut. Nevertheless, it is important in thinking about an area as complex as responding to an enhanced greenhouse effect to try to keep separate the different issues pertaining to discounting.

D4.1 Cost - benefit analysis

In cost benefit analysis, the question at issue is the efficient allocation of the resources available for investment in total as between the competing claims upon such resources. The aim is to select those projects which are consistent with intertemporal efficiency, and to reject those which are not. Intertemporal efficiency exists when it is not possible to increase future total consumption except by reducing current total consumption. There are a number of rules which are designed to select projects which promote intertemporal efficiency: see Pearce and Nash (1981), for example. One such is the Net Present Value rule. This says that only projects with a non-negative net present value should be undertaken. The discount rate in this context is the interest rate used in calculating net present value.

There is a very extensive literature on the methods by which the discount rate for cost benefit analysis should be determined. While views among economists differ in terms of points of detail, it is fairly generally agreed that the basis for determination should be the requirement of securing an allocation of total investment across competing projects that is consistent with intertemporal efficiency. This rules out the use of the rate zero.

Non-zero discount rates frequently arouse the ire of those who are concerned to protect the natural environment. It is argued that at high discount rates, long lasting adverse impacts on the environment have very little impact on the net present value of a project. This is true. It is also true that high discount rates have the same effect on long lasting benefits associated with a project. It is not difficult to show that lowering the discount rate can increase the net present value of an environmentally damaging project: Common (1988) provides an example in his Chapter 8. Reducing the discount rate to zero makes project appraisal impossible.

The problem of long lasting adverse environmental effects associated with projects is one of valuation rather than discounting per se. Given the assumption that environmental impacts of all kinds can be made commensurable with ordinary produced commodities and project inputs, by pricing either through markets or using surrogate market prices, the logic of discounting in project appraisal is unassailable. What many who object to discounting are really taking issue with is the commensurability assumption. The operational version of this position within the standard cost benefit framework is the, implicit, view that certain environmental damages should be given prices so large, at all points in time, that the negative values arising would produce a negative net present value. An alternative version of the same position is that the standard framework should be modified so as to incorporate environmental constraints which would over-ride the net present value criterion: see Pearce and Markandya (1991), Collins and Young(1991), or James (1991) for further discussion.

D4.2 Intergenerational equity

Cost benefit analysis is not intended to address intergenerational equity issues. It is intended to select projects which maximise future aggregate consumption for a given level of current aggregate consumption. In practice, problems arise in that many projects have very long lasting consequences, and span generations. However, in principle the question of intergenerational equity is to be addressed within the context of optimal growth theory, which is concerned with shifting aggregate consumption over time. This, of course, assumes that the concept of aggregate consumption makes sense. It assumes, that is, that all of the various items that yield satisfactions to individuals can be made commensurable, and added up, according to some set of relative prices. This assumption is questioned by some in the intergenerational equity context as in the project appraisal context, again principally in connection with environmental impacts.

The point of departure for optimal growth theorising is the tension between two opposing forces. First, it is apparent that typically individuals prefer consumption now to consumption in the future. Second, it appears that there is a pay-off to deferred consumption, in that current saving invested in adding to the capital stock increases future consumption possibilities. The first of these forces is captured in the notion of a social rate of time preference, the second in the notion of the marginal productivity of capital. The second is essentially a technological matter, while the first involves ethical considerations.

The optimal rate of saving is that which balances these two forces at the margin, and there corresponds an optimal growth rate. A low rate of social time preference combined with a high marginal productivity of capital would imply high current sacrifice for future prosperity, and vice versa. The important point is that the outcome depends upon both the social rate of time preference and the marginal productivity of capital. Choosing the balance between current and future consumption is not an ethical matter alone. It also involves taking a view on the technological basis for growth prospects.

The usual assumptions made by economists about the latter have been questioned. It has been argued that finite natural resources and/or environmental degradation mean that the technological basis for future growth is limited. This type of consideration has most recently been raised in the context of the debate over sustainable development. Concern has been expressed that in the absence of policies designed to avoid the problem, current economic activity could undermine the resource and environmental base for future economic activity. In effect, in the optimal growth theory context, it is being suggested that the effective marginal productivity of capital is reduced by resource depletion and environmental degradation. The issues involved concern the substitutability of man-made capital for environmental assets. They are addressed in Collins and Young (1991) and Quiggin (1991), for example.

An enhanced greenhouse effect is seen by some as a threat to sustainable development. It is also widely seen as requiring current consumption sacrifices to avoid future consumption losses, and therefore involving intergenerational equity issues. These can, in principle, be considered within an extended optimal growth framework of analysis. An attempt to do this is considered in the next section of this appendix, where attention is especially paid to the origin and determination of the discount rate used.

D5 The Nordhaus model of optimal greenhouse gas abatement

Nordhaus (1991) attempts to compute an estimate of the optimal target for global greenhouse gas emissions abatement. Essentially, this involves an analysis of the nature illustrated in Figure D1 above. The major analytical innovation required by the greenhouse context is to identify a marginal abatement benefit function that reflects the displacement in time of the benefits of abatement. To do this it is necessary to use a dynamic model of the climate system and the global economy.

The physical model involves two equations: 1. describes the increase in global temperature rises as a response to the difference between the equilibrium temperature increase and the actual increase, and 2. is a simplified two-box diffusion model describing the atmospheric concentration of carbon dioxide equivalent GHGs.

Eqn. 1 $\dot{T}(t) = \sigma[g[M(t)] - T(t)]$

Eqn. 2 $\dot{M}(t) = \beta E(t) - \delta M(t)$

where, $T(t)$= temperature increase from greenhouse warming since mid-19th century

$M(t)$= atmospheric concentration of carbon dioxide equivalent GHGs

$E(t)$= emissions of carbon dioxide equivalent GHGs

$g[.]$ = equilibrium increase in global temperature in response to increasing carbon dioxide equivalent concentration

σ = delay parameter of temperature in response to radiative increase

β = fraction of carbon dioxide equivalent emissions that enter the atmosphere

δ = rate of removal of carbon dioxide equivalent from the atmosphere

The economic analysis involves three components:

1. the simplified model of the concentrations and temperature system

2. an economic model that incorporates the economic tradeoffs involved in reducing greenhouse gases; and

3. a representation of how society chooses between alternative consumption paths.

In order to simplify the overall model, several assumptions and transformations are imposed upon the equations. Firstly, equation 1 is linearised:

Eqn.3 $T(t) = \sigma\,[\mu M(t) - T(t)]$

where, μ = linearised equilibrium sensitivity of temperature to concentrations of carbon dioxide equivalent emissions, i.e. $g'(M) = \mu$

Further, two assumptions are made about the structure of the economy:

- The economy is in 'resource steady-state', i.e. all physical flows in the global economy are constant although the value of economic activity may be increasing; and,
- There is 'balanced resource-augmenting technological change' at rate h. Which implies that:

Eqn.4 $C(t) = ye^{ht}(g[E^*] - p[T^*])$

where,
- $C(t)$ = per capita consumption at time t
- $y(t)$ = ye^{ht} = output before any emissions reduction and with no climate damage
- $g(E^*)$ = steady state cost function from reduction of emissions
- $p(T^*)$ = steady state damage from climate change
- $E(t)$ = emissions of GHGs
- $T(t)$ = temperature change as an index of climate change

The real discount rate to be used depends upon three parameters:

$r = \int + ah$

where,
- r = real discount rate on goods
- $\int$ = the social time preference rate
- $-a$ = the elasticity of the marginal utility with respect to per capita consumption
- h = the growth rate of per capita consumption

The optimal policy for allocating resources over time maximises the following:

Eqn.5 $$V = \int_0^{8} u[C(t)]e^{-\int t}\, dt$$

where, u = the utility of consumption
C(t)= per capita consumption

If we increase emissions by dE at t=0 only, this leads to an increase in temperatures given by,

$$dT(t) = \mu \beta \sigma \left(e^{-\delta t} - e^{-\sigma t}\right) dE/(\sigma - \delta)$$

The impact on consumption of an increase in emissions at t=0 is given by:

For t=0, $dC(t) = yg'(E^*)dE$

For t>0, $dC(t) = -\, ye^{ht}\, \pi'(T^*)dT(t)$

where the right hand side for t=0 is the instantaneous increase in consumption, and where the right hand side for t>0 is the future climate change associated with that increase. If the original path was an optimum path, the present value of a change in the emissions path for a small variation is zero, implying:

Eqn.6 $$yg'(E^*)dE = \int_0^{8} [(ye^{ht})\, \pi'(T^*)dT(t)]e^{-rt}\, dt$$

This can be solved for:

Eqn.7 $$g'(E^*) = \mu\beta\, \pi'(T^*)r^*$$

where, $r^* = \sigma/[(r+\delta-h)(r+\sigma-h)]$

The interpretation of equation 7 is as follows. It states that the optimal abatement level is where the marginal current cost of reducing emissions, left hand side, equals the present value of marginal damages from higher concentrations, right hand side. In interpreting this it is important to note the parameters upon which the discount factor, r*, depends:

δ = the rate of disappearance of greenhouse gases from the atmosphere

σ = the lag of temperature behind increases in concentrations

h = the growth rate of per capita consumption

r = the real discount rate on consumption

It is also important to note that the last of these itself depends on h and two other parameters:

⌠ = the social time preference rate

a = the elasticity of marginal utility with respect to per capita consumption

The social time preference rate is not a technological parameter. It is to reflect society's preferences as between present and future utilities based upon consumption. As such it is the legitimate subject of debate from ethical premises. The standard view in economics would be that a social time preference rate should reflect the time preference rates of the individuals comprising society.

In any case, the real rate of discount on consumption also depends upon h, the anticipated growth rate. If h=0, then r is equal to the social time preference rate. This illustrates an important general point. Thinking about the intergenerational equity is not a matter which involves only ethical considerations. The prospects for growth are also important. The implications of a zero social time preference rate depend upon future growth prospects. In the enhanced greenhouse context, the extent to which the costs of abatement are considered worth bearing now in order to avoid future damage will depend not just on an ethical position on intergenerational equity, but also as an assessment of how well off, climatic problems aside, it is thought future generations will be in comparison to the present. The Nordhaus model allows these considerations to be brought to bear on the analysis.

As a study examining an economic approach to preventative policies concerning greenhouse induced warming, the Nordhaus methodology is useful. Its merit lies in the techniques that allow the balancing of costs and benefits at different points in time, and revealing the factors that bear upon the discount rate to be used in so doing. However, the simplifications and information requirements of the model are so burdensome that the conclusions can only be considered robust in their most general form. There is nothing sacrosanct about Nordhaus' estimates for the most efficient level of control of greenhouse gas emissions.

In fact, Nordhaus concludes that the efficient level of control is 11 per cent of greenhouse gas emissions if one accepts a middle level of damages and the assumption that the discount rate to be used is one percent above the growth rate. For the abatement cost function that Nordhaus uses, an 11 per cent overall reduction would involve a 2 per cent cut in carbon dioxide emissions, with the other 9 per cent coming from reductions in CFC emissions. Nordhaus is himself careful to call attention to the analytical and empirical weaknesses in his work and to qualify the conclusions arising (see Chapters 4 and 6 of this report).

D6 Risk and uncertainty

The manner in which climate will respond to increasing concentrations of greenhouse gases is not well understood and current climate models cannot be used to predict regional impacts. There is uncertainty about the ability of natural environments to adapt to climate change, about whether climate change is already under away, and about the possibility of climate catastrophe. There is also uncertainty regarding the likely impact of technology. Clearly, such pervasive uncertainty makes it very difficult to determine whether or not action should be taken today to reduce emissions of greenhouse gases, and if action is to be taken there are the subsidiary questions of how much, how quickly and for how long. This section briefly reviews some of the economics literature which deals with decision making in the face of uncertainty.

D6.1 Risk, uncertainty and probability

In ordinary parlance uncertainty is likened to doubt and indecisiveness. For the economist, uncertainty conveys a more precise meaning. It is helpful to approach a definition of uncertainty by looking at risk. Risk refers to a situation in which those evaluating a project have some idea of the probabilities of various outcomes. These probabilities may be objective (events of the same type already abound and provide some indicative guidance) or alternatively, subjective (there are no occurrences of the same type from which to infer a probability). The decision maker may be risk neutral (indifferent to the different levels of risk between projects with the same expected return) or risk-averse (sensitive to the different levels of risk). Uncertainty, on the other hand relates to situations in which probabilities cannot be assigned. The question becomes one of:

> Is there enough information to justify the assignment of probabilities to different outcomes? If there is, the outcome is described as 'risky'. If not, it is said to be `uncertain' in the strictest sense of the word (Dasgupta and Pearce 1974).

Of course, the decision maker can attempt to convert uncertainty into a risk context by assigning subjective probabilities. For example, in considering whether greenhouse gas emissions should be reduced, a policy analyst might consider various states of the world. If the state of the world 'greenhouse problem' occurs, the outcome of preventative action will be a saving (relative to doing nothing). Conversely, if the state 'no greenhouse problem' occurs, the outcome of preventative action will be a loss (the cost of emissions reductions). A choice could be made by weighing up the various subjectively determined likelihoods and outcomes of different states of the world. For example, if a particular state of the world seems more likely then more account should be taken of the implications of this when making a decision. Probabilities must sum to unity. So, if the greenhouse state of the world was thought to be more likely it would be given a weight of 'p', greater than 0.5, and the no greenhouse state a weight of (1-p). The alternatives of acting to reduce emissions and not acting could then be evaluated according to the weighted values arising in each case, and the action with the larger weighted value would be chosen. This approach is always open to a decision maker:

> anyone can assign probabilities to any events. Obviously the amount of knowledge that a person has about the forces affecting an event will influence his judgement about its probability: and a third party may believe that one person's judgment is better than another's. But knowledge is not a precondition for being able to assign some probability to an event. Probability numbers are merely a language in which judgements of a particular kind can be expressed (Sugden et al. 1985).

However, given that views on whether or not the earth is currently facing a greenhouse problem are subject to debate, the subjective probability route would be controversial with substantial disagreements as to the appropriate weights to be attached to alternative states of nature. Other means of dealing with uncertainty need to be explored.

This appendix next reviews a number of other approaches to addressing the problem of uncertainty. These involve the adoption of decision rules which reflect the outlook of the decision maker.

D6.2 The pay-off matrix and decision rules

The basic element of a decision analysis framework is the pay-off matrix. The ideas involved can be illustrated using the following entirely hypothetical data for a very simple version of the decision making problem. It is supposed that the problem is to decide whether or not to adopt some program of emissions control, a reliable estimate of the costs of which is available. A decision not to adopt the program is S1, a decision to adopt the program is S2. The consequences of either decision depend upon the state of nature, which in this case relates to the seriousness of the enhanced greenhouse effect. For simplicity it is assumed that there are just two states of nature W1 and W2. If W1 is the true case, then there is no enhanced greenhouse problem. If W2 is the true case, there is an enhanced greenhouse problem.

Two possible decisions and two possible states of nature gives the four cell pay-off matrix shown below. The entries in each cell arise as follows. The top left is the base case that arises if no emissions abatement program is adopted and there turns out to be no problem. It is convenient to treat this as the reference point, and to define the pay-off as zero. If no program is adopted and it turns out that there is a problem, costs arise shown here as an amount 10 in the top right cell. The costs of the program are taken to be an amount 2. The bottom left cell shows minus 2, with the costs being incurred needlessly given that there is no greenhouse problem. If the program is adopted and there is a problem, the illustration assumes that it offsets 40 per cent of the costs due to climatic change in the absence of any emissions reduction from business as usual. This leaves damage costs still arising as 6, which together with the costs of the program give rise to an entry of minus 8 in the bottom right cell.

	W1	W2
S1	0	-10
S2	-2	-8

Several approaches to dealing with information of this nature have been discussed in the literature (see for example, Pearce and Nash, 1981). The basic issues are captured by considering here just one, that which uses an ‘index of pessimism’, also known as the Hurwicz criterion. This assigns weights to the best and worst outcome for each decision or strategy, and selects the strategy with the highest weighted pay-off. In this case the best/worst outcomes are :

	Best	Worst
S1	0	-10
S2	-2	-8

Using weights of 0.9 for the worst outcome and 0.1 for the best outcome, S1 gets assigned the score -9.0 (0x0.1 plus -10x0.9) and S2 gets -7.4 (-2x0.1 plus -8x0.9). Given these weights, the preferred strategy is S2, adopt the emissions reduction program. If the weights are reversed, so that the worst outcome gets 0.1 and the best 0.9, then the preferred strategy is S1, which scores -0.1 as against -2.6 for S2, and the decision would be not to adopt the emissions reduction program. If the weights assigned to best and worst outcomes are equal, at 0.5 each, then the scores tie and the decision maker is indifferent as to which strategy is adopted.

This example was constructed so as to highlight the critical role of the assignment of weights in this approach to decision making in the face of uncertainty. The question which naturally arises is how the weights should be assigned. The answer is implicit in the `index of pessimism' label. It is that they are to be assigned by the decision maker on the basis of his attitude to the various prospects set out in the pay-off matrix. A relatively large weight given to worst outcomes reflects an aversion to large losses, a relatively low weight a concern for the prospect of gain. Which of these is the correct position for a decision maker to take is not something on which the natural or social sciences can offer definitive recommendations. If the decision maker is acting on behalf of society rather than individually, as is the case in the enhanced greenhouse effect, then the matter is essentially a political one.

It is necessary to make two points here. First, that it is being assumed that there is no basis on which to consider either of W1 or W2 as the more probable. That is, that the situation is one of true uncertainty. If the decision maker is prepared to view one outcome as the more likely, the problem can be addressed within the framework of decision-making in a risky environment, using subjective probabilities as discussed above.

Second, it might be argued that in the enhanced greenhouse context, albeit highly stylised here, heavy weight should be given to worst outcomes on the grounds that they are in some sense more serious than best outcomes. However, the relative seriousness of outcomes should be reflected in the pay-off matrix entries. In practice it is not always possible to do this in such a way as to capture all of the dimensions of the problem. It may be, for example, that while there is consensus about the appropriate entries for the cells in the column headed W1, there is within the scientific community disagreement as to the appropriate entries under W2. Specifically in the enhanced greenhouse context, it has been noted that the consequences of doing nothing could be much worse than envisaged in IPCC scenarios, with the climate flipping into a new regime. This is a minority view, but cannot apparently be assigned zero probability. If the figure of -10 in the pay-off matrix above is taken to correspond to the majority, IPCC based, assessment, the question arises as to how the possibility of a much worse outcome can be taken into account. One route to take would be to create a third column corresponding to a climate surprise. However, this in turn raises the questions of what numbers to put in it -- by definition they are both large relative to those in the second column and largely unknowable -- and the proper assignment of weights.

The problem of thinking about the adoption, or otherwise, of a target for the reduction of GHG emissions has features in common with that of thinking about whether or not to allow land use which carries the risk of species extinction. In both cases it is impossible to assign probabilities to alternative states of nature, and the sizes of the appropriate entries in the pay-off matrix are themselves uncertain. The Safe Minimum Standard Approach (Bishop, 1978) was developed in the latter context, and can be applied to considering the enhanced greenhouse effect problem.

Consider the following pay-off matrix for the enhanced greenhouse problem, where illustrative numbers are replaced by x, y and z representing unknown costs. The only pay-off now taken to be known is the zero cost arising if no emissions reduction action is taken and it turns out that there is no enhanced greenhouse problem.

	W1	W2
S1	0	-x
S2	-y	-z

An extremely cautious version of the index of pessimism approach, setting the weight on the worst outcome to 1 and that on the best to 0, is the minimax criterion. This involves finding the largest loss for each strategy, max, and selecting the strategy which offers the smallest of such, mini. This approach does not necessarily require that it is possible to put numbers in each cell of the pay-off matrix. The minimax strategy may be identifiable on the basis of reasonable arguments as to the relative sizes of the cell entries. Those who argue the case for now adopting Toronto, or even deeper, emissions reductions targets can be understood in terms of adopting a minimax criterion together with an argument about the relative sizes of the costs involved.

The argument would be that there are strong grounds for taking x to be larger than either y or z. First, there is the possibility of climatic surprise. The argument here would be that the costs associated with abrupt major shift in climate regime are by definition of an order of magnitude greater than could be involved in an emissions reduction program. If that program can be assumed to eliminate the climatic surprise possibility, then x must be the largest prospective loss, and the adoption of strategy 2 is indicated. Second, leaving aside climatic surprise, there is the argument that the enhanced greenhouse effect will cause species extinctions. This is the context in which the Safe Minimum Standard Approach was originally put forward. Species extinction it was argued could entail the irreversible destruction now of resources of very large, but now unknowable, future value to mankind.

On these arguments, which in effect mean that x should be considered infinitely large, an emissions reduction program would be adopted whatever its cost. The so-called `Modified Safe Minimum Standard' approach seeks to meet this difficulty by proposing that where a strategy avoids an outcome involving the possibility of irreversible changes and very large costs, it should be adopted unless it entails current costs that are unacceptably large. In the enhanced greenhouse context, this says that an emissions reduction program should be adopted unless its costs are unacceptable. This modified approach does not answer the question of whether the program is worthwhile. Rather, it re-formulates the question as: how much is society now willing to pay to insure against unknown future contingencies? This can be a useful way of considering the problem: the insurance based approach to thinking about the enhanced greenhouse problem is developed further in Section D6.4 below.

These rules rely on some prior attitude on the part of the decision maker. In the greenhouse context, decision makers are politicians acting on behalf of society. If social attitudes appear cautious, then cautious rules should be adopted and vice-versa. However, with the uncertainty surrounding the possibility of an human induced greenhouse effect, it is difficult to determine social attitudes. For example, the Australian Institute of Petroleum noted that their view was:

> that until the significant scientific uncertainties surrounding the enhanced greenhouse effect are better understood, governments should not adopt policies which carry a high economic cost and which may prove unnecessary or misdirected.

On the other hand, others believe that the risks of climate change dictate that abatement action be undertaken immediately. The Australian Conservation Foundation, for example, submitted:

> Although there are many uncertainties remaining to be resolved in our scientific understanding of the nature and scale of the problems posed by the build up of greenhouse gases in the atmosphere, our present scientific understanding compels action. The long life time of many greenhouse gases, the slow response time of the climate system, major uncertainties in the climate sensitivity factor and the feedbacks in the climate system all point to the need to take precautionary action to reduce emissions.

In summary, these rules cannot resolve the controversies inherent in selecting either greenhouse prevention or adaptation (ie do nothing now) policies. They can, however, focus debate on the crucial role of attitudes to the uncertainties involved.

D6.3 Catastrophic risk

A catastrophic risk exists when there is a chance of a project going badly wrong with severe (possibly irreversible) consequences. Should such projects go ahead? In attempting an answer, Collard (1988) suggests subjective expected utility theory (SEU). Under SEU the expected utility of an outcome is equal to the utility of the outcome multiplied by its probability.

Collard suggests that agencies will ignore social costs or repeatedly postpone consideration of them until forced to take action. To model dramatic possibilities (eg reactor failure, adverse climatic ‘surprises’ etc.) an environmental disutility function is developed. Expected disutility is disutility times probability. These probabilities are subjective. In the catastrophic risk case the probability density function may be skewed with a tail of potentially large disasters carrying very small probabilities.

Exponentially increasing disutility is multiplied by decreasing probabilities to obtain the expected disutility arising from any hypothetical level of externality. This raises the question of whether expected disutility from catastrophes should be very large because of their disastrous outcomes or very small because of their low probabilities. The results indicate that strong catastrophic risk occurs when the probability of catastrophe decays less rapidly than its prospective disutility increases. Thus, expected disutility is large even though probabilities are low. Collard notes:

> We have isolated the case of strong catastrophic risk; it occurs when the probability of catastrophe decays less rapidly than its prospective disutility increases. Expected disutility therefore becomes very large indeed *even though* the probability of disaster is extremely small. If the analysis is correct, strong catastrophic risk should, in the limit, not be undertaken at any price.

Thus, the perspective is cautious. SEU requires the assignment of subjective probabilities. As noted in Chapter 2 the probability of a climatic catastrophe occurring in not known. However, it is known that the earth's temperature has swung within a 5 to 6 degree Celsius range over the last million years. A rise of that magnitude is not predicted to occur for at least a century which may indicate that the potential for a catastrophic surprise is a long way off. There has been further work in this area. Prospect theory provides an additional reason for believing that social costs are underestimated.

Prospect theory is an extension to SEU whereby differences in risk attitudes are incorporated into the analysis through a variable weighting function (Rosenman et al. 1988). Prospect costs relate to potential failure at some future date (in this case nuclear waste leakage, but also applicable to `climate breakdown') in the same way that an individual's perception of insurance premiums is related to the contingent loss that caused the person to pay insurance premiums in the first place. For example, the individual's perception of welfare changes from a nuclear waste siting decision requires compensation. Without compensation there are implicit transfers from individuals at storage sites to individuals at waste generating locations occurs and these transfers involve both current and future generations.

The study concluded that prospect theory reveals the costs that arise from subjective feelings about risk. Analysis which takes account of prospect costs was compared with that of the general case of a risk neutral decision maker. For a particular nuclear waste repository site, the difference between prospect costs and the costs perceived by the risk neutral decision maker ranged from tens of millions of dollars (with future welfare discounted, the value at risk declining over time, for either probability specification) to hundreds of billions of dollars (with no discounting of future welfare, the value at risk constant over time, for parabolic probability). Thus prospect theory yields much higher estimates of social loses than other approaches.

Although the emphasis of Rosenman et al. is about a need for compensation, by exposing additional social costs, prospect theory would probably tend to support a cautious approach where catastrophic risk is at stake. Both subjective expected utility theory and prospect theory require the assignment of subjective probabilities. Hence, they cannot resolve the problem of decision making in the face of uncertainty. They do offer ways of thinking about what is involved which may be relevant in the context of the enhanced greenhouse effect problem.

D6.4 Uncertainty and greenhouse insurance

The reliance on judgment evident in the decision rules reviewed above tends to polarise views into two distinct camps. On the one hand, optimists argue for a wait and see approach before embarking upon expensive greenhouse reduction measures. On the other hand, pessimists believe that the risk of an irreversible climatic catastrophe dictates that action be undertaken now. The decision maker is caught in the middle. All of the measures discussed above would tend to lead a decision one way or the other. They do not appear to have the flexibility to accommodate strategies which might lie in the range between the extremes (ie do nothing, or do something).

Thrifty insurance

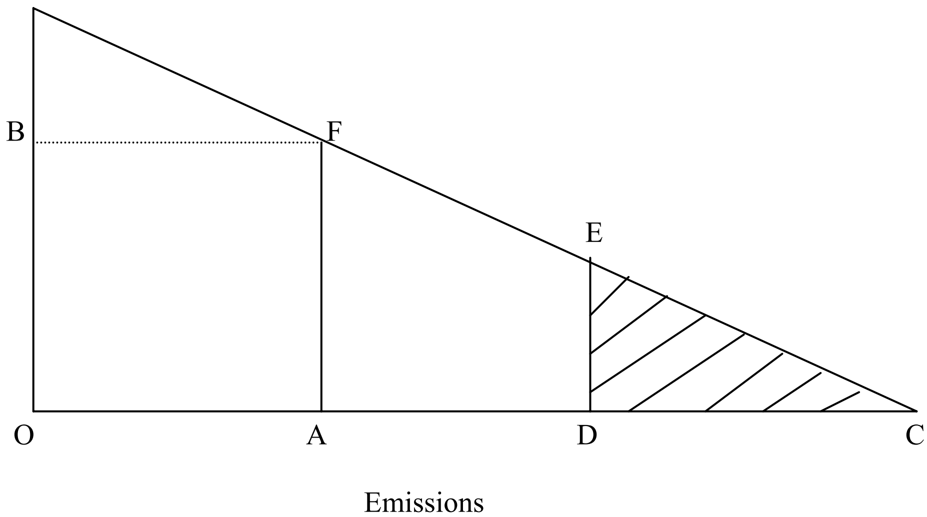
There is some recent work which may shed some light on the decision maker's dilemma (see Manne and Richels 1990). They take the view of a thrifty purchaser of insurance who is aware that the scientists are currently divided on the chances of global calamity if `business as usual' is pursued. Three forms of greenhouse insurance are identified: more intensive research to reduce uncertainty; development of new supply and conservation technologies to reduce abatement costs; and immediate reductions in emissions.

Manne and Richels argue that it need not be a case of selecting one strategy or the other. A blend of policies can be adopted and greenhouse insurance dollars allocated accordingly. The portfolio is dependent on how the options interact. For example, more research leading to improved information can influence the level of technological development.

Manne and Richels select as the starting point the call for near-term emissions reductions in the face of scientific uncertainty. A simple calculation is used to introduce some basic concepts and to illustrate how the optimal hedging strategy varies with the timing and accuracy of climate research. A central theme of this work is to avoid the controversy inherent in the debate about whether benefits exceed costs.

A single period demand curve for emission rights (Figure D2) depicts willingness-to-pay for emission rights as a linear function of the quantity of emissions. The identical function is used for willingness-to-pay in the two thirty-year periods before and after the resolution of climate uncertainties in 2020.

Figure D2: **Willingness-to-pay for greenhouse emissions**



Without a greenhouse tax, emissions during each period (1990 to 2020 and 2020 to 2050) would be OC. With a high tax (OB), emissions are reduced to OA. Now assume that AC is the total cumulative reduction required to avert a catastrophe if the pessimists are right. One option would be to hedge a small reduction (DC) in period 1 and a large reduction (AD) in period 2 -- if it turns out the pessimists were right. In the worst case (business as usual with DC=0) a rapid replacement of capital stock (housing, power plants etc) would be required during 2020 to 2050. *By assumption, the danger will be identified early enough so that there is no irreversible damage from hedging.*

Manne and Richels argue that without loss of generality the units of emissions and of willingness to pay can be chosen so that AC=AF=1. Then let, x be the decision variable that denotes the fraction of the total reductions to be undertaken in period 1 and (1-x) represent the fraction of the reductions during the second period. That is, x corresponds to DC and the shaded area DCE is the immediate cost of the decision. Therefore, the overall costs of the first period's reductions are $.5x^2$, and $.5(1-x)^2$ during the second period. Let, p be the probability that the greenhouse effect will be catastrophic. The expected money value (EMV) of the costs incurred during the two periods together would depend on the probability p and the near term decision variable x: $EMV(x) = .5x^2 = .5p\ (1-x)^2$.

From this cost function, Manne and Richels show that the optimal policy is to set $x = p/(1+p)$. Thus, if it was certain that the enhanced greenhouse effect will be catastrophic (ie $p=1$) the optimal policy would be to undertake half of the cumulative reductions in both the first and the second period. If there is a 50/50 chance of catastrophe, the optimal hedging strategy would be to undertake a 33 per cent reduction in the near term and a 67 per cent reduction later -- should it prove necessary.

With p=.5 and therefore the optimal x=.33, the expected money value of costs, EMV(.33), is .167. This is the cost of 'first act, then learn'. Under the `first learn, then act' scenario the EMV drops to .125 (Box D3).

Box D3: **First learn, then act**

'(a) If we know that there is no need to act, then the cost is zero in both time periods. (b) If we know that we do need to act, the optimal policy is to set x=.5. The total cost in the two periods will then be : $.5(.25^2 + .25^2) = .25$. Since outcomes (a) and (b) are equally likely, the expected costs are .125. Therefore, the expected value of perfect information EVPI = .167 - .125 = .042. Note that EVPI = .042/.167 = 25% of the expected costs under a `first act, then learn' policy. In plain English, this means that there is a large pay-off to the resolution of uncertainties prior to 2020.' (Manne et al. 1990)

Manne and Richels extend the example to include non-linear demand functions that shift between periods, time discounting and economic growth. These factors were incorporated into the Global 2100 model (see Manne & Richels 1989). The main conclusions are:

- there is a large pay-off to reducing climate uncertainty but the value of information is sensitive to the individual's confidence in its reliability;
- better climate information is less important to the technology optimist and vice versa for the pessimist;
- the optimal size of near term emission cutbacks as a hedge against climate change is sensitive to the availability of better information and the prospects for new energy supply and conservation technologies;
- optimism about the prospects for new energy supply and conservation technologies reduces the need to hedge and there is less pressure for abatement measures;
- there is less need for precautionary emission reductions if expenditure is undertaken to reduce uncertainty and develop new conservation and supply options; and

  better climate information reduces the need to hedge against the future.

References

Baumol, W.J. and Oates, W.E. 1988, *The Theory of Environmental Policy: Externalities Public Outlays and the Quality of Life,* Second Edition, Englewood Cliffs, New Jersey: Prentice Hall.

Bertram, D. and Toman, M.A. 1991, *Equity and International Agreements for CO2 Containment*, Discussion paper ENR91-07, Resources for the Future.

Bertram, I.G., Wallace, C.C. and Stephens, R.J. 1989*, Economic Instruments and the Greenhouse Effect,* Dept of Economics, Victoria University of Wellington, New Zealand.

Bishop, R.C. 1978, *Endangered Species and Uncertainty: The Economics of a Safe Minimum Standard. American Journal of Agricultural Economics, February 1978.*

Blamey, R.K. 1991, Economic Valuation of Non-market Goods: The Contingent Valuation Method, paper submitted for B.Sc. Honours, School of Environmental Studies, Griffith University.

Bohm, P. and Russell, C.S. 1985, 'Comparative Analysis of Alternative Policy Instruments', in Kneese, A.V. and Sweeney, (J.L. eds) *Handbook of Natural Resource and Energy Economics,* Vol 1. Amsterdam: Elsevier.

Collard, D 1988, Catastrophic Risk: Or the Economics of Being Scared, *in Economic Growth and Sustainable Environments,* Collard, D., Pearce, D., and Ulph, D.

Collins, D. and R. Young 1991*, Taking Account of the Future: The Role of Discounting and Intergenerational Equity,* Paper presented to the DASETT Conference on Climate Change, 12 April.

Common, M. S. 1988, *Environmental and Resource Economics: An Introduction*. London: Longman.

Common, M. S. 1990, 'Policy Instrument Choice' in M.S. Common and S. Dovers (eds*), Moving Toward Global Sustainability* -- Policies and Implications for Australia, Centre for Continuing Education, Australian National University.

Commonwealth of Australia 1989, *Ozone Protection Act 1989*, Commonwealth Act of Parliament, No. 7 or 1989, AGPS, Canberra.

Cummings, R.G., Brookshire, D.S. and Schultze, W.D. 1986, *Valuing Environmental Goods: An Assessment of the Contingent Valuation Method*, Totowa, Rowman and Allanheld.

DASETT (Department of the Arts, Sport, the Environment, Tourism and Territories) 1990*, Annual Report 1989-90 on the operation of the Ozone Protection Act 1989,* Parliamentary Paper No. 344/1990, AGPS, Canberra.

Dasgupta, A.K. and Pearce, D.W. 1974*, Cost Benefit Analysis: Theory and Practice*. Macmillan Press Ltd.

Frey, B.S., Schneider, F and Pommerehne, W.W 1985, 'Economists' Opinions on Environmental Policy Instruments: Analysis of a Survey' *Journal of Environmental Economics and Management*, Vol. 12.

Grubb, M. 1990, ‘The Greenhouse Effect: Negotiating Targets’, *International Affairs*, 66, 1, 67-89.

Hahn, R.W. 1989, ‘Economic Prescriptions for Environmental Problems: How the Patient Followed the Doctor's Orders’, *Journal of Economic Perspectives*, No. 2, Vol. 3.

Hahn, R.W. and Hester, G.W. 1989a, ‘Marketable Permits: Lessons for Theory and Practice’, *Ecology Law Quarterly*, No. 2, Vol. 16.

Hahn, R.W. and Hester, G.W. 1989b, ‘Where did all the Markets Go? An Analysis of EPA's Emissions Trading Program’, *Yale Journal on Regulation*, Winter 1989.

Hufschmidt, M.M., James, D.E., Mesiter, A.D., Bower, B.T. and Dixon, J.A., 1983, *Environment, Natural Systems and Development: An Economic Valuation Guide,* John Hopkins University Press.

Imber D., Stevenson, G. and Wilks, L 1991, *A Contingent Valuation Survey of the Kakadu Conservation Zone*, Resource Assessment Commission, Research Paper No. 3.

Industry Commission 1991, *Annual Report 1990-91*, Appendix 3, pp. 95-110

Ingham, A and Ulph, A 1991, ‘The Economics of Global Warming’ in Bennett, J and Block, W (eds) *Economics and the Environment: An Australian Reconciliation*, Institute of Public Affairs, Perth.

James, D.E. 1991, ‘*Economic Analysis for Responding to Greenhouse Climate Change’*, paper presented to DASETT Conference on Climate Change, 12 April 1991.

Kneese, A.V. 1977, *Ecomomics and the Environment*, Penguin, London.

Mäer, K.G. 1990, `International Environmental Problems', *Oxford Review of Economic Policy*, 6.

Manne, A.S. and Richels, R.G. 1989, *CO_2 Emission Limits: An Economic Cost Analysis for the USA.*

Mitchell, R.C. and Carson, R.T. 1989*, Using Surveys to Value Public Goods: The Contingent Valuation Method,* Resources for the Future, Washington.

Morissette, P.M., Darmstadter, J., Plantinga, A.J., and Toman, M.A. 1990*, Lessons from other international agreements for a global CO_2 accord,* Discussion Paper ENR91-02, Resources for the Future.

Nelson, R.H. 1987, ‘he Economics Profession and the Making of Public Policy’*, Journal of Economic Literature*, XXV.

Nordhaus, W.D. 1991, To Slow or Not To Slow: The Economics of the Greenhouse Effect, in *The Economic Journal*, Vol. 101, July, pp. 920-937.

Odgers, B. 1991, *Economic Instruments for achieving Environmental Objectives and Sustainable Development,* Environment and Conservation Policy Division, DASETT, March

OECD 1989a, *Environmental Policy Benefits: Monetary Valuation,* OECD, Paris.

OECD 1989b, *The Application of Economic Instruments for Environmental Protection in OECD Member Countries*, OECD, Paris.

Pearce, D. W., Markandya, A. and Barbier, E.B 1989, *Blueprint for a Green Economy*, Earthscan Publications, London.

Quiggin, J. 1991a, *Discount Rates, Future Generations and Sustainability*, Paper presented at the Ecologically Sustainable Development Working Groups Intersectoral Issues First Technical Workshop 9-10 May 1991.

Quiggin, J. 1991b, *Referendums and Pseudo-Referendums in Contingent Valuation*, mimeo, Department of Economics, Research School of Social Sciences, ANU.

Rosenman, R., Fort, R. and Budd, W. 1988, 'Perceptions, Fear, and Economic Loss: An Application of Prospect Theory to Environmental Decision Making', Policy Sciences 21, Kluwer Academic Publishers, Dordrecht, Netherlands.

Sedjo, R.A. 1989, 'Forests: A Tool to Moderate Global Warming?' *Environment*, 31.

Sugden, R and Williams, A 1985, *The Principles of Practical Cost-Benefit Analysis*, Oxford University press.

Tietenberg, T. H. 1990, 'Economic Instruments for Environmental Regulation', *Oxford Review of Economic Policy*, 6, 1, 17-33.World Commission on Environment and Development 1987, Our Common Future (WCED: the Brundtland Commission), Oxford University Press, London.

Young, R 1990, *Evaluating long lived projects: the issue of intergenerational equity*, Submitted to the Australian Journal of Agricultural economics.

APPENDIX E: LESSONS FROM INTERNATIONAL AGREEMENTS

A significant reduction in greenhouse gas emissions from anthropogenic sources would require the commitment of many countries to an international agreement. While there has been considerable international activity, many issues and concerns still have to be addressed before an agreement can be struck. This appendix reviews international treaties on five different environmental issues in order to gain some insights into the factors influencing the achievement and scope of an international agreement to reduce greenhouse gas emissions.

E1 Overview

The Montreal Protocol

The *Montreal Protocol on Substances that Deplete the Ozone Layer* is an agreement which aims to prevent the destruction of stratospheric ozone by chloroflurocarbons (CFCs) and halons. For almost half a century, CFCs were considered miracle chemicals. They were chemically inert, stable, neither toxic nor flammable, easy to store and cheap to produce. In the early 1970s, however, it was claimed that CFCs might be destroying the layer of stratospheric ozone that protects the Earth from harmful ultraviolet radiation. In response, the United Nations Environment Programme (UNEP) outlined a strategy for addressing the ozone depletion issue. At the same time, the US and the EC took unilateral measures to reduce CFC emissions.

By 1980, the UNEP began work on developing a framework convention for the Protection of the Ozone Layer which was adopted after nearly four years of negotiations in Vienna in 1985. Under the terms of the Convention, nations agreed to take appropriate measures to protect human health and the environment from any adverse effects resulting from modification of the ozone layer (UNEP 1989, p. 8). The UNEP convened another full scale conference which was to build on the base of the Vienna Convention and develop a protocol on the reduction and eventual elimination of ozone damaging CFCs and halons. This became known as the Montreal Protocol. The Protocol came into force with 29 countries and the EC, covering approximately 82 per cent of world consumption, signing the final document. By the end of 1990 another 27 countries had ratified the agreement.

The Law of the Sea

In 1945 the United States unilaterally claimed the seabed resources of the continental shelf surrounding its land territories. Similar claims were made by other countries in the years that followed. These claims, coupled with the increasing use of the oceans for commercial purposes, led to conflicts over fishing rights, the passage of foreign ships and access to waters for research. The United Nations (UN) in an attempt to resolve these problems adopted a series of largely ineffective conventions in the late 1950s.

By the 1960s, support for a comprehensive Law of the Sea (LOS) treaty was mounting among nations with large maritime and naval fleets, particularly the US and the Soviet Union (Morrisette, Darmstadter, Plantinga and Toman 1990). This support culminated in the Third United Nations Conference on the Law of the Sea (UNCLOS III) which involved eleven major meetings between 1973 and 1982 and the participation of over 150 countries.

The treaty attempted to address a number of issues including the right of passage for ships through different legal jurisdictions, the exploitation of continental shelves, environmental safeguards and scientific research. In each of these issues, countries agreed on criteria to determine sovereignty over certain waters and the rights and duties attached to that sovereignty. In addressing these issues, the LOS clarified points of contention regarding individual nation's sovereignty but it did not alter the generally recognised property rights of individual nations. Agreement on these issues was reached relatively quickly.

All that remained by 1978 was to agree on a management regime for deep sea mining. The LOS proposal was to implement a management regime from which all countries would benefit. In effect, the LOS treaty would change the nature of the deep sea bed from a `common property' resource, where nations had free access to the sea bed, to a managed resource, where countries' access was restricted. The United States and a number of other countries opposed the management regime that would restrict their access to the sea bed and refused to sign the LOS treaty.

One hundred and fifty-nine countries signed the LOS treaty. However, the treaty has only been ratified by 39 of the 60 countries required for it to enter into force. Six countries, including the US, Britain and West Germany, refused to sign the final document.[1]

[1] The other nations were Israel, Turkey and Venezuela. Venezuela stated that it refused to sign because it might affect its position in its dispute with Columbia over the Gulf of Venezuela.

The Antarctic Treaty

Between 1908 and 1947 seven nations announced claims to parts of Antarctica.[2] In 1948 the United States was preparing to make a claim to a large portion of the Antarctic that would have overlapped all existing claims. To avoid conflict the US, with the support of Britain, proposed an eight way division of the continent between itself and the other countries with formal claims. This was opposed by most of the claimant nations and the Soviet Union. The division of Antarctica became an increasingly pressing issue during the 1950s. By the end of the decade, however, sovereignty objectives were replaced with scientific objectives. All the claimant nations agreed to suspend their claims and they adopted the Antarctic treaty which specified that the Antarctic region was to be used for scientific and other peaceful purposes (Morrisette et al. 1990).

The Antarctic Treaty itself does not address the question of exploitation, ownership, or management of living or non-living resources in Antarctica. However, it does allow the parties to the treaty to recommend measures with respect to these resources. In this regard the parties to the Antarctic Treaty have adopted a number of conventions to protect the environmental integrity of Antarctica including the *Convention on the Conservation of Antarctic Marine Living Resources* (CCAMLR). The CCAMLR was adopted in 1980 by 15 countries and came into force in April of 1981. Since 1981, a further 11 countries and the EC became parties to the treaty. Another environmental convention, the *Convention on the Regulation of Antarctic Mineral Resource Activities* (CAMRA), took 11 years of negotiation before it was adopted in 1988. Ratification, which is required before the treaty can go into effect, has been delayed because of disagreement over the rights of countries to mine in the Antarctic (Morrisette et al. 1990).

The Whaling Convention

The first *International Convention of the Regulation of Whaling* was adopted by the League of Nations and opened for signature in 1931. It was ratified by 17 states and adhered to by 10 others and came into effect in 1935. The Convention was limited in scope. It prevented the killing of calves, suckling whales, immatures, and female whales accompanied by calves or sucklings. However, with the exception of bowhead and right whales, the Convention did not limit the number of whales allowed to be killed. Five major whaling nations refused to accede to the Convention.[3] The Convention was amended by a number of protocols and agreements until in 1946, 15 whaling nations signed the present International Whaling Convention (the Whaling Convention) which established the *International Whaling Commission* (IWC) to provide for the proper conservation of the whale stocks and orderly development of the whaling industry (Rengger 1990).

[2] The seven nations were Britain, New Zealand, France, Australia, Norway, Argentina and Chile.

[3] These nations were Japan, Germany, Chile, Argentina and the USSR.

While the Whaling Convention was adopted as a means of managing whale stocks for an efficient whaling industry, as more non-whaling nations acceded to the Convention, the emphasis moved toward the conservation of whales. The shift in emphasis has seen catch quotas reduced significantly. In the first 15 years of the Whaling Convention few restrictions were imposed and in the 1960-61 season an unprecedented 64 000 whales were killed. Since then the IWC progressively imposed smaller catch quotas until, in 1982, the IWC imposed a ban on all commercial whaling from 1985-86 until at least 1990, although continuing to allow whaling for scientific purposes and by indigenous peoples. Although four countries initially objected to the ban, each withdrew their objections and all countries ended ‘commercial’ whaling activities (Rengger 1990). Several countries, including Japan, Iceland and the Republic of Korea have, however, allegedly continued the harvesting of whales at commercial levels under the scientific research provisions of the Whaling Convention. Norway has also considered authorising the `scientific' harvesting of whales (Environmental Policy and Law 1988).

Acid Rain Agreements

Acid precipitation (acid rain) occurs when certain acidic atmospheric gases (particularly sulphuric and nitric acid) dissolve in precipitation and are then deposited in water bodies and vegetation. Atmospheric sulphuric and nitric acids are primarily caused by the emission of sulphur dioxide (SO_2) and nitrogen oxides (NO_x) both of which are associated with the combustion of fossil fuels. NO_x is also released as a result of using nitrogen fertiliser and the combustion of biomass.

All countries in Europe suffer from acid rain. Much of it is transported across national borders. The transboundary nature of acid rain emissions resulted in a number of responses by European nations. The first multicountry policy response occurred in 1979 when, under the auspices of the UN Economic Commission for Europe (ECE), the *Convention on Long-Range Transboundary Air Pollution* was negotiated. This was later supplemented by a number of protocols. The EC also imposed limits on acid rain emissions. These multilateral agreements have also been augmented by a number of bilateral agreements on acid rain.

The various international agreements on acid rain involve different numbers of countries. The UN ECE, for instance, involves the countries of Western and Eastern Europe as well as the US, the USSR, and Canada. The EC agreement involves only the countries that are members of that group. There are also some bilateral arrangements (eg the United States and Canada) and a number of countries have undertaken unilateral abatement measures. These agreements are by no means mutually exclusive and several countries are members of the UN ECE and EC agreements as well as having bilateral agreements in place.

General messages

Each of the five sets of agreements reviewed have their own circumstances and, consequently, contain different provisions to deal with the particular problems they faced. The agreements, however, do share some features and experiences in common. One of these is that no matter how readily identifiable a problem and how well intentioned the countries involved, an international agreement can take many years to negotiate. For example, even after the problem of depletion of the ozone layer was widely accepted and individual countries were banning CFCs, an agreement took almost two years to achieve. Other agreements took much longer to negotiate. The Law of the Sea treaty, for instance, took nine years to negotiate. Similarly, agreement on the UN ECE Convention on Long-Range Transboundary Air Pollution took 12 years. And even though the Convention required countries to ‘develop without undue delay policies and strategies which shall serve as a means of combating the discharge of air pollutants’, the United States and Canada took another seven years to agree on a plan to address their acid rain problem (Rengger 1990).

Another theme is that agreements and circumstances tend to evolve over time and, as a result, countries may be willing to accede to a treaty after the initial agreement is negotiated. The Whaling Convention, for example, began with a limited number of countries all of which had commercial whaling operations. As the potential extinction of whale stocks came to light, non-whaling nations saw that there were benefits in the conservation as well as the harvesting of whales. In order to protect their interests in the conservation and protection of whales, more and more non-whaling countries joined the Whaling Convention.

Similarly, when the Montreal Protocol came into force at the beginning of 1989, just 29 countries and the EC were members. By the end of 1990, however, another 27 countries had ratified the agreement. One reason for this may be the sanctions imposed by the Protocol against the import of ozone depleting products from non-signatory countries.

Another possible reason for the expansion in the Montreal Protocol's membership was the willingness of the original signatories to alter the Protocol to take into account the requirements of other countries. For example, the establishment of a `global defense fund' and other measures designed to reduce the costs of developing country compliance, prompted both China and India to indicate that they would sign the amended Protocol.

The treaties also show that even when an agreement is reached, the enforcement of its provisions and conditions can prove very difficult. In the Whaling Convention, for instance, many countries breached the conditions of the agreement, in some cases by exploiting loopholes, particularly the scientific research clause.

Perhaps the most important and unsurprising message, however, is that countries can generally be expected to pursue their own interests as they see them and will not join or adhere to an agreement when the perceived benefits are outweighed by the perceived costs.

E2 Incentives to participate

International agreements are not costless. There are costs associated with performing treaty obligations, such as reducing national consumption of CFCs. There are also costs associated with the negotiation and enforcement of the agreement itself. With these costs being non-trivial in many cases, countries will require incentives to initiate and participate in an international agreement. The most powerful of these incentives is the perception that a country will gain more than it loses from participating in an agreement.

Costs and benefits

Commitment to an international agreement generally involves countries taking actions which impact on their domestic economies with a view to generate benefits on a broader front. In the case of the Whaling Convention, for instance, the global benefits of securing the long term survival of whales had to be weighed against the benefits countries derive from harvesting whales for commercial purposes. Similarly, the benefits of CFCs in uses such as refrigeration had to be weighed against the costs associated with the destruction of the layer of stratospheric ozone that filters harmful ultraviolet radiation.

All things considered, the greater the perceived costs and the lower the perceived benefits, the less enthusiasm a country will show in joining an international agreement.

The *Montreal Protocol* illustrates how countries' perceptions of the costs and benefits of an international agreement can vary and how this can influence their position on an international agreement. By and large, developed countries supported the protocol. CFC consumption and production in these countries accounted for only a small proportion of total economic activity and the anticipated cost of reducing CFC emissions was reduced by the known availability of CFC substitutes.

The difference between the costs and benefits is illustrated by the US Environmental Protection Agency's (EPA) cost-benefit analysis of reducing the consumption and production of CFCs under the Montreal Protocol. Their conclusion was that if CFC use went unchecked, an additional 150 million cases of skin cancers with more than three million additional deaths in the US population born before 2075 would occur. This is approximately twice the number of deaths that would be expected without CFC induced ozone depletion. The EPA estimated that many of these deaths could be avoided at an estimated saving to the United States of US$ 6.4 trillion. The cost of regulating CFCs under the Montreal Protocol was estimated by the EPA as being between US$ 20 to US$ 40 billion in the long term (from 1989 to 2075) (Morrisette et al. 1990). For the US the benefits of saving the ozone layer clearly outweighed the costs of reducing CFC emissions.

Conversely, several developing countries considered that the costs of adopting the Montreal Protocol would outweigh any benefits they might enjoy. One reason for this was that developing countries envisaged themselves as future producers and users of CFCs. Many possessed a sizeable potential market for consumer items such as refrigerators that used CFCs in their manufacture. Items such as refrigerators are also important because they contribute to better health and sanitary conditions. Because of their low incomes, developing countries may also have been more sensitive to the costs imposed by CFC reductions than were developed countries.

The initial response of the developing countries was to argue for a redistribution of the costs and benefits associated with the Montreal Protocol. It was argued, for instance, that it was unfair that the developing countries should be denied access to technologies that were available in the developed countries. China, in particular argued that it was the developed countries that caused the problem, so the developed countries should be the ones to solve it (Morrisette et al. 1990). Eventually the developed countries undertook to transfer technological and financial resources to the developing countries, to ease the burden of reducing the consumption of CFCs. This led several developing countries to revise their positions. Both China and India, for instance, have indicated that they will sign the revised protocol which included an international fund to aid the development of non-CFC based industries in the developing countries.

Perceptions of the problem

Many factors can influence a country's appraisal of the costs and benefits of participating in an international agreement. Governments generally interpret costs and benefits broadly and are ‘influenced by efforts to satisfy objectives not explicitly defined in the terms of the agreement’ (Morrisette et al. 1990, pp. 48-49). These objectives may involve other areas of international diplomacy or strategy, or the protection of national sovereignty. The initial opposition of the United States to a perpetual ban on mining in Antarctica, for example, may well have been an instance of that country protecting its ‘sovereign right’ to exploit resources over which it believed it had a formal claim, rather than an illustration of the United States’ desire to mine the Antarctic.

Pressure groups can also play a role in influencing the way in which governments assess costs and benefits. The political costs of alienating environmental groups, for example, may have been a factor in some countries' decisions to push for a mining ban in the Antarctic (Environmental Policy and Law 1990b).

Certainty and scientific knowledge

Countries' perceptions of the costs and benefits of participating in an international agreement will obviously be affected by the level of knowledge about causes and consequences of the problem. In a number of the treaties examined by the Commission, the ability to define the problem and show how action would be beneficial was critical in achieving widespread support.

In some cases the problem and its causes, are easily recognised. The Whaling Convention, for instance, was adopted to prevent a problem that had been apparent since the earliest days of whaling. Since the thirteenth century when Basque whalers were forced to venture outside of the Bay of Biscay after over-hunting the right whale (Lyster 1985), the over-exploitation of whale stocks has been a recognised problem. The discovery of new whaling stocks and new whaling techniques has led to a rapid depletion of one whale population after another. The Whaling Convention was adopted, first and foremost, to address this very problem.

Acid rain is another example of agreements being negotiated to address a problem that is widely recognised and easily seen. While there are some scientific uncertainties surrounding acid rain, the science of the acidification process is relatively robust. The scientific consensus is accompanied by easily observable impacts on forests, agriculture and man made structures: in some parts of Europe, 20 per cent of forests have been visibly affected.

The importance of establishing a compelling case for international action is highlighted by the experience with the CFC treaty. The problem of establishing a link between the ozone depletion and the role that CFCs played in the process was a scientific problem. Scientists hypothesised the relationship between ozone and CFCs and warned about the potential effects of ozone depletion on human health and welfare. One of the most important features of the Montreal Protocol was the role that science and scientists played in convincing policy makers that a problem of international dimensions existed and that without action the problem could involve large costs.

The importance of science and scientific research in the campaign to protect the ozone layer was recognised early by the UNEP. In the mid-1970s, the UNEP adopted a comprehensive research program addressing all areas of uncertainty regarding CFCs and the ozone layer. Throughout the 1970s, this research program yielded little useful evidence and the uncertainty led some people to doubt the links between CFCs and ozone depletion. By the beginning 1980s, however, the UNEP produced assessments of ozone depletion in which scientific confidence was high. This provided the necessary impetus for the UNEP to convene a series of conferences between 1981 and 1985 to negotiate an international framework convention. The result was the Vienna Convention in which 20 nations agreed to an ‘in principle’ recognition of the problem and the need to take action.

Despite the agreement of a framework convention, there was still a considerable degree of scientific uncertainty surrounding the depletion of stratospheric ozone. Several scientific studies strongly supported a link between CFCs and the depletion in stratospheric ozone. However, differences between various computer models of the atmosphere inspired reluctance among some negotiators who claimed that all predictions should be discounted, leaving no justification for anything stronger than a freeze in CFC consumption and production. In response, a comparison of the models was organised with each modelling team using the same data. In April 1987, each of the teams arrived at similar conclusions and reported that unless very strong regulations covering a full range of halons and CFCs were adopted, any protocol would be ineffective. According to the UNEP (1989) this was a turning point in the negotiations on an ozone protection protocol and in September of 1987, with a strong scientific consensus, the Montreal Protocol was adopted.

E3 Institutional factors

The success of international agreements in addressing a particular problem hinges on securing widespread support from countries. Harnessing this support depends on the ability to negotiate an agreement which addresses the particular concerns of the countries involved. These generally relate to the perception of some countries that the agreement will inflict net costs. A number of institutional mechanisms have been used to address these concerns. Some of these reduce the costs associated with agreeing to an international treaty. Others are designed to redistribute the costs so that a greater number of countries enjoy net benefits from an international agreement.

Measures to reduce costs

Flexibility

Allowing countries some flexibility in the way they fulfil their obligations under the terms of a treaty or agreement encourages more countries to join an international agreement by reducing the costs of participation.

The Third Law of the Sea Treaty, for instance, has a number of provisions requiring countries to undertake, among other things, the protection of the marine environment and the transfer of technology. Neither provision specifies how, or to what extent, countries should observe these obligations. Rather it is up to individual countries to decide on how they will fulfil their obligations under these and all other provisions that require no specific action. Allowing countries this flexibility enables them to reduce the costs of participation and may encourage countries to not only become parties to agreements, but also to adopt specific provisions that they might otherwise oppose.

Another example of an international agreement permitting countries some flexibility in performing their obligations under the terms of the agreement is the Montreal Protocol. Unlike the Law of the Sea, the Montreal Protocol's flexibility does not stem from the vagueness of its provisions. Rather, it is the result of a deliberate effort to build into the Protocol a means by which costs would be minimised while ensuring that strict standards were maintained. One example of the Protocol's flexibility is the way in which it allows countries to cut consumption of CFCs and halons. The Montreal Protocol requires that countries reduce their consumption of CFCs and halons by a set percentage over a period of time. However, rather than requiring countries to reduce consumption of all controlled substances by the same amount, the Montreal Protocol allows countries to choose a mix of reductions that best suits its own situation. It does this by attaching to each controlled substance a value that reflects their potential to damage the ozone layer. This value is known as the Ozone Depleting Potential or ODP. The amount of controlled substances that a country is assumed to consume is the actual amount of consumption of controlled substances multiplied by their ODPs. Under this scheme a country can choose to cut its consumption of a large amount of CFCs with low ODPs or a smaller amount of CFCs with high ODPs or some combination of the two. This allows countries some flexibility in deciding how they will cut consumption while still meeting the reduction targets set by the Montreal Protocol. Importantly, it also allows countries to reduce the costs of participating in the Protocol.

Reservation clauses and consensus decision making

A concern that many countries have is that after they commit themselves to an agreement the conditions might be changed at their expense. The Whaling Convention was signed by a number of whaling nations in the expectation that it would ensure the orderly exploitation of whale stocks. But as the agreement began to focus more on conservation than on the commercial management of whaling stocks, whaling nations found themselves members of an agreement that was increasingly being used to halt commercial whaling.

The concern over the danger of changing circumstances and changing conditions has been overcome in a number of treaties by the inclusion in the original agreement of reservation clauses and consensus decision making rules.

Reservation clauses allow countries to be exempt from changes to parts of treaties to which they have raised objections. The Whaling Convention, for instance, allows countries to avoid being bound by any amendment to the agreement by registering an objection within 90 days of the notification of the amendment's adoption.

There are several instances where countries that are parties to the Whaling Convention have used reservation clauses. In 1954, Canada, Japan, the USA and the USSR objected to a prohibition on the taking of blue whales in the North Pacific. Similarly, in 1981, Brazil, Iceland, Japan, Norway, and the USSR objected to the banning of the ‘cold grenade’ harpoon as a means of killing minke whales. In 1982 Peru and Chile objected to the whaling quotas allocated to them and, in 1986, Japan, Norway and the USSR all objected to a call for the temporary halt to commercial whaling (Lyster 1985). In each of these cases, the countries that objected to the decisions were the countries that stood to lose the most from changes. However, by objecting to the decisions the countries avoided the costs of complying with amendments without having to fully withdraw from the agreement and forgo the benefits of participation.

Many international agreements and treaties require a two-thirds or three-quarters majority voting procedure. Some, however, require that decisions are made on a *consensus* basis. One treaty that does require decision making by consensus is the Antarctic Treaty’s Convention on the Conservation of Marine Living Resources (CCAMLR). The CCAMLR requires that matters of substance be decided on a consensus basis. Lyster (1985, p. 168) makes the point that the consensus decision making rule was adopted as a compromise that ‘was thought would not fatally prejudice the interests of either the conservation-oriented members of the [CCAMLR] or those most interested in fishing.’

The outcome of the consensus decision making rule is that any country can block a measure from being adopted by voting against it. This permits countries to easily protect their own interests. It also leads to the initial conditions of the agreement being particularly significant because of the difficulty associated with a large number of countries agreeing on any changes.

Measures to redistribute costs

Starting points and targets

International agreements, particularly those that are concerned with the environment, often require countries to meet specific targets. The Montreal Protocol, for instance, required countries to freeze their consumption of CFCs at 1986 levels by 1989. Countries were then required to meet further targeted reductions in 1993 and 1996. Differentiated targets and starting points, afford some countries another means of reducing the costs associated with a particular international agreement. The Montreal Protocol and the *European Communities Large Combustion Plant (LCP) Directive* provide two examples of how different targets and different base years can reduce the costs and encourage countries to participate in international agreements.

The participation of the third world countries was seen to be crucial to the success of the Montreal Protocol and the original Protocol made allowances for certain countries to change the year on which the targeted reductions were based. Developing countries were allowed to delay the implementation of the phase down schedule for ten years so that 1996 rather than 1986 would be the year on which reductions would be based. This was in recognition of the fact that developing countries may need to increase their consumption of CFCs as they develop. Its effect was to reduce the net costs borne by the developing countries that join the Montreal Protocol. It also had the effect, however, of reducing the benefits enjoyed by all countries because the stock of ozone destroying CFCs and halons in the atmosphere would take longer to decline.

Centrally planned economies were accorded similar concessions. They were allowed to include in their 1986 production levels the projected output from facilities contracted before the agreement of the Protocol, provided they were completed by 1991 and did not raise the country's consumption above 500 grams per head (UNEP 1989). Allowing countries to include some future production in the base year used to calculate future reductions means that countries will be able to make smaller production cutbacks while still fulfilling the terms and conditions of the agreement. The result is that centrally planned countries are able to comply with the Montreal Protocol but the costs of their doing so are reduced.

The European Communities Large Combustion Plant (LCP) Directive to limit acid rain provides another example of some countries being allowed to use different targets or base years to reduce the costs of their agreeing to the terms and conditions of a particular treaty. The LCP Directive specifies national Sulphur Dioxide (SO_2) and Nitrous Oxide (NO_x) emission ceilings and reductions from 1980 levels to be achieved in a staged sequence over a period of time. However, ‘due account’ was taken of the technical and economic constraints facing individual countries and the national targets were set accordingly. The result is that major European industrial countries face reductions of 60 to 70 per cent on SO_2 by 2003 while Spain has been granted a concession that reduces its obligation to decrease its SO_2 emissions (Morrisette et al. 1990, p. 27). The LCP directive also allows a number of other concessions including that:

> Substantial and unexpected changes in energy demand, unavailability of certain fuels, and technical problems in the installation of pollution abatement equipment in existing plants are grounds for `modification' of the emission reduction targets.
>
> New plants burning ‘indigenous solid fuel’ whose characteristics demand ‘excessively expensive’ abatement technology may exceed prescribed sulphur dioxide emission limits.
>
> Member states whose use of indigenous lignite is an ‘essential source of fuel for the plants’ are likewise allowed to exceed emission limits (Morrisette et al. 1990, p. 28).

These provisions allow countries that face high acid rain emission abatement costs a number of significant concessions which appears to have contributed to their acceptance of the final Directive.

Concessions and trade sanctions

A number of the agreements reviewed by the Commission have used several other mechanisms to limit the costs borne by certain countries. The Montreal Protocol, for instance, granted developing countries access to alternative substances and technologies as well as being offered subsidies, aid, credit guarantees and insurance programs (UNEP 1989). In 1990, the parties to the Montreal Protocol also established an `ozone defence fund' designed to facilitate developing countries' switch to chemicals that will not damage the ozone layer (Rosencranz and Scott 1990). The fund has a three-year budget of US$ 160 million with another US$ 40 million being earmarked for both China and India when they join the Protocol (Environmental Policy and Law 1990a).

The Montreal Protocol also made use of a limited tradeable permits system which allowed countries with small CFC industries (producing less than 25 000 tonnes annually) to trade any excess production with other countries, providing that the total combined production did not exceed the combined allowable production level for the countries concerned. This provision was adopted to allow countries to rationalise their CFC industries without the need for unnecessary closures (UNEP 1989). The relatively small number of producers of CFCs mean that the transaction costs associated with trading production between countries would be likely to be low because many multinational firms may be able to conduct trades in production excesses internally.

The Montreal Protocol also put in place a number of sanctions aimed at increasing the costs borne by non-signatory countries. These include limited trade restrictions against countries that were not members. All members were required to ban imports of bulk CFCs and halons from non-parties from the beginning of 1990 and to ban imports of products containing the chemicals from non-party countries from 1993. Developing countries enjoying the ten-year delay in implementing the cuts in consumption were not allowed to export the chemicals to non-parties from the start of 1993 (UNEP 1989).

E4 Monitoring, enforcement and effectiveness

Clearly the prerequisite for an ‘effective’ agreement -- one which meets its objectives -- is its substantive provisions. While trade-offs, such as those discussed, can ensure participation, they can also jeopardise underlying goals. This can also occur through ambiguities and lack of clarity in the text of an agreement.

Loopholes and trade-offs

If an agreement is weakly or ambiguously specified then countries may be able to use loopholes to circumvent the spirit of the agreement. The Whaling Convention, for instance, provided for limited whaling for scientific purposes and aboriginal or subsistence whaling. In the face of the Whaling Commission’s complete ban on whaling from 1986, a number of countries, including Japan, the

Republic of Korea and Iceland issued permits to allow scientific whaling which resulted in the killing of large numbers of whales (Environmental Policy and Law 1988, p. 97). Japan, with the support of Norway, also tried to exploit another loophole in the Whaling Convention in 1988 by proposing the reclassification of certain types of commercial whaling as aboriginal or subsistence whaling (Environmental Policy and Law 1988).

Flexibility delivered by vague provisions and conditions will reduce the effectiveness of a treaty. For instance, as already noted, the Law of the Sea requires countries to protect the marine environment and to transfer technology to those countries which 'may need technical assistance' and in particular developing countries (United Nations Convention on the Law of the Sea 1983). But how and to what extent countries should observe these conditions are not specified. Countries, in practice, need do very little to comply with the conditions of the agreement.

When countries are explicitly required to undertake specific actions, an international treaty is more likely to achieve its objectives. The Montreal Protocol, for instance, allows countries some flexibility in *how* they cut consumption of CFCs and halons, but it does not allow any flexibility on the *size* of the cuts made.

Reservation clauses and consensus decision making, while helpful in encouraging participation, can compromise the ability of an agreement to cope with changed circumstances, such as better information on sustainable exploitation of a particular resource. The experience of the Whaling Convention, for instance, has been that countries which have opposed amendments to reduce whale harvesting quotas have simply objected to the amendment and continued to harvest whales. In this case the objectives of the Whaling Convention are not being achieved. Nevertheless, reservation clauses and consensus decision making are necessary to protect the sovereign right of nations. When countries disapprove of changes to an agreement, what may be needed is a new redistribution of the costs and benefits.

Monitoring

The effectiveness of international agreements, given the temptation not to comply (to 'free-ride') is also affected by the ability to enforce its provisions. In turn, enforcement depends on the ability of countries to monitor and detect non-compliance by others.

The ability to monitor and detect non-compliance is an important feature of successful agreements. The importance of monitoring is highlighted by opposition to a nuclear test ban treaty on the grounds that an adequate system of monitoring is technically impossible.

In some of the treaties reviewed by the Commission, monitoring of countries' compliance was effected through a series of public reporting requirements by both the countries involved in a treaty and, in some cases, a central administrative body. Both the CCAMLR and the Whaling Convention, for instance, require that countries submit reports on their harvesting activities, their vessels and their compliance with the conditions of the agreement. The Whaling Convention also requires that countries report annually on any action taken on infractions of the whaling regulations (Lyster 1985).

These reporting requirements are often accompanied by international supervision. The CCAMLR, for instance, requires that its central administrative body report publicly on the activities of both member and non-member nations that affect the implementation of the CCAMLR's objectives. The Whaling Convention has a system of international observers appointed by the Whaling Commission, who are placed on whaling vessels to ensure that the whaling of prohibited species does not take place.

The reporting requirements and the international supervision are supposed to ensure that non-compliance with the terms and conditions of the agreement will be detected. Like most other areas of international agreements, however, monitoring is only worth what the members of agreement want to make of it. In the case of whaling, several countries have refused to supply data on their whaling vessels (Environmental Policy and Law 1988) and the number of international observers is too small for an effective check to be kept on all whaling operations (Lyster 1985).

Enforcement

Once an effective monitoring system is in place, there is the problem of ensuring that countries comply with the terms and conditions of an international agreement.

One possible enforcement mechanism is the International Court of Justice at the Hague. However, this has not been much used (50 cases in 40 years) and when it has the result has generally been unsatisfactory. There are several reasons for this: proceedings in the International Court of Justice cannot take place without the consent of the prospective defendant; 'taking a country to court' is often seen as a politically unfriendly act; and perhaps most importantly, the decisions of the court are not themselves externally enforceable on sovereign nations.[4]

A country may also be forced to comply with the terms and conditions of an international treaty by having an action taken against it in its national courts. So long as the international agreement is implemented through national legislation and the legal system of the country permits legal challenges to the government, this is potentially a more effective means of ensuring a country's compliance.

4 For instance, in the first case, ever brought before the court, 834 947 pounds were awarded to the UK against Albania but none of the damages have ever been paid.

Many international agreements are, however, not implemented through national legislation and so non-compliance cannot be challenged in a country's courts. These so called `soft treaties' have to rely on other means to enforce compliance. One of the simplest of these other means is to require that countries meet regularly. This ensures that countries are constantly reminded of their obligations and prevents the agreement becoming a `sleeping treaty' that is ignored by all parties.

Other means of enforcing compliance are `retaliation' and `moral pressure'. The General Agreement on Tariffs and Trade (GATT) is an agreement that provides a legal framework for the conduct of trade relations as well as being a forum for trade negotiations and an organ for the conciliation and settlement of disputes. The GATT provides for countries that suffer damage from the actions of others to take retaliatory action by the withdrawal and suspension of tariff and other concessions. But moral or peer pressure has also played a significant role in moderating the behaviour of some contracting parties (Long 1987).

Trade or financial sanctions can be a powerful enforcement technique and need not always be included in the terms of the agreement. The US Government, for instance, has enacted laws that allow economic sanctions to be imposed against any state whose activities diminish the conservation measures of the International Whaling Commission (Lyster 1985). These sanctions are not included in the terms and conditions of the Whaling Convention but they apply to breaches of that agreement.

Even sanctions may not be enough to ensure that countries comply with the terms and conditions of an agreement. Japan, South Korea and Iceland have all conducted whaling operations that breach the provisions of the Whaling Convention. Yet sanctions, or the threat of sanctions, have not prevented these activities. Nor have sanctions ensured that Japan, Iceland and Norway comply with the reporting requirements of the Convention.

Clearly if a country is resolved to breach the terms and conditions of an agreement there is little that can be done to stop it. Agreements with enforcement mechanisms, however, tend to increase the general level of compliance. As Lyster (1985, p. 301) states:

> The treaties which have achieved the greatest level of compliance are, by and large, those which keep their Parties active, have a central administrative body to oversee enforcement and have some means of chastising Parties which do not comply with their treaty obligations.

E5 Conclusions

While the international agreements reviewed each have their own distinguishing features, it would appear that a number of lessons of general applicability can be drawn:

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

- The strength of commitment of individual countries to participate in international action then depends on the extent to which they perceive net costs or benefits to themselves from such an 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 that 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 important factors in this regard are establishing that a problem exists and bargaining over the distribution of the costs and benefits associated with remedial action.
- Finally, economic instruments such as taxes and tradeable permits are rarely used despite offering, in principle, an efficient means of reducing and redistributing costs.

References

Environmental Policy and Law 1988, 'IUCN General Assembly : Resolutions', *Environmental Policy and Law*, vol. 18, no. 3, pp. 92-98.

Environmental Policy and Law 1990a, 'Montreal Protocol: Phase-Out of CFCs Achieved', *Environmental Policy and Law*, vol. 20, nos. 4/5, pp. 134-135.

Environmental Policy and Law 1990b, 'Antarctica: How to Protect?', *Environmental Policy and Law*, vol. 20, no. 6, pp. 204-205.

Long, O. 1987, *Law and its Limitations in the GATT Multilateral Trade System*, Graham & Trotman/Martinus Nijhoff, London.

Lyster, S. 1985, *International Wildlife Law*, Grotius Publications, Cambridge.

Morrisette, P., Darmstadter, J., Plantinga, A. and Toman, A. 1990, *Lessons From Other International Agreements for a Global CO_2 Accord*, Resources for the Future, Washington DC.

Rengger, N. J. (ed.) 1990, *Treaties and Alliances of the World*, Longman, Harlow.

Rosencranz, A. and Scott, A. 1990, 'Bringing the Developing World on Board', *Environmental Policy and Law*, vol. 20, no. 6.

UNEP 1989, *Action on Ozone,* United Nations Environment Programme, Nairobi Kenya.

United Nations Convention on the Law of the Sea 1983, in *The Law of the Sea,* United Nations, New York, pp. 1-186.

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F1 Introduction and outline

Purpose of case studies

Many participants from various industries and community groups suggested numerous different ways in which emissions from particular activities could be reduced. Several published studies have also sought to identify the activities which cause emissions, to quantify the extent of those emissions and propose ways of reducing them.

Case studies can serve three purposes:

- they can identify reductions in emissions that might occur through evolutionary change, eg through technological innovations and their adoption over time;
- they can identify factors that might influence the rate of innovation and adoption. Some of these factors may be open to the influence of governments while others may not; and
- if sufficient reductions in emissions are not induced over time or encouraged by general policy measures, case studies may identify areas where the intervention of governments may be justified.

In its discussion of ways to reduce the emission of greenhouse gases, the Commission has expressed a preference for economy-wide measures such as taxes and tradeable permits which seek to reflect environmental costs in prices. In general, it would be expected that such economy-wide measures would be more efficient at bringing about emissions reductions required of Australia than a series of particular policies for particular industries or sectors.

The important point is that consideration of the appropriate government response must be set in a wider context of the efficiency and effectiveness of general measures, as well as industry or activity-specific measures.

Approach

Each case study uses available data to identify: the extent of greenhouse gas (GHG) emissions; what reductions are technically possible; the costs and benefits of reductions measures; and whether market imperfections, institutional impediments or consumer behaviour inhibits adoption of the measures.

The studies draw heavily on information and views contained in participants' submissions. The Commission has also drawn on published studies, particularly for data and for identifying obstacles and impediments to reductions in emissions. There have been numerous studies in recent years and many have much in common in the manner in which they have approached the issue. However, in many instances estimates made of the potential reductions in emissions and their cost effectiveness vary markedly. For example, some commentators such as Greene (1991) claim very large reductions are feasible while others such as the Business Council of Australia (1991) are less convinced.

The studies do not include assessments of the appropriateness or impact of general measures, such as a carbon tax, which may have an important economy-wide role to play in reducing emissions, and which may have an important impact in particular industries and sectors. For example, a carbon tax could be expected to considerably reduce the reliance on coal for electricity generation. Rather the studies concentrate on the more particular measures.

Steps taken to reduce GHG emissions can have other environmental advantages such as reduction of smog and noise. The case studies concentrate on the GHG implications of proposed measures and do not deal in detail with such other environmental externalities.

Some findings

The case studies cover a wide range of activities in which measures could be taken to reduce GHG emissions. The studies do not attempt to fully investigate every possible reduction measure in every activity. Rather they outline the possibilities in several areas. Although drawing general conclusions is difficult because of the diversity of the activities, some observations can be made.

The extent of reductions which are technically possible is large for some activities; for example, in the generation and distribution of energy (on the supply side), and in the use of energy in households and in the fuel efficiency of cars (on the demand side). In other cases, such as a shift in urban transport from cars to public transport, the potential reductions appear to be considerably less.

The ease with which potential reductions can be realised also differs between activities. Removal of institutional barriers facilitates emissions reductions and also brings other benefits to the community. Examples of such barriers are restrictions on the interstate movement of natural gas and the lack of integration of State railway systems. But the achievement of some other reductions would require changes in lifestyles or patterns of behaviour. This is particularly so in the residential sector and in transport modes. These changes are not easy to achieve without some significant change in incentives or costs facing individuals.

In many cases the existence of a stock of capital equipment with a long life makes it difficult to introduce changes quickly to reduce emissions. The funds borrowed to purchase existing capital equipment still have to be repaid. Further, it could be uneconomic to discard such assets before their useful life has expired. This capital equipment ranges from fossil fuel fired power stations to cars and houses.

The information provided by participants on the cost of change was often limited, but in several cases the cost of the environmentally friendly alternative is currently prohibitive: for example, the widespread replacement of conventional electricity generation with solar and/or wind power. In others the reductions could be achieved at a cost, but other issues such as equity would have to be considered. For example, compulsory minimum efficiency standards for homes and domestic appliances could discriminate against the less well off. In some cases, such as iron and steel smelting, the relatively easy reductions have been made, or are planned, and further reductions will be hard won.

A number of themes run through several of the case studies. There is a need for the reform of energy generation and distribution to provide opportunities at present denied natural gas and other alternatives to conventional coal fired electricity. Reform of the transport sector is required to enable railways and motor vehicles to compete without the distortions there are at present in the freight and commuter markets. In some cases there have been information gaps due to consumers' limited knowledge of energy efficiency, such as about houses and domestic appliances. A move to overcome this has been the provision of mandatory efficiency labelling of electrical appliances in several States. There are also areas in which the Government has traditionally provided research funds because of a perceived inadequacy of research effort.

F1.1 Barriers to efficient energy production and use

Some participants made proposals to overcome what were seen as barriers to the more efficient supply and use of energy. The general proposition is that quite apart from action taken directly to reduce greenhouse gas emissions, correcting any existing market failures associated with the production and use of energy would bring about a substantial reduction in greenhouse gas emissions. Many proposals related to energy conservation measures.

The following sections examine the most common barriers identified in terms of whether they constitute market failures. The barriers examined are: underpricing of energy; required rate of return on investments; access to information; distortion of incentives; and bias in the capital market.

Underpricing of energy

Some inquiry participants considered that electricity is underpriced and as a consequence there is a bias against investment in alternate technologies for the production of electricity and a disincentive for consumers to make energy-saving investments. Section F2 of this appendix reports on the evidence the Commission received. In summary, electricity authority pricing policies were seen to discriminate against the further extension of solar technologies into remote areas, and to encourage the inefficient use of energy. The ability to charge prices which did not reflect the full cost of production was attributed to the capacity to operate at low rates of return on capital, and to the availability of tax concessions and incentives for exploration.

The Commission's 1991 report on ‘Energy Generation and Distribution’ provides details of the current distortions in the pricing of electricity. That report recommended, among other things, the restructuring of electricity pricing so that charges to users more accurately reflect supply costs, and that supply utilities be required to operate on a more commercial basis. The net outcome of such reforms was expected to be a decline, rather than an increase, in the average price of electricity although the removal of cross-subsidies to consumers would eliminate discrimination against alternative technologies in rural areas. In the short term the residential sector (and some industrial users) would pay more. Requiring utilities to operate at normal rates of return on capital would increase prices, although given overcapacity now, the value of the capital stock on which that return is required in future would be smaller, tending to reduce energy prices. Longer term production efficiencies were another factor expected to decrease prices.

Environmental impacts of energy production

Energy will be underpriced if the value of environmental damage caused by burning fossil fuels is not accounted for in production costs. Several participants quoted from a study for Western Australia which nominated mining, emission of carbon dioxide, nitrous oxide and sulphur dioxide, and resource depletion as sources of externalities caused by generating power from fossil fuels. That paper quoted a wide range of values for external costs from studies done for Europe and the United States, but cautioned that there is a high degree of uncertainty about actual external costs in any particular circumstance. It noted that there are some important differences between the countries the studies relate to and Western Australia. Thus, while the externalities of burning fossil fuel may be present in Australia, the extent is not currently known.

It is also relevant to note that for some time in Australia Governments have been aware of the environmental impacts of energy production and have already taken steps to address them. The draft Energy Production report of the Ecologically Sustainable Development (ESD) Working Groups reported that:

> Production from refineries and power stations is regulated by state/territory environmental authorities through licences which set maximum allowable rates of emissions. Licence conditions usually set maximum concentrations for selected emissions and may also require that emissions do not lead to ambient air quality objectives being exceeded. Where adopted ambient air quality objectives are based on national Australian guidelines developed by the AEC (now ANZEC) and the NH&MRC or, in some cases, on other standards such as those prepared by overseas environmental protection bodies. (ESD, 1991, p. 27)[1]

1 A comprehensive record of Australia’s current environmental emission standards and environmental impact control mechanisms in the energy production sector is contained in Appendix 2 (pp 129-34) of that draft report.

The working group also said that Australian operators often perform well within prescribed standards (p. 28). In complying with these standards and control measures, energy producers already pay to prevent environmental damage from the burning of fossil fuels. The relevant consideration in these circumstances is thus whether the standards they are required to meet are adequate to meet all externalities. On this point the ESD Energy Production Working Group reported:

> While we are unable to determine with certainty whether these mechanisms are effective in minimising community risks, Australia so far does not appear to suffer, to the same extent, the environmental impacts from energy production and use activities experienced in other major industrialised countries. (ESD, 1991, p. xxvii)

But, again, conclusive evidence on the adequacy of current measures specific to energy production is not available.

If greenhouse gas emissions are identified as an externality to be addressed by global action, one approach would be to tax those emissions generally. In that event, an additional environmental tax would be imposed on energy production and the price of energy (and most other things) would increase. The Commission's estimates of price increases for certain emission reductions are reported in Chapters 5, 8 and 9 of this report.

Required rate of return on investments

One reason often cited for the apparent reluctance of consumers to make energy saving investments is that they are said to require a higher rate of return for energy-efficient investments than for other investment opportunities. Another way of expressing this proposition is that consumers place a high discount rate on the future benefits, in terms of energy savings, and the future capital value of such investments.

It is well-documented that consumers require lower returns on government bonds or commercial bank bills compared with energy efficient and many other investments. There is also ample evidence that the required rate of return for such investments varies between the industrial, commercial, and residential sectors, and even within sectors a wide range of discount rates, according to the precise nature of the energy efficient investment, have been reported (see for example Williams et al. 1983, pp. 284-6).

Do these differences in required rates of return constitute evidence of market failure? To answer this question first requires an outline of the factors which underlie any investment decision and which determine whether any particular investment opportunity will be taken. The main factors are:

- the risk of the investment -- secure investments (such as government guaranteed bonds) require lower rates of return than speculative investments (such as unproven products and technologies) which will require larger returns;

- the liquidity of an investment -- investors are likely to require a higher rate of return if their capital is locked in for long periods and cannot be readily converted to cash;
- transactions costs -- higher returns are likely to be required to compensate investors for high costs of gathering the information necessary to make a decision; and
- the timing of returns -- investors may want the cost of their investment fully recouped relatively quickly, which means higher (early) returns will be required for the investment to be undertaken.

Application to energy saving investments

One of the uncertainties associated with an energy saving investment is whether the expected energy savings will be delivered (the annual return). A reason this may not occur is that performance of the equipment -- whether it be industrial machinery, thermal insulation, or a domestic appliance -- is difficult to determine prior to installation. For example, claims made for thermal insulation could refer to ideal conditions or to the average savings in a typical building. In either case, the savings realised in an individual application might not match pre-investment expectations. Another reason predicted energy savings may not be realised is that energy prices may change. This will affect returns in all activities which use energy but is particularly important when an investment is made on the basis of a potential reduction in energy costs based on a particular form of energy; for instance, if a gas water heater is chosen in preference to an electric one.

In common with investment in any new technology, there is always the possibility that a new energy saving product will fail, that the technology will rapidly become obsolete, or that it will become available at a much reduced price. Consider energy efficient light globes for example. No matter how persuasive the advertising literature, consumers may be sceptical about the claims of longer life in relation to conventional globes, may prefer a more aesthetically pleasing globe and believe that it is just around the corner, or may delay their purchases in the expectation that prices will plummet, as they have done for some other new products after they had widespread market acceptance.

Transactions costs can be high when making an energy-saving investment. Information is not as readily available as for stocks and bonds for example, and for resale, the transaction cost of finding a buyer and settling on a price can be high for energy-conserving products, especially if they are an integral part of a building such as an air-conditioning system or wall insulation.

From the above discussion it would seem to be a rational decision for a consumer investing in energy efficiency to require a higher rate of return than for some other investment opportunities. This notion is supported by Sutherland (1991) who uses a conventional capital asset pricing investment model to show that investments in energy efficiency are made with the same decision rules as any other investments. The issue then is whether the requirement for a high rate of return constitutes a market failure. In this context it is relevant to note that perceived high risk, low liquidity and high transaction costs are not peculiar to investments in energy efficiency. Many investment opportunities will have these characteristics to a greater or lesser degree and the rate of return required will vary accordingly. Consequently a high discount rate on its own does not provide evidence of market failure. But it is possible that perceptions of risk are based on inadequate information, and it may be that a market failure exists with respect to access to information. This possibility is taken up in the following section.

Access to information

Information needs to be assembled if a householder is to make a fully informed choice about whether or not to undertake an energy-efficient investment. In the case of thermal insulation for example at the most basic level the purchase price, installation costs, and thermal properties of the alternatives available will need to be known. To calculate the potential energy savings from the investment, information on how the insulation will perform in the house for which it is being considered is required, and performance will vary according to the characteristics of the house and the lifestyle of the householder. Energy savings will be less for an open-plan house with large conventional windows than for one in which windows are double glazed and areas not in use from time to time can be closed off. The savings in a household which is unoccupied, and not heated, for most of the day will be less than for a household which requires a constant comfortable temperature.

A fully informed decision therefore has a substantial information load. Consumers obviously have to make decisions with less than perfect information in most cases. Areas in which information may be improved to help decision making are:

- the energy-saving and energy-using potential of individual products;
- the performance of those products in practice; and
- the circumstances of particular locales that will affect energy use.

Information on the energy-saving and energy-using potential of individual products varies in its detail and usefulness. The rating on home insulation products facilitates comparisons between alternative products but provides no guide to the purchaser about its thermal properties apart from the higher the 'R' rating the better. An appliance may be labelled as having a 750 watt motor, but for the householder to calculate energy savings from its purchase, information on its expected life and running costs is required. Few consumers could compare the energy efficiency of an electric appliance with its gas counterpart on the basis of information supplied with the products, but there is evidence that for major energy-using appliances consumers are aware of the difference in running costs (see section below on ‘distortion of incentives’).

Rheem advised the Commission that:

> ... anecdotal and fairly strong evidence indicates that energy labelling is too difficult for the consumer to understand and that the awarding of stars is perceived more as a statement of quality (rather like the value for money concepts of the NRMA star rating for hotels and motels), rather than a statement of energy efficiency. (Sub D102, p. 5)

Although product information may not fully inform consumers, the relevant question is whether the benefit they may gain from additional, albeit limited, information outweighs the cost of providing that information. It is often suggested that mandatory labelling would assist consumers to make more rational choices when purchasing major appliances, but there are existing State regulations for the labelling of certain appliances and it is an open question as to whether more information on labels would provide a net benefit to consumers.

Information on the actual performance of products is to some extent available through information provided by energy authorities, consumer organisations and research bodies. Such information usually refers to typical or average conditions.

The problem is that the information provided is necessarily general and cannot give consumers an accurate guide as to what savings can be expected. For that, detailed knowledge of each household's individual circumstances is required. According to Gates (1983):

> Research studies have shown wide variation between energy savings using identical conservation measures on different homes. Homes are complex energy-using structures and there is much the technical experts do not know about how homes use energy. Undetected infiltration, thermal bridges, poor quality installation, and lifestyles all affect energy use sufficient for it to be difficult to accurately predict energy savings for any one measure in a particular home.

If the savings from energy efficient investments are substantial, and the reason such investments are not made is because consumers are poorly informed, there would seem to be scope for the formation of a market in the provision of such information, or if it has public good features, for information to be supplied by governments. Such markets do exist in the commercial sector for the construction of new buildings and for the operation of industrial processes for example.

In the case of construction, consultants are often engaged at the design stage of the project to provide advice on energy efficiency, and for industrial processes energy audits are undertaken for the purpose of reducing energy consumption. The market in information for a consumer contemplating the purchase of a major appliance or the replacement of light globes is much more limited, presumably because the cost of supply exceeds the amount consumers are prepared to pay for such information.

Lack of information is not confined to energy efficiency, as many consumption decisions are characterised by imperfect information. In terms of market failure, a relevant consideration is whether there is some externality which prevents the socially optimum level of information being made available. If so there is a case for its public provision as long as the cost of supply does not exceed the benefits and other more efficient means of encouraging energy conservation have been exhausted. Certain information would then have the features of a public good in that it could be used by the consumer at zero marginal cost to the producer and without reducing its availability to other consumers.

Another consideration is whether greenhouse constitutes a special case, and this may be so if it is ultimately decided that large reductions in emissions are required within a time frame too short for a normal market response to price signals to be effective.

One hypothesis which supports the notion that information on energy efficiency should be provided as a public good, argues that mandatory labelling of appliances for example provides information at lower cost than does private markets, and that such labelling would make consumers more aware of the benefits of energy efficiency. As a consequence, producers will seek to exploit that energy awareness by manufacturing more energy-efficient appliances and advertising them as such. Similarly the application of energy ratings to new homes would provide incentives for more energy-efficient investment decisions.

In the past, governments at all levels have implicitly given some information on energy efficiency the status of a public good. Appliance labelling has been made mandatory and there have been many programs designed to encourage energy conservation and the purchase of energy efficient products. The Commission was told of the Victorian Government's plan to extend an existing appliance labelling scheme to include all major energy using appliances in the residential sector (sub. 74). Estimates of the net benefits of the existing or extended scheme are not available.

In the United States there is a wealth of experience with energy conservation programs introduced since the early 1970s. The results of such programs have been extensively reviewed and could best be described as mixed.[2] They suggest that while conservation programs may be useful, they cannot be considered as a panacea.

Greater energy efficiency could also be encouraged through the price mechanism. As previously stated, if prices reflect all costs, including environmental damage, consumers would be provided with the signals to take appropriate energy conservation action.

2 Clinton et al. (1986) reviewed a wide range of united States government and utility energy conservation programs and reported that studies of information programs generally conclude that they had a small direct impact on energy conservation. Walker et al. (1985) reviewed a major federal program aimed at the residential sector and concluded that it had not made a significant contribution to energy conservation and cited a Department of Energy review which said that the program was not cost effective.

Distortion of incentives

Worthwhile energy savings may be overlooked if decision makers are faced with incentives that point them towards other choices. For example, it is argued that a builder has little incentive to incorporate energy-efficient features in a new home. His primary motivation is said to be to minimise the capital cost of a construction rather than subsequent running costs. The BCA told the Commission that:

> ... the consumer often has little opportunity to influence the choice of water heating appliance. Water heaters for new homes are chosen, usually on a least-cost basis, by builders and developers ... (Sub. 91 p. 14)

It is argued that low cost, rather than energy-efficient equipment is chosen and that if the eventual purchaser were able to make decisions as to the type of equipment to use, more energy-efficient features would be incorporated. The heart of the argument thus lies in the separation of decision making between producer and consumer, and the producer not taking account of consumer preferences.

However, there is evidence that builders do take energy costs into account when making production decisions. Although their capital cost is low, very few oil heaters are now installed in new homes. There is also evidence that consumers are not indifferent to the fuel efficiency of appliances installed in new homes and that builders respond accordingly. The Australian Gas Association (AGA) provided the data in Table F1 on major gas appliance ownership as a proportion of households in areas which had reticulated gas supply in 1985-86. The table shows an Australian penetration rate at that time of 80 per cent for cooking appliances, and lower rates for hot water and heating (66 and 63 per cent respectively). The AGA quoted from a Gas and Fuel Corporation of Victoria document which said that in the new homes market, gas appliances were continuing to dominate with an average of 2.6 units out of every 3 possible end uses going into new homes, with gas hot water penetration rates reaching over 90 per cent in recent years (sub. 73 p.30).

Table F1: **Gas appliance ownership as a proportion of households with gas supply, 1985-86**

State	*Cooking*	*Heating*	*Hot water*
NSW/ACT	85	37	55
Vic.	76	86	67
Qld	88	0	54
SA	86	54	82
WA	80	46	74
Australia	80	63	66

Source: AGA, Sub. 73, p. 20.

Evidence shows that where consumers have the relevant information the market does respond to the relative prices of different forms of energy (running costs). This is illustrated by the Gas and Fuel Corporation of Victoria's expectation that, following an intensive campaign conducted by the competing utilities, new off-peak electric tariffs will challenge the dominance of gas in new home installations. For the new home water heating market they said:

> ... given the emphasis placed on this market by the SECV and with access to the full benefits of the TOU tariff tied to the installation of an off-peak electric water heater, the gas share is expected to decline significantly to 72% by 1994-95 (Sub. 73, p. 30).

If builders do not incorporate energy-efficient features in new homes it is possible that they either misjudge consumer preferences or that consumers would in fact have made the same choices. The latter may be the case in light of the earlier discussion on required rates of return and, if so, the failure of builders to incorporate available energy-saving equipment in new homes would not constitute a market failure.

A variation on this same theme is known as the landlord/tenant problem. The hypothesis is that neither landlords nor tenants have an incentive to purchase energy-efficient products. For residential buildings, installation by the tenant is not undertaken because there is no tenure in the property, and the landlord is said to have no incentive because the benefit from an energy-saving investment accrues to the tenant. But the same considerations apply to the provision of other improvements, for example the construction of a carport.

To the extent that the landlord/tenant relationship is a barrier to investment in energy efficiency it can be shown to be a short term phenomenon. The reluctance of tenants to make capital investments in property they do not own does not constitute a market failure. If tenants are concerned about energy efficiency there is always the option to move to a different residence.

For landlords seeking new tenants, presumably a higher rental could be charged for dwellings with energy-efficient features in much the same way as it could for other desirable characteristics such as a carport. If a higher rental could not be obtained, that would reflect potential tenants' valuation of the energy-efficient features, and any argument that this represents a market failure relies on an artificial set of preferences being imposed on tenants. In the case of existing tenants, a revised rental agreement would need to be negotiated for the landlord to gain any short term benefit from the investment and, since this could incur significant transaction costs, the investment may be delayed until the expiration of the existing agreement.

Bias in capital markets

Another question that arises is whether capital markets are biased against energy-efficient investments through differential interest rates and access to capital between suppliers and consumers of energy. It is observed that utilities are able to finance their expenditure on capital stock at less than half the rates many consumers are required to pay when purchasing energy-efficient appliances. Typically utilities borrow from the public at less than ten per cent whereas consumer credit-card rates are currently in excess of twenty per cent. This interest rate differential is seen to bias the community's investment decisions in favour of energy generation and against energy conservation. In order to redress this perceived bias it is advocated that utilities should finance the provision of energy conservation equipment to consumers at interest rates similar to those faced by utilities on their borrowings. See for example the submissions of the Australian Conservation Foundation (sub. 137), and the Centre for the Environment and Sustainable Development (sub. 29). Such proposals raise a number of issues.

The interest rate differential

The most fundamental consideration is whether the perceived bias in the capital market is caused by interest rates faced by utilities being too low, or by rates faced by consumers for energy-efficient investments being too high.

At present utilities may be able to borrow at favourable rates because their borrowings have the status of semi-government securities and their monopoly position enables them to set prices so as to ensure that interest payment commitments are honoured. In effect, they are able to offer a very low risk investment opportunity to the public. However the interest rate margin which could be attributed to their government endowed position is likely to be one or two percentage points at the maximum. A comparison of rates offered on 5-year finance company debentures with rates offered on 5-year Commonwealth Government bonds between 1979-80 and 1989-90 shows an average spread of 0.64 percentage points, with a maximum spread for any single year of 1.65 percentage points (RBA 1991). In the event that utilities are advantaged to this extent in borrowing funds, it is not a market failure so much as government intervention distorting the efficient functioning of the capital market, and the appropriate response would be to directly address that distortion. In its recent `Energy Generation and Distribution' (1991a) report the Commission argued that public utilities should be corporatised, and access to concessional finance removed, thereby eliminating any unfair advantages they posses over private sector suppliers of energy services.

In the case of rates faced by consumers on their borrowings for energy-efficient investments it should be noted that there is no observed direct discrimination against such investments. If the energy-saving expense is made at the time of construction, or is included in the purchase price of a dwelling, the interest rate which applies to the bricks and mortar also applies to the wall and ceiling insulation. There is no interest rate discrimination between borrowings to install gas and electric hot water services, and neither is there discrimination on the credit-card account between electric blankets and flannelette sheets.

Utilities financing energy-efficient expenditure

Previous sections have outlined how energy supply utilities should, and could, be required to operate on a more commercial basis. This would require them to fully recognise the costs of supply, and to reflect those costs in their pricing practices. Included in such costs would be a commercial rate of return on the capital they employ and the value of environmental damage caused by the production of energy.

Exposure to these requirements would make it more difficult than it has been in the past for utilities to finance new capital expenditure for the purpose of servicing growing demands for energy, and would encourage them to consider alternative ways of satisfying energy consumers' demands. The options available include demand-side management programs under which consumers are encouraged to alter the time at which energy is used (load management) or to use less energy (energy conservation).

The most common load management instruments used by utilities are off-peak hot water tariffs, and for some large volume customers, time of use tariffs and interuptible supply contracts. The adoption of these pricing practices reduces system costs by shifting pressure from peak load demand.

For energy conservation, utilities provide energy-conservation advisory services and participate in implementing various energy-conservation goals. In Victoria for example, the State Electricity Commission of Victoria (SECV) will spend $5 million over 3 years on demand-side management programs.

Several participants in this inquiry suggested that a cost-effective option for utilities to encourage energy conservation would be for them to be providers and financiers of items such as energy-efficient appliances to households. The Centre for the Environment and Sustainable Development said that:

> A free market in hot water would be created by either requiring an up front contribution to the capital and maintenance costs of the power station/pipeline or by having an energy utility organise the purchase, installation and maintenance of the solar collector and recovering the costs through quarterly bills. (Sub. 29, p. 6)

The proposal is sometimes put in terms of the community investing in energy efficiency. The relevant consideration here is whether the utility would be able to supply and finance the equipment under conditions better than are available from conventional sources. In a sense the utility would be acting as a financial intermediary, borrowing from one section of the public and lending to another. For the borrowing transaction the utility would have to compete with other financial intermediaries (banks, credit unions etc.) for funds, and provided that capital market distortions discussed in the previous section were removed, there does not seem to be a reason for utilities to be able to borrow funds on better conditions than other financial institutions.

Utilities have a choice as to whether to invest borrowed funds in extra generating capacity or to invest in energy-efficient appliances for supply to households. Associated with each of these options is a different level of risk, cash flow, and transaction cost.

As lenders to energy consumers, utilities would be in a similar position to other lending institutions in terms of the liquidity of their investment and the transactions costs they face. Whether utilities' interest rates would be similar to those charged by conventional financiers of household improvements and appliances is an open question which could only be resolved if the utilities decided that it was in their commercial interest to operate as financial intermediaries for this purpose in the market place.

They are unlikely to be less risk averse than banks, and since the set of borrowers under consideration is the same for utilities and other potential lenders, utilities could be expected to face the same risk of default on loan repayments as other lending institutions. Energy distributors who require a security deposit ($120 for supply from Sydney Electricity for example) already demonstrate an aversion to the risk of default on payment for energy supply.

In light of the above discussion it would seem that if utilities are to be required to make a commercial rate of return on their activities, the interest rate at which they could finance the provision of appliances to consumers would be higher than the rates at which they would be able to borrow from the public. The terms under which appliances were supplied would need to ensure that utilities' return on investment in energy efficiency was at least as high as the return which could be achieved by investing in new generating capacity.

Access to capital

A related reason given for utilities to finance energy-efficient investments is that some consumers, even though they have a desire to install energy-saving measures, are unable to borrow the finance to do so. If that is the case, they would be similarly restricted in their ability to finance any cost-effective investment requiring similar funds, either because they cannot raise the initial deposit or do not have an income sufficiently high to meet the necessary repayments. However this problem is essentially about welfare and the distribution of wealth, but is sometimes confused with capital market performance. It is not unique to energy-saving investments and does not represent a distortion or failure of the capital market.

Choosing between investment opportunities

A firm evaluating a range of investment opportunities invariably is required to make a choice between a number of options which have been shown to be cost-effective. One of the many reasons some projects will not be undertaken is that access to finance is limited. The firm must make a choice as to how a scarce resource (access to finance) is allocated, and sometimes that will mean that energy-efficient investments are not made. In theory, firms would apply a cost-benefit rule and invest first where returns are greatest.

Similar considerations apply to the household. When access to finance is limited, a choice must be made as to how available finance will be used, if at all. Many will choose not to incur a debt for any consumer durable purchase, while others who already have sufficient accumulated savings will choose to leave their investment in a savings account rather than to convert it into an energy-efficient appliance. Again, a cost-benefit rule would apply.

Summing up

This brief review of potential barriers to greater use of energy-efficient techniques, while not comprehensive, would suggest that some of the apparent barriers may not be due to market failure. In other areas, however -- including access to information by households and institutional arrangements in the energy and transport sectors -- there is more scope for taking `no regrets' action.

It could be the case that some of the proponents of imposing energy efficiency through regulation are not primarily concerned with market failure, rather they are focusing on wider objectives. If this is the case, their proposals are not `no regrets' policies, in the sense of involving negligible costs.

The case studies which follow seek to provide a more detailed examination of a range of potential means of improving energy efficiency.

F2 Renewable energy for electricity generation

Electricity generation in Australia at present is predominantly based on burning fossil fuels. An alternative would be to rely more on renewable energy technologies which use natural phenomena to provide a virtually inexhaustible supply of energy. The fuel for these technologies costs little or nothing. Generation of electricity from renewable energy would avoid emissions of GHGs, although as with non-renewable technologies, energy must be expended in the initial construction of capital equipment. A wide range of technologies fall into the renewable category. However, apart from hydro, their contribution to Australia's electricity requirements is low at present. No contribution is made by nuclear technology, which is not discussed in this section.

Several participants, including Greenpeace Australia, the Australian Conservation Foundation and the Australia New Zealand Solar Energy Society, advocated greater use of renewable technologies as a means of meeting Australia's energy requirements. A few participants, including the Chamber of Mines, Metals and Extractive Industries (NSW) and the Australian Coal Association, said there are limitations on the contribution that renewables could make. The Chamber of Mines and Energy of WA, Shell Company of Australia and other participants pointed to the relatively high cost of renewable energy technology.

F2.1 Carbon dioxide emissions

Most of the emissions associated with electricity generation are the result of using coal as fuel (see Table F2). Emissions from renewable sources are insignificant. The supply of electricity is responsible for over 40 per cent of Australia's carbon dioxide emissions and at least 20 per cent of Australia's total GHG emissions.

Table F2: **Total emissions of carbon associated with electricity generation: 1986-87**

Fuel type	*Emissions of carbon*	*Proportion of total*
	MtC	*%*
Black coal	18.02	59
Brown coal	10.12	33
Natural gas	1.94	6
Oil	0.56	2
Total	30.63	100

Does not cover cogeneration. MtC = mega tonnes of carbon.
Source: Based on information in Walker (1990).

Natural gas is used to a limited extent at present in Australia for electricity generation accounting for around 9 per cent of fuel (IC 1991a, Vol. 2, p. 12). Its use for this purpose is expected to grow in future years. Although this will reduce carbon dioxide emissions from those levels associated with coal, significant volumes of carbon dioxide will continue to be emitted. A major reduction in GHG emissions could be achieved by a significant swing to renewable energy.

The use of renewable technologies, other than hydro, for electricity generation in Australia is currently very small. About 11 per cent of electricity is generated from hydro (IC 1991a, Vol. 2, p. 12). Solar is often used as a direct source of energy and is the most widely used of the other renewables, but this technology probably accounts for less than 1 per cent of total energy consumption in Australia.

A study by Walker (1990) into the technical potential to reduce GHG emissions from electricity generation over the next 15 years found that there are possible savings through increased use of hydro. Planned additions to existing capacity, together with small scale hydro, could reduce carbon dioxide emissions by an estimated 1 mtC annually. Walker considered that other renewable technologies are not likely to make a major contribution to Australia's electricity generation in the next 15 years. Similarly, a Business Council of Australia study concluded that renewable technologies, excluding hydro, are expected to contribute no more than 1 per cent of national electricity generation requirements by 2005. These forecasts did not assume significant government intervention to meet reduction targets.

ABARE has carried out preliminary work using the MENSA model to determine the least-cost combination of fuels which will need to be used in electricity generation if emission reduction goals are to be achieved. The simulation indicated that, in the absence of nuclear power, the role played by renewable technologies will have to increase substantially if the 2005 target is to be met.

F2.2 Forms of renewable energy and their costs and benefits

In this section the various types of renewable technologies are outlined together with information on their costs and benefits. Some of the data is indicative, as most are new technologies that have not been used commercially in large-scale operations in Australia. The major benefit they all have in common is that, as discussed previously, GHG emissions resulting from their adoption and use are negligible.

Hydro

Hydro differs from most other forms of renewable electricity generation in that it is not a new technology. While most renewables are in their relative infancy, much of the hydro-electric potential in some States has already been developed. The further contribution this technology can make to electricity generation is limited by the relatively low rainfall in much of Australia. Moreover, where suitable sites remain, environmental considerations often place constraints on decision makers. For example, the Tully-Millstream project in Queensland would necessitate wilderness being flooded and the area has been placed on the World Heritage List. However, small-scale hydro developments were said by the Ecologically Sustainable Development Working Group on Energy Production (1991) to be a GHG reduction option which could be implemented relatively quickly -- and which may already be economic -- although with varying degrees of environmental sensitivity.

The Electricity Commission of NSW said that conventional hydro-electricity does not have the very high capital costs which other renewable technologies tend to have at present. The Snowy Mountains Hydr-Electric Authority said that hydro-electric power is not only cheap (2.6 c/kWh in 1990-91 from its Scheme) but also virtually non-polluting and based on proven technology developed over 100 years. The Tasmanian Government said that Tasmania is coming close to the limit of currently available hydro-electric energy and consideration is being given to gas as a future energy generation option. The study by Walker (1990) found that, although Australia's hydro-electric resources have been largely developed, by 2004-5 planned additions to existing capacity are expected to supply an additional 9.3 PJ of electricity annually and small-scale hydro has the potential to supply a further 4.5 PJ (representing an increase of around a quarter in hydro's contribution).

Tidal and wave

Tidal and wave power can also generate electricity. Tidal energy involves trapping tidal water and using its release as the tide recedes to power a hydroelectric generator. There are large tides in the remote Kimberly region of WA which may have long run potential but this technology is generally not considered to be a viable alternative in Australia in the foreseeable future.

Table F3: **Indicative comparison of alternatives for generating 10 000 GWh/yr**

Generation technology	*Capacity*	*Capital cost*	*Operating cost*	*Total cost*	*Total cost*	*CO_2 production*
	MW	*$ billion*	*$ billion*	*$ billion*	*c/kWh*	*t/GWh*
Conventional coal	1600	1.8 - 2.0	1.8 - 2.0	3.6 - 4.0	3.4 - 3.8	900
Combined cycle	1600	1.2 - 1.3	2.9 - 3.3	4.1 - 4.6	3.9 - 4.3	450
* Pressurised fluidised bed	1600	2.8 - 3.0	1.7 - 1.9	4.5 - 4.9	4.3 - 4.6	750
* Integrated gasification combined cycle	1600	3.4 - 3.7	1.7 - 1.9	5.1 - 5.6	4.8 - 5.3	750
* Nuclear power	1600	7.0 - 8.4	3.4 - 3.8	10.4 - 12.2	9.8 - 11.5	negligible
* Wind power	3800 - 4500	5.3 - 7.2	1.2 - 1.4	6.5 - 8.6	6.1 - 8.1 -	
* Wave	3700 - 4300	11.1 - 15.1	1.3 - 1.8	12.4 - 16.9	11.7 - 16.0	-
* Solar thermal	4300 - 4800	17.2 - 23.0	3.9 - 4.5	21.1 - 27.5	19.9 - 26.0	-
* Solar photovoltaic	4100 - 4600	45.1 - 55.2	2.4 - 3.0	47.5 - 58.2	44.8 - 54.9	-

* The costs presented for these technologies are indicative only.
Costs are calculated as `Net Present Worth' over a 20 year life time and using a 7% discount rate 1990-91. Capacity factor of non-renewable - 70%. Capacity factor of renewable varies with location and available source.
Source: Electricity Commission of NSW (1991), p. A.1.

Wave energy is one of the more expensive technologies (see Table F3). According to the Electricity Commission of NSW (1991), wave energy is reduced significantly by the existence of the continental shelf along the coastline but suitably sited it may be beneficial to coastal communities remote from the electricity supply network. Walker and Stevens (1990) in their study concluded that wave energy technology did not appear likely to become competitive in the short to medium term.

Wind

Progress has been made in several countries, in particular Denmark and the United States, in the commercial use of windmills to power generators to produce electricity. The presently operational wind farms are often integrated into the local electricity transmission networks. In Australia there is a small wind farm of 360 kW operating in the isolated town of Esperance where it supplements diesel generators, and a 150kW wind turbine generator has been installed in Coober Pedy.

The variability of weather means that wind power has a low capacity factor (actual energy production compared to total energy production if operated continuously at full production). This constraint was emphasised by CRA Ltd, which stated that natural processes limit the amount of energy that can be produced by wind. Owing to its low capacity factor, wind power is much more likely to play a supplementary rather than a central role in electricity supply.

Wind farms have potential environmental problems including the amount of land required, visual impact and noise. Further, the cost of generating electricity in this manner has so far been an obstacle, as it has a relatively high capital cost. It can be seen from Table F3 that electricity generated from the wind on a large-scale is estimated to be about twice as costly as coal fired electricity.

Walker (1990) considered that wind is possibly the most promising (non-hydro) renewable energy technology for grid connected power supply to 2005. Similarly, the Business Council of Australia (1991) found wind power to be the most promising of the alternative renewable technologies for substantial future applications in suitable locations. Indeed, the study concluded that good prospects exist for the capital cost of wind generation to be reduced to $1000/kW from the present capital cost of $2500-$3000/kW through further technical improvements resulting in increased machine capacity and performance. Unisearch Ltd (1991) anticipated falls to below $US1000/kW by the late 1990s, and quoted a current cost of $2200/kW for a fully imported 10 MW windfarm.

However, a simulation by the BCA found that large-scale installation of wind power (approximately 9000 MW capacity) between 1991 and 2005 would cause a significant increase in the average cost of electricity generation in Australia, probably 15 per cent. This additional cost would have an adverse economic effect and it was considered that wind generation would be difficult to justify in terms of the comparatively small reduction it would make of 12 per cent in carbon dioxide emissions in 2005.

Nevertheless, at present it is the cheapest of the (non-hydro) renewable means of energy generation and there is the likelihood that the technology will continue to improve. Expectations are that costs will continue to fall -- Unisearch Ltd (1991) estimated that the fall could be from 6-8 c/kWh to around 5 c/kWh in 2005 for a 10-50 MW windfarm, with further reductions possible in later years.

Solar photovoltaics

Solar photovoltaic technology directly converts sunlight into electricity through the use of thin sheets of semiconductive material in solar cells. Little maintenance is required, as there are no moving parts and operational life is in excess of 20 years. Photovoltaics are the most widely used renewable energy technology in remote areas of Australia. It is used to offset the cost of diesel fuel for small communities and single dwellings not on the electricity grid, and provides the electricity for facilities such as water pumps and telephone systems. Telecom has about 10 000 sites powered by solar energy and while many of these are individual phones in remote areas its most important use is on repeaters on cross-country networks. The potential market for small-scale use of renewables in remote areas is large. More than 10 000 households and 300 communities throughout Australia generate their own electricity -- the majority currently use diesel generators.

There are problems in collecting and concentrating the heat of the sun to produce electricity, particularly for large-scale projects. A difficulty with photovoltaics is the relatively low energy conversion rate which contributes to its high capital cost. Most commercially available photovoltaic systems convert sunlight into electricity with an efficiency of only around 15 per cent. Improving this conversion efficiency is currently the subject of research.

Photovoltaics has problems of intermittent and unreliable supply which necessitates storage facilities and/or a backup electricity source. CRA Ltd stated that the intrinsic limitations on the amount of energy that can be produced by solar and the timing constraints are often overlooked, and that solar technologies would be essentially peak load sources.

The information in Table F3 indicates that photovoltaic technology at present has relatively high operating costs and particularly high capital costs. Consequently, the electricity it generates is estimated to cost more than 40 c/kWh in large-scale use, over 10 times as much as coal fired electricity. The Australian Conservation Foundation claimed that these costs are outdated. Kuhn (1991) referred to a `dramatic decline' in the cost of photovoltaics from around $150 per watt in 1974 to $10 per watt in 1985, and said the cost in early 1991 was about $6 per watt. Unisearch

(1991) said that at present photovoltaics costs $6_7 per peak watt, and the cost of this technology is 3 to 4 times too high for centralised generation of electricity, but that photovoltaic modules costs are projected to decline to $1.5 per peak watt around 2005.

Solar thermal

Solar thermal involves the use of solar collectors to gather energy to heat a fluid. This can be used directly, to provide hot water, or to power a generator. So far, the generating technology has only operated commercially on a large scale in California where it is used in conjunction with gas. There have been experimental projects in Australia at White Cliffs (NSW) and Meekatharra (WA). On a small scale, solar thermal is significant in the provision of hot water to individual households. About 6 per cent of Australian residences have a solar hot water heater and the local industry produces about 30 000 units annually.

The information in Table F3 indicates that the capital and operating costs of this technology when used on a large scale are presently high. The Australian Conservation Foundation and the Energy Research Centre claimed that this solar thermal information is outdated. The Energy Research Centre stated that the costs of solar thermal power have dropped by over 90 per cent in the last decade, and that the Australian solar thermal power systems being constructed at the ANU are conservatively projected to cost 5.5 to 6.5 c/kWh in 100 MW sizes (with 100 per cent gas backup or without gas backup in remote locations) which is well below the estimates of costs of solar thermal shown in Table F3. The Electricity Commission of NSW indicated that it has no information which shows that the information on solar technologies in Table F3, which it prepared, is not still current.

The Plastics Industry Association drew attention to the `high energy' materials used in solar energy collection and distribution quoting a study which showed that the energy used in the manufacture and installation of a solar collection system was as much as would be collected in four years operation of the system. Consequently, the Association claimed that, unless construction materials were subsequently completely recycled, there would not be a net energy gain for the initial four-year period. The Energy Research Centre responded to these statements by claiming that an ANU solar thermal system with a 20-year life will completely repay all the energy used in manufacture in 5 to 10 months.

The Senate Standing Committee on Industry, Science and Technology (1991) concluded that solar offers the greatest potential of the renewable technologies. It drew attention to developments in the field, particularly the photovoltaics cells project at the University of NSW and the solar steam project at the University of Sydney.

Heat to generate electricity can be obtained from specially constructed solar ponds which produce heat through high salinity. There is a solar pond power plant operating and connected to the electricity grid in Israel and there has been some experimental work conducted in Australia.

Landfill gas

It could be argued that landfill gas is not a renewable energy source in the same sense as the wind or sun as it is depleted through use. However, it is a more environmentally friendly means of generating electricity than burning fossil fuels.

Landfills and rubbish dumps produce gas when natural decomposition of waste takes place without air being present. This gas, which can be captured using drill holes, can be used to generate electricity. Not only does this have the potential to reduce the reliance on electricity from more conventional fossil fuel burning sources but it reduces seepage into the atmosphere of the gas which is typically 40 to 60 per cent methane. There have been small-scale projects using this technology, such as that at Northcote. This contributed 80 000 kWh of power to the Victorian electricity grid but has been discontinued. The South Australian Gas Company, working with a private company, recovers landfill gas from the Wingfield tip in Adelaide and research is continuing by bodies such as the State Energy Commission of WA.

Geothermal

Geothermal activity is used to generate electricity overseas but Australia's geothermal resources are limited to low grade heat from the Great Artesian Basin. Although the artesian water often contains impurities which can cause corrosion and deposits in turbines and other equipment, a suitable heat engine has been developed. The technology is operating in the remote communities of Mulka station in SA (using a 20 kW power plant) and Birdsville (using a 120 kW power plant).

Biomass

Biomass is any organic material that can be converted into energy or into a source of energy and in Australia comes in various forms including sugarcane bagasse and wood. Stewart (1991) of the CSIRO Division of Forestry has said that 6.6 per cent (169 PJ) of Australia's total energy requirements presently comes from biomass.

Sugar mills generate their own normal operational electricity requirements by burning bagasse. Stewart estimated that sugarcane bagasse burnt in sugar mills amounts to 75 PJ (which compares with 1266 PJ of fuel used for direct electricity generation in 1986-87). The Sugar Research Institute stated the mills could play a greater role by supplying the grid and substituting for coal fuelled electricity generation. A single large cogeneration factory could, it was estimated, reduce carbon dioxide emissions by 0.21 Mt/year, while complete industry conversion to efficient cogeneration could reduce emissions by 3.3 Mt/year. However, the Institute said the grid buying price in

Queensland is less than $0.02 per kWh which is considered uneconomic by the mills. See section F4 for further discussion.

The use of biomass as fuel for energy production, unlike most other renewables, does result in GHG emissions, but growing the organic material in the first place absorbs GHG. The net carbon dioxide emissions from this recycling process are nil or small depending on the type of biomass resource, and all are far lower than from fossil fuel burning.

F2.3 Factors limiting renewables

Technical impediments and costs

This outline of renewable technologies has highlighted several problems which are hindering their commercial adoption, particularly for large-scale operations. Intermittent and unreliable supply of energy is a considerable problem with some otherwise promising technologies. This restricts the scope for using a renewable technology as a prime source of electricity for a major supply system. The impact on the landscape and some other environmental problems can also be a constraint in some cases. The amount of energy required to construct the capital equipment can also be significant.

However, probably the biggest obstacle is that, with the exception of hydro, large-scale electricity generation using renewable technology presently costs far more than electricity produced using conventional coal or gas methods. Wind power may be the technology which is currently the most competitive, with an estimated cost of 6 to 8 c/kWh compared with conventional coal with a cost of between 3 and 4 c/kWh (see Table F3). This does not take into account any environmental externalities caused by burning fossil fuels when conventional technologies are used. Green (1991) of the Centre for Photovoltaic Devices and Systems of the University of NSW has pointed out that the cost of photovoltaic devices have come down by a factor of 3-4 over the last decade but said that a further reduction of the same magnitude is required for them to compete `across the board' with present large-scale electricity generation options.

Not only is conventional energy generation currently more economic, but power stations have a productive life of about 30 years and in several States the industry is characterised by excess capacity. This further reduces early opportunities for phasing out conventional plants and the adoption of renewables.

The Business Council of Australia (1991) found that factors such as capital cost, operating cost, capacity factor and reliability offer little prospect for significant use of renewable resources for electricity supply in Australia in the years to 2005. Electricity production costs from renewable sources (other than hydro) are, the study found, expected to exceed 8 c/kWh during the next 15 years which would mean a substantial cost penalty when compared with the fossil fuel alternatives.

The Energy Research Centre responded by saying that capital and operating costs for solar thermal and wind power in volume production are not an issue as costs will come down to 4 to 5 c/kWh, and neither is reliability an issue when hybrid solar thermal systems use gas or diesel as backup.

The Ecologically Sustainable Development Working Group on Energy Production (1991) observed that:

> Despite the rapid technological advances and cost reductions that have occurred over the past two decades in renewable energy technologies, the cost of energy is still significantly higher than for conventional fossil fuel production of electricity for supply to electricity grids, and liquid fuels.
>
> The costs of new technologies currently being developed, however, are also projected to decline substantially over the next decade at which stage some of these technologies could be competitive with existing sources of electricity derived from fossil fuels in some circumstances. However, it is not possible to be definitive on these costs, at least in part, because some of these renewable energy technologies have not reached commercial scale production. (pp. 78-79)

The ABARE work using the MENSA model indicates that if the 2005 emission reduction target is to be met, renewable technologies will have to play a significantly increased role in electricity generation, unless a nuclear alternative is available. The additional energy system costs of meeting the Toronto target, without nuclear power and with renewables playing a major role, is estimated to peak at about $5.9 billion per annum around 2005.[3]

Electricity supply arrangements

Some participants said that existing electricity pricing arrangements hinder the adoption of renewable energy technology. The Shell Company of Australia Ltd stated that the uniform pricing of electricity within individual States reduces the attractiveness of solar energy in remote areas. Further, the company said that to the extent that the rate of return earned by utilities is below market levels, electricity may be underpriced to some customers, encouraging them to use more of this form of energy relative to alternatives. George Wilkenfeld and Associates advocated energy prices which better reflect costs of production. Enersonics Pty Ltd said that the price of electricity is too low and does not adequately reflect the scarcity of the resources used as fuel. The Australian Conservation Foundation claimed a number of factors have slowed both supply and end-use efficiency improvements. These include electricity and gas prices to consumers which are not fully determined by the market with cross-subsidies between classes of users often encouraging inefficiency.

3 If it is feasible to have base load solar, the additional annual energy system cost may drop to about $4.9 billion around 2005.

The Snowy Mountains Hydro-Electric Authority said that the present efforts to adopt pricing structures which reflect the true cost of electricity generation will enhance the cost-effective use of hydro-electric generation. Further, they will minimise production of carbon dioxide by encouraging the use of hydro-electric generation to replace fossil fuel for peak load generation. The Centre for the Environment and Sustainable Development stated that fossil fuels are given an unfair advantage through incentives for exploration, tax concessions for assessing environmental impact and for rehabilitation, and the access of their customers to payment over time of the capital cost of equipment such as power stations and gas pipelines. The Total Environment Centre said removing the institutional and financial barriers which prevent more widespread exploitation of demand-side and renewable energy resources might include equitable finance for energy/greenhouse-efficient technology at point of use, or separate specific institutional support for renewable energy in the form of a Renewable Energy Authority.

Several participants referred directly to the role and market dominance of electricity authorities as constituting an impediment which they claimed discouraged the adoption of renewable technologies. Dr David Mills said the energy market is dominated by a few, mainly conservative, organisations and that probably the greatest barrier to renewable technology is the inability of utilities and governments to set up structures to finance renewable technology in the same way as they do for conventional energy technology. Similarly, Greenpeace Australia said that a preoccupation with centralised electricity supply by state electricity authorities, and their monopoly over all supply, are institutional impediments. The Australian Conservation Foundation stated that if appropriate institutional and regulatory reforms were implemented, such as authorities providing an energy service rather than selling energy as a commodity, a number of the newer energy alternatives would become far more cost-effective. The Australian and New Zealand Solar Energy Society also considers that utilities should be providers of end use energy services, not just gas and electricity, and should treat renewable energy and energy-efficient technologies as options of equal standing with conventional energy supplies. The Society also stated that direct or indirect subsidies to non-renewable energy options should be removed or equalised. The Australian Mining Industry Council said there is an urgent need to reform the supply of electricity, and the inefficiencies identified by the Commission in its `Energy Generation and Distribution' report may contribute to excessive GHG emissions.

Reforming electricity supply

Current distortions in the pricing of electricity, nearly all of which is produced by burning fossil fuels, are detailed in the Commission's 1991 report on `Energy Generation and Distribution'. For example, there are cross-subsidies between different classes of users, and between urban and country users, under the supply arrangements of the public utilities. These would reduce the incentive to residential consumers and country residents to pursue renewable alternative sources of electricity such as solar. In its report the Commission recommended, among other things, the restructuring of electricity pricing so that revenue is sufficient to recover the economic cost of supply and that charges to users more accurately reflect supply costs.

The Commission also found that electricity supply industries have not been performing to their full potential. As the Commission's report points out, their performance has been well below international best practice. The Commission recommended a range of measures to get the supply utilities to operate on a more commercial basis and to introduce greater competition into the electricity supply industry. The Commission considered that all publicly owned electricity generation assets and at least some distribution assets should be progressively sold to the private sector.

The Commission concluded that in the long run, improvements in productive efficiency would result in a decrease in average electricity prices. In the short run, the removal of cross-subsidies could advantage some industrial and commercial users but increase prices to domestic users. There would be some cost increases for utilities as they were placed on a commercial footing, arising from the requirement to pay tax and dividends to governments and meet rate of return targets. The effect of the introduction of these requirements may be offset by factors such as the cost savings achievable as corporatisation is introduced and through better use of current surplus capacity.

Decreases in the average price for electricity, at least in the long run, could make it more difficult for renewables to compete with the conventional forms of electricity generation. However, there could be an opening for the direct use of solar in households if the cost of electricity to domestic users increases in the short term, particularly as a result of the removal of cross-subsidies. Further, if charges to users reflect supply costs there could be niches for direct use of renewables in rural areas. Solar in particular may be a more economical option, even with diesel backup, than paying for the true cost of connection to the grid.

Other recommendations were that existing publicly owned generating capacity be broken up to form a number of independent generating bodies and that ownership of generation, transmission and distribution functions be separated. If these and other recommendations were to be accepted, those who seek to generate and sell electricity using renewable technologies would face fewer barriers to market entry than at present.

It was announced in July 1991 following a Special Premiers' Conference that a National Grid Management Council will be established to encourage and coordinate the most efficient, economic and environmentally sound development of the electricity industry in eastern and southern Australia. The Council, among other things, will encourage open access to the eastern and southern electricity grid and free trade in bulk electricity for private generating companies, public utilities and private and public electricity customers. This will increase the opportunities for renewable energy suppliers to compete in the energy market.

Progress and research

There has been rapid advancement in several of the renewable technologies in recent years. Governments and government instrumentalities have provided and continue to contribute to research. Renewable energy research was supported by the Commonwealth Government through the National Energy Research, Development and Demonstration Program. About $33 million was provided under this program between its commencement in 1978 and 1990. The Government more recently established an Energy Research and Development Corporation to administer publicly funded support for non-coal energy research and development. The Corporation, which is the new mechanism for funding renewable energy research and development, announced $2.7 million in funding of renewable projects in October 1990. Around $3 million has been committed by the Corporation in 1991 to new projects which involve renewable technology. The NSW Electricity Commission, among others, is funding research into wind and solar energy including the allocation of $1.2 million by the Commission over four years to establish a photovoltaics centre at the University of NSW.

In future, renewable energy will play an increased role in electricity generation as research reduces capital costs and electricity pricing is reformed, and as GHG emission reduction strategies are put in place.

F2.4 Summary

- Australia relies heavily on burning fossil fuels to generate electricity; over 40 per cent of carbon dioxide emissions come from this source.

- Using renewable technologies to generate electricity on a large scale would substantially reduce carbon dioxide emissions, as these technologies produce negligible emissions.

- The relatively high cost of renewables is the main impediment to their greater use, although costs in Australia are difficult to estimate precisely due to limited commercial experience with these technologies.

- But their costs have fallen in recent years due to research in Australia and overseas, to which governments have contributed, and these cost reductions will continue.

- Reforming the electricity supply industry, although it could lead to lower average electricity prices in the long run, should improve prospects for renewable energy in some ways: it will remove impediments to market entry, and reduce the competitive disadvantage of renewables in the residential sector and in remote areas.

- Carbon dioxide reduction strategies will enhance the prospects for renewable technologies.

F3 Coal or gas as fuel for electricity generation

Nearly all electricity generated in Australia is produced by power stations which burn fossil fuels. These are responsible for over 40 per cent of Australia's carbon dioxide emissions and at least 20 per cent of Australia's total GHG emissions. Reductions in emissions would be achieved by adopting cleaner coal-based technologies. CSIRO said that in the medium term Integrated Gasification/Combined Cycle technology offers most promise of limiting carbon dioxide emissions from power generation. Emeritus Professor O Potter claimed that new brown coal steam-fluidized bed drying technology patented by Monash University will reduce carbon emissions from delivered energy to about 74 kg C per GJ, comparable with current emissions of 71 kg per GJ from black coal.

Reductions could also be achieved if fuels which have relatively high GHG emission levels were replaced by those with lower levels. One way this could be done is by using black coal instead of brown coal in conventional electricity generation, which CRA Ltd said would reduce carbon dioxide emissions by 33 per cent per unit of electricity produced. Another is by increasing the share of natural gas at the expense of coal.

The substitution of natural gas for coal in electricity generation was strongly advocated by gas industry organisations such as the Australian Gas Association and the North West Shelf Domestic Gas Joint Venture Participants. Their views were shared by several participants, including the Centre for the Environment and Sustainable Development, who consider gas is a more environmentally friendly way of generating electricity than coal. However, some other participants, including Greenpeace Australia expressed doubts about whether electricity generation would be the best way to utilise Australia's gas resources. The Australian Coal Association said that, while there is scope for greater use of gas in the energy sector, the prospects of natural gas being able to compete with coal in electricity generation have been overstated.

F3.1 Carbon dioxide emissions and the potential for reductions

Coal in Australia is abundant, conveniently located near major population centres and of relatively high quality. Most States rely heavily on coal for the generation of the bulk of their electricity. Black coal is used in NSW and Queensland and brown coal plays an important role in Victoria, South Australia and Western Australia.

Natural gas plays a lesser role (see Table F4). In South Australia just over half the electricity is generated by this means, and in Victoria and Western Australia gas makes a relatively minor contribution. Tasmania relies mainly on hydro-electric power. Small amounts of oil are used in Tasmania and the Northern Territory.

Table F4: **Fuels used for direct energy generation 1986-87**

Fuel type	*PJ of fuel*	*Proportion of fuel*
		%
Black coal	720.7	57
Brown coal	389.2	31
Natural gas	129.0	10
Oil	26.6	2

Does not cover cogeneration. PJ = Petajoules.
Source: Based on information in Walker (1990).

Coal produces about twice the amount of carbon dioxide per unit of electricity as natural gas (see Table F5). The latest coal technologies -- Integrated Gasification/Combined Cycle and Pressurised Fluidised Bed Combustion -- have the potential to reduce carbon dioxide emissions but they will still exceed emissions from using gas. Some methane is also released in the distribution of natural gas and the mining of coal.

Table F5: **Carbon emissions from different fossil fuel based electricity generation technologies**

(KgC per GJ)

Technology	*Carbon emissions for delivered energy*
Conventional black coal	71
Conventional brown coal	93
Integrated gasification & combined cycle	54
Pressurised fluidised bed combustion	54
Gas in steam plant	43
Gas in combined cycle plant	31

KgC per GJ = Kilograms of Carbon per Gigajoule.
Source: Based on information in Walker (1990).

Several studies have examined the effects on GHG emissions of greater use of gas for electricity generation. A recent ABARE (1991a) study of energy supply and demand to 2004-2005, included a scenario in which existing black and brown coal fired power stations were closed, together with existing natural gas fired stations, and replaced with more efficient units burning natural gas. This action, combined with other efficiency gains, could reduce carbon dioxide emissions from an anticipated business-as-usual level of 379 Mt to 239 Mt (this latter figure would still be well above the Government's interim planning target). An estimated 42 per cent of this reduction would result from using gas as the sole fuel for electricity generation.

The Business Council of Australia (1991) found that significant reductions in carbon dioxide emissions could be achieved through the substitution of gas for coal. One scenario studied was the installation of natural gas plant to meet increased electricity demand to 2005 in place of the black coal fired capacity which would otherwise be required. In this case carbon dioxide emissions in 2005 relative to 1988 are likely to be in the range 118-124 per cent. If no such action to replace coal is taken, carbon dioxide emissions in 2005 relative to 1988 were estimated to be in the range 136-155 per cent. The BCA concluded, after studying several scenarios, that reductions in emissions that could be achieved would be well short of the Government's interim planning target and any attempt to achieve the target by fuel substitution would result in heavy economic penalty.

The Australian Gas Association (1990) studied the effect of electricity generation requirements being supplied by greater use of natural gas and less coal. The study found that a 50/50 mix of gas and coal -- which took into account practical constraints on the displacement of coal -- in NSW, Victoria and South Australia would result in a long term reduction in carbon dioxide emissions from electricity generation of about 20 per cent.

ABARE has carried out work to determine the most cost-effective combination of changes in fuels used in electricity generation to achieve emission reduction targets. A number of simulations have been done using the MENSA model. The preliminary work indicates that if the 2005 target is to be met, the amount of coal used in electricity generation must fall substantially. The amount of natural gas used may rise but this depends on the assumptions made and in particular the availability and cost of a nuclear alternative.

Another approach to reducing GHG emissions, referred to by several participants, is to increase the direct use of natural gas in households for purposes such as water and space heating and cooking, thereby reducing the use of coal generated electricity. This approach is discussed as a separate issue in section F7.

F3.2 Costs and benefits of more gas in electricity generation

Participants and studies have drawn attention to the advantages and disadvantages of greater use of natural gas in electricity generation. A clear benefit would be the lower level of GHG emissions.

Some participants consider that reliance on gas for electricity generation would increase costs. The State Energy Commission of WA, for example, said that if there were to be complete substitution of gas, generation costs would increase due to the higher cost of gas relative to coal. Moreover, the Commission said further cost pressures are likely, due to worldwide demand for natural gas as the preferred fossil fuel.

The Australian Coal Association drew attention to a recent long term comparative cost study by the Japanese Institute of Energy Economics. This showed a cost of electricity generated by coal of

10.45 Yen per kWh compared with a cost of liquid natural gas of 12.43 Yen per kWh. The Association said that this and other studies confirm that coal and nuclear are the two most cost-competitive energy sources and are likely to continue to underpin base load electricity generation in the foreseeable future.

A study by the Electricity Commission of NSW (1991) found that for generating 10 000 GWh/yr, conventional coal technology was slightly cheaper at 3.4 to 3.8 c/kWh compared with 3.9 to 4.3 for gas combined cycle technology. The study found that while the capital cost of conventional coal for this size generation was 38 to 67 per cent higher for conventional coal than for combined cycle, the operating cost of combined cycle was 45 to 83 per cent higher (see Table F5).

However, if used to supplement coal, some increase in the proportion of gas might be possible without cost penalty. The Business Council of Australia (1991) found that the installation of 3000 MW of gas combined cycle, in place of part of the new black coal capacity required to 2005, could possibly be achieved without an increase in average electricity cost. If combined cycle were used in place of all the new black coal capacity otherwise required, the average cost of electricity generation could increase by about 5 per cent. The Australian Gas Association (1990) estimated that a 50/50 mix of gas and coal can bring down the cost of electricity. However, the Association said the realisation of cost reductions requires the deferment of the bulk of the increases in gas use until relatively recently built coal stations are retired, starting about 2010.

The Department of Primary Industries and Energy (1991) has addressed this issue and drew attention to a study by the International Energy Agency (1989) which concluded that gas fired generation does not appear to be competitive with coal fired plant for base load generation. Nevertheless, gas combined cycle systems become competitive at lower gas price forecasts. The study indicated a typical gas plant has lower capital costs than a typical coal fired plant but, per kilowatt hour of electricity generated, coal fuel costs are cheaper than gas.

The Department of Primary Industries and Energy went on to say that:

> Demand for electricity is subject to daily and seasonal peaks and electricity generating plant is therefore underutilised to the extent that the additional capacity required to meet peaks is not used during periods of moderate demand. Typically, periods of peak demand are relatively short. With such demand patterns it could be expected that a preferred characteristic of plant required to meet peaks would be low capital costs, while plant preferred for continuous base load duty would have relatively low fuel costs. Such preferences provide a rationale for a generating plant inventory made up of an optimum mix of coal plant and gas plant. (p. 62)

The Shell Company of Australia summed up the differing industry views on relative merits of gas and coal as follows:

> Many in the gas industry are confident that gas's share of the market will increase considerably. They point to the lower capital cost involved in gas fuelled generating plant; the increased flexibility that can be offered owing to the relatively small scale of gas plant; the higher energy efficiency of gas turbines relative to conventional coal fired plants; likely improvements in gas turbine efficiency; and the lower CO_2 emissions associated with natural gas.

> The coal industry, on the other hand, points to the costs of transporting gas across the continent; the CO_2 content of the gas itself; new technologies which are increasing coal fired power station efficiency and reducing emissions; the very large reserves of low cost accessible coal, and its frequently low sulphur content, which reduces concerns about acid rain. (Sub. 52, p. 13)

Recent experience in WA relating to new generating capacity illustrates the various factors -- economic, social, environmental -- which come into contention when a decision is being made on the appropriate fuel on which to base electricity generation. The State Energy Commission of WA referred to a number of constraints on complete reliance on gas. These included cost pressures arising from the higher cost of natural gas compared with coal and the need to resolve long term coal contracts, the capital cost of converting power stations and extending pipelines, the strategic disadvantage of relying on one fuel piped through a single pipeline and the dependence of the Collie coal field on supplying coal for electricity.

In May 1991, the Western Australian Government announced that the State's next power station would be coal fired. A Review Committee on Power Options for WA had in 1990 recommended that the State Government adopt combined cycle gas turbines as the next base-load plant. The power station is intended to be privately owned and operated and the Government decision followed an agreement reached with unions and coal companies. The Minister for Fuel and Energy said the outcome of the agreement for households and industry will be important tariff reductions during the next five years compared with the gas alternative. Reafforestation programs are intended to be part of the arrangement, apparently to offset GHG emissions.

There is a further type of cost associated with both technologies. Methane, a particularly damaging GHG, is lost into the atmosphere during production and distribution of natural gas. Overseas studies indicate that methane leakage by the natural gas industry can be less than 1 per cent of wellhead production rather than almost 2 per cent as at present in Australia (Dixon 1990).

Methane is also released during coal mining and is extracted prior to and/or during the mining operation using wells, bore holes or vents. It is collected and used on a large-scale in some locations in the United States and on a small-scale at some locations between Sydney and Wollongong. The economics of using this by-product as a fuel at particular mines would depend partly on the quantity and quality of methane, and electricity tariffs, including that for cogeneration.

Total losses from these sources may amount to 400 kt of methane or about 12 per cent of Australia's annual methane emissions (Table C14, Appendix C). The natural gas industry has moved to address the problem, particularly the urban reticulation systems where most losses occur. An example is the inserting of nylon pipe in old cast iron mains by AGL in Sydney which is expected to reduce methane emissions by 60 kt by 1995. Similarly, the Electricity Commission of NSW and CSIRO are conducting field tests and undertaking trial projects, and AGL is also undertaking research and development, into utilising the methane from coal mines. Often the gas contains impurities and the cost of removing them makes it difficult to use the gas as a commercial fuel source.

F3.3 Impediments in the gas supply industry

Several participants, including the Australian Gas Association and the North West Shelf Joint Venture Partners complained that the price of electricity generated from coal does not reflect its cost of supply. This was said to put gas at a competitive disadvantage. In its report on `Energy Generation and Distribution' the Industry Commission made a number of recommendations which address these issues. The Commission proposed a range of measures to increase efficiency by putting public electricity utilities on a more commercial basis and introducing more competition into the electricity supply industry. These were outlined in Section F2.

The Commission also proposed several measures to promote competition in the natural gas industry. These included the proposals that ownership of major transmission and distribution assets be separated and that all pipelines be required to operate on an open access basis. Several recommendations were intended to remove impediments resulting from government regulation of the natural gas industry. Distribution franchises usually give the holder sole right to reticulate gas within a prescribed area. The Commission considered that exclusive franchising arrangements should be abolished. Franchises should be non-exclusive, tradeable and be allocated for approximately 10 to 15 years, with restrictions which limit individual shareholdings in utilities ended.

All private gas utilities are currently subject to some form of tariff regulation, primarily because of certain `natural monopoly' characteristics. The Commission favoured monitoring of gas tariffs by `light handed' regulation by a body such as the Trade Practices Commission (or if this proved ineffective, industry specific monitoring based on a price capping formula). The Commission also considered that Government policies that restrict the use of gas or its sale interstate or overseas should be abolished.[4]

The wide-ranging recommendations of the Commission covering both gas and electricity supply should encourage competition between gas and coal in the generation of electricity. Among other things, unrestricted interstate movement of gas may make more feasible an extension of the existing pipeline network to north west Australia as the reserves closer to the eastern States run out. The current restrictive policies may also be reducing the incentive to explore for gas.

4 Examples of restrictions are South Australian legislation which limits the supply of gas to NSW to the current contract, and the Northern Territory refusal of a proposal to permit SA to be supplied with gas from the Amadeus Basin in Central Australia.

The establishment of the National Grid Management Council, outlined in Section F2, will be a significant step towards freeing-up the energy market and increasing the opportunities for natural gas.

Some participants said that new electricity generating capacity should be based on fuels other than natural gas. Gas, it was argued, is a finite resource with advantages from using it as a direct energy source and prolonging the life of the resource for purposes such as a transport fuel, rather than for electricity generation.

In contrast, the Australian Gas Association stated that if no additional natural gas discoveries were made there would be sufficient gas until 2035 but it is more realistic to assume on the basis of overseas and Australian experience that reserves will be significantly upgraded. Allowing for this, it was estimated that there will be sufficient gas until well beyond 2050 by which time it was forecast by the Association that other technologies with low GHG emissions would be economic.

Nevertheless, the Senate Standing Committee on Industry, Science and Technology (1991), when it considered this issue, recommended against using gas for base-load power generation. The Committee stated that the estimated eighty-year reserve of gas could be rapidly diminished if demand for gas as a direct source of fuel or as a transport fuel expands significantly. The versatility and attractiveness of gas as an energy source, the Committee said, makes it a valuable resource which should be conserved rather than depleted for short term gains, be they economic or environmental.

In contrast, in the report on `Energy Generation and Distribution' (1991a) the Commission said that it could not establish any justifiable basis for governments restricting trade in natural gas. Present policies appear to be heavily influenced by notions of scarcity and a `premium' fuel status for natural gas, as well as parochial interests. Such restrictions can lead to uneconomic investments and to a reduced exploration and production effort. The Commission concluded that it favours the termination of policies that place restrictions on the use of gas, other than for safety reasons, or on its sale interstate or overseas.

F3.4 Summary

- Most of Australia's electricity is generated using coal, with natural gas playing a minor role -- but coal produces about twice as much carbon dioxide per unit of delivered energy as gas.

- Coal is an established and currently a cheaper means of generating electricity for base-load requirements, but gas may be a less expensive means of supplementing the base load; there could be some scope for gas to increase its share of energy supply.

- There are some barriers which restrict the ability of gas to compete with coal, such as restrictions on interstate trade and the pricing arrangements of supply utilities; removing such barriers is likely to lead to an increase in the proportion of energy supplied by gas with a consequential decrease in emissions.

- Reforming the electricity supply industry should foster a more competitive environment and remove the impediments gas suppliers currently face.

- Adoption of carbon dioxide reduction strategies would encourage the use of gas in electricity generation relative to coal.

F4 Cogeneration

Cogeneration is the combined generation of electricity and other useful energy (steam, process heat or mechanical power) from the same fuel source. There are two methods of cogeneration, topping and bottoming. Topping uses steam to generate electricity then applies the exhausted steam in a production process. Bottoming systems convert waste heat into steam which is then used to cogenerate electricity. Major industries using topping are pulp/paper, food and chemicals, while bottoming systems are used in the glass and metals industries. Non-industrial applications for cogeneration include medical centres, hospitals, swimming pools and restaurants.

Wilkenfeld (1991) said that cogeneration is technically possible where power and heat requirements are continuous and steady. However the advent of cheap, reliable energy from central power stations had resulted in many industries choosing to purchase electricity rather than generate their own energy requirements. CSIRO said that efficiency improvements such as cogeneration are the quickest and cheapest method of impacting on the power generation sector's carbon dioxide emissions.

Cogeneration has two advantages in terms of carbon dioxide reductions. The first is thermodynamic efficiency -- which can be as high as 80-90 per cent in some applications as opposed to between 30-40 per cent for conventional coal power stations. The second advantage is that most new cogeneration capacity is based on gas -- thereby reducing carbon dioxide emissions where it replaces coal based electricity.

Some participants said that more should be done by Government to realise the potential carbon dioxide reductions from cogeneration. For instance the South Australian Government said it encouraged the Commonwealth to provide tax incentives for cogeneration measures.

Other participants said that further cogeneration is not currently viable. Pasminco Metals stated that financial incentives will be needed if cogeneration is to be effective in reducing carbon dioxide emissions. The Business Council of Australia study (1991) found that there is only limited potential for encouraging cogeneration until the year 2000 due to current electricity generation overcapacity. The study concluded that, even then, only those new cogeneration schemes with favourable economics and high capacity factor would be commercially feasible.

Table F6: **Estimates of Australian cogeneration capacity and potential**

State and author:	*Current /proposed capacity*	*Technical # or potential capacity*	*Economic # (achievable) capacity*	*By year:*
	MW	*MW*	*MW*	
New South Wales:				
BCA	100		350	2005
Energetics [a]			200	1995-2000
Greene [b]		1827	960	996
NSW Government [c]	100		800 (1700)	2005
Wilkenfeld			200	1995-2000
Victoria:				
BCA	170		375	2005
DITR (1990)	225	1250	585	n/a
Energetics [a]			250	1995-2000
Greened			1000	1996
NIEIRe			700	2005
Wilkenfeld			250	1995-2000
Southern Australia:				
BCA	40/120		220	2005
SA Govt [f]	68	200	80-100	1994
Queensland:				
BCA [g]	105		150	2005
Western Australia:				
BCA	180		170	2005
Gawler	180	\`limited'		n/a
SECWA	150			1995
Northern Territory:				
BCA	106			n/a
Australia:				
AGA [h]			2000	2000
BCA		1800i	1265 [j]	2005
Energetics [a]			675	1995-2000
Greene [k]			2700	2005
Wilkenfeld			650	1995-2000

In addition to existing capacity.
[a] Estimate by Energetics Pty Ltd \`Opportunities for reducing Greenhouse emissions', in Greene (1990). [b] Study by Greene (1989) for the ECNSW. [c] Many of these cogeneration systems were installed over 20 years ago. [d] Study by Greene (1984) for the SECV. [e] Combined estimate of new private generation and cogeneration capacity. See NIEIR (1990). [f] South Australian Climate Change Committee (1991). [g] Although 100 MW is installed in sugar mills, this only operates for 1/3 of the year during processing of sugarcane. [h] According to the AGA this is a \`conservative' estimate for NSW and Victoria (based on Greene 1989). [i] KCA estimate of the technical cogeneration capacity likely to be economic by 2005. [j] The BCA assumes that 70 per cent of the technical capacity that might be economic by 2005 is practical. [k] Greene et. al. (1990) report to the DASETT.

Sources: Participant submissions, various references.

F4.1 Carbon dioxide emission reduction potential

Wilkenfeld (1991) estimated that new cogeneration capacity in Australia in the next 5-10 years would be 90 per cent gas, displacing 19.7 PJ of electricity and reducing emissions by 3.6 Mt of carbon dioxide or 3.5 per cent of 1986-87 industrial emissions.

The Business Council of Australia study (1991) put carbon dioxide reductions from `practically achievable' new cogeneration at 3.3 Mt per annum by 2005 (or 2 per cent of ABARE's (1991a) estimate for 2005 of electricity carbon dioxide emissions).

Greene (1990) estimated cogeneration could replace 37 PJ of energy by 2005, reducing emissions by 26.7 Mt per annum relative to base case projections. The Australian Gas Association (AGA) said a ‘conservative’ estimate of cogeneration capacity would mean reduced carbon dioxide emissions by 10 Mt per annum by 2000 (representing 8 per cent of current electricity sector emissions or 1.7 per cent of national emissions).

The Australian Minerals and Energy Council (1990) estimated that cogeneration could contribute a potential 2.3 Mt of contained carbon, of a projected industry reduction of 8.0 Mt by 2005 or 8 per cent of national reductions.[5]

The Sugar Research Institute claimed that complete sugar industry conversion to cogeneration using cane fibre (bagasse) could reduce carbon dioxide emissions by 3.3 Mt per year or 1.3 per cent of present Australian emissions. A single large cogeneration facility could reduce carbon dioxide emissions by 0.21 Mt year but generation would only be possible in the 25-week crushing season. Kimberly-Clark Australia Pty Ltd said that cogeneration at its APCEL pulp mill at Millicent SA could reduce carbon dioxide emissions by 46ÿ000 tonnes or 23 per cent of total carbon dioxide emissions.

The Electricity Commission of NSW said that latest estimates by Energetics put estimated carbon dioxide savings at 2.58 Mt per annum (8 per cent of 2005 industrial emissions) in NSW by 2005 from `viable' projects achieving at least a 25 real rate of return (Sub. 100, vol. 2, table 3.2b). The State Energy Commission of WA said that the 150 MW of potential cogeneration in that State could reduce net carbon dioxide emissions by 0.4 Mt per annum by the mid-1990s.

Most estimates assume the majority of new cogeneration projects will use gas. Dr David Mills said that solar cogeneration, either combined solar/off-peak electric with storage or solar/gas, is suited to industrial processes such as fluid heating and drying. These processes accounted for 28 per cent of industrial carbon dioxide emissions in 1986-87. Dr Mills estimated that solar cogeneration could meet around 20 per cent of the industrial sector's heat demand (which totalled 854 PJ in 1986-87) (Sub. D123, Attachment 1)[6].

5 AMEC bases its estimate upon technically and economically feasible energy efficiency measures and ‘greenhouse positive’ energy sector policies.

6 This estimate is based on energy and emission data from Wilkenfeld (1991).

F4.2 Costs and benefits

The North West Shelf Domestic Gas Joint Venture Participants said that greater utilisation of natural gas in high efficiency applications such as cogeneration is desirable from both a greenhouse gas emission perspective and on economic grounds. Dr David Mills said that supplying electricity and hot water using moderate temperature solar cogeneration had more favourable `lifecycle costs' in industry than conventional cogeneration. Dr Mills noted that while current cogeneration systems can be limited by local pollution requirements, solar cogeneration resulted in little pollution near the point of thermal use.

Benefits can accrue to the cogenerator from reduced energy purchases and/or the sale of surplus electricity to the utility. Benefits to the electricity utility take the form of `avoided costs' which are the marginal cost of operating an electricity generation system. Cogeneration is highly sensitive to electricity tariff structure and utility buy-back rates. Buy-back rates can have a short run (operating cost) and long run (capacity deferral) component. In the short run, avoided cost will be the operating costs of marginal generating equipment. Bottoming can incur extra fuel costs as the large volume of high temperature waste heat required can make boosting necessary, increasing GHG emissions.

The generation costs of current coal based systems are very low. The Electricity Commission of NSW (1991) estimated the cost per kilowatt hour for conventional coal of 3.4-3.8 cents (see Table F3). The Sugar Research Institute noted that the Queensland grid buying price for surplus electricity is less than 2 cents per kWh while the cost of cogeneration is 5-7 cents per kWh. However NSW, Victoria and SA now have policies to increase cogeneration capacity, including increased buy-back rates. For example, the South Australia Government (1991) has offered buy-back rates -- to highly reliable suppliers -- ranging from 2.5 cents per kWh off-peak to 10.6 cents per kWh peak (see Table F8 for Victorian buy-back rates).

The extent of utility savings from deferring the construction of electricity generation capacity, such as coal based power stations, depends on whether the cogeneration capacity is available long term. Where a utility has excess generation capacity there is little benefit from deferral and buy-back rates will reflect operating costs. Pasminco Metals said that utility reluctance to pay industry the same price it charged industry for its power could undermine cogeneration. However, the company recognised that a utility could not rationally offer a better rate than its marginal power cost. The AGA said a utility that did not use cogeneration may not minimise its medium and long term costs.

A major factor preventing more cogeneration is the installed cost (capital and grid connection) of such systems. The Victorian Department of Industry, Technology and Resources estimated that the capital costs of implementing cogeneration systems are \$0.6-1.3 million per MW for gas and \$1-1.5 million per MW for coal. Coal systems have extra labour requirements of \$150 000 per annum (DITR 1990). Gas cogeneration operating costs -- mainly fuel -- are high due to the current price of gas relative to coal. Pasminco Metals said that the relatively high capital charges on small cogeneration facilities can offset cost savings from the low cost or free energy source. The Sugar Research Institute said complete sugar industry conversion to cogeneration would involve considerable cost and require reliable markets for surplus electricity.

Dr David Mills claims that solar thermal cogeneration is a serious option for replacing peak load fossil fuel power as improved solar thermal power plants (with storage) should be able to deliver base load electricity at around 5 cents per kWh. Dr Mills states that:

> ... we anticipate that the timescale would be a 30 MW plant in 1997, and 1-200 MW plants as required after 2000 A.D. (Sub. D123, p. 1)

An estimate of the cost of replacing suitable industrial processes (fluid heating and drying) with low temperature solar cogeneration was made by Dr David Mills. He stated:

> Suitable industrial heat applications consume about 171PJ (million GJ) per annum in Australia. Solar collectors of our own design to supply 90% of this would deliver about 5 GJ per square metre per annum, so about 31,000,000 square metres would be required costing $7 billion. This is equivalent to around $400,000,000 in annual costs, a figure which should be compared to annual fuel and energy infrastructure costs currently devoted to this major energy sector. It appears that optimisation of solar heat technology and maximising its market penetration would not only be the least polluting process heat option, but perhaps be cheapest option. (Sub. D123, Attachment 1)

The Senate Standing Committee on Industry Science and Technology (1991) found that though cogeneration was not economic at present, it could be of value as a carbon dioxide reduction strategy. The Committee recommended that cogeneration `be encouraged, even if some short term cost is incurred' and that utilities be required to assess cogeneration potential and set targets for a minimum proportion of cogeneration to be achieved within a five-year period.

F4.3 Factors limiting or inhibiting adoption

The Industry Commission in its report on `Energy Generation and Distribution' (1991a) identified a number of institutional factors constraining the use of cogeneration, including utility buy-back tariffs and associated charges, uncertainty as to buy-back terms and long term fuel supply, differences in investment appraisal, tax/depreciation treatments and reluctance by utilities to accept cogenerated electricity.

Utility efficiency, cross-subsidies

If poor productivity performance by an energy utility is reflected in higher average energy prices, excessive levels of cogeneration could be encouraged. Further, utility and government energy pricing policy may not reflect the true cost of supply to some users. The effect on potential cogenerators will depend on how these inefficiencies affect electricity tariff structures.

Price penalties on industrial and commercial users in Victoria from cross-subsidisation range from 13 per cent for large users to 34 per cent for small users (see Industry Commission 1991a). Removing these price penalties would reduce the attractiveness to these users of cogenerating their energy requirements. Smelters in this State (as large users of high voltage electricity) would not be affected by the removal of cross-subsidies. ‘Other’ large high voltage users (some presumably with cogeneration potential) would face price increases of 14 per cent, increasing the short run attractiveness of cogeneration to these users.

The Industry Commission (1991a) estimated in the long run that improved productivity and removal of cross-subsidies could lower average electricity tariffs by about 15 per cent if international best practice were achieved. Such a fall in average electricity prices would affect the viability of potential (and current) cogeneration projects. However, reforms recommended in the natural gas industry could offset this effect.

Competition

Some participants commented that significant savings are available through microeconomic reform of the energy sector. The Institute of Engineers Australia said that a particular `no regrets' policy would be the:

> facilitation of cogeneration by reducing the monopoly control exercised by the power utilities, e.g. by privatising the distribution of electricity, and thus offering more realistic buy-back prices for cogenerated power. (Sub. D156, p. 5)

This issue was also raised in the Commission's `Energy Generation and Distribution' inquiry, where some participants contended that state energy utilities viewed cogenerators as competitors in electricity generation and had consequently discouraged cogeneration, principally through very low buy-back rates.

The Commission's recommendation was to separate the generation, transmission and distribution functions. This should expose the utilities to a more competitive environment, and increase the scope for development of cogeneration where it is economically justified. The establishment of the National Grid Management Council, announced in July 1991 following the Special Premiers' Conference, is intended to encourage open access to the east and southern Australian electricity grid. It will encourage the competitive sourcing of generation capacity. This should remove some impediments to the greater use of cogeneration.

Utility buy-back policy

Buy-back rates set by utilities have been recognised as the key factor affecting cogeneration project viability, for example by the Senate Standing Committee (1991). Some participants claimed that buy-back rates are too low. The AGA said that:

> It is likely that avoided costs, to date, have been underestimated or not fully taken into account by utilities in setting purchase prices. (Sub. 73, p. 48)

Similarly, Kimberly-Clark Australia Pty Ltd (KCA) said:

> The major impediment to many industries installing their own electricity generating equipment are some unsympathetic policies of the government electricity supply authorities. Commonly a private cogenerator will want to sell his spare electricity production, which is often quite substantial, into the state grid. However the state's purchase price in such situations is commonly a small fraction of their selling price -- a buying price of 20% to 30% of the selling price is not uncommon. (Sub. D114, p. 9)

Furthermore, KCA said that the development of a 12 MW cogeneration plant at its South Australian pulp mill at Millicent depended upon the Electricity Trust of South Australia (ETSA) purchasing the residues ‘at a reasonable price’.

Victoria, South Australia and New South Wales have published buy-back schedules with rates varying according to the time of day and reliability of supply (Table F8 summarises energy utilities buy-back rate policies). Gawler (1991) notes that while Queensland has no published buy-back policy, standard rates based on long run marginal costs (time of day/average rates) are available on request.

Table F7: **Summary of energy utility buy-back rate policies**

	ECNSW	*SECV*	*QEC*	*ETSA*	*SECWA*	*HECT*
Published policy	Yes	Yes	No	Yes	No	No
Based on long run discount rates	Yes	Yes	Yes	Yes	Yes	na
Peak/off-peak rates	Yes	Yes	Yes	Yes	Yes	na
Incentive for No cogen/renewables	Yes	No	No	No	No	
Size breaks (MW)	30	10, 50	na	na	na	na
Proponent pays connection costs	Yes	Yes	na	na	na	na
Minimum duration for full rates (yrs)	na	15	10	na	na	na
Wheeling allowed	No	No	No	No	Yes	na
Limits on new capacity (MW)	Yes[a]	Yes[b]	na	na	na	na

na. not available. [a] 200 MW over any two-year period. [b] 220 MW by 1994-95.
Source: Gawler (1991).

Current State Electricity Commission of Victoria (SECV) buy-back rates (Table F8) are an example of how rates can be structured to increase the incentives for cogeneration.

Table F8: **SECV buy-back rates for cogeneration**[a]
(c/kWh)

		Option 1	*Option 2*	*Option 3*	*Option 4*
Voltage (kV)		6.6,11,22	66	220,330,500	Low
Normal rates[b]	peak	2.55	2.52	2.48	2.66
	off-peak	1.28	1.26	1.23	1.33
Max. long term[b]	peak	8.00	7.83	7.61	8.34
	off-peak	1.91	1.89	1.85	1.99
Incentive rate[c]	peak	10.29	10.14	n/a	10.83
	off-peak	1.65	1.63	n/a	1.73

[a] For small to medium projects (0-50 MW). Rates negotiated for projects of 50 MW or more. [b] Performance standards apply. [c] Only available to private cogeneration or renewable projects of not more than 10 MW registered before 31 December 1991.
Source: SECV, Schedule S.

Utility excess capacity

The Industry Commission (1991a) estimated that current utility overcapacity ranged from 18 per cent in NSW to 4 per cent in WA, based on current pricing policies and an international best practice level of 20 per cent. The Business Council of Australia study (1991) noted that this supply capacity will probably be absorbed in demand growth by the end of the decade. It stated that current electricity prices are low in most States reflecting fuel costs and the adequacy of installed capacity. The BCA study concluded:

> There will therefore only be limited incentive available through attractive electricity buy-back prices for the installation of cogeneration schemes in Australia until new capital investment is required ... .(p. 95)

Cogenerator diversity

The AGA noted that where there is only one small cogenerator of unproven reliability, the electricity utility will need as much generating capacity as they would without the cogeneration capacity. Increasing buy-back rates to reflect long run capacity deferral is only possible where there are sufficient cogenerators of known reliability. The AGA said that to achieve long run diversity in cogeneration supply, a utility may need to set buy-back rates greater than current marginal cost, incurring short run losses. The Association stated:

> ... it may be worthwhile to sustain the initial losses. Alternatively, the community may find it worthwhile to assist during the transition period. (Sub. 73, p. 46)

Some States already offer special encouragement packages to cogenerators. For example ETSA has a package which includes feasibility studies, finance, operation and maintenance, as well as funding of cogeneration projects through the joint-venture company SAGASCO. The Victorian Government noted that a previous encouragement package had 70 MW committed and other projects were being investigated.

Stand-by tariffs

Stand-by tariffs are levied on cogenerators to cover the cost of maintaining generating capacity for occasions when a cogenerator is unable to match energy production and consumption and where electricity is required from the grid. The AGA noted that such charges have tended to be high and that a more rational approach to setting stand-by charges is needed.

The Industry Commission (1991a) concluded that there was little reason for supply charges not to be levied in accordance with standard supply tariffs -- except where the cogenerator was a large user of electricity and an outage (a period of non-supply) would place a significant demand on the grid. Where this condition applied, the charge should reflect both the capacity set aside and the probability of an outage.

Wheeling

`Wheeling' is the transfer of electricity from a private generator to another company site or to an independent buyer through the State utility's transmission network. Greene (1989) noted prohibitions on wheeling had impeded `logical' cogeneration projects in NSW. The Industry Commission stated in a working paper on `The Environmental Implications of a National Electricity Grid' (1991c) that most State utilities do not permit private parties to use their transmission links for wheeling electricity. It noted that the national grid concept would allow such transactions, at a price, and that this would remove one factor currently impeding some private cogeneration projects.

The South Australian Government (1991) said that current wheeling restrictions may discourage private generation (including cogeneration) and noted that ETSA was considering indicative transmission charges to facilitate wheeling.

Taxation

One participant to the Industry Commission's `Energy Generation and Distribution' (1991a) inquiry claimed that sales taxes on cogeneration plant discourage commercial cogeneration. This is because commercial cogeneration facilities are subject to a 20 per cent sales tax while industrial facilities are exempt. The Industry Commission (1991a) found that taking sales tax in isolation is misleading as service industries were taxed on inputs but not outputs (to avoid the problem of double taxation) whereas industry is taxed on outputs.

F4.4 Summary

- Cogeneration reduces carbon dioxide emissions through greater energy efficiency and substitution of gas based energy generation for coal based electricity purchases.

- Cogeneration has the potential to replace the separate generation of heat and electricity requirements in industrial and institutional applications where power and heat requirements are continuous and steady.

- Current cogeneration reduces Australian carbon dioxide emissions by around 1 per cent; cogeneration capacity has the potential to more than double by 2005.

- If the Government's interim planning target is confirmed, cogeneration could increase even more.

- Increased cogeneration could be achieved by increasing utility buy-back rates to reflect long run marginal costs, scrapping stand-by charges and removing wheeling barriers.

- Measures such as premiums for cogenerated power or tax breaks could increase cogeneration capacity but would incur costs for the community.

F5 Road or rail freight

In 1987-88, around 69 Mt of carbon dioxide was released by Australia's domestic transport sector (ie about 26 per cent of the Australian total). Non-urban freight accounted for some 19 per cent of these emissions. (BTCE, Sub. 84, pp. 12-13)

One way of reducing these emissions is by encouraging a shift in freight to more fuel efficient modes of transport. Rail transport is more efficient than road for bulk freight movements, and for non-bulk freight movements over longer distances. Road transport is more efficient than rail for short freight journeys, and for moving small volumes of freight. The Bureau of Transport and Communications Economics (BTCE) said:

> To the extent that there is contestibility between modes in non-urban freight transport, it is probably largely limited to the interstate segment of the non-bulk task, where there is some scope for rail to increase its share. (Sub. 84, p. 43)

The table below shows freight movements between mainland Australian capitals during 1988-89.

Table F9: **Interstate capital city freight tonnages: 1988-89**

	Road	*Propn. of total*	*Rail*	*Propn. of total*	*Total*
	Mt	*%*	*Mt*	*%*	*Mt*
Sydney[a] Melbourne[b]	5.12	69.9	2.20	30.1	7.32
Sydney Brisbane	1.84	47.2	2.06	52.8	3.90
Sydney Adelaide	0.93	55.0	0.76	45.0	1.69
Sydney Perth	0.19	22.9	0.64	77.1	0.83
Melbourne Brisbane	1.02	72.9	0.38	27.1	1.40
Melbourne Adelaide	1.94	53.9	1.66	46.1	3.60
Melbourne Perth	0.22	25.6	0.64	74.4	0.86
Brisbane Adelaide	0.27	60.0	0.18	40.0	0.45
Brisbane Perth	0.06	54.5	0.05	45.5	0.11
Adelaide Perth	0.12	14.5	0.71	85.5	0.83
Total	11.71	55.8	9.28	44.2	20.99

[a] Sydney includes Newcastle and Wollongong. [b] Melbourne includes Geelong and Westernport.
Source: Laird and Adorni-Bracessi, Sub. D113, p. 2.

F5.1 Potential reductions in carbon dioxide emissions

Australian National (AN) provided detailed calculations of the possible reduction in emissions from a shift in freight from road to rail. Based on improvements in rail infrastructure expected to be made this decade, AN said:

> The modal shift (from road to rail) by 1998-99 would be 4.2 million net tonnes and 7000 million NTK (net tonne kilometres). (Sub. 86, p. 2)

Using average road and rail fuel consumption figures, and relative emission factors, AN concluded:

> The reduction in [greenhouse] gas emissions generated by a 7000 million NTK modal shift from road to rail will be ... 4.41 million kgms. (Sub. 86, p. 3)

George Wilkenfeld and Associates also estimated the reduction in carbon dioxide emissions which may occur if long haul freight is shifted from articulated trucks to rail. Wilkenfeld said:

> The amount of CO_2 saved depends on the ratios of marginal CO_2 -intensiveness of the modes. (Sub. 9, p. 144)

Wilkenfeld estimated this ratio for rail and road freight to be 0.25. Using this ratio, he concluded that carbon dioxide emissions for 1986-87 could have been reduced by some 376 kt, if a 10 per cent shift in freight volumes from articulated trucks to rail had occurred. This was equivalent to around 0.5 per cent of Australia's transport sector emissions.

Wilkenfeld and the BTCE also provided information on truck and rail average emission rates, expressed in grams/tonne km. Using 1986-87 data, Wilkenfeld calculated average emission rates of 27 grams per tonne kilometre for bulk and non-bulk rail, 90 grams per tonne kilometre for articulated trucks, and 250 grams per tonne kilometre for rigid trucks.

The BTCE, using 1987-88 data, calculated average emission rates of 60 grams, 104 grams and 237 grams per tonne kilometre for non-bulk rail, articulated trucks and rigid trucks respectively. The BTCE estimated an emission rate of 29 grams per tonne kilometre for government bulk rail.

However, one problem with using such measures as `proxies' for GHG emissions is they do not take into account the relative efficiency with which each mode performs different freight tasks. The Australian Road Transport Federation (ARTF) said:

> the energy efficiency of each mode holds certain advantages for certain types of operations. Rail is not universally superior to road, nor is road universally superior to rail. (Sub. 24, p. 32)

The Federation also said:

> In general, we consider fuel productivity as the surrogate for greenhouse emissions. That is to say, if the MJ/tonne-km productivity index is reduced 20 per cent by a certain strategy, implicitly it would be expected that there would be a 20 per cent reduction in greenhouse emissions. (Sub. 24, p. v)

The ARTF estimated road and rail energy consumption for four distinct freight tasks. Its data is set out in Table F10.

Table F10: **Comparisons of road and rail energy consumption**
(MJ/t)

Scenario	*Rail*	*Road*		
		Articulated	*B-double* [a]	*Road train* [b]
Mine to port[c]	157	460	388	295
Farm to port[c]	273[d]	460	388	295
General freight[c]	435[e]	302	258	205
General freight[f]	523	310	289	264

[a] A B-double is a double short-trailer articulated vehicle. [b] A road train is a two or three standard length trailer, articulated vehicle. [c] Inter-capital city trip, based on a 400 km road trip and a comparable rail trip 15 per cent longer (to account for lesser grades on railway tracks). [d] Includes an 80 km truck feeder trip for rail at one end of the linehaul. [e] Includes an 80 km truck feeder trip for rail at both ends of the linehaul. [f] Based on a 150 km road trip and a rail trip 15 per cent longer. Includes a 60 km truck feeder trip for rail and a 40 km truck feeder trip for road.
Source: ARTF, Sub. 24, pp. 25-28.

These ARTF figures indicate that emissions could be reduced by shifting bulk freight from road to rail, and by shifting general freight from rail to road. But this conclusion must be qualified by the assumptions on which the calculations were based. In its draft report into rail freight, the Industry Commission said:

> The tabulated results for general freight between capital cities require some qualification. The ARTF results are based on a 400 km road trip which is unrealistic for Australian capital cities. (IC 1991b, Vol. 2, p. 58)

The Commission repeated the ARTF's calculations using actual road and rail distances between Sydney and Melbourne, and using a more conservative estimate of road freight energy efficiency. The results indicate that, taking both factors into account, trains use less fuel than articulated trucks when transporting freight from Sydney to Melbourne door-to-door.

Laird and Adorni-Braccesi estimated the potential reductions in fuel use resulting from a modal shift from road to rail on Australia's ten interstate corridors. These estimates are given in Table F11. Each option is based on an assumed improvement in rail freight fuel efficiency, and on assumptions about the potential improvement in rail freight volumes along particular routes.

The impacts of these assumptions can be gauged by comparing the different options. Comparing options 1 and 2 or 3 and 4 shows the marginal impact of increasing rail freight fuel efficiency by different degrees on different routes. Similarly, comparing options 1 and 3 or options 2 and 4 shows the marginal impact of achieving different improvements in rail freight volumes on different routes.

For example, comparing options 1 and 2 or 3 and 4 shows that increasing rail fuel efficiency an additional net tonne km/MJ on routes other than the Perth-Adelaide-Parkes line, may reduce carbon dioxide emissions by around 75 kt.

Table F11: **Freight tonnages and energy use -- various options**

	Actual	*Option 1* [a]	*Option 2* [b]	*Option 3* [c]	*Option 4* [d]
Tonnage (M tonnes)					
Road	11.7	9.1	9.1	8.3	8.3
Rail	9.3	11.9	11.9	12.7	12.7
Energy use (PJ)					
Road	13.1	9.9	9.9	9.0	9.0
Rail	5.6	4.6	5.5	4.8	5.9
Feeder	1.0	1.3	1.3	1.4	1.4
Fuel (M litres)					
Total use	509.0	409.0	434.0	393.0	419.0
Savings	-	101.0	76.0	117.0	90.0
Reduction in					
CO_2 emissions [e] (kt)	-	292.1	224.7	337.1	254.7

[a] Increase rail efficiency to 4 net tonne km/MJ. Increase rail's share of freight to 50% on medium distance routes and 80% on longer distance routes. [b] Increase rail efficiency to 4 net tonne km/MJ between Perth, Adelaide and Parkes, and to 3 net tonne km/MJ elsewhere. Increase rail's share of freight to 50% on medium distance routes and 80% on longer distance routes. [c] Increase rail efficiency to 4 net tonne km/MJ. Increase rail's share of freight to 50% on short distance routes, 65% on medium distance routes and 80% on longer distance routes. [d] Increase rail efficiency to 4 net tonne km/MJ between Perth, Adelaide and Parkes, and to 3 net tonne km/MJ elsewhere. Increase rail's share of freight to 50% on short distance routes, 65% on medium distance routes and 80% on longer distance routes. [e] Commission estimates, using energy content figures from ABARE (ADO - 38.6 MJ/litre), and carbon dioxide emission coefficients from Wilkenfeld (average for all petroleum products - 74.9 kg CO_2/GJ).
Source: Laird and Adorni-Bracessi, Sub. D113, p. 4.

F5.2 Costs and benefits

Few participants provided information on the dollar costs and benefits associated with achieving a shift in freight from road to rail. AN provided information on the investment in infrastructure planned for the years from 1991 to 2000. AN believes that this expenditure, by improving rail delivery times and other standards of service, will facilitate a modal shift of 4.2 million net tonnes of freight by 1998-99.

Table F12: **Planned national network and equipment upgrades: 1991 – 2000**

	Cost by 2000 (1991 dollars)
	$M
High speed wagon conversion	14.0
Terminal upgrades (7 centres)	158.6
Servicing, fuelling facility upgrade	20.0
Control systems	170.7
Track upgrading on intercapital corridors	1506.9
Standardisation of Melbourne-Adelaide line	154.0
Wagons, roadrailers	206.0
Locomotives	363.1
Other capital (motor vehicles, plant, buildings)	100.0
Total	2693.3

Source: ANR, Sub. 86, p. 2.

Laird provided estimates of the savings in diesel fuel consumption, and other transport costs, of a shift in freight travelling between Sydney and Melbourne from road to rail. He said:

> If the ruling gradients and limiting curvature were improved to Fast Freight Train (FFT) standards, and if rail was to increase its modal share of land freight on the Sydney Melbourne corridor to 70%, there could be savings of roughly 70 million litres of diesel each year. (Sub. 39, p. 2)

This fuel saving would translate into a saving of around 202 kt of carbon dioxide. Upgrading the line to FFT standards could cost around $210 million (exclusive of freight terminals). Hence, carbon dioxide emissions may be reduced by upgrading the Sydney Melbourne rail corridor to FFT standards at a cost of around $1040/tonne of carbon dioxide saved.

Laird and Adorni-Bracessi qualified this estimate of fuel savings in their submission responding to the draft report. They said:

> It now appears to us that ISC/ABS fuel use figures may have overstated average fuel use by six-axle articulated trucks ... As there is room for considerable variation in fuel use between different trucks, and even the same truck depending on whether it is working in urban areas or highways along with how it is driven, the average energy efficiencies should be used with considerable caution. (Sub. D113, p. 3)

They suggest that if an average energy efficiency of around 1.04 net tonne km/MJ is used, rather than the ABS based one of 0.75 net tonne km/MJ:

> the fuel used for 5.12 million tonnes a year of road haulage falls from about 154 to 111 million litres a year, thus significantly affecting the potential fuel saving for modal shift to rail. (Sub. D113, p. 3)

The costs incurred in encouraging modal shift may be partly offset by the benefits of reducing road freight. Some of the benefits mentioned by participants include: reduced road maintenance and construction; reduced noise and air pollution; and less congestion for other road users. The BTCE (1988) estimated the total annual cost of road congestion at about $2 billion.

F5.3 Factors limiting modal shift

There are a number of factors which may be limiting modal shift between road and rail freight. One factor raised by participants was the difference in the quality of present services. The BTCE said:

> Major structural changes are required in rail if it is to offer the quality of service, transit times and rates necessary to win a larger share of the market. This will require improvements in labour productivity and in organisation. (Sub. 84, p. 43)

The ARTF also considered reliability of delivery to be an important factor limiting the use of rail freight services:

> Just-in-time freight is of growing importance to industry today, and such vital aspects of manufacturing must not be compromised by ignoring its importance in transport decisions. (Sub. 24, p. 19)

The lack of integration of Australia's railway systems was seen by some to limit the use of interstate rail services. Some participants suggested a national development strategy for rail is needed to encourage greater use of rail services.

Current funding arrangements for road and rail services were another factor raised by participants. Their comments focused on differences between Commonwealth funding of road and rail services, and on `the current underrecovery of road system costs from heavy vehicle operations' (Laird, Sub. 39, Appendix, p. 4). The BTCE said:

> The road system is a major public investment and there are sources of inefficiency in the way it is funded and managed, and in the way heavy vehicles are charged for using it. (Sub. 84, p. 43)

There have been a number of studies into road pricing in recent years, which participants referred to in their submissions. Laird said:

> Underrecovery of road system costs from heavy vehicle operations was also found in an Australia-wide context by the Bureau of Transport (and Communications) Economics, the National Road Freight Industry Inquiry, the Industries Assistance Commission, and for heavier trucks moving long annual distances, the ISC. (Sub. 39, Appendix, p. 4)

At the recent Special Premiers' Conference, government leaders (with the exception of the Northern Territory) signed an Intergovernmental Agreement establishing a national heavy vehicle registration, regulation and charging scheme. Under the scheme, road charges will be collected from heavy vehicles through a component of the Commonwealth diesel excise and a registration (or mass-distance) charge for those vehicles which do not meet their road costs through fuel payments alone.

Registration charges and the road use charge component of Commonwealth excise on diesel are to be set to recover fully distributed road costs, while minimising overrecovery of costs from any vehicle class.

Uniform national standards for vehicle dimensions, weights and emissions will also be introduced under the scheme. This will address one of the concerns raised by the ARTF, which said:

> Very substantial improvements in productivity per unit energy consumed can be achieved by increasing the greater utilisation of heavier and longer trucks. The limits to such increased use currently lie within the hands of State Governments in the setting of mass and dimension limits within each respective State. (Sub. 24, pp. 9-10)

According to the communique from the Conference:

> As an early priority, the new system will allow the operation of B-doubles and road trains under nationally uniform conditions. While their operation will continue subject to certain limitations such as designated routes, this will lead to significant increases in productivity for some freight operations. (SPC 1991, pp. 14-15)

At the Conference, government leaders and representatives also signed an agreement which formally established the National Rail Corporation. The corporation will become the sole marketer of interstate freight services in Australia in early 1992.

According to the communique:

> The National Rail Corporation is envisaged as a commercial venture. It is expected to break-even within three years and become totally self-supporting after five years...
>
> Leaders and representatives emphasised that the Corporation is to be a commercially run company. Only on this basis will it become a fair and competitive alternative carrier to road transport. (SPC 1991, pp. 22-23)

In its report on rail transport, the Industry Commission made a number of recommendations to improve the efficiency of rail and road transport in Australia. These include:

- that governments eliminate all their subsidies to bulk rail freight;
- that individual freight services, in particular LCL, should be retained only if they at least cover short run marginal costs (including all applicable taxes and financial imposts), and in the longer term make a contribution to fixed costs; and
- that State Governments eliminate all regulation of traffics to rail, with the possible exception of dangerous goods, at the same time as appropriate road user charging mechanisms for pavement damage and externalities are introduced.

These reforms, if implemented, could facilitate modal shift, and hence have some impact on Australia's GHG emissions.

However, the main factor which limits modal shift is the different types of freight the two modes carry. Bulk freight and long haul freight is usually most efficiently carried by rail. Smaller volumes of freight and short haul freight is usually most efficiently carried by road. As a result, the range of freight tasks over which the two modes compete is limited.

F5.4 Summary

- The domestic transport sector is responsible for about a quarter of Australia's carbon dioxide emissions; non-urban freight accounts for about a fifth of the sector's emissions.
- Road is generally more fuel efficient for small freight volumes and for short freight journeys, and rail for large volumes and long journeys.

- Shifting long haul freight from articulated trucks to rail has the potential to reduce carbon dioxide emissions by about 0.5 per cent of Australia's transport sector emissions.

- The main costs of such a shift would result from line upgrading and infrastructure investment; but these would be partially offset by reduced road maintenance, decreased noise and air pollution, and less road congestion.

- The introduction of full road cost recovery for heavy vehicles and reforms to rail pricing through the establishment of the National Rail Corporation will alter the volumes of freight carried by each mode; these changes will affect the level of GHG emissions from the sector, but the net effect is unclear.

- While factors such as low productivity, poor organisation and a lack of integration between state rail systems may restrict the greater use of rail freight, the main factor is the limited range of freight tasks over which the two modes compete.

F6 Urban passenger transport

Urban passenger transport is a significant source of GHG emissions, accounting for around 45 per cent of transport sector emissions, according to the Bureau of Transport and Communications Economics (BTCE). The Bureau said:

> cars are by far the biggest single contributor, being responsible for around 88 per cent of urban transport carbon dioxide emissions in 1987-88. (Sub. 84, p. 36)

These emissions may be reduced by improving car fuel efficiency, by adopting fuels which release fewer GHG emissions than petrol and diesel, and by using modes of transport which release fewer GHG emissions.

The main alternatives to driving cars in urban areas are walking, cycling, and using public transport. Estimates of the proportion of people using each of these modes for three typical urban journeys -- trips to and from work, trips to and from school, and major shopping trips -- for the years 1970 and 1984, are set out in the table below.

The figures, which relate to Victoria, show that the proportion of people travelling by car increased between 1970 and 1984. The use of public transport for journeys to work declined, as did the proportion of people walking to work and walking or cycling to school.

Table F13: **Urban passenger journeys in Victoria, by mode: 1970 and 1984**

Mode	*1970 average propn.*	*1984 average propn.*	*Average distance 1984*
	%	*%*	*km*
Journey to work			
Car	60.9	78.5	11.2
Public transport	25.8	12.5	12.8
Walking	10.6	5.2	0.5
Other	2.7	3.7	
Journey to school			
Car	16.0	36.0	4.0
Public transport	23.2	23.1	8.7
Walking	48.7	31.7	0.9
Cycling	12.2	9.6	1.7
Major shopping trips			
Car		81.1	
Public transport		5.3	
Walking		13.0	

Source: Brotchie et al. (1990b), p. 373.

This section examines the scope for reducing emissions by making greater use of urban public transport. The scope for fuel efficiency improvements and the use of alternative fuels are examined in a later section.

F6.1 Potential reductions in GHG emissions

Carbon dioxide emission rates of buses and urban rail are well below car and light commercial vehicle emission rates (see Table F14).

Table F14: **Emissions from urban passenger transport, Australia: 1987-88**
(grams/pass km)

Mode	*Rate of CO_2 emissions*
Bus	120
Rail	150
Car[a]	190
Light commercial vehicle	270

[a] Based on an average vehicle occupancy of 1.2 people for journeys to and from work, and 2.0 people for non-work related journeys.
Source: BTCE, Sub. 84, p. 36.

But these figures are averages for all urban transport. They do not distinguish between journeys which are more efficiently handled by public transport and those which are more efficiently handled by motor cars. The BTCE said:

> Further research would be desirable to permit a distinction in emission levels by time of day (especially between peak and off-peak) and by routing (for example, between radial and lateral movements). (Sub. 84, p. 35)

The Bureau also said:

> When used for journeys to work, the car will usually have a much worse energy intensity and carbon dioxide emission rate per passenger kilometre than when used for other private purposes. This follows from the especially low average occupancy rate and from the poor energy efficiency resulting from driving in congested conditions ... In other uses, the energy intensity of automobiles may not be very different from that of public transport, and its advantages in utility are usually considerable. (Sub. 84, p. 36)

Similarly, commuter railways and buses are more efficient during peak hours, when moving large numbers of people, than the figures in Table F14 may suggest. The BTCE said:

> In peak-hours, emission intensity per passenger kilometre [for rail] might average roughly a quarter of the corresponding figure for cars with the average journey-to-work occupancy. (Sub. 84, p. 37)

The Bureau added:

> During off-peak periods, low occupancy often implies high energy intensities per passenger kilometre for public transport. For the bus fleet, the major part of energy use (and consequently, the major part of carbon dioxide emission) occurs during off-peak periods. (Sub. 84, p. 38)

George Wilkenfeld and Associates provided estimates of emission rates for urban passenger transport in Melbourne in 1988-89. These differ from those presented by the BTCE for at least two reasons. The BTCE figures relate to 1987-88, whereas Wilkenfeld's relate to 1988-89. Secondly, the BTCE figures are averages for the whole of Australia, and Wilkenfeld's relate to Melbourne.

Table F15: **Emissions from urban passenger transport, Melbourne: 1988-89**

Mode	*Average loading*	*Rate of CO_2 emissions*
	passengers	*grams/pass km*
Govt bus	10.6	120
Private bus	6.9	130
Tram	27.5	140
Rail	103.0	250
Car - all travel	1.5	200
- to/from work	1.2	280

Source: Wilkenfeld, Sub. 9, p. 151.

Wilkenfeld said:

> For the journey to work, all public transport modes appear to have a CO_2 advantage over the car. The transfer of metropolitan Melbourne work trips from car to rail (especially light rail) would have advantages, particularly if the system has spare peak hour capacity, and the extra trips could be accommodated without running more vehicles.
>
> However, work travel accounts for only a quarter of car use, and the higher occupancies at other times reduce the average car emissions to 0.20 kg CO_2/pass-km, less than electric rail. (Sub. 9, pp. 138-139)

Wilkenfeld also estimated the reduction in carbon dioxide emissions which might occur if passengers were diverted from cars to public transport modes. He calculated a reduction in carbon dioxide emissions of around 965 kt per annum, assuming that 1 per cent of car passengers shifted to trams, 2 per cent shifted to electric rail and 2 per cent shifted to buses. This shift would be equivalent to less than one-quarter of car travel to and from work. He qualified the estimate, saying:

> The fuel savings potential of modal changes are extremely difficult to estimate, without detailed modelling of the entire transport system ... Data are needed on the marginal energy consumption of each mode at the times of day when the mode change is envisaged. For example, the transfer of work trips from cars to already heavily loaded peak hour trains may require extra trains and hence more energy, whereas many more passengers could be carried without appreciable energy increase at other times. (Sub. 9, p. 143)

Bessarab and Kenworthy (1991) estimated carbon dioxide emissions for rail, `based on BTCE emission figures and actual data on current system and loading for Sydney and Melbourne' at 124 grams per passenger km, placing `electric rail in the same range as diesel buses in terms of emissions, and considerably less than cars'. (p. 4)

They suggested two reasons why greater use of urban rail systems may reduce emissions. Firstly, the structure of cities changes around rail-based transport, tending to reduce the need for infrastructure and energy use, and therefore reducing emissions.

Secondly, rail journeys tend to be shorter than similar journeys undertaken by road. Based on a survey of 32 cities around the world, Bessarab and Kenworthy suggest this leverage factor may be as high as 3.6 to 1. That is, each additional passenger kilometre travelled by rail reduces the passenger kilometres travelled by road by 3.6.

One reason for this is that people may travel the additional distance on foot or by bicycle, before and/or after each rail trip.

The BTCE also compared the potential to reduce emissions through modal shift against improvements in vehicle economy:

> If patronage of the public transport system during peak periods (assumed to account for 60 per cent of the public transport task) were doubled, by drawing commuters away from private car use, total carbon dioxide emissions would be reduced by no more than could be achieved by an increase in the average fuel economy of the Australian car fleet of between 2 and 4 per cent. (Sub. 84, p. 38)

F6.2 Costs and benefits

Reducing car use would also reduce the other emissions produced by cars -- hydrocarbons, carbon monoxide, and nitrogen oxide. However, greater use of buses and diesel trains could increase particulate emissions. The Australian City Transit Association (ACTA) provided comparisons of emissions from cars and buses, estimated on a passenger kilometre basis. (See Table F16.)

Table F16: **Relative emissions per passenger kilometre of cars and public buses**

Vehicle type	*CO_2*	*CO*	*NOx*	*NMHC*	*Particles*
Car without converter [a]	100	600	300	1000	>200
Car with converter [b]	100	100	100	100	100
Diesel bus [b]	100	21	21	210	165
Gas bus [b]	80	28	28	42	7
Improved gas bus [c]	75 1	4	63	28	7

[a] 1985 model. [b] 1990 model. [c] 1992 model (estimate).
Source: Australian City Transit Association, Sub. 79, p. 5.

Assuming an increase of 15 per cent in the usage of urban public transport, the ACTA estimated reductions in hydrocarbon, carbon monoxide and nitrogen oxide emissions of approximately 322 kt, 2211 kt and 173 kt respectively. The Association also said:

> an increase of 15 % in the usage of UPT [urban public transport] for commuter travel could realise: savings in petroleum of 70,027,650,000 litres of fuel per annum ... This transfer also offers a potential saving of up to $2,600,000,000.00 per annum in purchases of overseas sourced petroleum. (Sub. 79, pp. 3,5)

F6.3 Factors limiting greater use of public transport

Participants mentioned a number of factors which influence the mode of transport people choose to use. Many participants focused on trips to and from work, where the potential to use public transport is greatest. The ACTA said:

> Estimates indicate that 12.5 % of all journeys to the Central Business Districts (CBD) of Australia's cities in peak periods are made using UPT and up to 5 % of all journeys to the CBD are made using UPT. (Sub. 79, p. 1)

But some participants said there may be limited scope for increasing the use of public transport. The BTCE said:

> only a small percentage of urban passenger kilometres are car journeys to work to central areas, perhaps around 6 per cent, and this would be one area where public transport might offer an alternative.
>
> A Melbourne survey found that only 8 per cent of car drivers (and 10 per cent of car passengers) thought they had a convenient alternative [form of public transport], while only 18 per cent of public transport users *had* a car available. (Sub. 84, p. 38)

The AAA also made this point in its response to the draft report:

> The Association is concerned that there is an apparent belief that there is substantial scope to increase patronage levels by a simple transfer from car to public transport. A survey of journey to work and travel requirements will show this not to be the case. (Sub. D136, p. 4)

In any case, the AAA said:

> A transfer of only 10 % of car trips to public transport will almost double the number of public transport trips. The difficulties and costs of such a transfer are considerable and should not be ignored. (Sub. D136, p. 4)

The NSW Government made a similar point in its submission, saying:

> Although public transport efficiently serves urban areas, the widely dispersed origins and destinations of work and leisure related travel are such that private travel is far more economical in many cases. Further, extensive infrastructure investments would need to be made in the public transport system in NSW to provide for even small increases in demand for public transport. (Sub. 100, p. 11)

The NSW transport administration is currently developing a number of strategies including operating feeder buses in growth areas; trying to match services to population levels; introducing more express services; and introducing more park and ride facilities in an effort to increase public transport's modal share.

People's attitudes to public transport are also considered an obstacle to increasing the use of urban public transport services. The Senate Standing Committee on Industry, Science and Technology (1991) commented:

> Unfortunately, public transport has a reputation for being uncomfortable, inconvenient, inaccessible, unreliable and increasingly dangerous in many Australian cities.

> Particular attention needs to be paid to passenger comfort and security, increasing effective catchment areas, improving ticketing and most importantly, to ensuring reliability of service. (p. 79)

Others mentioned the poor reliability of urban public transport services as a factor which discourages its use. The ACTA said:

> The perceived growth in exhaust emissions over the past years has been due [in part] to: inadequate public transport coupled with the convenience of the motor car resulting in very low motor car occupancy rates together with extensive motor car utilisation. (Sub. 79, p. 3)

Changing people's perceptions takes time. And encouraging them to use public transport is different from encouraging them to purchase a more efficient appliance because, as Walker (1990) said:

> [using public transport] require[s] individuals to change behaviour patterns, while technical options are in large part transparent to users. (p. 18)

For example, purchasing a more efficient refrigerator still gives the purchaser the same service -- cold and frozen foods. But using public transport means people may have to change their lifestyle in some way.

Another factor with the potential to limit the use of public transport mentioned by participants was the pricing of facilities used by motorists. The BTCE said:

> Congested urban roads are not usually priced to users. Parking access is frequently underpriced. Developers of both residential and commercial properties are frequently undercharged for the extra demands which their developments place on the urban road and public transport infrastructures. (Sub. 84, p. 56)

Similarly, the Centre for the Environment and Sustainable Development (CESD) said:

> For [a] significant reduction of transport GHG emissions it will be necessary to provide the correct market signals to the consumer. At the moment the consumer is not fully aware of the full financial cost of using cars for trips that could be accomplished by other less costly and more greenhouse efficient methods.
>
> The obscure nature of the cost of using a car contrasts with more obvious cost of using an alternative such as a bus. With a bus the cost is reflected in the fare. (Sub. 29, p. 4)

However, there are often subsidies associated with public transport. Laird said:

> The desirability of alternatives to car use in urban areas is one reason why Governments are prepared to subsidise large operating losses of urban public transport and contribute to the cost of associated capital works.
>
> In the case of Australia's major cities, this includes extensive operating subsidies to urban rail, tram and bus services paid by the State or Territory Governments. (Sub. 39, Appendix, p. 6)

Some participants advocated increasing these subsidies to encourage greater use of urban public transport services. The AAA, opposing subsidies, said:

> [The Association] supports the use of public transport. However the Association does not believe that further subsidisation of public transport is an effective means of achieving ESD or Greenhouse objectives. (Sub. D136, p. 4)

The Industry Commission considered the question of subsidies for public transport in its inquiry into rail transport. The Commission said:

> Studies indicate that car drivers are unresponsive to changes in rail fares. Therefore, it would be difficult to attract them off the road. (IC 1991b, p. 192)

The Commission identified four factors which may limit the scope for modal shift between cars and urban passenger trains:

- many trips cannot be undertaken by rail;
- rail's service is perceived to be poor so that even at very low prices people are not inclined to use it;
- once a person has bought, insured and registered a car the cost of each additional journey is low, making it difficult for rail to compete; and
- the flexibility of car travel is highly valued, so that people are reluctant to change to rail. (IC 1991b, p. 103)

These factors may also limit the scope for modal shift between private cars and other forms of public transport.

The Commission made a number of recommendations to encourage the efficient use of rail services. For urban services, the Commission recommended that existing deficit funding be replaced with community service obligation contracts. Specifically the Commission recommended that:

- if governments require railways to provide community services, the conditions of provision should be set out in contracts, the details of which are made public, and which should include the pre-determined fees to be paid to the railways. All such contracts should be in effect within three years; and
- community service contracts between government and railways should be as specific as possible, identifying exactly what particular market segments or lines are to be explicitly funded as community services. These contracts should also include criteria for evaluation of the performance of the rail authority in meeting each particular community service.

Urban planning

One factor mentioned by participants as an impediment to greater use of urban public transport is the impact of the design of Australian cities on the demand for transport and on the most appropriate form of transport. The Town and Country Planning Association (TCPA) said:

> Urban sprawl is actively promoted by all levels of government at present because the underlying market mechanism is distorted by a whole package of tax incentives, planning regulations and local by laws. (Sub. 34, Appendix, p. 5)

The Association suggested that Australia should:

> accelerate the introduction of town planning and other measures to consolidate existing urban areas and contain all new urban growth along development corridors well-served by public transport. (Sub. 34, Appendix, p. 7)

Many participants suggested increasing housing densities within cities to make public transport more efficient and more effective. The Centre for the Environment and Sustainable Development said:

> Greater integration of working and living areas, especially in the CBD will help to reduce transport's contribution to GHG emissions. (Sub. 29, p. 4)

The ACTA came to a similar conclusion. The Association said:

> a substantial increase in usage of UPT ... will require structural change to higher density living, better UPT, with large parking facilities at feeder stations and a policy of constraining parking in the CBD.

One factor that would also need to be resolved is the dispersal of employment into suburban and regional centres where the economics of UPT [urban public transport] are hampered. (Sub. 79, pp. 11-12)

However, the Australian Automobile Association (AAA) warned against discouraging private vehicle use in and around city CBDs. The Association said:

> Measures aimed at discouraging cars from CBDs could also result in decentralisation of business activity and a consequential reduction in the use of public transport, which tends to be centred on the CBD. (Sub. 14, Appendix, p. 11)

Such changes in Australia's cities could only come about slowly, over time, as the housing stock changes, and as planning regulations are modified to encourage different patterns of settlement and employment.

A number of participants also commented on the role urban planning could play in reducing energy consumption, and hence greenhouse gas emissions, in their responses to the Commission's draft report. They stressed that the links between urban planning, transport and energy consumption were such that a discussion of any one of them also required that some consideration be given to the others. McGlynn, Newman and Kenworthy (1991) said:

> Automobile dependence and urban sprawl feed on and support each other so intimately that it is virtually impossible to study or understand one without the other. (p. i)

The Institute for Science and Technology Policy (ISTP) suggested that urban planning was one area where changes could be made which would reduce carbon dioxide emissions at a low or even negative cost. The Institute said:

> The strong impression from the IC [draft] report is that CO_2 reductions will have costs that are probably excessive. This is not the case in the urban arena where Australian cities are excessively subsidised to produce expensive low density suburbs that are highly energy/CO_2 intensive. (Sub. D124, p. 2)

Greenpeace Australia supported this view, saying:

> Another hidden cost associated with widespread funding of road based transport arises from the resultant sprawling car dependent cities; incorporating energy intensive urban structures.
>
> Governments are currently subsidising urban sprawl at around $35,000 per block for water, electricity, sewerage, roads and up to $70,000 per block if the provision of schools, hospitals, and other facilities are included. (Sub. D117, p. 13)

By increasing urban densities, some of these ‘costs’ may be avoided.

Taking a similar line in its response to the draft report, the TCPA said:

> We are convinced of the need to integrate transport, land use and regional planning for all the coastal capital cities in Australia. It is necessary to put a freeze on all urban sprawl and contain population increase within satellite new towns that are designed with energy-efficient housing and transport facilities as greensite developments. (Sub. D115, p. 5)

The Association went on to say:

> The notion that transport modes can be compared in isolation from the transport system is naive ... car dominated transport systems have certain characteristics compared to other systems. In particular car and public transport travel are not interchangeable because in more greenhouse friendly transport systems the non-motorised modes replace car trips. (Sub. D115, p. 5)

The Association does not consider that changes to a more greenhouse-friendly state would be costless, nor that people would freely adopt those changes. Rather, the Association said:

> A package of regulatory measures, disincentives and subsidies has to be designed to guide market forces and individual initiatives towards sustainable urban development. (Sub. D115, p. 7)

The NSW Department of Planning also commented on the role of urban planning in helping to reduce greenhouse gas emissions. In its Planning Strategy, it said:

> The pattern of land use is one of the main factors determining the fuel efficiency of cities and regions ...
>
> The metropolitan strategy for the Sydney Region aims to create a more compact and efficient city over the next 20-30 years than we would otherwise have. Energy Conservation is one of the strategy's objectives. (Sub. 100, Attachments, Volume 3, Department of Planning, Planning Strategy, p.8)

However, the Department added:

> Land use planning alone cannot achieve a more fuel efficient city. It is essential that transport planning and investment priorities complement land use policies. (Sub. 100, Attachments, Volume 3, Department of Planning, Planning Strategy, p. 8)

Relating this to public transport, the NSW Department of Transport said:

> The ultimate performance of public transport is very much dependent upon the degree of integration of land use and transport planning functions.
>
> Accordingly the Transport Administration is very supportive of land use planning initiatives which promote urban consolidation and promote the growth of sub-regional centres that are located on the heavy rail network. (Sub. 100, Attachments, Volume 3, Department of Transport, p. 6)

F6.4 Summary

- Urban passenger transport accounts for about 45 per cent of transport sector GHG emissions; cars are responsible for nearly 90 per cent of urban transport emissions.

- One means of reducing emissions is through less use of cars and greater use of public transport in journeys to and from work; increasing the share of public transport at other times is more problematical.

- The extent of potential emission reductions is uncertain but may be less than could be achieved by other strategies such as marginally improving the average fuel economy of cars.

- The potential for increasing the share of public transport may be limited by factors such as the dispersed nature of Australian cities, the trend towards decentralised employment, and increasing cost recovery from urban bus and rail systems.

- Introducing reforms into urban public transport along the lines suggested by the Industry Commission's report on rail transport will help improve productivity and efficiency in these areas, and may lead to some reduction in transport sector GHG emissions.

- Greater urban consolidation and regional planning may encourage greater use of public transport systems and reduce total commuter distances travelled, hence reducing total energy use and GHG emissions in urban areas.

F7 Efficiency in the residential sector

The residential sector accounts for about 13 per cent of energy demand and 19 per cent of carbon dioxide emissions in Australia (Wilkenfeld 1991). Energy is used primarily for cooking, water and space heating, refrigeration and lighting.

Many participants said that this sector has considerable potential for reducing energy use and carbon dioxide emissions. They advocated more efficient use of energy in the household suggesting a range of measures which may contribute to the achievement of this efficiency improvement. Several particularly supported the direct use of natural gas and solar energy instead of electricity.

Specific efficiency measures which have been proposed by participants and in studies include: modern gas heaters instead of older models; electric heat pumps instead of electric fan heaters; compact fluorescent lights instead of incandescents; clothes lines instead of clothes driers; higher efficiency refrigerators and clothes washers; low flow shower and tap fittings; cooking with microwave ovens; improved water tank insulation; lagging.

F7.1 Carbon dioxide emissions

In the residential sector, electricity provides 43 per cent of the energy used but is responsible for 75 per cent of the carbon dioxide emissions. Gas provides 29 per cent of energy (10 per cent of emissions), followed by wood/solids with 24 per cent (14 per cent) and oil 3 per cent (1 per cent). Space heating/cooling accounts for 43 per cent of the energy used in the residential sector and water heating 26 per cent. The other applications, mainly cooking, refrigeration and lighting, each account for less than 10 per cent (Wilkenfeld 1991).

Heating water and household heating/cooling are two activities which together account for slightly over half the carbon dioxide emissions for which the residential sector is responsible, and almost 10 per cent of total Australian carbon dioxide emissions. Other residential activities account for another 9 per cent of total carbon dioxide emissions (see Table F17).

Table F17: **Carbon dioxide emissions in the residential sector**

	Emissions	*Sector*	*Total*
	Mt	*%*	*%*
Water heating	13.6	26.8	5.1
Space heating & cooling	12.9	25.5	4.8
Cooking	4.5	8.9	1.7
Refrigeration	7.7	15.3	2.9
Lighting	3.2	6.3	1.2
Other	8.7	17.2	3.3
Total	50.7	100.0	19.0

Mt = mega tonnes.
Source: Based on information in Wilkenfeld (1991).

F7.2 Potential to reduce carbon dioxide emissions

Several estimates have been made of the potential to reduce carbon dioxide emissions attributed to energy use in the residential sector. These highlighted the substantial possible energy savings in water and space heating and the potential for fuel switching.

Wilkenfeld estimated that possible reductions in carbon dioxide emissions from the residential sector could amount to 16.8 Mt or a decrease of 33 per cent (using data for 1986-87 as the base case). Over three-quarters of the total potential savings are estimated to come from reduced use of electricity (see Table F18). Emissions from water heating and space heating/cooling are estimated by Wilkenfeld to each have the potential to fall by over 40 per cent and together have the potential to account for almost 70 per cent of the reduction in emissions in the residential sector (see Table F19).

Table F18: **Residential sector carbon dioxide reductions, by energy form**
(per cent)

	Individual saving	*Share of total saving*
Electricity	34.0	77.0
Gas	-8.4	-2.4
LPG	2.1	0.1
Oil	18.5	0.6
Wood/solid	60.4	24.8
Total	33.1	100.0

Source: Based on information in Wilkenfeld (1991).

Table F19: **Residential sector carbon dioxide reductions, by end use**
(per cent)

	Individual saving	Share of total saving
Water heating	43.4	35.1
Space heating/cooling	44.1	33.9
Cooking	30.9	8.3
Refrigeration	22.2	10.2
Lighting	19.9	3.8
Other electrical	16.5	8.6
Total	33.1	100.0

Source: Based on information in Wilkenfeld (1991).

Other studies, although done on a different basis, support Wilkenfeld's finding that considerable reductions in emissions could be in made the residential sector. A study published by Walker (1990) estimated that there was potential to reduce emissions in the residential sector by almost 9 Mt of carbon in 2004_05. The Australian Minerals and Energy Council (1990) similarly found that energy policies have the potential to reduce emissions by 8.9 Mt tonnes in that sector in 2005. The Council considered there could be a fall in the sector's carbon dioxide emissions from a forecast growth of 39 per cent over the period 1989-90 to 2004-05, to a reduction of 19 per cent.

Greene (1990) estimated that the adoption of `efficiency improvements and fuel substitution for end uses' could result in a 19 per cent reduction in carbon dioxide emissions below 1988 levels (virtually achieving the Toronto goal) and that the percentage reduction could be greatest for the residential sector. Greene estimated that by 2005, carbon dioxide emissions from residential energy use could be reduced to 48 per cent below the 1988 level. Major contributors could be a 76 per cent decrease in the use of electricity for water heating through use of gas boosted solar heaters, a 70 per cent reduction in energy use for lighting due to compact fluorescent lights, and reduced use of energy for refrigeration due to more efficient models and fewer second refrigerators.

Some studies had a narrower focus and estimated carbon dioxide reductions which could be achieved in specific areas of the residential sector. The Australian Gas Association stated that about 7.6 Mt per year of carbon dioxide emissions could be avoided if the full potential of switching from electric to gas appliances were realised. The major potential savings were estimated to be in hot water systems (60 per cent) and to be in the States of Victoria and NSW (over 80 per cent). The Association stated that a reduction of 7.6 Mt is equivalent to about 3 per cent of total Australian carbon dioxide emissions in 1988 or 1.3 per cent of GHG emissions.

The Business Council of Australia's 1991 study assessed opportunities for reduction in electricity consumption in residential water heating and residential refrigeration. The study took into account practical considerations such as the low water heater replacement rate and restricted access to natural gas in the case of water heating. The long service life of refrigerators and the difficulty of improving energy efficiency with CFCs being phased out was taken into account in the case of refrigeration. The BCA concluded that the reduction in electricity which could realistically be achieved in forecast demand for 2005 was about 30 per cent for residential water heating and 25 per cent for refrigeration.

Dr D Mills said that in a program funded by the Electricity Commission of NSW the least expensive options for reducing GHG emissions in a typical Sydney home are being investigated. Solar collectors have been designed which should replace 90 per cent of the thermal energy used in the home, including space heating, water heating and cooking. Dr Mills said that initial indications are that this new solar approach, which requires limited off-peak backup, may be cost effective at current energy prices.

F7.3 Costs and benefits

Most participants and studies concentrated on the potential benefits arising from energy conservation and energy efficiency and the consequent reductions in GHG emissions. Proposed measures were commonly said to be cost-effective or to have short pay-back periods.

A few participants drew attention to the likelihood that moves to improve efficiency could impose costs which are likely to fall inordinately on the poor. The United Mineworkers' Federation of Australia said that those who have little wealth also have little choice in their work, consumption and lifestyle. The costs of achieving ecological sustainability, the Federation said, must be borne equitably and cannot be at the expense of the disadvantaged. The Energy Action Group stated that the relatively high capital costs associated with energy-efficient technology means that low income consumers have less access to the better technology than high income consumers.

F7.4 Factors limiting implementation of energy-saving measures

Participants nominated a number of factors considered to impede achievement of greater efficiency and reduced carbon dioxide emissions in the residential sector. Several comments related to impediments to the replacement of existing appliances with others which use more environmentally friendly fuels. For example, the effect of low off-peak electricity tariffs, the Australian Gas Association said, has slowed the penetration rate of gas appliances. AGL referred to the extra cost imposed on gas distribution because common trenching is not allowed in NSW, although it is permitted in the ACT.

The Centre for the Environment and Sustainable Development said that in the provision of services such as hot water, suppliers of energy based on fossil fuels have a competitive advantage as users are not faced with up-front capital costs like users of solar power. The Australian Gas Association said that a similar problem applies to gas. The Association stated that the purchase of high efficiency gas appliances often involves an initial cost penalty and consumers tend to apply a very high discount rate to future savings on energy costs.

Several participants drew attention to the need for information services. The Australian Conservation Foundation, for example, said private households generally have limited knowledge about the possibilities for energy savings and a lack of skills to implement them. The Shell Company of Australia said that there may be a case for governments to provide information to the community with the intention of encouraging the adoption of more efficient energy strategies but warned this needs to be handled very carefully to ensure that a balanced message is delivered.

The Commonwealth and State Governments currently provide information to the public on energy conservation and energy efficiency measures. The form this has taken ranges from energy advisory and educational services to appliance energy labelling. These types of arrangements fill an information gap while allowing the energy users to make their own choice.

Energy labelling of major electricity appliances is compulsory in NSW, Victoria and South Australia. In other states it is voluntary. The label follows a standard method of rating energy efficiency and energy consumption which provide information to the consumer about energy use. For gas water heaters and gas space heaters, the Australian Gas Association has introduced a self-regulatory energy labelling scheme.

There have been some suggestions that the effects of education and the provision of information to consumers may be ephemeral if not persisted with or reinforced with stronger measures. The United Mineworkers' Federation of Australia said reductions could be achieved in the residential sector if people could be persuaded to alter the way they heat and light their homes, travel to work and take their recreation, although the extent to which this could be achieved by simple education and information programs is debatable. The Australian Gas Association said that a comprehensive education program would help improve public understanding of the issue, but practical government approaches are also required.

Mandatory minimum efficiency standards imposed by governments is one method of reducing energy use which has been proposed. This has the advantage of more certain reductions in the long term. However, it can raise other issues of cost and equity. Further, ABARE (1991b) has stated that higher capital costs from mandatory standards can encourage deferral of the scrapping of energy inefficient units already installed, and in the short term they could theoretically even reduce the average energy efficiency of the installed stock of equipment.

Another approach proposed by participants such as the Australian Gas Association is for relatively low sales tax on gas appliances. This raises issues about the role of the sales tax system and whether it should be used to discriminate between similar types of goods on the basis of relative technical efficiencies. It has also been proposed that all new State housing should have gas heating and cooking appliances installed. This would have the advantage of reducing emissions, but would also raise costs.

ABARE (1991b) said that taxes and subsidies appear to be a preferable policy to mandatory standards. However, to correctly set such policies requires more information than is available to the public sector. ABARE said that inappropriate settings could even reduce welfare below that in the absence of government intervention.

Some participants said that current distortions in the pricing of energy lead to excessive use and resultant high levels of emissions. George Wilkenfeld and Associates, for example, stated that energy prices which better reflect costs of production are among a range of measures needed to overcome barriers to energy efficiency improvements.

In the report on `Energy Generation and Distribution' (1991a) the Commission included a number of recommendations which should have the effect of removing impediments to competition between electricity and gas. For example, under the recommendations, exclusive franchising arrangements would be freed-up and regulations obstructing interstate trade in gas removed. These are discussed in Section F3. They should increase the ease with which gas can be used as a direct source of energy in the home. The report also recommended the cessation of cross-subsidies which provide electricity for residential use at concessional rates, most of which is generated using coal and which competes with the direct use of gas.

F7.5 Summary

- The residential sector currently accounts for around a fifth of total carbon dioxide emissions in Australia, with heating water and home heating/cooling responsible for around half residential emissions.
- Substantial reductions could be made in these emissions in various ways such as using energy less often, adopting more efficient appliances, and using less electricity and more natural gas and solar energy.
- Information and education can play a role as components of strategies to reduce GHG emissions.
- Extending the existing energy labelling schemes for appliances could further encourage energy efficiency.
- Mandatory minimum efficiency standards would achieve reductions in the long run; they would also raise issues of cost and equity.

- Selective taxes and subsidies for appliances would also achieve reductions; but taxes also raise costs, and there could be problems in determining levels and coverage.

- Reforming the energy generation and distribution sector should increase the ease with which gas can be adopted for direct use in homes.

F8 Motor vehicle fuel efficiency and alternative fuels

Motor cars are a principal source of transport sector carbon dioxide emissions. In 1986_87, cars and station wagons accounted for about 50 per cent of total transport sector carbon dioxide emissions (Wilkenfeld 1991). This section examines how these emissions might be reduced through fuel efficiency improvements, and the adoption of alternative fuels.

F8.1 Fuel efficiency improvements

Average new car fuel consumption has declined steadily since 1979, largely as a result of changes in vehicle technology. According to the BTCE:

> In 1979 the average fuel economy rating of new cars was 10.9 litres per 100km in Australia ... By 1988 the new car average in Australia had fallen to 9.1 litres per 100km. (Sub. 84, p. 17)

Wilkenfeld said:

> There is no doubt that the fuel efficiency of the transport sector could be much improved. The principal proof of this is the fact that it has improved considerably already, and continues to do so, albeit at a diminishing rate. (Sub. 9, p. 139)

Participants suggested that future developments were likely to focus on improving transmission and driveline efficiencies and body aerodynamics. Some also expected small improvements in engine efficiencies.

Potential reductions in GHG emissions

Some participants estimated the potential reductions in fuel usage associated with ongoing technical development.

Their estimates differ because participants assume different improvements in fuel efficiency are made, and they assume that fuel improvements filter through the Australian fleet at different rates. Most assume all reductions in fleet average fuel consumption come through vehicle replacement, rather than through vehicle modifications.

The lowest estimate of potential improvements was presented by the Federal Chamber of Automotive Industries (FCAI):

> FCAI member companies will aim to progressively reduce, on a voluntary industry basis, the national average fuel consumption of the new car fleet by a further 5 per cent by 1995. This would represent a NAFC [national average fuel consumption] of 8.7 L/100km based on the present model mix. Further target reductions to 8.2 L/100km by 2000 and 8.0 L/100km by 2005 would represent a further NAFC improvement of 13% between 1989 and 2005. (Sub. 62, p. 6)

In its response to the Commission's draft report, the FCAI said:

> Technology for incorporation in domestically produced cars is largely sourced from overseas, primarily from Japan and the United States. The domestic industry is therefore very much `locked-in' to the adaption of proven new technologies from overseas vehicle and component suppliers at a time when those technologies become readily and economically available. (Sub. D143, p. 2)
>
> Should there be a new and concerted international push to reduce fuel consumption through the widespread adoption of new design technologies in major world automotive centres, national average fuel consumption could fall below 8 litres/100 kilometres. This process could also be helped if the model mix on a sales basis evolves to a smaller car preference. (Sub. D143, p. 4)

Others said such improvements may be possible now if local manufacturers adopted the best of existing technology. The Australian Automobile Association (AAA) said:

> Cars exist which achieve fuel consumption rates of less than 6 litres per 100 kilometres ... Current AAA policy recommends that the vehicle industry be encouraged to develop more fuel efficient vehicles with a target NAFC of 6.0 litres per 100 kilometres by 2000. (Sub. 14, p. 2)

Hagen and Kenaff referred to the FCAI's target in their submission on the draft report saying:

> The FCAI offer to improve to 8 l/100 km by 2005 is clearly foot dragging reminiscent of Detroit's performance since 1974 ... at least 50% improvements in car fuel efficiencies are commercially available now with further improvements in technology possible. (Sub. D148, pp. 14-15)

The AAA also estimated the reductions in fuel savings if the FCAI and the AAA targets were reached:

> If Australia can achieve the AAA target of 6 L/100 kms then fuel consumption savings of about 25 per cent are obtainable. If the FCAI target of 8 L/100 kms is achieved then savings of approximately 15 per cent will be obtained. (Sub. 14, p. 3)

Carbon dioxide emissions are directly related to fuel use, so moves which reduce current fuel use by a fixed percentage, for example by 25 per cent, will reduce current carbon dioxide emissions from cars roughly by the same proportion.

Wilkenfeld calculated that car carbon dioxide emissions would be reduced by about 27.6 Mt, assuming an improvement in car fuel efficiency of 20 per cent on current levels. (Sub. 9, p. 154)

> However, the most rapid way to improve fleet efficiency would be for purchasers to select more fuel efficient models from the existing range ... diverting sales from the mean to the most efficient in each size class would have reduced the average consumption of the new vehicle fleet by about 6% to 8.55 l/100km ... Downsizing the fleet one class would have improved efficiency by over 14%, and if additionally there were shifts to the most efficient in each class, the total reduction would be about 22%. (Sub. 9, p. 140)

Walker (1990) estimated the reduction in carbon emissions leading from improvements in car fuel efficiency:

> Overall, it seems that reductions (in fuel consumption) of up to about 30% on 1986-87 levels may be achievable without strong Government intervention. Assuming that the fuel consumption of the fleet as a whole is reduced by the same relative amount as fuel use by new vehicles, this would result in savings of 5.85 mtC annually by 2005 compared with the continuation of current patterns and practices. (p. 14)

Greene (1991) estimated a 40 per cent reduction in current car fuel consumption would be possible through downsizing[7], continuous gearing, electronic ignition and aerodynamics. She based this estimate on:

> the best technologies known to be currently available internationally, compared to the current average stock in Australia. (p. 7)

Marks, Swan, McLennan, Schodde, Dixon and Johnson (1989), in a report to CRA Ltd, examined the reduction in fuel consumption possible if all potential fuel efficiency improvements available today were introduced. These include: making all new cars open-chamber diesel powered; reducing tyre rolling resistances; reducing aerodynamic drag to 0.3; using continuously variable transmissions with a range of up to 10:1; reducing weight; and turning engines off while idling and coasting. They said:

> This would increase the average fuel efficiency of the new vehicles from 11.0 l/100 km in 1988 to an extreme of 4.6 l/100 km in 2005, an extraordinary reduction, if it occurred. (p. 52)

Walker (1990) also referred to overseas studies into fuel efficiency improvements:

> In the USA, estimates of the technologically achievable fuel consumption of new vehicles range to as low as 6.2 litres/100 km by 1995. However, the same study suggests a more realistic scenario for the US is 7.4 litres/100 km by that time. (p. 13)

The Plastics Industry Association provided estimates of reduced emissions associated with the use of plastics in car bodies:

> The substitution of steel components by 70 kg of plastics in a car has been shown to reduce fuel consumption by 4.5%. This could result in an estimated saving of 432 million litres of fuel in Australia each year, and almost one million tonnes of carbon dioxide and nitrous oxides. (Sub. 88, p. 4)

Costs and benefits

As well as reducing greenhouse gas emissions, some of the other benefits participants mentioned which could flow from an improvement in car fuel efficiency included: reduced energy demand; reduced energy imports; and reduced urban air pollution.

7 'Downsizing' occurs when a person purchases a smaller class of vehicle, in terms of body and engine size, than the vehicle they currently use, or than they would currently prefer to drive.

Participants did not provide many estimates of the cost of introducing fuel efficiency improvements. Marks et al. (1989) said:

> The drastic improvements in fuel efficiency [mentioned above] can do no more than hold the growth in fuel use by road transport to 16.2 per cent by 2005 ... and at a cost of at least a 25% increase in the price of a new vehicle in real terms, and unspecified costs on the part of the petroleum refinery industry in increasing their production of ADO [automotive diesel oil] and reducing their production of motor gasoline. (p. 52)

The BTCE provided estimates of the costs of reducing fuel consumption overseas. A cited study, by Difiglio, Duleep and Greene, estimated the capital costs of reducing fuel consumption to 6.9 litres per 100 km at $US 372 per car. An additional reduction to 6.5 litres per 100km was estimated to cost an additional $US 492 per car. And radically downsizing the US fleet was expected to reduce fuel consumption to 5 litres per 100km, but at a cost estimated at $US 3500 per car (sub. 84, p. 22). The BTCE also said:

> Some of the improvements in car technology could be more costly, particularly in Australia, than is anticipated in ... the Difiglio study. (Sub. 84, p. 24)

Several participants commented on the Difiglio study in their responses to the draft report. For example, the FCAI said:

> This [Difiglio] paper has been widely debated and evaluated in North America. This extensive review has shown the study overestimates the fuel consumption improvements that can be achieved through the technological processes reviewed.
>
> FCAI has evaluated the potential of the technologies listed by Difiglio, using material developed by General Motors Corporation applied to the new car fleet composition of Australia. The outcome was a NAFC of 7.2 litres/100 kilometres, but to the `maximum technology' case described in that paper which was claimed to result in 6.0 litres/100 kilometres. (Sub. D143, pp. 4-5)

The Chamber also questioned the costs cited in the Difiglio study, saying:

> In the case of the Difiglio study, costing is supplied by the authors ... This cost does not reflect the impact retail price translation effect, nor does it take into effect the lower production volumes of the Australian industry. Higher estimates have been made by a more recent study. (Sub. D143, p. 5)

General Motors Holden (GMH) also expressed doubts about the study, saying:

> The Difiglio study severely overestimates the fuel consumption benefits to be achieved through the technological changes surveyed. (Sub. D146, p. 8)

Using data developed by General Motors Corporation and applying it to the new car fleet composition of Australia, GMH calculated a NAFC of 7.2 litres per 100 km. This compares with the results of the Difiglio paper which suggests that such measures should result in a NAFC of 6.0 litres per 100 km, and with the figure of 8.0 litres per 100 km which the FCAI consider a feasible target for new car fuel economy to reach by 2005.

GMH added:

> It is important to recognise that the technology level which resulted in the figure of 7.2 litres per 100 km constitutes an ‘ultimate’ case, not a practical or economically viable case. It reflects full deployment of all listed fuel saving technologies regardless of practical considerations. (Sub. D146, p. 8)

GMH did not estimate the cost of achieving this reduction but said it considered this cost to be substantial. It also emphasised that improvements in vehicle technology could only be implemented in Australia after they were adopted in most other countries. Elaborating on this point, GMH went on to say:

> Australian car manufacturers and importers stand ready to adopt cost effective technological improvements, provided they are first adopted by overseas affiliate companies. On the other hand, if they are not adopted by overseas affiliates, no amount of regulatory pressure can induce their incorporation into any but the two Australian cars which are locally designed. Even in the case of local design, it is only possible to select from existing technologies, the development costs of which have been amortised over higher volumes than those achievable here. (Sub. D146, p. 9)

GMH also commented on the `costs' of `downsizing' the US car fleet according to the Difiglio study. GMH said:

> The Difiglio study also notes that an effect of a downsizing policy would be to cause major write-off of existing capital investment in the car industry, cancellation of planned new investment, loss of employment, reduced exports and increased imports. These costs do not appear to be encompassed in the $US3,500 figure quoted in the report. (Sub. D146, p. 11)

Factors limiting greater uptake of fuel efficiency improvements

Some participants questioned why Australian manufacturers did not include all the technological devices currently available in their cars. The Town and Country Planning Association said:

> Proven technology needed to drive 30 kilometres on a litre of petrol already exists. (Sub. 34, Appendix, p. 10)

The Association called for government intervention to ensure that the car industry uses this technology.

But local manufacturers said they introduce fuel saving technology as it becomes available, and when it is profitable for them to do so. GMH said:

> most Australian cars are made to the same design as overseas cars and have much the same fuel consumption as the overseas models. The remaining local cars are designed around modern overseas technologies, resulting in similar fuel consumption to overseas equivalents. (Sub. 58, p. 7)

The FCAI commented on delays in the uptake of fuel saving technology by local manufacturers. The Association said:

> The size of the locally manufactured vehicle market in Australia, with consequent lower volume production runs and longer model cycles, means that Australian industry have to adopt globally-developed technologies at a later time than those with larger domestic markets like Japan, USA and Europe. (Sub. 62, p. 5)

Fuel consumption standards

Participants suggested introducing fuel consumption standards, enforced by the government, which would require local manufacturers to improve new car fuel efficiency, or pay a penalty for failing to do so. The AAA said:

> One way to achieve a more open and competitive market is for a National Average Fuel Consumption target to be specified by the Government. (Sub. 14, p. 2)

The Council of ACT Motor Clubs said:

> Given that voluntary reductions in AFC [average fuel consumption] have shown little capability in achieving more than slight real improvements in AFC ... the Council recommends that Australia should introduce measures to mandate reductions in new vehicle fuel consumption. (Sub. 95, p. 8)

The Shell Company of Australia opposed regulated fuel consumption standards on a number of grounds. For example:

> [they] require that firms devote resources which could have been used elsewhere to the design and development of new, more fuel efficient cars. Hence there is a direct cost involved, which may be higher than consumers would have been prepared to bear had their choice not been constrained. (Sub. 52, p. 27)

They may also increase energy use by making cars more expensive, which may lengthen the economic lives of existing, less fuel efficient cars.

Several participants commented on the role of fuel consumption standards in their submissions responding to the draft report. The FCAI said:

> FCAI is opposed to the introduction of specific consumption standards or CAFE [Corporate Average Fuel Consumption]-type procedures believing they have been shown to be ineffective in the United States, are likely to disadvantage domestically produced cars and incorrectly place emphasis on supposed fuel efficiency as opposed to actual fuel usage. (Sub. D143, p. 7)
>
> Any policy options introduced to achieve a lowering of the national average fuel consumption of new cars beyond the technical or economic capability of industry to deliver can only resort to `downsizing' to achieve their objectives. (Sub. D143, p. 2)

Hagen and Kenaff took an opposing view, saying:

> mandatory standards have been the most effective method of achieving least cost to consumers as well as least total costs to society. Australia is indirectly benefiting from the standards imposed by other countries, but is not seeing the full benefits to the economy that could be obtained from major increases in automotive fuel efficiency.
>
> We recommend legislation that specifies that the fleet efficiency of new vehicles should be greater than some weighted average of the efficiency of new vehicles in California, Japan and Europe so that there is a continual tightening of efficiency standards. Mandatory efficiency labelling should include life cycle costs including fuel and external costs as well as quantity of greenhouse gases generated. (Sub. D148, p. 15)

Impediments to imports

There may also be factors impeding the importation into Australia of more fuel efficient foreign built cars. The Council of ACT Motor Clubs said:

> Compared with new vehicles sold in overseas countries, the average new vehicle sold in Australia is larger, more powerful, and less fuel efficient. (Sub. 95, p. 5)

The AAA suggested that:

> Cars exist which achieve fuel consumption rates of less than 6 litres per 100 kilometres. Many of these cars are not available in Australia. The Association believes that the market currently inhibits the importation of fuel efficient vehicles. (Sub. 14, p. 2)

Rather than reflecting some market impediment, however, this may reflect the small part fuel costs contribute to the total cost of owning and operating a car. Factors such as initial cost, performance, comfort and safety may have a greater influence on buyers' choices than petrol prices.

But sudden, significant increases in petrol prices may influence car buyers, as happened when Australia adopted world parity petrol pricing in the 1970s. However, such `shocks' have not tended to influence new car buyers for long.

Laird said:

> [Following] the raising of the price of petrol ... sufficient numbers of smaller and/or more fuel efficient cars were sold to improve the average car fuel efficiency in Australia, [but] the demand for car travel has continued to increase. (Sub. 39, Appendix, p. 6)

The age of the vehicle fleet

The average age of the Australian vehicle fleet was considered by some participants to be an impediment to introducing new technology. For example, the MTAA said:

> One of the major environmental factors which needs to be taken into account in Australia is the increasing age of the motor vehicle fleet. (Sub. D131, p. 3)

The MTAA suggested there was a need for further research into ways of reducing the average age of the Australian vehicle fleet in order to reduce environmental pollution and greenhouse gas emissions in the long term. The Association said:

> MTAA considers that a significant contribution could be made to reducing greenhouse gas emissions if all registered vehicles were required to undergo annual inspections to ensure that they comply with emission standards. (Sub. D131, p. 5)

This point was also made by the FCAI, who said:

The FCAI supports actions to reduce the age of the vehicle fleet in order to improve not only greenhouse gas emissions but also other emissions, vehicle safety, leaded petrol usage, etc. (Sub. D143, p. 7)

The BTCE cited three reasons why the average age of the motor vehicle fleet may have risen: vehicle design lives have been increasing; the real cost of new cars has been rising; and high interest rates have discouraged borrowing. By reducing the demand for new cars, these factors may have also encouraged local manufacturers to delay the introduction of new technology.

However, the Council of ACT Motor Clubs saw little reason to increase the rate of turnover of the vehicle fleet. The Council said:

> as vehicles age, their average annual travel is for progressively shorter total distances ... Additionally, older vehicles tend to be owned by less affluent sectors of the community who find operating costs a constraint on the extent of vehicle use. (Sub. 95, p. 4)

The Council also said:

> A very high proportion of new vehicle sales are believed to be for `company' or `business' cars. Because purchase and operating costs are not a constraint on the individual user, demand in this area is relatively inelastic to other than the broader economic state of industry. (Sub. 95, p. 7)

Another consideration is that turning over the vehicle fleet more rapidly would require increased use of energy for vehicle manufacture. The increase in GHG emissions from this additional energy should be offset against the reduced emissions of a more efficient vehicle fleet.

Two factors which may hasten the introduction of fuel saving technology are: greater competition between local and overseas manufacturers; and a demonstrated willingness on the part of new car buyers to pay for improvements in fuel efficiency.

In its recent report on the automotive industry, the Industry Commission recommended reducing assistance to local car manufacturers by reducing tariffs on imported cars. The Commission said:

> assistance can inflate the price of new cars and thereby reduce the scrapping rate of older and more polluting vehicles. Thus, implementation of the Commission's proposals -- which would place downward pressure on new car prices -- should be environmentally beneficial. (IC 1990, p. 170)

The Commission's proposals may also place greater pressure on local manufacturers to meet the fuel efficiency standards of imported cars. This may hasten the introduction of new fuel saving technology by local manufacturers.

However, the Commission also considered:

> that industry policy measures should not be tailored specifically to achieve environmental objectives: rather, such objectives are generally best pursued through direct measures. This suggests that, once policies governing vehicle emissions are in place, vehicle producers should be allowed to adjust their production and marketing decisions as they see fit. By augmenting rather than supplanting market forces, such an approach should achieve environmental objectives in a way that least distorts consumer preferences, and hence maximises overall community well-being. (IC 1990, p. 170)

F8.2 Alternative fuels

The main alternative transport fuels to petrol are diesel, liquefied petroleum gas (LPG), compressed or liquefied natural gas (CNG or LNG), methanol and ethanol. Hydrogen, electricity and solar power are being developed as alternatives to petrol.

Potential reductions in carbon dioxide emissions

Participants provided a range of estimates of the changes in emissions which may occur from using alternative fuels in motor cars. The estimates are expressed in terms of carbon dioxide and carbon emissions, and also vary depending on whether emissions released during production and distribution are taken into account. Another source of variation is how other emissions (for example, methane and nitrous oxides) are treated. In the case of Wilkenfeld's estimates, for example, they are converted into carbon dioxide equivalents and added to actual carbon dioxide estimates.

Wilkenfeld provided estimates of carbon dioxide emission coefficients for four alternative transport fuels: petrol; diesel; CNG; and LPG. These were: petrol - 241 grams/km; diesel - 201 grams/km; CNG - 200 grams/km; and LPG - 204 grams/km.[8] (sub. 9, p. 153) He said:

> This analysis suggests that the three [other] fuels are about equally desirable as alternatives to gasoline, and that there is little greenhouse emissions advantage to be gained by substituting CNG or LPG for diesel. (Sub. 9, p. 142)

He also estimated the impact on transport sector emissions if most of Australia's road fleet was converted to natural gas:

> If 50% of trucks and buses were converted, 3% of transport sector CO_2 would be saved, and if 50% of all vehicles were converted, the savings would be 15.5%. (Sub. 9, p. 143)

However, he did not expect such a shift to occur. Rather, he assumed:

> that the potential for cost-effective conversion to lower CO_2 alternatives (LPG, diesel or CNG) is 1% of the light vehicle fleet, 5% of utilities and panel vans ... 5% of buses ... 2% of trucks ... (Sub. 9, p. 143)
>
> These shifts would reduce carbon dioxide emissions by around 41 kT, 47 kT, 8 kT and 29 kT respectively. (Sub. 9, p. 154)

The BTCE also provided estimates of the net change in carbon dioxide emissions of using certain alternative fuels in place of petrol.

8 Wilkenfeld assumed a CH_4 equivalence ratio of 6 and an N_2O equivalence ratio of 350.

Table F20: **Greenhouse emissions of alternative transport fuels**
(per cent)

	Change in greenhouse emissions, CO_2 equivalent
Petrol from gas	0 to +30
Diesel from gas	0 to +30
Liquefied petroleum gas	+10 to +14
Compressed natural gas	-19
Methanol from gas	-3
Methanol from coal	+51
Methanol, ethanol from biomass	-100
Electric, hydrogen from non-fossil	-100
Electric from coal	+26
Electric from natural gas	-18

Source: BTCE, Sub. 84, pp. 27-28.

The BTCE made additional comments on the use of ethanol:

> Estimates of the net carbon dioxide emissions from use of ethanol from biomass vary widely. Rogers argued that net emissions would be nearly zero because the atmospheric carbon dioxide consumed in photosynthesis would offset that released in burning the fuel. However, this would be the case only if the feedstock crops did not displace other crops or natural vegetation, and if no carbon-based energy were consumed in fertilising, harvesting and processing the crops. (Sub. 84, p. 31)

The Bureau also said:

> The NSW Department of Minerals and Energy study concluded that ethanol produced from sugar cane could generate emissions of 34 to 40 per cent of those of gasoline, since bagasse would provide additional energy to be used in the conversion process. (Sub. 84, p. 31)

The Australian Institute of Agricultural Science (AIAS) estimated a reduction in carbon emissions of 2 Mt a year could be possible if all cars began using a 10/90 ethanol-petrol blend.

Walker (1990) provided estimates of the reduction in carbon by using LPG in place of petrol, and of using natural gas to replace diesel. Due to constraints on supply, LPG would be able to displace at most an additional 15 PJ of petrol by 2005. This would reduce emissions by about 0.06 MtC.

Regarding natural gas as a transport fuel, Walker (1990) said:

> the balance of evidence suggests that there would be a net reduction in greenhouse gas emissions of 20-25%. (p. 16)

Walker (1990) also estimated that if natural gas replaces 10 per cent of diesel fuel used for road transport by 2004 -5, emissions may be reduced by 0.15 MtC. (p. 16)

Walker (1990) concluded:

> Other alternative transport fuels, such as synthetic fuels from natural gas, are mildly greenhouse negative or strongly greenhouse negative (eg synthetic fuels from coal or oil shale). (p. 17)

In a submission responding to the Commission's draft report, the Australian Gas Light Company (AGL) said:

> Use of natural gas in vehicles, with currently available technology, could remove around 20 per cent of the 21 million tonnes of CO_2 emitted annually from petroleum fuelled vehicles. AGL proposes an initial substitution level of 1.6 PJ by 1995, mainly in buses. (Sub. D121, Attachment, p. 3)

Costs and benefits

Just as each alternative fuel has different carbon dioxide emission rates relative to petrol, so too the costs and benefits of introducing each fuel differs.

Some participants provided information on the costs of producing different fuels relative to the cost of producing petrol and diesel fuel. For example the MTAA said:

> it is estimated by the Service Station Association of NSW [that] the resources required to produce methanol could add as much as one dollar per litre to the existing costs to consumers of fuel for motor vehicles. (Sub. D131, p. 4)

And referring to the cost of ethanol production, the Association said:

> Without government subsidies ethanol is a high cost option and in cost-benefit terms could not be considered unless the price of crude oil was to rise above $US50 per barrel. (Sub. D131, p. 4)

The Association concluded by saying:

> While technologically it is possible to produce a range of alternative fuels, MTAA would support the view that production of such fuels is not cost effective while the price of crude oil remains at a price of $US20 per barrel ... Until fuel prices reach $US50 or $US60 per barrel, most alternative fuel technologies would seem to be economically unviable. (Sub. D131, p. 5)

Le Cornu (1990) provided estimates of the cost of modifying vehicle engines and fuel systems to accommodate particular alternative fuels. The estimates applying to new vehicles reflect the additional cost payable if the vehicle is built to use an alternative fuel. In the case of existing vehicles, it is the cost of modifying a vehicle's engine or fuel system to accommodate the alternative fuel. He also said:

> the use of diesel engines in cars, so as to permit the use of an alternative fuel, would increase their cost by $1000. (p. 300)

Table F21: **Vehicle modification penalties**

Fuel	*Vehicle type*	*Modification penalty*
		$
LPG	- new car	200
	- existing car	1 500
CNG	- new car	500
	- existing car	1 500
LNG	- light commercial vehicle	7 000
	- rigid truck	8 000
	- articulated truck	10 000
	- bus	10 000

Source: Le Cornu 1990, p. 299.

The Australian City Transit Association (ACTA) also provided estimates of the cost of converting to, or purchasing, natural gas powered buses. The cost of an average conversion of an existing bus using an OEM system[9] could cost around $26 000. Average on-costs (additional costs) for a new bus are estimated at around $19 000. The Association added:

> The simple pay back period [varies] between four to six years. However, when a full financial analysis is undertaken the positive NV is relatively small and very sensitive to interest rates. The project would become financially neutral at interest rates of about 17 %. (Sub. 79, p. 9)

Another significant cost of introducing alternative fuels is the provision of refuelling facilities. For example, the Australian Gas Association (AGA) said:

> For instance ... it can be estimated that the cost of establishing the 700 (CNG) refuelling stations required for 10% substitution of petroleum is $400 million. (Sub. 37, p. 58)

The ACTA also estimated the cost of providing a gas compression station and high pressure gas reticulation system to service 200 buses:

> The infrastructure costs associated with the provision of CNG fuelling facilities has been estimated at $1 800 000.00 for a 200 bus depot. Using this figure as a guide the total infrastructure costs for both the public and private fleets would be in the vicinity of $ 90 000 000.00. (Sub. 79, p. 10)

Greater use of alternative fuels may also affect Australia's international trading position, depending on whether the new fuel has to be imported or can be sourced locally. The AGA said:

> Increasing reliance on oil imports will exacerbate Australia's balance of payments problem and leave Australia liable to both price and supply instability ... If gas powered vehicles were to substitute for, say, 10 % [of refinery production], the overseas exchange saving would be almost $600 million per year. (Sub. 37, pp. 53-54)

9 Original Equipment manufacturer system

Conversely, greater use of diesel fuel could increase oil imports, particularly of different crude oil types. This is because diesel fuels release considerable particulate emissions. These emissions could be avoided by the use of `light diesel'. The ACTA said:

> Light diesel ie desulphurised diesel fuel with the aromatic fractions removed, can be utilised effectively to reduce GHG emissions, but has a cost penalty and requires the expenditure of foreign exchange to purchase low sulphur crude oil supplies. (Sub. 79, p. 6)

Some of the other alternatives (for example, LPG and CNG) produce few or no particulate emissions. They also release fewer other pollutants (for example, reactive hydrocarbons, carbon monoxide, sulphur compounds and nitrous oxides) than petrol or diesel, another benefit which a number of participants pointed out.

Factors limiting the uptake of alternative fuels

Major factors limiting the uptake of alternative fuels are the cost of converting new and existing vehicles, and the lack of a dispersed refuelling network for alternative fuels. These impediments are likely to be reduced over time as alternative fuel production costs decline, and refuelling networks begin to be developed.

But most participants were more concerned with the apparent failure of the Government to indicate what excises are likely to be imposed on alternative fuels, and when such excises are likely to be imposed. Most participants would like an assurance from Government not to levy excises on the alternative fuels at least until they have become established in the transport fuel market. Some participants claimed that imposing excises would make the use of alternative fuels uneconomic.

The AGA in particular were concerned about the introduction of fuel excises on CNG, and requested a five-year moratorium on the introduction of any such tax or excise. The AGA is also seeking sales tax exemptions for natural gas powered vehicles, infrastructure and other equipment, and accelerated depreciation for the same.

The NSW Department of Transport also expressed concern at the possible introduction of excises on alternative transport fuels. The Department said it considers it essential that the use of alternative fuels for transport be encouraged, given their environmental benefits, and added that the STA's plans to introduce CNG powered buses could be adversely affected by the introduction of any excise on CNG (sub. 100, Attachments, Volume 3, Department of Transport, p. 20).

Individual fuels also have specific problems which could be discouraging people from using them. For example, diesel is produced in conjunction with petrol, and any serious drop in the volume of petrol produced will also affect diesel supplies. Alternatively, refineries will face high costs in having to alter their current production mix as the demand for diesel rises and the demand for petrol falls.

LPG supplies are limited by small Australian reserves of propane. The AAA suggested an Australian mixture standard for LPG was needed to ensure that the most is made out of Australia's propane reserves. But even with a standard of 50 per cent, as it recommended, others consider LPG is unlikely to replace more than 7 per cent of Australia's petrol needs. LPG cylinders are large and bulky, and reduce load space. This is a major consideration, especially for owners of smaller cars.

There are a number of factors limiting conversion to CNG or LNG. As with LPG, both require bulky storage containers. Both require considerable energy at refuelling stations to compress, or to compress and refrigerate, the natural gas. LNG must be bled frequently, to avoid pressure build-up. This `bled' gas is mainly methane, itself a greenhouse gas. CNG has a lower energy density than the liquid fuels. This severely reduces the range of a CNG powered vehicle relative to one carrying liquid fuel.

Some participants also suggested that a lack of equipment suppliers and fitters may be limiting the uptake of CNG or LNG by motorists.

The use of ethanol is limited by a number of factors. Citing a study by White (1990), the AIAS said:

> significant amounts of nitrous oxide are emitted during ethanol fermentation. This could have a significant negative effect on the greenhouse gas balance. (Sub. 80, pp. 17-18)

According to White (1990):

> the NO_X emissions from ethanol fermentation are 800g/MJ of ethanol produced ... the production of 1 MJ equivalent of ethanol will release about 52,000g of CO_2 from end-use. If all NOx released during fermentation becomes N_2O, this would be equivalent to 140,000g of CO_2, almost three times the amount of end-use CO_2 release[d]. (p. 241)

However, the AIAS added:

> White's calculations are based on a number of assumptions and no consideration has been given to whether the process might be modified to exclude such emissions or whether they can be easily trapped. (Sub. 80, p. 18)

Ethanol production also requires large areas of agricultural land on which feedstocks can be grown. Adverse results from demonstration programs held in the past may also colour perceptions of the fuel now, some participants said. Problems with poor performance, handling and driveability, and corrosion in fuel tanks and fuel systems were common in a number of ethanol trials.

However, Hagen and Kenaff considered this was a problem with converting any existing vehicle to an alternative fuel. They said:

> Referring to handling and corrosion problems in the existing fleet is equivalent to suggesting leaded fuel be put into cars designed for unleaded fuel. Any problems of handling and corrosion do not exist in vehicles designed or adapted for alcohol use. (Sub. D148, p. 17)

The Australian Cane Growers' Council said the main factors limiting the greater use of ethanol were: resistance from the petroleum industry; higher production costs than conventional fuels, and problems with handling ethanol. Ethanol has a high affinity to water, and accidental spills could lead to contamination of groundwater supplies.

Methanol use may also be hampered by problems of handling and use. The AAA said pure methanol produces formaldehyde when used in spark ignition engines, is toxic, and burns with an invisible flame.

Hagen and Kaneff also opposed this view in their response to the Commission's draft report, saying:

> [The Swedish Motor Fuel Technology Co.] conclude that `the relative hazards associated with the use of methanol appears to be similar to LPG, lower than for gasoline, but higher than for diesel oil.' (Sub. D148, p. 16)
>
> Reference to higher formaldehyde is misleading. In regard to smog production, it is true that methanol has higher formaldehyde emissions. However other emissions such as NOx and hydrocarbons are much lower. Consequently, methanol fuelled vehicles result in much lower overall emissions and ozone and smog formation. (Sub. D148, p. 17)

A number of participants sought greater government involvement in introducing alternative fuels. For example, while the AGA said:

> Current gas industry planning is for a 10% substitution of transport petrol and diesel fuel by NGV within 10 years, (Sub. D138, p. 1)

it also said:

> whether the NGV industry is established will depend upon how seriously governments regard their own aims and objectives. (Sub. D138, p. 4.)

Suggestions of actions governments may take included: continued support for research and development into alternative fuels; subsidising the costs of producing alternatives; providing refuelling networks for alternative fuels; and introducing legislation requiring the use of alternative fuels.

Governments have already played a major role in encouraging the development of alternative fuels, through research funding and public education, and by not introducing excises on alternative fuels.

In its submission to this inquiry, the NSW Department of Minerals and Energy said:

> The Minister for Minerals and Energy announced on 16 October 1990 a package of initiatives for support of alternative transport fuels development in New South Wales. (Sub. 100, Attachments, Volume 1, Department of Minerals and Energy, p. 12)

The Department is currently funding a project by AGL:

> to demonstrate the effectiveness of natural gas as an alternative transport fuel and in particular to demonstrate the long term potential of the Home Refuelling Appliance which produces compressed natural gas. (Sub. 100, Attachments, Volume 1, Department of Minerals and Energy, p. 12)

The NSW STA has also recently announced that it is planning to invest in 250 natural gas powered buses, as part of its planned extension into alternative fuels.

In its submission, the NSW Government said:

> The potential benefits of CNG powered buses include lower fuel costs, reduced noise and air pollution levels (including a 25% reduction in carbon dioxide emissions) and reduced reliance on oil imports. The successful introduction of CNG buses by the STA may also prove to be a catalyst for private bus operators to follow a similar course. (Sub. 100, p. 17)

Others also expressed the hope that through government demonstration programs such as this, private fleet operators may begin testing the use of alternatives as well.

Participants also raised the issue of introducing emission taxes on transport fuels. Some considered that existing excises on petrol and diesel fuels (when used in some applications) amounted to de facto emissions taxes. However, other transport fuels do not face fuel excises.

When considering introducing GHG emission taxes, or carbon taxes, the government may take two approaches. Retaining existing fuel excises, it may choose to levy additional excises on petrol and diesel, and introduce excises on each of the other alternative fuels, so that each fuel carries additional charges commensurate with the level of emissions released from producing, distributing and/or using the fuel.

Alternatively, the Government may scrap existing excises on petrol and diesel in favour of new excises on all transport fuels which solely reflect the level of emissions released from producing, delivering and/or using the fuel.

At the Special Premiers' Conference in July 1991, government leaders looked at introducing road cost recovery charges on alternative fuels. According to the communique from the conference:

> In regard to the treatment of alternative (especially gas-based) transport fuels, it was acknowledged that there are broader energy policy issues which need to be taken into account. For this reason, it was agreed that road track costs should not be attributed to these fuels at this stage. (SPC 1991, p. 17)

F8.3 Summary

- Cars are responsible for about half of the carbon dioxide emissions from Australia's transport sector.

Fuel efficiency improvements

- Average new car fuel consumption has declined steadily over at least the last 12 years; some further improvements are likely particularly in transmissions, drivelines and body aerodynamics.

- Carbon dioxide emissions are directly related to fuel use, so that reducing fuel consumption by 25 per cent would reduce emissions by a similar percentage.

- Improvements in car fuel efficiencies of at least 20 per cent on current levels may be possible.

- Such improvements, as well as reducing emissions, could reduce energy demand, energy imports and urban air pollution; but even modest improvements are likely to increase the capital cost of cars by several hundred dollars.

- Mandatory improvements in fuel efficiency for new vehicles would, if considered in isolation, increase costs and could discourage the trade-in of older, less efficient cars.

Alternative fuels

- The main alternative fuels to petrol are diesel, liquefied petroleum gas (LPG), compressed or liquefied natural gas (CNG or LNG), methanol and ethanol; hydrogen, electricity and solar power are still in the experimental stage.

- Diesel, CNG and LPG are all approximately equal in terms of GHG emissions, each producing fewer GHG emissions than petrol.

- The potential for emission reductions is significant; the use of natural gas instead of petrol for a transport fuel may be able to reduce GHG emissions by 2-25 per cent.

- To build a new car which uses LPG or CNG instead of petrol costs hundreds of dollars extra; to convert an existing car costs well over $1000; there is also the cost of providing refuelling facilities.

- The relative levels of excise on fuels could have a significant bearing on the uptake of alternative fuels.

F9 Building design and modification

Two areas of energy efficiency with the potential to reduce ongoing carbon dioxide emissions from both commercial and residential infrastructure are energy-efficient building design and energy-saving building modifications.

Energy-efficient design takes energy efficiency back to the planning and construction stage where it is relatively easy to implement efficiencies. Examples of this are passive solar heating, building orientation (north-south facing) and window area.

The importance of design is that it can be impossible (eg passive solar heating) or un-economic (eg automatic control systems, light switches) to install later, while including energy efficiency in design can obviate the need for later modification.

Examples of energy efficiency modifications with potential to significantly reduce carbon dioxide emissions from the existing housing stock are ceiling insulation, external shading for windows, double glazing and the sealing of cracks to prevent draughts.

F9.1 Carbon dioxide emission reduction potential

Many participants suggested that significant carbon dioxide emission reductions could be achieved by energy-efficient design. For instance the Australian Council of Professions suggested that a design principle of `long life, loose fit, low energy' be applied to new buildings (loose fit buildings accommodate new purposes as circumstances change), while the Forest Industries Federation (WA) said that more effective design and building practices could achieve longer lasting, energy-efficient structures. CSIRO said:

> There is a need to quantify the life cycle energy use of buildings and their components so that appropriate energy reducing strategies can be identified in the medium term. In the long term, urban planning will require strategies for lowest possible energy use. (Sub. D101, p. 19)

Institutional aspects of the design process, such as urban planning, have the potential to reduce carbon dioxide emissions. The NSW Government said that the NSW Department of Planning contributes to GHG emission reduction and stabilisation through metropolitan and regional planning policies relating to urban form, housing density, building and subdivision design. An example of planning policies reducing carbon dioxide emissions would be urban consolidation policies that encourage medium and high density housing over single unit homes.

Dr David Mills (Sub. 25) commented that the residential sector would need to be an early target in any serious GHG limitation program due to the long life of residential structures. For example solar design measures will need to be retrofitted (where possible) to most buildings and it could take decades before this design measure has a significant impact on emissions. Any approach would need to be comprehensive to attain high reductions.

While few estimates are available as to specific reductions from better design or modifications, some observations can be made about the sector's potential for areas influenced by energy-efficient design. Wilkenfeld (1991) estimated that the commercial and residential sector are responsible for around 29 per cent of Australian carbon dioxide emissions, with the residential sector contributing 9.8 per cent (5.3 per cent of total energy end use) and the commercial sector 19 per cent (12.7 per cent of total energy end use).[10]

In the commercial sector, about 85 per cent of energy use -- lighting, space cooling, ventilation-pumping and space heating -- can be influenced by energy-efficient design. The bulk of commercial energy use is electricity.

In the residential sector about 47 per cent of energy use (33 per cent of carbon dioxide emissions) is directly influenced by building design. The major residential energy end use affected is heating, comprising 42.5 per cent of residential energy use (but only 24 per cent of emissions due to the use of gas heating). Cooling and lighting requirements are also influenced by design, though these are minor energy uses (Wilkenfeld 1991 Table 5.1, p. 130).

While Brotchie, Ehmke, Rodger, Sharpe & Tucker (1990a) make no estimate of emission savings in commercial buildings, they conclude that using machine based knowledge and intelligence systems in building applications to optimise design features -- such as location and layout, use of windows, material use, energy systems and of use of lifts/escalators -- can minimise GHG emissions. They note that:

> Integration of design and management allows the optimisation of greenhouse gas emissions over the life cycle of the building. (p. 359)

Similarly, CSIRO said:

> Energy use can be significantly affected by incorporating passive solar design concepts. Optimisation techniques, measuring and control systems, and their implementation offer fruitful shorter term savings as relatively small research cost. (Sub. D101, p. 19)

Dr David Mills (Sub. D123) stated that solar technology and energy efficiency measures could reduce electricity demand by as much as 90 per cent in new houses, based on Electricity Commission of New South Wales (ECNSW) research into energy-efficient residential housing design. However, the long life of many houses means that such measures would have to be mainly retrofit in nature, where this is possible.

10 Wilkenfeld’s commercial and residential energy saving and carbon dioxide emission estimates include measures other than those directly affected by design, for example, appliances.

F9.2 Costs and benefits

The available information on the costs of most design and modification measures is sketchy. One example of costing efficient building design is given by Walker and Stevens (1990), who claimed that passive solar design is a viable option throughout Australia. They stated:

Careful attention to building design, materials and orientation can greatly decrease heating and cooling requirements (and increase comfort) for a modest increase -- estimated to average around $2000 -- in construction costs over conventional houses. (p. 3)

It should be noted that the actual savings and costs vary according to site and design specificities, geography and local installation costs. With regard to insulation for instance, the Australian Government and the Australian Consumers' Association (1991) stated:

> While geography and climate are important factors in determining the R-value (properties of an insulation material) required, other considerations are important too -- such as the way your house faces, construction materials, shading by trees, roof colour and the amount of glass ... (p. 22)

Increased housing density and consequent reductions in urban sprawl may have significant benefits. Greenpeace Australia said that:

> Governments are currently subsidising urban sprawl at around $35,000 per block for water, electricity, sewerage, roads and up to $70,000 per block if the provision of schools, hospitals, and other facilities are included. (Sub. D117, p. 12)

Brotchie et al. (1990a) noted that `smart' energy management systems, which can minimise energy use (and hence carbon dioxide emissions), can have other benefits. They stated:

> A `smart' environmental control system could evaluate user preferences from user control adjustments over time, and `personalise' the environment accordingly. (p. 359)

However, at present costs it may be that sophisticated energy management systems are only viable in commercial buildings.

‘Intelligent’ design computer programs can optimise energy efficiency according to effectiveness, cost, climate and local terrain for both residential and commercial buildings while giving the purchaser an interactive choice of design features. Brotchie et al. (1990a) noted that sophisticated systems have been available for commercial developments for some years.

F9.3 Factors limiting or inhibiting adoption

Participants identified several factors claimed to impede energy efficiency investment, including a lack of information on energy efficiency measures (this includes the landlord/tenant problem), building regulations, the up-front costs of energy efficiency (low initial capital cost of inefficient options) and the consumption preferences of purchasers.

Lack of information and the landlord/tenant problem

Participants including the Victorian Government and the Australian Conservation Foundation (ACF) claimed that a lack of information inhibited energy-efficient investments in both commercial and residential buildings. It was variously claimed that builders and plumbers lack design and installation expertise, that households, small/medium business and small public administrations lack information and technical skills and that architects, engineers and builders have little knowledge of or interest in energy conservation. Enersonics commented that:

> There are many examples of equipment having the highest running cost also having the lowest purchase price. Poor and poorly informed purchasers are most likely to choose this inefficient equipment. Examples are: incandescent lighting, electric resistance heating ... large windows and skylights without shading. (Sub. 26, p. 7)

However, choosing cheaper, less energy-efficient options or designs does not necessarily imply the purchaser is ill-informed or poor; such decisions also depend on consumption preferences and the opportunity cost of the purchaser's time. It may be rational in many cases for a consumer to choose a less energy-efficient, but less expensive, option.

The `landlord/tenant' problem occurs where a landlord is unable to realise a return from an energy-efficient investment, either through higher rents or property resale values. Similarly, tenants are unlikely to invest in energy efficiency unless the full investment is recoverable during the tenancy. A similar problem may exist for building owner-occupiers where a lack of market recognition of the benefits from energy-saving investment can result in an inability to capitalise such benefits in property values.

Most energy utilities and State Governments already undertake information programs. However, the fact that information is provided on the efficiency of the choices available does not mean this will suddenly shift consumption patterns. For instance Walker and Stevens (1990) state:

> ... there is no doubt that the community is far more aware of the potential of passive solar design than five years ago. An increasing number of builders offer energy-efficient designs ... (pp. 4-5)

But the Energy Action Group (EAG) stated that `barely 1 per cent of new houses are built to a solar-efficient design' (Sub. 74, Attachment). It is clear other factors such as cost and people's consumption preferences are also important. The EAG claimed that public and private tenants are locked into energy inefficient housing by their low incomes.

Some participants suggested governments should do more than provide information. For instance the ACF said intervention was necessary to remove market imperfections, hidden costs and the economic irrationality of some consumers. The EAG said that government programs were necessary to ensure low income earners had access to an efficient housing stock.

Regulation proposals by participants include changing building regulations, setting national energy efficiency standards for lighting/heating/cooling, establishing energy rating systems and performance standards using whole-building energy simulations, energy audits and the mandatory disclosure of energy operating costs to purchasers/tenants. The Victorian Government has introduced insulation regulations for all new housing (from March 1991) and is committed to introducing energy standards for all new housing and new commercial buildings after 1993.

But increased regulation is not the only way to pursue energy efficiency in building design and modification. There are a number of market solutions to information problems, for instance, information can be provided as part of the normal marketing process. For commercial buildings, energy advisory firms specialising in energy efficiency have been established to advise building users. Some of these energy advisory firms provide their services at no net cost by sharing any energy savings achieved with the client (Industry Commission 1991a).

Building regulations

The National Association of Forest Industries (NAFI) said that institutional barriers within the Australian building regulatory system are restricting the use of timber in residential construction. NAFI said that greater use of wood in housing could reduce carbon dioxide emissions by substituting for energy intensive materials (eg steel or aluminium) and by providing a long term carbon store (as wood products).

Up-front costs and access to/availability of finance

Up-front costs, access to and availability of finance were cited in some submissions as factors impeding energy-efficient investments. Some participants said high up-front costs are an impediment to `profitable' energy efficiency investments, such as ceiling insulation and solar hot water systems. It has been claimed by a number of participants (eg Energy Action Group, ACF) that people are unwilling, or unable, to install insulation in homes. New home buyers were cited as being particularly vulnerable.

The ACF claimed households and small businesses have more pressing uses for their money than energy conservation investments, while borrowing by individuals is subject to more restrictions than utilities. It was suggested by the ACF that financial incentives -- such as low-interest loans, subsidies, cost transfer schemes and tax incentives -- might be used to encourage conservation. However, the ACF indicated that ‘broad incentive schemes for common consumer investments can lead to high costs per incremental investment’.

The Centre for the Environment and Sustainable Development suggested that renewable energy utilities should be set up to assist with energy-efficient building design as well as provide and install insulation at the cheapest possible price, among other things. A suggestion made by the ACF was for energy utilities to allow competitive tendering for additional supply capacity. Bidding for new energy supply would include energy conservation proposals from households (eg insulation) and commercial users (eg cogeneration). If the conservation bids are cheaper than new conventional supply capacity, the utility pays the bidder to install the conservation measure.

Consumer behaviour

When consumers place a high value on current consumption (ie have high discount rates), apparently `profitable' energy efficiency investments with long pay-back periods will not be undertaken. An example would be where prospective home owners decide not to invest in passive building solar heating.

The Senate Standing Committee (1991) noted that good design did not ensure building operating efficiency as the behaviour and attitudes of occupants -- both `difficult to influence' -- also affected energy use and carbon dioxide emissions. The Committee noted that though education campaigns have some effect this faded with time.

Some participants noted the importance of energy pricing in determining consumer decisions. The ACF stated electricity pricing according to long run marginal cost would overcome many of the barriers to investments in energy efficiency. Enersonics claimed that real electricity prices are too low and should be increased, while the Victorian Government noted conventional energy's low cost. Under the current energy pricing policies of both Governments and utilities, residential users of electricity benefit from significant cross-subsidies (Industry Commission 1991a).

F9.4 Summary

- Energy-efficient building design consists of construction features such as wall and ceiling insulation, passive heating, layout, orientation and window area; including energy efficiency in the design stage can obviate the need for later energy saving modifications.

- Cost is the major impediment to the use of carbon dioxide emission reducing measures such as insulation, building management systems and machine based design systems, with a lack of consumer information a diminishing impediment with increasing information flows.

- Removing cross-subsidies to residential users of electricity would increase the incentive to adopt energy saving designs and modifications.

- Building regulations or national building energy efficiency standards would reduce emissions but would also impose costs and could discriminate against less well-off users of residential and commercial accommodation.

- While efficient design can significantly reduce energy use, the long life of many buildings limits the scope for rapidly introducing energy-efficient design features.

F10 Iron and steel

In any analysis of the potential to reduce greenhouse gas emissions, it is important not to overlook secondary industry. Industries such as iron and steel, aluminium smelting and cement emit considerable amounts of carbon dioxide. This case study examines the iron and steel industry to illustrate the potential for carbon dioxide reductions.

The initial processing of iron ore adds significantly to Australian carbon dioxide emissions as iron and steel smelting is an energy intensive process that is heavily dependent on coal. BHP Steel estimates the total carbon dioxide generated by its three integrated steel plants -- `by far' the largest carbon dioxide sources in the iron and steel industry -- to be 6 per cent of Australian 1988 carbon dioxide emissions. BHP exports about 25 per cent of annual steel production.

F10.1 Carbon dioxide emission reduction potential

Walker (1990) estimated that the iron and steel industry has the potential to improve efficiency in the use of fossil fuels by 15 to 20 per cent by 2004-5 and efficiency in the use of electricity by 10 per cent. Carbon dioxide emissions from the iron and steel industry could fall by almost 15 per cent from 1986-87 levels.

Wilkenfeld (1991, p. 81-82) said energy used in smelting in 1986-87 was 18 per cent of industrial energy consumption and a `similar share' of carbon dioxide emissions.[11] Energy use per tonne was 20 per cent more than that of European and Japanese producers, largely in response to lower unit fuel costs. While many energy conservation measures had been implemented in the Australian industry, Wilkenfeld expected further efficiencies in the next decade from better process control (including blast furnaces 2 to 5 per cent, computer control of coke ovens 5 to 10 per cent) and improved downstream processing operations including rolling of about 10 per cent. A 6 per cent reduction in energy use would reduce carbon dioxide emissions by 1 MT per annum, or 1 per cent of industry emissions.

The Australian Coal Association said that the increased use of pulverised coal injection and oxygen enrichment are steadily reducing coal consumption per unit of iron produced. BHP Steel stated that planned energy saving measures (full implementation of continuous casting, blast furnace relines/rebuilding and scrap recycling) are expected to reduce carbon dioxide emissions by 15 per cent per tonne of steel by 1998.

Walker, Wilkenfeld and BHP Steel basically agree that the industry can achieve further efficiencies of about 15 per cent, with BHP Steel stating that improvements would be incremental rather than by sudden breakthroughs.

11 Energy used in smelting includes that for some copper and lead-zinc smelting.

BHP Steel said that two marginal projects, off-flue gas recovery and coke dry quenching (using inert gas to remove the sensible heat in hot coke), would reduce industry emissions by an additional 2 per cent and 2.6 per cent respectively. However, increased steel production is expected to put emissions from steel production 44 per cent above the Toronto target by 1998.

BHP Steel stated that taking 1988 as a base year would cause problems as this was the second lowest production year for the decade. The company said:

> With a production level about 10% below the mean it is clearly seen that the steel industry is disadvantaged by the apparently arbitrary nature of this choice. (Sub. 27, p. 8)

Meeting the Toronto target of a 20 per cent reduction from the 1988 level by 2005 would therefore be extremely difficult, as technical factors mean that 75 per cent of total carbon dioxide emissions relate to the fundamental smelting process. The company estimated that by 2005 its carbon dioxide emissions, assuming 1998 production levels were maintained and a further 15 per cent carbon dioxide reduction achieved, would still be 23 per cent above the Toronto target.

BHP Steel said that any reduction in carbon dioxide emissions from alternative iron making processes -- which would entail replacing existing capital -- may only be marginal.

There are various views on the timing of other new technologies, such as direct reduction smelting. The Australian Coal Association claim that new developments `on the horizon' (such as direct smelting) could lift energy efficiency sharply with corresponding emission reductions. Although CRA Ltd has recently announced a demonstration plant for the direct smelting of iron, Walker and BHP Steel do not expect the commercialisation of semi-steel processes (such as HI-SMELT) for at least another 10 years.

F10.2 Costs and benefits

Essentially, costs comprise any additional capital and operating costs that may be incurred by measures designed principally to reduce carbon dioxide emissions.

Two measures were costed by BHP Steel. The company commented that coke dry quenching would be uneconomic, with energy savings of $10 million a year and capital costs of approximately $100Ä130 million. The company stated that off-flue gas recovery:

> For the Port Kembla works of the BHP Steel group, a preliminary evaluation suggests a capital cost of $40 million at a DCF [discounted cash flow] rate of return of only 8 per cent from energy saving. This project is currently to be further evaluated, but at first pass these savings look marginal. (Sub. 27, p. 10)

BHP Steel noted the use of steel scrap as an emission reduction possibility, stating that by 1994 all available scrap except that from WA and Tasmania is likely to be used by a new $300 million Sydney mini-mill of 250 000 to 300 000 tonnes capacity.

BHP Steel said that while the greenhouse benefits of replacing existing capital were uncertain, the capital cost would be substantial. According to the company:

> Initial evaluations of an alternative ironmaking process indicates that to replace 1.8 million tonnes (p.a.) of ironmaking plant could cost between $600 million and $1 billion. Any improvement of the greenhouse effect by such a technology may only be marginal. (Sub. 27, p. 9)

While new iron and semi-steel processes have been suggested as offering the possibility of carbon dioxide emissions reductions, the cost of commercialising such technologies is high. According to CRA, the demonstration plant for direct smelting of iron will cost $100 million.

F10.3 Barriers and impediments

Two participants, BHP Steel and CRA, commented that there is only limited scope for reductions in carbon dioxide emissions through energy efficiencies due to a steady adoption of the `easy' options over many decades. CRA stated:

> Certainly there is no obvious scope for the spectacular, rapid pay-back investments asserted by some to be currently available for implementation in much of Australian industry. As of 1991, there are no quick fixes, soft options or easy solutions. Energy efficiency will remain an important criterion in respect to new investment, but it will not be the only criterion. (Sub. 38, p. 10)

BHP Steel said the large amount of investment and upgrading of existing industry capital over previous decades meant there was only limited potential for further gains in the industry. It considered that any emission reduction strategy should ensure industries that had already undertaken efficiency measures were not discriminated against.

BHP Steel commented that the capital intensive nature of the industry would mean any change would come incrementally rather than by a sudden leap in technology and that any measure to replace fixed capital prematurely would be costly. The company claimed the high cost of capital funds (eg compared to Japan) had limited the opportunities for `small step improvements' in energy efficiency. The company said that the cost of capital and taxation regimes may need to be considered to provide incentives for the two technically feasible energy-greenhouse reduction measures noted previously be undertaken.

BHP Steel noted that conflicting environmental objectives can cause problems. For example, a BHP proposal to burn coal washery refuse instead of placing it in landfill was likely to increase carbon dioxide emissions by 4.8 per cent.

F10.4 Summary

- The iron and steel industry has been included in these case studies to illustrate the potential for carbon dioxide reductions in secondary industry.
- Iron and steel smelting is an energy intensive process heavily dependent on coal; carbon dioxide produced by BHP's three integrated steel plants was 6 per cent of Australia's 1988 carbon dioxide emissions.
- BHP's steel production could be disadvantaged by the choice of 1988 emissions as a base year as 1988 recorded the second lowest annual steel production for the decade.
- Planned energy efficiency measures are expected to reduce emissions by 15 per cent per tonne of steel by 1998; but increased production is expected to increase emissions to 44 per cent above the Toronto target by 2005.
- The major impediments to achieving further efficiencies are costs and the past upgrading of capital equipment which has reduced the scope for further easy emission reductions.

F11 Agriculture

Agriculture is responsible for between one-quarter and one-third of anthropogenic greenhouse gas emissions (CSIRO sub. D101). Methane and nitrous oxide emissions contribute equally while agricultural carbon dioxide emissions are less significant. Agricultural practices can also enhance the operation of natural carbon dioxide sinks.

F11.1 Greenhouse gas emissions

Carbon dioxide emissions from the use of fossil fuels in agriculture are relatively minor, amounting to some 5.8 Mt of carbon dioxide emissions per annum or 2.2 per cent of Australian end-use emissions in 1986-87 (Wilkenfeld 1991). The Australian Institute of Agricultural Science (AIAS) said that net deforestation and land disturbance contribute about 10 Mt per annum of carbon dioxide, while soil cultivation and cropping produced a net 15 Mt per annum (see Table C12, Appendix C).

The AIAS estimated that the net contribution of agriculture to Australian GHG emissions is 3.7 per cent per annum, taking into account the sequestering of about 143 Mt of carbon dioxide per annum in land systems (Table C12, Appendix C). The single largest anthropogenic sink is believed to be the carbon dioxide fertiliser effect (the increase in plant material resulting from increased atmospheric concentrations of carbon dioxide), which sequesters 110 Mt of carbon dioxide per annum (AIAS). However, this estimate relates to the increase in total land systems biomass rather than just to agriculture.

A particular agricultural net sink identified by the AIAS is improved pasture, which sequesters an estimated 30 Mt of carbon dioxide per annum as organic matter.

Agricultural methane emissions are estimated to be 2.5 Mt per annum, with ruminant animals the major source. These animals -- principally sheep and cattle -- contribute about 2 Mt of methane annually (AIAS). However, detailed estimates by the Bureau of Rural Resources (BRR) put total livestock emissions much higher at 3.3 MT per annum (Table F22). Intentional burning of biomass (eg of forests, grasslands and crop waste) is also a source of methane. According to Galbally et al. (1990) and the AIAS, about a third of annual biomass burning is deliberate, with consequent emissions estimated at about 0.4 Mt of methane per annum.

However, more work is apparently needed to quantify both the sources and sinks of methane (AIAS; Galbally et al. 1990).

Table F22: **Methane emissions from Australian livestock in 1987-88**

	Numbers	*Methane from digestion*	*Methane from faeces*	*Total methane emissions*
	million	*kT*	*kT*	*kT*
Sheep	152.	41372	95	1467
Beef cattle	19.3	3165	99	1264
Dairy cattle	2.6	238	70	308
Pigs	2.7	4	235	239
Poultry	64.2	n/a	16	16
Other livestock	1.0	13	7	20
Total		2792	522	3314

kT = kilotonne.
Source: Adapted from BRR Sub. D150, Attachment 2.

With a global warming potential of 270 times that of carbon dioxide over 20 years (Table C5, Appendix C), nitrous oxide emissions are particularly significant. There is a substantial range between the CSIRO upper and lower estimates of nitrous oxide emissions (Table C15, Appendix C). CSIRO's best estimate (late 1980s) of anthropogenic emissions is 0.14 Mt per annum. According to Galbally et al. (1990), the major sources of nitrous oxide are natural with anthropogenic emissions about 20 per cent of an estimated 0.96 Mt per annum. Estimates by the AIAS put anthropogenic nitrous oxide emissions at about 0.15 Mt per annum, or around 16 per cent of total nitrous oxide emissions of 0.97 Mt per annum.

The AIAS gives major anthropogenic sources of nitrous oxide as cropland and cultivation, including fertiliser (0.06 Mt per annum), sown legumes (0.05 Mt per annum), sown grass (0.02 Mt per annum) and ley cropping (0.025 Mt per annum). CSIRO attributed 72 per cent of anthropogenic nitrous oxide emissions to legume pasture, with cropping -- including fertiliser use -- responsible for 27 per cent (Sub. D101).

The AIAS estimates that nitrogen losses from nitrogen fertilisers, as nitrous oxide, are about 0.42 per cent by weight per annum. However, Galbally et al. (1990) noted that nitrous oxide emissions depends on the fertiliser used, with measured emissions from nitrogen fertilisers ranging from 0.05 to 0.7 per cent by weight per annum.

F11.2 Emission reduction potential

Enhancing agricultural `sinks'

The AIAS said there are opportunities in agriculture to sequester significant net amounts of carbon dioxide for long periods by appropriate land management practices eg improved pasture (30 Mt per annum), suppression of fires and/or less frequent burning (23 Mt per annum).

The only known land surface sink of methane is soil microflora, and as such there appears little potential to significantly increase methane up-take through land management or other means.

While there are known non-agricultural sinks for nitrous oxide, no estimates of agricultural sinks have been made (Galbally et al. 1990; AIAS).

Reducing agricultural sources

- Land management practices

The Australian Cane Grower's Council said that a switch in the sugar industry from mechanical cultivation to a low tillage system returned some organic matter to the soil while reducing fuel consumption (and carbon dioxide emissions).[12] Similarly, the AIAS suggested that minimum tillage and a greater use of herbicides would reduce soil organic matter loss from cultivation and cropping. Increased use of legume ley systems and grass-legume pastures, and limiting the practice of burning stubble could also increase organic matter content. The Institute claimed that an opportunity exists to reduce soil carbon losses to zero and, over time, to increase organic carbon above current levels.

The CSIRO said that agricultural emissions of nitrous oxide could be limited by influencing soil conditions, stating that:

> Management measures can play a role in reducing oxidation/reduction alternation and soil nitrogen content. Proper dosage, timing and placement of nitrogen fertilisers in relation to crop growth stages serves to minimise periodic nitrogen excess in soils. Tillage practice, drainage and/or cultivation to avoid compaction of soil and increase aeration will minimise the chances of anaerobic reduction in crop land and pastures. In wetland soils, efficient water management can avoid periodic oxidation and hence limit nitrification. (Sub. D101, p. 23)

Leguminous crops are a significant source of nitrous oxide emissions (Galbally et al. 1990; AIAS). There is some evidence to suggest that such emissions are particularly high when leguminous crops are ploughed in and left fallow over summer and that nitrous oxide emissions may be reduced by changing this practice (Galbally et al. 1990).

The AIAS noted that systems analysis technologies have the potential to help define the best combination of emission minimising land management practices.

The BRR said that an integrated land management simulation model (GRASSMAN) could evaluate the effect that management decisions -- such as changed stocking rates, tree clearing and changed burning regime -- has on pasture condition, animal performance and farm financial returns.[13] The Bureau has modified the GRASSMAN model to include carbon flows/storages, methane simulation and other emissions from cattle, termites and burning. The BRR stated that model results for the tropical Queensland beef pastures show that:

[12] A low tillage system involves leaving the blanket of leaves formed when cane is harvested without burning.

[13] The GRAAMAN simulation models the beef cattle industry of tropical Queensland. The model gives an average optimal stocking level for a particular region.

> Minor changes in pasture and stock management can result in large changes in emissions without large reductions in farm income. Hence, reducing greenhouse gas emissions from these pasture systems by about 20% over the next 15 years could be achieved with little economic cost. (Sub. D150, p. 6)

The BRR noted that the applicability of the results to other grazing systems is limited, with a similarly detailed analysis required to determine the management options and emission reductions.

- Animal management

The CSIRO suggested three ways that methane emissions from ruminant animals could be reduced. The first was to reduce ruminant animal populations. It stated:

> ... it is not clear whether the reduction due to less animals would be offset by natural processes acting on the increased biomass. Use of other forage-eating animals for meat production (eg horses, kangaroos) would only have a marginal effect because microbial fermentation still occurs ... (Sub. D101, p. 21)

The BRR noted that proponents of this view often assume that stock reductions resulted in proportional emission reductions. It stated:

> ... such approaches are often inaccurate because they fail to take into account non-linearities and interactions that occur in grazing systems (and all other biological systems for that matter) and changes in carbon storages and emission rates that may occur with changes in stocking rate. (Sub. D150, p. 1)

A second option is to modify ruminant digestion. CSIRO noted that this could occur in a number of ways, including ionophore antibiotics (eg Monensin). The AIAS said that Monensin could reduce the risk of bloat when cattle grazed lucerne and other types of legumes in pasture, and that such antibiotics:

> ... may also improve the digestibility of the food slightly, with proportionately more carbon dioxide being produced and better animal performance. The amount by which the methane eructation is reduced varies from 15 to 25% depending on feed quality (Thornton and Owens, 1981). (Sub. 80, p. 19)

The third option suggested by CSIRO is to reduce the amount of methane emitted per unit of product or service by increasing the reproductive efficiency of the animal (thereby reducing the size of the breeding stock) or by improving feed efficiency. The AIAS said that methane emissions from adult cattle are up to 33 per cent lower with high quality feed than with high roughage diets. The Institute said that further pasture improvement in northern Australia could reduce methane emissions, provided stocking rates did not increase. The CSIRO said that grain feeding ruminant animals could reduce methane emissions in two ways:

> Firstly, there is less CH_4 produced per unit of metabolisable energy (ME, the absorbed energy utilisable by the animal). Secondly, the greater energy intake by the animal means the animal grows faster, reaches market weight

> sooner and consequently less CH_4 is produced per unit of meat produced. However, feeding grain is not a sensible strategy because ruminants have developed to cope with roughage diets and if animal protein is to be produced from grain, it would be more efficient to utilise pigs... (Sub. D101, p. 22)

According to the Australian Council of Professions there are broader issues with regard to meat production:

> Australian meat is almost entirely range fed. It is therefore almost impossible to control methane production, but because Australian meat does not depend on high energy and highly fertilised animal feed stuffs it causes a relatively smaller release of carbon dioxide and nitrous oxide. It may therefore have overall greenhouse effect benefits as compared to the intensive methods of meat production used elsewhere and notably in North America and Europe. (Sub. 33, p. 17)

The Coast and Wetlands Society Inc. proposed that greater use be made of feedlot manure and effluent by collecting and processing such waste to produce methane gas, a practice that had been trialled at some Australian piggeries. This would reduce methane emissions to the atmosphere from the current composting of feedlot wastes. Where the collected methane gas replaced coal based electricity this could also reduce carbon dioxide emissions.

F11.3 Costs and benefits

The AIAS said that measures taken to increase soil organic matter levels -- such as minimum tillage technologies -- can give significant benefits. However, this could result in a greater use of herbicides. In addition the Australian Cane Grower's Council stated that low tillage systems are unviable in some areas due to soil temperature/moisture and problems with soil/irrigation management.

Means of increasing soil organic matter other than low tillage systems include legume-ley cropping and grass-legume pastures. These methods fix nitrogen, reducing fertiliser requirements. Benefits in low fertility soils include increased plant productivity, improved soil structure and reduced soil erosion. Some additional costs from such measures are likely, for example from an increased use of lime to reduce soil acidity from legumes.

There are other benefits from land management practices that improve pastures, for example better quality stock feed that improves the physical condition of stock can also reduce methane emissions. The BRR noted that:

> The small reductions in stocking rate needed to reduce greenhouse gas emissions significantly would also have the effect of reducing soil and vegetation degradation and hence improving the sustainability of these enterprises. (Sub. D150, p. 6)

The Australian Council of Professions said that controlling methane emissions from ruminant animals using anti-bloat medication is not a practical option in many situations. Similarly, the AIAS stated:

> The cost per animal is high ($3 per month) and the treatment of sheep and cattle which are infrequently yarded is likely to be difficult to achieve. The effect of the capsules can last for up to 3 months before re-dosing is necessary. (Sub. 80, p. 19)

However, some of the cost of reducing GHG emissions would be offset through increased productivity. The CSIRO stated that nitrous oxide emissions represent a loss of available nitrogen for plant production, reducing soil productivity. Similarly, methane emissions reduce animal productivity. CSIRO said:

> A 20% reduction in animal methane production has been estimated to translate to a 10% increase in sheep and cattle growth and a 2% increase in wool production from sheep. (Sub. D101, p. 21)

F11.4 Factors limiting or inhibiting adoption

Apparent factors limiting or inhibiting adoption of the various management practices outlined include cost, lack of information and uncertainty as to the impact of land management techniques. Measures suggested to reduce emissions or act as sinks can also have undesirable impacts. Practices that raise soil organic levels, such as ley cropping, sown grass and legumes, effectively act as net sinks to carbon dioxide while increasing soil fixed nitrogen content. However, like fertilisers, there is some evidence that these increase nitrous oxide emissions from the soil (Galbally et al. 1990).

Other measures suggested by participants, for example anti-bloat capsules, are currently expensive. Though some productivity improvement is possible from better digestion, farmers are unlikely to carry out this measure solely to reduce methane emissions. However, improved stock feed can reduce methane emissions and increase animal productivity.

The effect of land management techniques on emissions of gases other than carbon dioxide is less clear. It was claimed by some participants that a better understanding of soil management and the factors influencing emission levels is needed before an effective emission reduction soil management program could be operated. The AIAS stated that nitrous oxide emissions from mineralisation of soil organic matter require better definition if a national emission policy is to be developed. It stated:

> This will require the establishment of a high priority research in sources and sinks of N_2O emissions. (Sub. 80, p. 12)

The Australian Cane Grower's Council concluded that organic matter build-up in the soil and the effect of fertiliser practice on nitrous oxide emissions should be investigated further. Similarly, the Australian Fertiliser Manufacturing Committee stated that the:

> Effects of soil management on emissions of oxides of nitrogen from soil have been poorly researched to date and there appears to be insufficient information currently available to suggest preferred management practices for farmers to employ. (Sub. 63, p. 1)

The CSIRO said that:

> CSIRO research is instrumental in determining best practice and consequently improving overall efficiency. A promising line of research currently in train involves the inhibition of a key enzyme in the conversion and loss of urea to nitrous oxide. The success for this work will lead to lower fertiliser cost as well as lower emissions ... Field tests are currently underway with the next stage being to transfer the results to the farmer as an economic proposition. (Sub. D101, p. 23)

The Rural Industries Research and Development Corporation believed the results of current research programs should be `disseminated and discussed fully in an agricultural context'. It went on to say:

> ... an annual workshop and a series of smaller specific seminars could achieve a very valuable coordination function and greatly increase the responsiveness of the rural industries to climate change. (Sub. 47, p. 3)

The Australian Council of Professions said that because of the uncertainty about local greenhouse impacts and the implications for agriculture, further research is a high priority. The Council said that while climate research should have priority, it should be accompanied by research into the implications for forestry, fishing and agriculture.

F11.5 Summary

- Agriculture is the source of one-quarter to one-third of Australia's GHG emissions.
- Emissions are mainly methane and nitrous oxide; carbon dioxide emissions are minor.
- Methane emissions come mainly from ruminant animals, while nitrous oxide is emitted principally from cultivation, including fertiliser use, and growing certain pastures.
- Agriculture acts as a sink for carbon dioxide through land management practices such as improved pastures and fire suppression.
- According to the BRR, GHG emissions from the north Queensland beef industry could be reduced by 20 per cent in the next 15 years at little economic cost.
- Measures to reduce emissions or increase sinks face problems of cost (eg anti-bloat capsules for animals), lack of information (eg land management techniques), and uncertainty (eg factors which contribute to nitrous oxide emissions).

F12 Forestry

Forests are a natural 'sink' for carbon dioxide. Trees absorb carbon dioxide as they grow, converting it into carbon. This carbon is released back into the atmosphere, as carbon dioxide, when the trees decompose. A growing forest absorbs more carbon dioxide than it releases. A mature forest releases the same amount of carbon dioxide as it absorbs. But mature forests store considerably more carbon than growing forests do.

Some participants advocated planting new forests as part of the solution to greenhouse problem. The South Australian Government said:

> Afforestation programs also have a major role in combating the Greenhouse problem. (Sub. 75, p. 5)

But most participants considered that planting trees was only a short term solution to reducing atmospheric carbon dioxide concentrations. The CSIRO (Division of Plant Industry) said:

> planting trees on land that did not have trees before contributes to carbon dioxide absorption until they reach maturity when further new growth is matched by an equal amount of decomposition. Tree planting on such land therefore acts as a temporary means of offsetting fossil CO_2 emissions. It is not a permanent substitute for ceasing fossil fuel combustion. (Sub. 17, p. 6)

For these forests to provide ongoing reductions in atmospheric carbon dioxide, they need to be harvested in such a way that the stored carbon is not released or is released very slowly back into the atmosphere. The land on which the timber is harvested can then be resown to grow more trees. The Chamber of Mines, Metals and Extractive Industries said:

> To maintain the role of vegetation in mopping up CO_2 there needs to be a cycle of forest utilisation followed by regeneration and growth. For this to have a net beneficial effect, the harvested wood needs to remain in use rather than being burnt or left to decay. (Sub. 8, p. 2)

Or more and more land can be forested. Alternatively, the timber harvested can be used in place of fossil fuels, as suggested by the Centre for Environment and Sustainable Development. This would also give a net reduction in GHG emissions.

Of greater importance to some was the protection of carbon in Australia's mature forests, currently being released through their harvesting. The Australian Conservation Foundation (ACF) said:

> the rate of CO_2 uptake or carbon fixing in young forests is greater than in mature forests ... When examining the impact of the forestry operations on the greenhouse effect, however, the important consideration is not so much the rate of carbon fixing, but the total store of carbon in the forests. (Sub. 46, p 29)

And Greenpeace Australia said:

> the best CO_2 sink is to protect rather than cut down and burn existing native forests and other vegetation. Afforestation alone is not capable of countering the problem while GHG concentrations continue to increase. (Sub. 23, p. 6)

F12.1 Potential to reduce emissions

Reforestation

Barson and Gifford (1990) estimated possible reductions in carbon dioxide under three different tree planting scenarios (see Appendix C, Section C2.6). Two relate to plantations operated on a forty-year rotation, where the timber harvested has a half-life of 10 years. The third relates to forests used for paper pulp production and operated on a ten-year rotation. The trees planted were eucalypts and pines.

The plantations operated on a forty-year rotation were assumed to sequester up to 390 t of carbon per ha, at an average annual rate of 7.5 t/ha. This rate was expected to peak at 11 t/ha after 40 years (Barson and Gifford 1990, p. 438).

The pulpwood plantation was assumed to sequester carbon at an average annual rate of 7.1 t/ha. After ten years, this rate falls to zero, offset by emissions of carbon dioxide from the paper products produced. A plantation of 100 000 ha is assumed to store 3.2, 4.2 and 7.2 Mt of carbon, assuming the paper products produced have half-lives of 1, 2 and 5 years respectively (Barson and Gifford 1990, p. 439).

Other participants also provided information on the carbon take-up rate of growing forests. The ACF said:

> the annual average rate of CO_2 sequestration in Eucalyptus oblique forests peaks after 40 years at about 10 tonnes of fixed carbon per year per hectare. After about 100 years the rate of sequestration declines dramatically. (Sub. 46, p. 29)

The ACF added:

> To absorb the 75 million tonnes of carbon produced annually in Australia by fossil fuel burning would require converting to forest an estimated 150 000 square kilometres of land. This estimate is based on the capacity of wet schlerophyll forests to absorb carbon at an average rate of 5 t/ha/yr over the first 100 years of their life. (Sub. 46, p. 30)

The National Association of Forest Industries (NAFI) gave two estimates of the uptake of carbon dioxide by growing forests. Citing Barson and Gifford (1990), it said:

> the establishment of 40 000 ha of new forest each year on a 40-year rotation could reduce net emissions of carbon dioxide by 7 million tonnes per year, which is approximately 10% of Australia's estimated carbon dioxide emissions from fossil fuel combustion in 1987.
>
> Further modelling of carbon dioxide consumption by Booth (1989) estimated that the coniferous plantations of Australia (approximately 1 million ha) would remove approximately 7.5 million tonnes of carbon annually. (Sub. 87, p. 5)

The Tasman Institute estimated that:

> if the world's forests were doubled in size, the effect would be a one-off reduction in the amount of CO_2 of only 5-10 per cent. (Sub. 55, p. 28)

The ACF also provided estimates of the net impact on atmospheric carbon dioxide of harvesting mature forests and establishing timber plantations on the cleared land. A study conducted in the US showed:

> the conversion of old growth forests to regrowth in Oregon and Washington over the last 100 years resulted in an average loss of 300 tonnes of carbon per hectare. (Sub. 46, p. 30)

According to the ACF, this loss was greater than those reported in Australian studies:

> A recent study of logging operations in the eucalypt forests of south east New South Wales calculated a net carbon loss of 95 t/ha over a 40-year thinning cycle due to forestry operations. This concurs with preliminary estimations of 100-115 t/ha of net carbon loss due to forestry operations in old growth Tasmanian wet schlerophyll forests. (Sub. 46, p. 30)

These losses reflect the typically greater carbon density of mature forests relative to plantations when each is harvested, and differences in the rates of decay of products harvested from forests and plantations. According to the ACF, much of the carbon stored in mature forests is returned to the atmosphere within a few years of harvest. The ACF said:

> approximately up to 95% of the biomass cleared from the forests is either pulped, burnt, or left to decompose. Only 5% of the biomass is stored as timber. (Sub. 46, p. 29)

Some governments and authorities have begun forest ‘sink’ projects, and made moves to protect native vegetation. In its submission, the Victorian Government said:

The Government has established a major tree planting program, Tree Victoria, aimed at planting 100 million trees by the year 2010. In addition, vegetation retention controls have been introduced to arrest the annual woody vegetation clearing rate of 16 000 ha. (Sub. 74, p. 9)

These programs were introduced to capture a wide range of benefits, including:

> the elimination of the current net annual releases of biospheric carbon and the restoration of terrestrial ecosystem carbon storage levels in terrestrial ecosystems. (Sub. 74, p. 9)

The State Transit Authority of South Australia is also conducting a carbon dioxide gas `sink' project. The Australian City Transit Association (ACTA) said:

> As a part of the project, STA is sponsoring the planting of 300 000 eucalyptus trees which are capable of meeting the CO_2 emission levels of the publicly owned STA bus and train fleet emissions. (Sub. 79, p. 5)

However, as the trees mature, their ability to absorb carbon dioxide will fall, requiring the STA to plant more trees to absorb emissions. They may choose to harvest the existing trees and store them in such a way that the stored carbon is not released, or to extend the area of land planted with trees. Either way, the current project is only a temporary means of storing the Authority's carbon dioxide emissions.[14]

14 How long carbon is stored in timber depends on its end use, for example using timber for house building stores carbon for a relatively long period.

The NSW Department of Planning is also considering what role tree planting could play in its response to the threat of global warming. The Department said:

> tree planting is not a total solution, but has a part to play in any strategy to mitigate global warming. It also has other benefits, such as helping to restore degraded land and improving the urban environment. (Sub. 100, Attachments, Volume 3, Department of Planning, Planning Strategy, p. 9)

As an example of what may be possible, the Electricity Commission of NSW said:

> Growing trees, such as pinus radiata will remove about five tonnes of carbon from the atmosphere per hectare per year. The establishment cost of such an operation is about $1,500 per hectare, and 400,000 hectares would be needed to absorb 20 per cent of the ECNSW's existing emissions. (Sub. 100, Attachments, Volume 2, The Electricity Commission of NSW, p. 34)

The NSW Government also said:

> The NSW Forestry Commission has proposed that an offset system for carbon dioxide emissions be developed for private or government organisations that produce greenhouse gases. This would be appropriate if international or national emission reduction strategies are based on monitoring net rather than gross emissions. (Sub. 100, p. 13)

Halting deforestation

The NAFI, in its submission on the draft report said:

> deforestation is largely a result of demand for cleared land that is used for purposes other than forestry. (Sub. D144, p. 1)

Participants provided a range of estimates of carbon dioxide losses from deforestation. The Australian Institute of Agricultural Science (AIAS) said:

> It has been estimated that assuming a constant rate over 200 years, losses of carbon associated with deforestation have been 35 Mt C per year. (Sub. 15, p. 7)

But some of that timber would have been used as a substitute for fossil fuels, and thus not have added to emissions totals.

Further, the AIAS commented that:

> Current losses [from net deforestation and land disturbance] are estimated at 10 Mt CO_2 annually. (Sub. 15, p. 7)

The ACF provided a range of estimates of current losses from deforestation. They said:

> estimates of CO_2 release due to current deforestation range from 800 to 2400 Mt C/yr, the most widely quoted estimate being about 1000 Mt C/yr. (Sub. 46, p. 28)

These estimates are based on the total area of forest removed, the biomass density of the area, the annual emissions released or absorbed by the existing vegetation, and the annual emissions released or absorbed by the biomass which replaces the forest.

F12.2 Costs and benefits

Reforestation and afforestation

Depending upon its previous use, a major cost of reforestation could be acquiring the land on which to grow trees. Additional costs include preparing the land to receive tree and shrub seedlings, planting them, and maintaining them once they become established.

One of the few to provide estimates of the costs associated with encouraging reforestation was the Tasman Institute which said:

> If some 75 per cent of the wood could be indefinitely sequestered, Nordhaus estimates that a subsidy of 10 per cent on tree planting could fix 31 million tonnes of carbon per year ... Though modest, this reduction could be achieved at a cost per tonne of $38, a low cost relative to some other options. (Sub. 55, p. 29)

The United Mineworkers' Federation of Australia said:

> the most cost effective way of engaging in afforestation programs to reduce GHG emissions is for coal companies or power utilities to fund international afforestation programs ... This option is cost-effective because of the relative costs of land between developed and developing nations. It also has interesting foreign aid aspects. (Sub. 53, p. 21)

Tree planting programs also have other environmental benefits, which `strengthen the rationale' for adopting them, the ACF said (sub. 46, p. 30).

They help protect water catchment areas, reduce soil erosion, and help control salinity. They reduce land degradation and methane emissions from degraded land. They increase timber supplies. And they can provide a more pleasant environment in which to live. These and other benefits add to the benefits planting trees may have on delaying climate change, and should be taken into account when evaluating projects to reforest specific areas.

The AIAS gave some indication of the benefits of establishing timber plantations: specifically, Tasmanian Bluegum plantations established on cleared land in the south west of Western Australia. The AIAS said:

> A new industry could be created which, within 10 years could generate up to $400 m in export income and make a significant contribution to the reduction of salinisation and phosphorus pollution. (Sub. 15, p. 18)

Such plantations may have only a minor impact on atmospheric carbon dioxide concentrations if the trees are harvested on a short rotation, and sooner or later release whatever carbon they contain into the atmosphere. But if they substitute for fossil fuels, then they may have a more significant impact.

The AIAS also said there was considerable potential to increase plant biomass and carbon sequestration over large areas through agroforestry -- growing trees and pastures together. Apart from its impact on atmospheric carbon dioxide levels, agroforestry may also: increase pasture growth and plant productivity; improve soil structures; reduce cold and heat stress on livestock; and provide emergency fodder in droughts. The AIAS concluded by saying:

Much more research is needed before definitive conclusions can be drawn, and estimates of economic benefits obtained. (Sub. 15, p. 16)

The impact of establishing or re-establishing forests on existing forest-based industries might be another significant cost of reforestation. The CSIRO (Division of Plant Industry) said:

> the role of tree planting to sequester CO_2 needs to be considered integrally with the management, utilisation and replanting of the existing national forest estate. This is because the carbon in most wood products, especially paper, is converted back to CO_2 or methane within years of their manufacture. (Sub. 17, p. 7)

Halting deforestation

The ACF said:

> policies to reduce clearing of native vegetation and to phase out logging in old growth forests offer a range of ecological benefits. These include maintenance of biodiversity, watershed protection, and prevention of long term land degradation. (Sub. 46, p. 31)

These policies could also impose significant costs on those involved in logging and land clearing operations, and limit the availability of cleared land for farming.

F12.3 Factors limiting the establishment of forest 'sinks'

According to the AIAS, a lack of information about the carbon sequestration rates of different trees and forest soils may be delaying the establishment of forest 'sinks'. However, information on sequestration rates is currently being collected through research programs and trial plantations across Australia. For example, the SECV is funding a study conducted by the Melbourne University which is looking at the sequestration rates of Victorian trees.

Uncertainty about future markets for the timber produced in new `sinks' may also be delaying their establishment. The NAFI identified a number of areas where timber or forest products may be used, but said that institutional and other barriers were preventing this from occurring.

> For example, institutional barriers within the Australian building regulatory system are restricting the use of timber and thereby the expansion of structural (long term carbon storage) applications in residential construction. (Sub. D144, p. 2)

Wood grown in new `sinks' may also be used in place of fossil fuels for space heating, water heating, or other similar purposes. BHP Environmental Affairs said:

> Burning of biomass (such as wood and bagasse) is potentially a sustainable activity so long as the rate of use is balanced by the rate of regrowth. (Sub. D134, p. 3)

The net carbon dioxide emissions from a program of growing, harvesting and burning, and regrowing trees in a plantation are negligible, amounting to those emissions released in sowing, maintaining, harvesting and transporting seedlings and timber to the plantation from greenhouses, and from the plantation to users, respectively. The net emissions from the use of fossil fuels are much greater. Assuming the net emissions from using timber for space heating are zero, and that wood was the sole fuel used for residential space heating in 1986-87, carbon dioxide emissions could have been reduced by around 6 513 Mt. The costs incurred in achieving this reduction are difficult to estimate, even in general terms, but could reasonably be expected to be high.

One of these costs is the increase in air pollution associated with burning wood. The Tasmanian Government has recently examined the impact of air pollution from wood burning stoves on the residents of Launceston where, in a city of 65,000 people, 65 per cent of all homes use wood burning slow combustion stoves for space heating. According to the Government:

> Preliminary evaluation of data suggests that wood smoke contributes to a serious smog problem in winter. It is considered that this may potentially lead to a deterioration in the health of the community in the long term. (Sub. D139, p. 3)

However, the Government added:

> The working group is mindful that, if the problem of emissions from wood stoves can be overcome, wood is a suitable renewable energy form for domestic heating. The group is therefore investigating ways in which wood stoves may be redesigned to avoid harmful emissions and thus reduce the smog problem ...
>
> Pollution ‘free’ wood stoves can be promoted which may utilise wood from plantations and thus reduce reliance on non-renewables and also save in the infrastructural costs of the provision of new, or upgraded, transmission lines. (Sub. D139, p. 3)

If such stoves do become available, then greater use of wood in place of fossil fuels could have a significant impact on carbon dioxide emissions. But the cost of changing over to this new technology would, again, make this a potentially very expensive way of achieving a sustainable reduction in carbon dioxide emissions.

Some participants saw an inconsistency in advocating reforestation for its greenhouse benefits, while allowing land clearing and logging of mature forests to continue. The ACF said:

> any greenhouse benefits accruing from ‘regreening’ programs, will almost certainly be negated by current logging practices and clearing of native vegetation. (Sub. 46, p. 30)

Addressing the issue of logging, the NAFI, in its submission on the Commission's draft report, stated:

> Modern forest management techniques use the principle of sustained yield where the amount of wood removed from a forest is calculated on the basis of that forest's ability to grow wood. Using this management regime the forest's yield of wood can be sustained. (Sub. D144, p. 1)

The Association said:

> native forest management for wood production is not responsible for deforestation. (Sub. D144, p. 1)

A potential impediment cited by the Australian Coal Association (ACA) was the tax system. The Association said:

> For example, taxation regimes have contained concessions for clearing native vegetation ... these represent potential distortions that encourage inefficient use of resources, and at the same time, contribute to the accumulation of greenhouse gases. (Sub. 36, p. 34)

The Resource Assessment Commission (RAC) has recently released a draft report into Australia's forest and timber industries. In the course of the inquiry, the RAC considered the impact the enhanced greenhouse effect could have on Australia's forest and timber industries. The RAC (1991) concluded:

> The Inquiry cannot determine with precision the effects of expected global warming on Australia's forests or on the Australian wood and wood products industry. Such an evaluation is beyond the capacity of current predictive techniques and is limited by existing knowledge of key biological and climatological processes. (p. xlv-xlvi)

F12.4 Summary

- Forests are a sink for carbon dioxide as they absorb this gas as they grow; when mature, a forest releases as much carbon dioxide as it absorbs.

- A program of tree planting results in a one-off reduction in atmospheric carbon dioxide levels, but there are also many other environmental benefits from tree planting.

- Reforestation programs can be particularly costly if land needs to be acquired.

- Refraining from deforestation ensures carbon stored in mature forests is not released; carbon dioxide losses due to past deforestation have been substantial.

- Halting deforestation would impose costs on those involved in logging, and limit the availability of cleared land for agriculture.

- There is currently a lack of information on the carbon sequestration rates of different trees and different forest soils, which may be delaying the establishment of some tree plantations.

References

ABARE (Australian Bureau of Agriculture and Resource Economics) 1991a, *Projections of Energy Demand and Supply Australia 1990-91 to 2004-05*, January, AGPS, Canberra.

ABARE 1991b, *The Issue of Domestic Energy Market Failure*, Technical Paper 91.5, AGPS, Canberra.

Australian Gas Association 1990, *Gas Supply and Demand Study: Opportunities for Gas in Electricity Generation*, October, AGA, Canberra.

Australian Government and the Australian Consumers' Association 1991, *The Energy Guide*, February, AGPS, Canberra.

Australian Minerals and Energy Council 1990, Energy and the Greenhouse Effect, June, AGPS, Canberra.

Barson, M.M. and Gifford, R.M. 1990, `Carbon dioxide sinks: the potential role of tree planting in Australia', in Swaine, D.J. (ed.), *Greenhouse and Energy*, CSIRO, Australia, pp. 433-444.

Bessarab, R. and Kenworthy, J. 1990, *The Greenhouse Contributions of Transport*, 10 June, ISTP, Murdoch.

Booth, T.M. 1989, *Forestry and the Greenhouse Effect*, Bureau of Rural Resources workshop, Canberra.

Brotchie, J.F., Ehmke, H.J., Rodger, A., Sharpe, R. and Tucker, S.N. 1990a, `Greenhouse implications for Building', in Swaine, D.J. (ed.), *Greenhouse and Energy*, CSIRO, Australia, pp. 359-368.

Brotchie, J.F., Sharpe, R. and Rodger, A. 1990b, `Greenhouse Implications for Urban Systems', in Swaine, D.J. (ed.), *Greenhouse and Energy*, CSIRO, Australia, pp. 369-379.

BTCE (Bureau of Transport and Communications Economics) 1988, *Review of Road Cost Recovery*, AGPS, Canberra.

Business Council of Australia 1991, *Energy Prospects: Realistic prospects for improved energy efficiency and the application of renewable energy resources*, prepared by Burmot Australia for the Business Council of Australia, Volume 1, Melbourne.

Clinton J., Geller H., and Hirst E. 1986, *Review of Government and Utility Energy Conservation Programs*, Annual Review of Energy, No. 11, pp. 95-142.

Dixon, B.F. 1990, `Methane losses from the Australian natural gas industry', in Swaine, D.J. (ed.), *Greenhouse and Energy*, CSIRO, Australia, pp. 137-146.

Department of Primary Industries and Energy 1991, *A National Strategy for the Natural Gas Industry, A Discussion Paper*, July, AGPS, Canberra.

DITR (Victorian Department of Industry, Technology and Resources) 1990, *Renewable Energy and Energy Conservation,* Green Paper, February, Melbourne.

Ecologically Sustainable Development Working Group 1991, *Draft Report - Energy Production*, August, AGPS, Canberra.

Electricity Commission of NSW 1991, *New and Alternative Technologies for Electricity Generation*, March, Sydney.

Galbally, I.E., Fraser, P.L., Meyer, C.P. and Griffith, D.W.T. 1990, Biospherical Atmospheric Exchange of Trace Gases over Australia, paper presented at the IGBP Workshop No. 14 Utilization of Renewable Biological Resources, Canberra, 3-5 October.

Gates, R. W. 1983, *Investing in Energy Conservation,* Energy Policy, March.

Gawler, Dr R. 1991, *Pricing Policies for Independent Generation*, paper presented at the Workshop on Efficiency and Renewable Energy, Canberra, 16-18 April.

Green, M.A. 1991, *Solar Voltaics,* paper presented to the Ecologically Sustainable Development Working Group on Energy Production, Canberra, April.

Greene, D. 1984, *Cogeneration in Victoria*, Melbourne.

Greene, D. 1989, *Cogeneration: An Assessment of Potential Resources, A report prepared for the Electricity Commission of NSW,* ELCOM NSW.

Greene, D. 1990, *A Greenhouse Energy Strategy: Sustainable Energy Development for Australia, A report prepared for the Department of Arts, Sports, the Environment, Tourism and Territories*, prepared by Deni Greene Consulting Services with the assistance of George Wilkenfeld and Associates and Energetics Pty Ltd, February, DASETT, Canberra.

Greene, D. 1991, *Energy Efficiency - How Large are the Recoverable Reserves,* paper presented to Workshop on Efficiency and Renewable Energy, Canberra, 16 -- 18 April.

IC (Industry Commission) 1990, *The Automotive Industry*, Report No. 5, 17 December, AGPS, Canberra.

IC 1991a, *Energy Generation & Distribution*, Report No. 11, 17 May, AGPS, Canberra.

IC 1991b, *Rail Transport,* Report No. 13, 21 August, AGPS, Canberra.

IC 1991c, *The Environmental Implications of a National Electricity Grid*, Working Paper, July, Canberra.

International Energy Agency 1989, *Projected Costs of Generating Electricity from Power Stations for Commissioning in the Period 1995-2000*, OECD, Paris.

Kuhn, D. 1991, *Photovoltaics -- A Viable Option*?, February, Australia.

Le Cornu, J.K. 1990, `Greenhouse gas emissions from the production and use of alternative transport fuels', in Swaine, D.J. (ed.), Greenhouse and Energy, CSIRO, Australia, pp. 293-303.

Marks, R.E., Swan, P.L., McLennan, P., Schodde, R., Dixon, P.B. and Johnson, T.D. *1989, The Feasibility and Implications for Australia of the Adoption of the Toronto Proposal for Carbon Dioxide Emissions, Report to CRA Limited,* September, Melbourne.

McGlynn, G., Newman, P.ÿand Kenworthy, J. 1991, *Transport Energy Scenarios for Australian Cities,* June, ISTP, Murdoch.

NIEIR (National Institute of Economic and Industry Research) 1990, *Efficient Renewable Energy Scenario Study for Victoria Study prepared for the Victorian Solar Energy Council*, 25 May, Melbourne.

RAC (Resource Assessment Commission) 1991, *Forest and Timber Inquiry Draft Report*, Volume 1, July 1991, AGPS, Canberra.

RBA (Reserve Bank of Australia) 1991, Occasional Paper No. 8: *Australian Economic Statistics*, 1949-50 to 1989-90, p. 143, p. 146.

Senate Standing Committee on Industry, Science and Technology 1991, RESCUE THE FUTURE, *Reducing the impact of the greenhouse effect,* January, The Parliament of the Commonwealth of Australia, Canberra.

South Australian Climate Change Committee 1990, *The Greenhouse Strategy for South Australia*, June, Department of Environment and Planning, SA.

South Australian Government 1991, *Future Directions for the Energy Sector in South Australia - Green Paper,* January, Govt. of South Australia, Adelaide.

SPC (Special Premiers' Conference) 1991, *Communique*, Sydney, July 30-31.

Stewart, G.A. 1991, A Preliminary Evaluation of Biomass as a Source of Renewable Energy, paper presented to the Workshop on Renewable Energy, Canberra, April.

Sutherland R. J. 1991, *Market Barriers to Energy-Efficient Investments*, The Energy Journal, Volume 12, No. 3.

Unisearch Ltd 1991, *The Role of Wind Energy in Reducing Greenhouse Gas Emissions, prepared for the Department of Arts, Sport, the Environment, Tourism and Territories*, June, AGPS, Canberra.

Walker, J. A., Rauh, T. N., and Griffin K. 1985, *A Review of the Residential Conservation Service Program,* Annual Review of Energy, No. 10, pp. 285-315.

Walker, I.J. 1990, *Potential to reduce emissions of Greenhouse Gases in the Energy Sector*, EPD Discussion Paper No. 1, May, DPIE, Canberra.

Walker, I.J. and Stevens, M.R. 1990, *Renewable Energy*, EPD Discussion Paper No. 3, November, DPIE, Canberra.

White, N 1990, `Production of liquid fuels', in Swaine, D.J. (ed.), *Greenhouse and Energy*, CSIRO, Australia, pp. 233-243.

Wilkenfeld, G. 1991, *Greenhose Gas Emissions from the Australian Energy System: the Impact of Energy Efficiency and Substitution*, prepared by George Wilkenfeld and Associates with Energetics Pty Ltd and the assistance of Enersonics Pty Ltd, February.

Williams, R. H., Dutt, G.S., and Geller, H.S. 1983, *Future Energy Savings in U.S. Housin*g, Annual Review of Energy, No. 8. pp. 269-332.

APPENDIX G: ECONOMIC MODELLING OF GREENHOUSE GAS EMISSIONS

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This appendix discusses in more detail the models used in Chapters 5, 8 and 9 and the implications of the main results generated. The three models used were ORANI-Greenhouse, GREEN, and WEDGE. It also compares in more detail the results from various Australian and international studies on reducing greenhouse gas emissions.

G1 ORANI

ORANI is a large-scale multisectoral model of the Australian economy. It contains considerable microeconomic detail on the nature of production and demand in the economy, capturing the interdependencies between industries that arise from the purchase of each others outputs of goods and services; competition for available resources, such as labour and capital; and other constraints that operate generally (for example, the government's real borrowing requirement and the balance of trade).

The ORANI model has been widely used for quantifying the economy-wide effects of various policy changes. It is an appropriate model to use for this inquiry as, for example, changes in fossil fuel prices that may result from the introduction of a carbon tax would affect the costs, and hence the price of other industries' output, not just the retail price of fossil fuels. These indirect effects could have significant implications for Australia's emissions of greenhouse gases that would not be identified in a model which only looked at the direct effects of price changes on the incentives to use fossil fuels.

The Commission has used ORANI to examine the implications of some possible greenhouse policy responses for the Australian economy because of its industry-specific detail and because of its ability to capture indirect effects. Fossil fuels and energy sources (black coal, brown coal, petroleum products, gas and electricity) and various agricultural sectors (for example, cattle and rice production) that are the primary sources of man-made emissions of carbon dioxide and methane are represented as separate commodities in the model. The model's database is for the year 1980-81.

For a more detailed explanation of the general versions of the ORANI model used by the Commission, the reader is referred to Dee (1989), IAC (1987) and Dixon et al. (1982). The currently used version is known as `Fiscal-Horridge ORANI' or FH-ORANI. For this inquiry, several major changes have been made to FH-ORANI in order to capture some of the key factors likely to be important in dealing with the greenhouse effect. The key features of this version of ORANI, called ORANI-Greenhouse, include the ability to substitute between different types of fuels and to become less energy intensive (essentially through substituting capital for energy), and to substitute between different methods of transport. The model also incorporates the man-made greenhouse gas emissions (carbon dioxide and methane). Details regarding the modifications are discussed in greater detail in following sections of this appendix.

Despite these modifications, ORANI remains an imperfect tool for looking at greenhouse gas emissions. In particular, the potential for energy savings through technological improvement have not been explicitly incorporated. Further, because of the extreme uncertainty at this stage regarding the likely regional climatic changes or their impacts on Australia, no possible feedback effects of climatic change on the economy have been incorporated.

Furthermore, being a static model, ORANI cannot deal with the inter-temporal issues that arise in the greenhouse problem, such as increasing atmospheric concentrations of greenhouse gases, or the effect of increases in the tax rates over time as the economy grows.

Despite these limitations, ORANI is a useful tool for examining some of the economic effects that result from actions taken to avoid global warming. Given the magnitude of the associated scientific and economic uncertainties, the effects should be taken as being broadly indicative, rather than as hard estimates of the costs to Australia, and should be interpreted in conjunction with other available information on the potential economic effects of policies chosen to combat climate warming.

Primary factor/inter-fuel substitution

In the standard version of FH-ORANI each industry is usually modelled as using all material inputs in fixed proportions. That is, if an industry's output increases by a factor of two, then so does the industry's intermediate usage of each commodity. Thus industries are unable to substitute one commodity for another in the production of their outputs.

Industry usage of the three primary factors -- labour, capital and land -- are not, however, constrained to be in fixed proportions, so there is the potential to substitute one primary factor for another. Thus an increase in capital costs will lead, other things being equal, to an industry using less capital, more labour and, for land using industries, more land. The primary factor bundle of labour, capital and land is, however, used in fixed proportions with each material input. So neither primary factors as a whole, nor each individual primary factor, can substitute with any commodity.
Clearly this specification fails to capture some important consequences of policies introduced to reduce greenhouse gas emissions. For example, the electricity industry could switch, in the long run at least, from using coal in electricity production to using gas in response to a relative price increase in coal. Further, in response to a general increase in fuel costs, more efficient technologies may become economically viable, thus leading to a reduction in fuel usage and an increase in capital usage.

Ignoring these substitution possibilities could have significant implications for modelling the effect of price increases for fuels. For example, when price increases are induced by a tax on carbon dioxide emissions, and where the price increase of each fuel will be more the greater the carbon content of the fuel, industries would be unable to substitute toward 'cleaner' fuels to reduce costs. Thus the impact of a given carbon tax on an industry will be much more severe than if substitution away from high carbon content fuels is allowed. ORANI-Greenhouse, unlike standard ORANI, allows for fuel substitution.

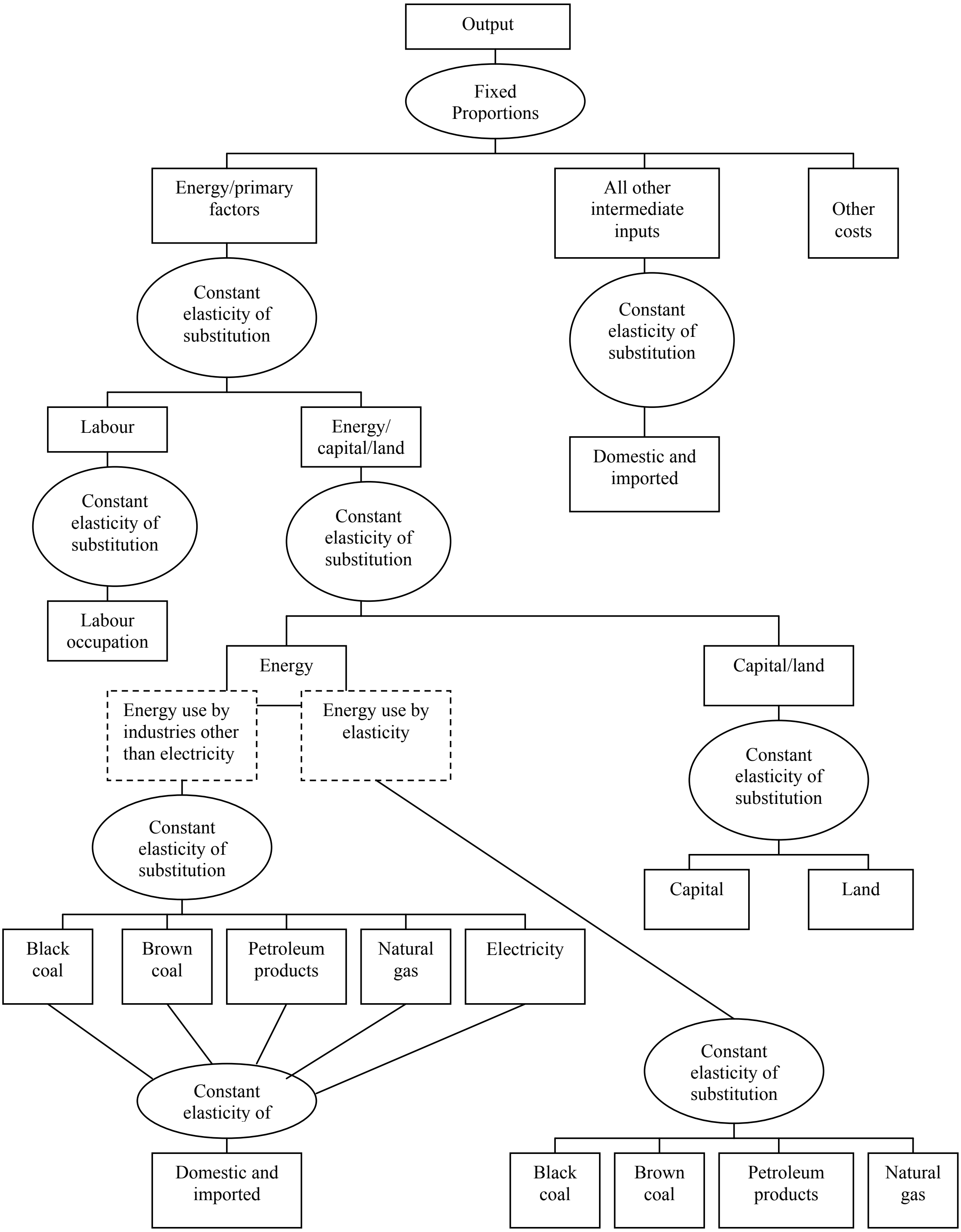
The size of the tax required on carbon dioxide emissions will also depend on how easy it is to switch to less carbon-intensive fuels which have lower tax rates applied to them. This ability to substitute between fuels can be summarised by the own- and cross-price elasticities for coal, petroleum products and gas.

Two econometric studies have estimated the substitution elasticities for manufacturing in Australia and NSW respectively (Turnovsky et al. 1982, Truong 1985). These studies found that certain fuels were complements. For example, as the price of electricity rises the demand for fuel oil would fall. Historically this may have been the case, but given the likely magnitude of price changes required to reduce greenhouse gas emissions, complementarity between these fuels is unlikely to persist. Indeed, as large price increases occur, these fuels are likely to become substitutes for each other. That is, as the price of electricity increases, the demand for fuel oil is also likely to increase, as an alternative source of energy to electricity.

The own- and cross-price elasticities used by the Commission in ORANI-Greenhouse to govern interfuel substitution were, therefore, obtained from the OECD's GREEN model. This ensures greater consistency in the results of the two models. One possible drawback with these elasticities is that they are estimated over the whole world, not just Australia. Thus the elasticities incorporate the different economic structures that exist overseas, rather than our domestic structure. They are also the same for each pair of fuels which is unlikely to be realistic.

The structure of substitution used is illustrated in Figure G1. The electricity industry is given a different treatment from other industries, as it uses the four fuels black coal, brown coal, petroleum products and gas, whereas other industries can use these four fuels as well as electricity to satisfy their energy requirements.

Figure G1: **Substitution possibilities in production in ORANI-Greenhouse**



As well as switching from one kind of fuel to another, firms may conserve energy in response to an increase in fuel prices. For example, the oil price shocks of the 70s forced production to become less energy-intensive as higher energy prices encouraged some substitution of other factors of production for energy. There have been considerable changes in the pattern of fuel demand since the mid-70s, in particular a substantial reduction in the use of petroleum products for process and space heating and in base and intermediate-load thermal electricity generation. However, petroleum products still comprise almost all of the fuel supplied to transport sectors (Naughten 1991) because alternatives are not economic at current and projected future prices. Households can also conserve energy as greater expenditure on insulation can reduce the need for heating fuel. Alterations in building design may also have an effect.

Table G1 presents some estimates of the degree of substitution between energy and capital in industrialised nations. Pindyck's data relate to the period 1963 - 73 so that they would be inappropriate for modelling post-OPEC energy demand patterns. Nevertheless, they are still instructive. Even before the large increases in oil prices in the mid- and late 1970s, there was evidence of considerable substitution between energy and capital in the industrial nations.

The estimates reported by Helliwell et al. for the period 1960 - 82 suggest that the substitution elasticities in the pre- and post-OPEC periods are broadly similar for industrialised nations. Should energy prices rise significantly (as is likely to occur with the introduction of a tax on carbon dioxide emissions), there is clearly the capacity on the part of energy users to reduce their energy consumption through capital investment over the next decade. A value of 0.5 was used in the ORANI-Greenhouse model to govern substitution between energy and the capital/land aggregate, this being in the mid point of Helliwell's range of estimates.

Table G1: **Elasticities of substitution between capital and energy**

Country	*Helliwell et al.*	*Pindyck*
United States	0.5	1.77
Japan	0.8	0.74
West Germany	0.5	0.66
France	0.8	0.56
United Kingdom	0.3	0.36[a]
Italy	0.5	0.67
Canada	0.9	1.48
Netherlands	-[b]	0.59
Norway	-[b]	0.59
Sweden	-[b]	0.63

[a] Not significant at 95% confidence interval.
[b] Not estimated.
Sources: Helliwell et al. (1986); Pindyck (1979).

There is also the possibility that increased use of labour can offset the need for energy. The studies of Helliwell et al. and Pindyck also include estimates of the elasticity of substitution between energy and labour for some countries. These are shown in Table G2. A value of 0.8 was used in ORANI-Greenhouse to govern substitution between labour and the energy/capital/land aggregate, again taken from the mid point of Helliwell's range of estimates.

Table G2: **Elasticities of substitution between labour and energy**

Country	*Helliwell et al.*	*Pindyck*
United States	1.01	0.05 [a]
Japan	0.70	1.15
West Germany	0.99	1.23
France	0.80	1.17
United Kingdom	0.60	1.10
Italy	0.80	1.11
Canada	1.01	0.42 [a]
Netherlands	- [b]	1.11
Norway	- [b]	1.14
Sweden	- [b]	1.10

[a] Not significant at 95% confidence interval.
[b] Not estimated.
Sources: Helliwell et al. (1986); Pindyck (1979).

Inter-modal substitution

Various modes of transport are used to facilitate the flow of commodities to industries, households, government and exports. In ORANI-Greenhouse, the modes of transport included were road freight transport, mining rail freight, non-bulk rail freight, water transport and air transport.

For most industries there is some flexibility in choosing the mode of transport to convey a commodity. This degree of flexibility, or inter-modal substitution, is largely determined by the commodity being transported. For example, rail is generally the cheapest way for long distance movement of many mining commodities, such as non-ferrous ores. Given this, many mines are served by dedicated railway lines, so for these commodities the elasticity of substitution between transport modes is relatively small.

In the standard version of FH-ORANI, each industry is usually modelled with its usage of each mode of transport to convey a particular commodity being in proportion to the industry's usage of that commodity. So if certain levels of road freight transport and water transport are used to convey cattle to a particular industry, and the number of cattle required by that industry increases by 10 per cent, then the usage of both road freight transport and water transport to convey cattle to that industry will increase by 10 per cent. (The total usage of each of road freight and water transport by the industry will not, however, necessarily change by 10 per cent.) This implementation of FH-ORANI does not permit industries to substitute between modes of transport in response to relative price changes in transport types.

As transport is a major contributor to the man-made emissions of greenhouse gases, and as different modes of transport use different fuels and/or have differing efficiencies in fuel usage, the ability to adequately model substitution between 'dirty' and 'clean' modes of transport may be important. Inter-modal substitution was therefore incorporated into ORANI-Greenhouse, as in IAC (1989). The elasticities of substitution were constant between all modes of transport used for conveying a particular commodity, and are shown in Table G3.

Table G3: **Elasticities of substitution between different modes of transport**

Commodity	*Substitution elasticity*	*Commodity*	*Substitution elasticity*
Wool	1.60	Export food	2.00
Sheep	2.00	Other food	2.00
Wheat	0.32	Cotton ginning/wool scouring	2.00
Barley	0.32	Other TCF	2.00
Other cereals	0.32	Wood, paper & printing	2.00
Meat cattle	2.00	Chemical fertilizers	2.00
Milk and pigs	2.00	Other basic chemicals	2.00
Other farming export	2.00	Other chemical products	2.00
Other farming import	2.00	Glass & cement products	2.00
Poultry	2.00	Fabricated metal products	2.00
Agricultural services	2.00	Motor vehicles	2.00
Forestry and logging	2.00	Railway rolling stock	2.00
Fishing and hunting	2.00	Other transport	2.00
Ferrous metal ores	2.00	Scientific equipment	2.00
Bauxite	0.00	Electronic & electrical equip	2.00
Copper ores	0.00	Agricultural machinery	2.00
Gold ores	0.00	Construction machinery	2.00
Mineral sands	0.00	Other machinery & equipment	2.00
Nickel ores	0.00	Miscellaneous manufacturing	2.00
Silver, lead, zinc ores	0.00	Electricity	2.00
Tin ores	0.00	Water & sewerage	2.00
Uranium ores	0.00	Gas	2.00
Non-ferrous metal ores nec	0.00	Residential construction	2.00
Black coal	0.00	Other construction	2.00
Brown coal	0.00	Wholesale & retail trade	2.00
Oil	0.00	Road freight transport	2.00
Gas	0.00	Road passenger transport	2.00
Other minerals	0.00	Mining rail freight	2.00
Petrol & mining exploration	2.00	Non-bulk rail freight	2.00
Mining & exploration services	2.00	Passenger railway	2.00
Petroleum products	0.00	Railway fixed costs	2.00
Coal products	0.00	Other transport & storage	2.00
Basic iron & steel	2.00	Water transport	2.00
Copper smelting, refining	2.00	Air transport	2.00
Silver, lead, zinc refining	2.00	Communication	2.00
Alumina	2.00	Finance, property & business	2.00
Aluminium smelting	2.00	Other business services	2.00
Nickel smelting, refining	2.00	Ownership of dwellings	2.00
Gold refining	2.00	Public admin. & defence	2.00
Non-ferrous metals smelting nec	2.00	Community services	2.00
Secondary recovery of non-ferrous metals	2.00	Entertainment etc	2.00
Aluminium rolling, drawing, extruding	2.00	Non-competing imports	2.00
Non-ferrous metal rolling, casting	2.00		

Source: ORANI-Greenhouse database.

Emissions coefficients

This section describes the greenhouse gas emissions coefficients used in the ORANI-Greenhouse database.

Carbon dioxide

The coefficients for carbon dioxide released per unit of energy produced vary considerably between studies (Table G4). Fuels from different sources have different chemical compositions, and different testing procedures are often used. As noted by ABARE (1991), the coefficients should be considered to be indicative only.

The emission coefficients used in ORANI-Greenhouse were Wilkenfeld's coefficients for black coal, brown coal, petroleum products and natural gas, and are shown in the second to last column in Table G4.

Table G4: **Estimates of carbon dioxide emission coefficients by fuel type** (kt/PJ)

Fuel type	*Energetics*	*Walker* [a]	*CRA*	*AIP*	*Steinberg* [b]	*Wilkenfeld* [c]	*NIEIR*
Black coal	-	92	92	104.1	87.0	89.3	93
Brown coal	106.4	94	95	112.7	-	94.4	96
Renewables							
(Wood & bagasse)	96.0 [d]	-	80	78.9	-	96.3 [d]	96
Petroleum products	76.4	77	73	73.2	68.2	68.6	78
Natural gas	54.2	55	59	54.9	49.1	52.7	67

[a] Converted from MtC to Mt CO2 by multiplying by 44/12. [b] Converted from lbCO2/1000BTU by multiplying by 426.54. [c] Primary form coefficients. [d] Wood only.
Units: Kt - kilotonne, PJ - petajoule (10 15 joules), MtC - million tonnes carbon, Mt CO_2 - million tonnes carbon dioxide, lbCO_2 - pounds of carbon dioxide, BTU - British thermal units.
Sources: Energetics (1990), Walker (1990), Common & Salma (1991), CRA (1989), AIP (1989), Steinberg et al. (1984), Wilkenfeld (Sub. 9) and NIEIR (1991).

Methane

Methane is the second most important greenhouse gas, and is believed to account for about 18 per cent of the Australian contribution to the greenhouse effect (ANZEC 1990) over a 100-year period. However, estimates of emissions levels (Appendix C) and of global warming potential vary greatly with the time scale under consideration, and substantial uncertainty may exist as to the accuracy of published statistics.

Calculation of methane emissions coefficients is extremely difficult. For example, methane emissions released from coal mining depend on the depth of the coal seam being mined (Hargraves

1990). Therefore estimation of emissions requires information not only on the amount of coal produced but also the depth from which it is mined.

The only available data on methane emissions from **coal mining** was provided in the Wilkenfeld submission and pertained to NSW and Queensland only. This was used as a proxy for the emission figure for Australia. Since black coal is the main coal type to be found in these States, the Commission was unable to include a methane coefficient for brown coal.

The coefficient used for the ORANI-Greenhouse commodity Black Coal was thus 0.1 Kg of methane per GJ of energy, or 100 tonnes per PJ as specified in the Wilkenfeld submission to the inquiry.

Methane is emitted from the incomplete combustion of **petroleum products** in transport usage. Australia's apparent consumption of petroleum products in 1987-88 was 294 PJ (ABARE 1989). Emissions of methane from transport usage of petroleum products was 93.4 kt in the same year (Australian Inventory Preparation Group 1991). This gives an emissions coefficient of 318 tonnes per petajoule for methane emissions from petroleum products.

Methane lost to the atmosphere from the natural **gas** grid totals 0.15Mt per year (Galbally et al. 1990). ABARE calculate that 712.75 PJ of gas were produced in 1989, giving a coefficient of 210.45 tonnes per petajoule.

Emissions per animal for a number of species are presented in Table G5. Two participants queries some of those figures. The AIAS (Sub. D109) considered the emission rate for kangaroos was 0.1 rather than 4.0, and considered that the ratios of emissions from adult to juvenile cattle and sheep implied by the figures were too high. Dr M. Howden of the Bureau of Rural Resources (Sub. D150) presented details of his work about methane emissions from animals. He estimated total emissions of 3314 tonnes from livestock in 1987-88, which exceeds the figure of 1893 shown in the table. Nevertheless, from the point of view of the modelling work it is the relativity between the emissions coefficients for methane and those for carbon dioxide which is important rather than the absolute size of the methane coefficients themselves.

Only **cattle, pigs and sheep** are incorporated into the ORANI-Greenhouse database. These are by far the most important sources of methane from grazing animals. Emission coefficients were calculated for ORANI-Greenhouse as weighted averages of emissions from adult or juvenile cattle, sheep and pigs as appropriate.

Table G5: **Methane emissions from grazing animals**

	Emission rate per animal	*Population of animals*	*Total methane emissions by species*
	kg/year/animal	*millions*	*tonnes/year*
Camels	58.0	0.1	2.9
Meat cattle- adult[cd]	55.0	14.3	786.5
- juvenile[bd]	20.0	5.3	104.0
Milk cattle	55.0	2.6	143.0
Buffalo (feral)	50.0	0.5	25.0
Horses- adult[b]	18.0	1.0	18.0
- feral	15.0	0.4	6.0
Wool sheep- adult[cd]	5.0	108.5	542.5
- juvenile[bd]	3.0	19.7	59.1
Meat sheep- adult[cd]	5.0	12.4	62.0
- juvenile[bd]	3.0	16.5	48.5
Goats- domestic	5.0	0.4	2.0
- feral[a]	4.0	1.6	6.4
Pigs- domestic[d]	1.5	2.7	4.1
- feral	1.0	1.4	1.4
Kangaroos[a]	4.0	20.0	80.0
Man	0.1	16.0	0.8
TOTAL	-	-	1893.0

[a] Assumed to be similar to other non-ruminants of similar size. [b] Assumed. [c] Animals over 1 year old. [d] Population from ABS data, for the financial year 1988-89.
Source: Williams (1989) and IC calculations.

The final methane coefficient was for rice cultivation. Australia produces 0.14 per cent of the world's rice production, representing about 0.7Mt a year (Williams 1989). The emissions coefficient is 0.057 tonnes of methane per tonne of rice (Galbally et al. 1990).

Rice is included in the ORANI-Greenhouse commodity Other Cereals. The coefficient was applied only to the quantity of rice produced (0.7Mt per year) to give the total emissions without influencing the other components of Other Cereals.

The methane emission coefficients incorporated into ORANI-Greenhouse are shown in Table G6.

Nitrous oxide

Estimates of nitrous oxide emissions are so unreliable or unpredictable that an emissions coefficient was not incorporated into the database. The Issues Paper (IC 1991) suggests that the current annual contribution to the greenhouse effect by nitrous oxide is 19 per cent. In its submission the Automobile Association notes we can as yet only speculate upon sources of its release, the main sources being those possibly coming from the degradation of nitrate fertilisers (30 per cent), and biomass burning (30 per cent). However, Galbally et al. (1990) estimate that up to 72 per cent of man-made nitrous oxide emissions can be traced to legume pastures.

Table G6: **Methane coefficients added to the ORANI-Greenhouse database**

ORANI-Greenhouse Commodity	*Emission Coefficient (t/unit)*
Meat Cattle[a]	0.046
Milk Cattle & Pigs[a]	0.022
Wool sheep[a]	0.005
Meat sheep[a]	0.004
Other Cereals[bd]	0.057
Black Coal[c]	100.000
Petroleum Products[c]	318.000
Gas[c]	210.450

Units: [a] number of animals. [b] tonnes. [c] petajoules. [c] Rice only.
Source: ABS data, Galbally et al. (1990) and IC calculations.

G2 GREEN

This section describes the structure of the GREEN model developed by the OECD to analyse international policies directed toward reducing carbon dioxide emissions. A full description of the model is in OECD (1991a).

GREEN is a multi-sectoral, multi-regional, dynamic model of the world economy. The model's database is for the year 1985. The sectoral detail is designed to capture the main links between energy production, energy consumption and the rest of the economy. The sectors distinguished are therefore limited to agriculture, four categories of fossil fuel production, energy intensive industries, energy distribution, and other industries.

There are three sources of fossil fuel energy and one source of non-fossil fuel energy (a combination of nuclear, hydro and solar). The non-fossil fuel does not emit carbon dioxide. Emissions coefficients for coal, oil and natural gas are shown in Table G7, as well as the values for various substitution elasticities which were used.

Figure G2: **The structure of production in GREEN**

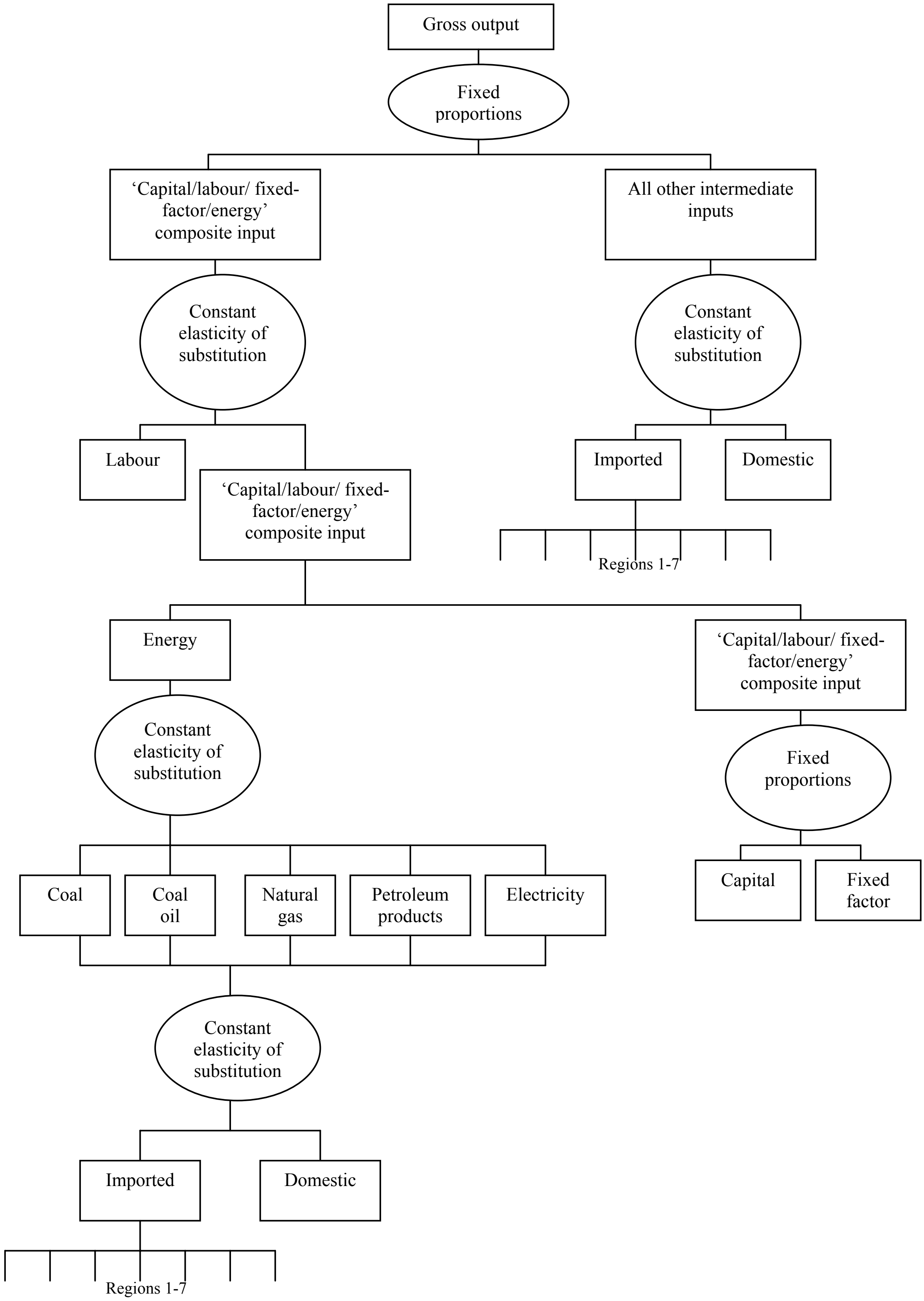


Table G7: **Emissions coefficients and selected substitution elasticities in GREEN**

	Agriculture	*Coal*	*Crude Oil*	*Natural gas*	*Electricity*	*Carbon-free resource*
Price elasticity of exports	-4.0	-5.0	∞	-5.0	-	-
Substitution elasticity between domestic and imported goods	-3.0	-4.0	∞	-4.0	-	-
Inter-fuel substitution elasticity	-	1.2	1.2	1.2	1.2	-
Supply elasticity	1.03.0[ab]	4.0-5.0[a]	∞	0.0	-	0.2
Carbon emissions [c]	-	0.61	0.12	0.60	-	-

[a] Depends on region.
[b] Supply elasticity of agricultural land.
[c] Tons carbon per unit of fuel. Units are: coal-tons, crude oil-barrels, natural gas-tons of oil equivalent.
Sources: OECD (1991 a,b).

GREEN explicitly models the economies of 6 regions; North America, Europe, the Pacific, the USSR, China and the energy exporting LDCs. As the Pacific includes Japan, Australia and New Zealand, GREEN cannot be used to focus on the specific implications for Australia of various policies to combat greenhouse warming. Nor is the rest of the world -- which includes Eastern Europe and Asia -- modelled explicitly. Nevertheless, the major regional sources of carbon dioxide, and the major regional sources of primary energy, are covered explicitly.

Consumers are allowed to choose between 4 main commodities -- food and beverages, fuel and power, transport and communication, and other goods and services. A transitions matrix converts the demands for these consumer commodities into demands for energy and the outputs of each sector. Given the energy intensity of each good, and relative fuel prices, consumers thus implicitly choose an optimal mix of fuels and are able to substitute away from the most carbon-intensive fuels in response to a carbon tax. For producing sectors, the substitution possibilities between input categories are shown in Figure G2.

The dynamic treatment in GREEN covers capital accumulation and natural resource depletion. Savings add to the capital stock over time by increasing capital accumulation. Current savings thus influence future economic activity in GREEN.

Coal is modelled as being in infinite supply, but oil and natural gas are not. Oil and gas supplies depend on the initial levels of proven and unproven reserves, the rate of reserve discovery, and the rate of extraction. Supplies of oil and gas are thus price sensitive, although given the assumption that the absolute stocks of oil and gas are finite, long term supplies must necessarily fall as reserves are depleted.

Finally, all regions are linked by trade flows. Imports from each region are treated as imperfect substitutes with the exception of oil, which is assumed to be homogeneous. Thus each region faces a downward sloping demand curve for each of its exports, except for oil.

G3 WEDGE

The OECD used GREEN to model a number of scenarios for reducing carbon dioxide emissions. Because the GREEN model does not identify Australia separately, and because the Commission wanted to explore further the implications for Australia of various multilateral and plurilateral scenarios, it constructed its own multi-sectoral multi-regional model of the world called WEDGE.

Unlike GREEN, WEDGE is a comparative static model, but it has greater sectoral detail and full global coverage. The model's database is for the year 1988. This section describes some of the key features that distinguish WEDGE from GREEN. Further details are available from the Commission on request.

WEDGE has considerably greater sectoral detail than GREEN, to reflect industry and commodity flows that are likely to be particularly important to Australia. The regional detail is also quite different from that in GREEN, again to reflect the trading patterns of importance to this country. The sectors and regions embodied in WEDGE are shown in Box G1.

Each sector can substitute land, labour, capital and fuels (coal, oil, gas and electricity) for each other, and substitution is also allowed between domestic and imported commodities. Non-fuel intermediate inputs, however, are used in fixed proportions. The structure of production is shown in Figure G3. The emissions coefficients and substitution parameters are shown in Table G8.

Table G8: **Emissions coefficients and selected substitution elasticities in WEDGE**

	Coal	*Oil and gas*	*Electricity*
Substitution elasticity between domestic and imported goods	2.8	2.8	2.8
Inter-fuel substitution elasticity	1.2	1.2	1.2
Carbon dioxide emissions[a]	89.3	63.8	-

[a] Tonnes per petajoule.

Finally, each region is linked via trade flows. Domestically produced and imported commodities are assumed to be imperfect substitutes, again implying that each region faces a downward sloping demand curve for its exports.

Box G1: **Industries and regions in WEDGE**

Agriculture

Paddy rice
Non-grain crops
Wheat
Other grains
Wool
Other livestock products

Resources

Forestry
Fishing
Coal
Oil and gas
Other minerals

Food

Meat products
Milk products
Other food products
Beverages and tobacco

Manufacturing - non-metallic

Spinning, dyeing and
made-up textiles
Wearing apparel
Leather, fur and their products
Lumber and wood products
Pulp, paper and printing
Chemicals, rubber and plastic
Petroleum and coal products
Non-metallic mineral products

Manufacturing - metallic

Primary iron and steel
Other metals and products
Transport industries
Other machinery and equipment
Other manufacturing

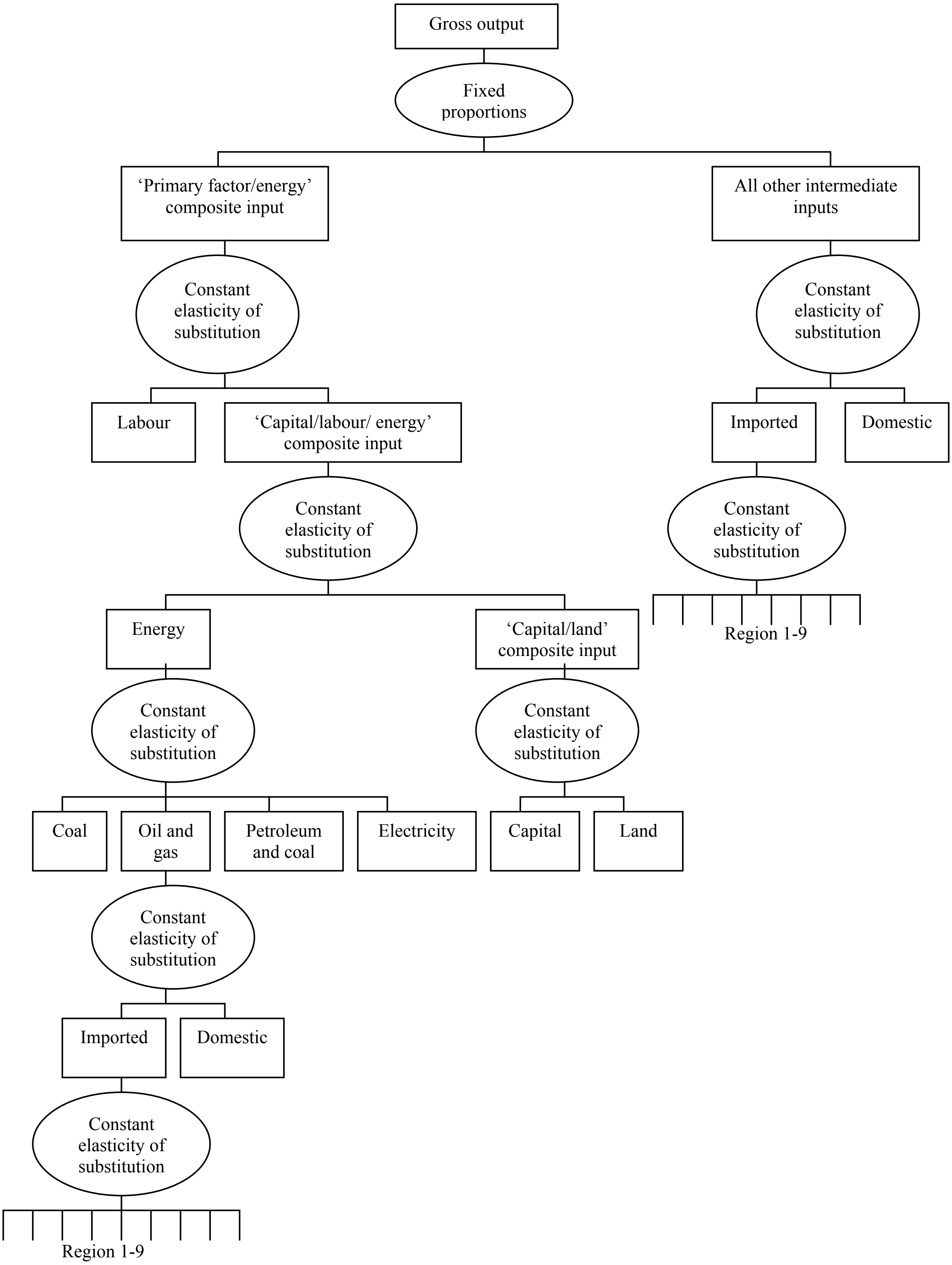
Services

Electricity, gas and water
Construction
Trade and transport
Other services (private)
Other services (government)
Other services (ownership of dwellings)

Regions

Australia
New Zealand
Canada
United States
Japan
Korea
European Community
ASEAN
Rest of World

Figure G3: **The structure of production in WEDGE**



An important aspect of any application of the WEDGE model is the specification of the economic environment in which the simulations are to be carried out. This specification is known as the ‘closure’ of the model. In this application of the model a medium run economic environment is used. This represents a time period long enough for primary factors to be reallocated between industries, but not long enough for aggregate factor endowments to substantially affect the composition of the world economy. The main features of this closure are as follows:

- The employment rate in each economy is fixed, and the wage rate varies so that aggregate quantity of labour demanded grows at the same rate as the quantity supplied.
- The aggregate capital stock in each economy is fixed, and the rental price of capital varies so that the aggregate quantity of capital demanded remains equal to the available stock.
- Capital use by individual industries varies, so as to maintain a uniform rate of return across industries.
- Aggregate real investment in each economy is fixed.
- In each economy, the household saving ratio adjusts to maintain a fixed ratio between the balance of trade and net domestic product.
- In each economy, aggregate government consumption expenditure moves in line with household consumption expenditure, and transfer payments move in line with net factor income.
- In each economy, the income tax rate adjusts to maintain a fixed ratio between the government budget deficit and net domestic product.
- Nominal exchange rates are fixed.
- Fob prices of exports from the rest of the world are fixed.

G4 Comparing results from different Australian studies

Section G4.1 reviews two recent general equilibrium studies of the costs of reducing emissions of greenhouse gases in Australia. One was prepared for CRA Limited using a version of the ORANI model (CRA 1989), while the other was prepared for the Victorian Solar Energy Council using the National Institute of Economic and Industry Research's IMP model (NIEIR 1990).

These two studies reached very different conclusions about the economic effects of action to reduce greenhouse gas emissions. The main concern here is with the reasons for these different conclusions; how far they result from differences in the purpose and coverage of the studies, how far from different factual assumptions in the scenarios modelled, and how far from differences in the model structures.

Section G4.2 compares the results presented in the submission by the Tasman Institute with the Commission's results in Chapter 9. Section G4.3 compares results from two versions of the ORANI model, one of which (ORANI-F) was used in the CRA study and another of which (FH-ORANI) has been used by the Commission. SectionÿG4.4 reviews the modelling work undertaken for the ESD Working Groups, while SectionÿG4.5 briefly considers work in progress for the Commission for the Future.

G4.1 CRA and VSEC

The CRA study used the ORANI-F forecasting model to estimate the economy-wide effects of various measures to reduce carbon dioxide emissions, for a report on `The Feasibility and Implications for Australia of the Adoption of the Toronto Proposal for Carbon Dioxide Emissions', commissioned by CRA (1989).

The report's explicit aim was to consider the economic consequences of adopting the Toronto goal for reducing emissions, and the likely costs of doing so. The study only examined two sectors of the economy, namely electricity generation and road transport. Options for reducing carbon dioxide emissions in these two sectors were examined independently of each other. This tied in with the report's main aim of illustrating key issues rather than a definitive resolution of them.

The second study was concerned with energy use in Victoria, and used the IMP model, with a model of the Victorian economy linked to an energy demand model to assess the macroeconomic implications. This study was conducted by the National Institute of Economic and Industry Research (NIEIR) and was initiated by the Victorian Solar Energy Council (VSEC). It was not primarily directed at the Toronto target, although relevant results were provided. Rather, it focused on the costs and benefits of an `efficient renewable energy use strategy, under which identified energy conservation technologies attained their maximum economic potential'. The emission reductions from this strategy would be insufficient to meet the Toronto target. The study also simulated a Toronto target strategy, involving a more optimistic assessment of future technologies, drastic `production and consumer acceptability' changes, and the adoption of some sub-economic emissions reducing techniques.

The CRA study estimated the cost of achieving emission reductions in line with the Toronto target, in electricity generation and road transport alone, at $19 to $32 billion (present value of GDP foregone over the period 1987-88 to 2004-05), depending on the discount rate used. The VSEC study estimated net benefits from the `efficient renewable energy' strategy over the period 1988 - 2030 of $8 billion, and benefits from the Toronto strategy, over the shorter period 1988 - 2005, of $5 billion.

The two studies have very different objectives. The aim of the CRA study was to estimate the costs of a feasible emissions reduction strategy. The VSEC study, on the other hand, did not attempt to develop policy options. The authors clearly state that the study examined what is possible in terms of energy conservation and renewable energy without examining the feasibility of implementing any of the substantial changes under consideration. This applies even to the 'efficient renewable energy' scenario, and would hold more strongly for the Toronto scenario.

Because of differences in coverage, the greenhouse gas emission projections in these two studies are not directly comparable. It is thus useful to compare both studies with the work of ABARE (1991).

ABARE undertook an analysis of fuel use projections obtained from its biennial fuel and electricity survey (FES). The FES does not provide economic cost estimates of reducing carbon dioxide emissions but rather provides projections of energy use and carbon dioxide emissions over the period to 2004-05 with business as usual and under a strategy of adopting all cost effective energy use technologies.

An examination of the two general equilibrium models follows a review of the ABARE study.

ABARE energy projections

Every two years ABARE publishes a comprehensive review of energy demand and supply in Australia (1991). In addition to extensive historical coverage from 1973-74, forecasts of energy demand and supply are also provided. The 1991 review also contained a detailed consideration of the greenhouse effect, which covered existing patterns of energy consumption and their associated carbon dioxide emissions, as well as possible future developments. Furthermore, the associated data covered emissions by fuel type, State and ASIC industry sector.

Account was taken of expected future energy consumption levels by large energy users, and the requirements of known and likely new projects coming on stream during the projection period. Several small econometric models were used to project energy use in sectors not covered by the FES. Assumptions concerning economic factors, population growth and the future course of energy prices were also incorporated into the projections. The most significant of these were average real GDP growth of 3 per cent, rising world oil prices and quite substantial population growth over the next decade and a half.

The base year used in this study was taken to be 1987-88, and calculations were taken up to 2004-05, as the ABARE data were only available on a financial year basis. The coefficients used to derive the carbon dioxide emissions were those presented in Wilkenfeld's submission to this inquiry.

Under the 'business as usual' scenario, carbon dioxide emissions and energy consumption were projected to increase by 40 per cent over the period 1988-89 to 2004-05. Over the same period GDP was projected to increase by 60 per cent. Thus the business as usual scenario incorporated a considerable reduction in the average energy intensity of economic activity.

The ABARE study did not report projections of carbon dioxide emissions disaggregated by State or by energy using sectors. It did, however, report disaggregated projections for energy use. Projected growth in energy consumption was less rapid in Victoria (24 per cent over the projection period) than for Australia as a whole (45 per cent). Energy consumption was projected to grow at relatively slow rates in electricity generation (15 per cent) and road transport (29 per cent) over the period between 1988 and 2005.

ABARE also included a Greenhouse reduction scenario which showed how reductions in emissions of greenhouse gases from the energy sector might be achieved given current technological capabilities and likely developments, assuming both increased efficiency of energy use and substitution towards fuels with a lower carbon content per unit of energy. The concentration on efficiency improvements reflected the view that the least costly route is likely to be where available opportunities for improving energy efficiency are exploited without altering demand for the services which energy provides (ABARE 1991, Ch. 4).

Specific estimates of potential efficiency gains in energy use were based on Walker (1990) and the Wilkenfeld (Sub. No. 9). Efficiency improvement measures were included or excluded from the scenario according to their cost effectiveness from the point of view of a new purchaser. This is a weaker condition than actual cost effectiveness, since it includes measures which involve premature retirement of capital equipment.

This greenhouse gas reduction scenario was projected to reduce energy use and carbon dioxide emissions in 2004-05 by 14 and 22 per cent respectively, compared with the business as usual scenario. But carbon dioxide emissions were still projected to increase by 16 per cent over the period, as compared with the reduction to 80 per cent of 1988 levels called for by the Toronto statement. Thus the ABARE energy conservation scenario falls far short of meeting the Toronto target.

Disaggregated projections by State for carbon dioxide emissions and energy use under the greenhouse gas reduction scenario are not available. Total fuel use in electricity generation in 2004-05 is projected to be 28 per cent lower than with the business as usual case, reflecting efficiency improvements both in electricity generation and electricity use, while fuel use in road transport is projected to be 29 per cent lower.

The subsequent work by ABARE, based on the MENSA model, for the ESD Working Groups, is discussed in subsection G4.4.

CRA Study

As already noted, the CRA report looked solely at carbon dioxide emissions arising from electricity production and road transport, and examined the economy-wide implications of abatement strategies in these sectors. Overall, CRA's assessment of their initial macroeconomic assumptions, such as the rate of employment growth, real wages and foreign debt/GDP stabilisation, were that some may have been overly optimistic (CRA 1989). That is, if they were not achieved then the economic costs of reducing emissions would be higher.

The ORANI-F model was initially used to generate a base case scenario, to indicate what the economy might look like in the year 2005. Assumptions were then made about the rate of energy efficiency improvement expected and other technical enhancements that would be needed to meet the Toronto target, and prices were allowed to fluctuate so that this target was met. Projections were made in two steps, the first period being 1988-89 to 1994-95, and then 1994-95 to 2004-05.

The anticipated annual growth in electricity demand was forecast to be 2.8 per cent annually in volume terms over the next two decades, which represents a significant slowdown from the 6 per cent annual increase of the proceeding 20 years. By the Toronto target date of 2005 it was expected that demand would exceed 1988 levels by approximately 50 per cent. Therefore the base case estimates of carbon dioxide emissions from electricity generation were 110.4 million tonnes (Mt) in 1988, increasing to 174.3 Mt in 2005, a rise of 57 per cent from the base level.

Thus the CRA projection for carbon dioxide emissions in electricity generation is similar to that of ABARE. The CRA study projects less rapid growth in electricity demand, but also projects growth, rather than decline, in the carbon dioxide intensity of electricity generation.

Emissions abatement in the electricity sector was accomplished through improvements in energy efficiency in generation, buying power back from privately owned facilities, and raising prices in order to suppress demand. The improvements in energy efficiency were insufficient to offset the cost of the new capital equipment required, so the unit cost of electricity generation grows relative to the base case, at a rate of 1.5 per cent per year.

Overall, improvements in efficiency were found to be insufficient to meet the desired objective. A levy was also needed to raise electricity tariffs by a further 0.5 per cent per year, so that overall tariffs rise at a rate 2.0 per cent per year above the base case.

Table G9: **Comparison of projections of electricity demand and carbon dioxide emissions from electricity generation**

	1988	*2005*	*Percentage change*
Electricity consumption (TWh)			
CRA	119	179	50
ABARE	143	231	62
Carbon dioxide emissions (Mt)			
CRA	110	173	57
ABARE	120	182	52

Units: TWh: terawatt hour; Mt: million tonnes.
Note: ABARE carbon dioxide estimates are extrapolated from their tables and therefore are indicative only.
Sources: ABARE (1991); CRA (1989).

Turning to road transport, in the absence of any measure specifically designed to meet the Toronto objective, the CRA study projected fuel energy consumption and associated carbon dioxide emissions to rise between 1988 and 2005 by 44 per cent. This exceeds the ABARE projections of increases in fuel use and carbon dioxide emissions by road transport.

The main measures considered were a tax-induced rise in fuel prices in order to suppress demand, and higher vehicle capital costs due to rapid technological improvements. The required rate of increase in the price of fuel above the base case was estimated to be 3.6 per cent per year.

VSEC Study

The VSEC study is more far reaching in its time frame in that it projects demands from 1988 to 2030, but it also gives projections for the shorter time frame from 1988 to 2005. Two base cases are analysed, one more likely than the other. The first base case's economic growth scenario is viewed by NIEIR as the most likely (this review therefore concentrates upon this case, and on estimates to the year 2005), the other -- a low economic growth scenario -- could eventuate given a range of economic and social circumstances. Again the study is conducted in a step wise fashion.

The main feature of the reference energy projections are the slow growth of energy demand past 2005, particularly in transport and electricity generation. On the supply side, the average growth rate for petroleum is negative over the 1988 - 2030 period, while strong growth was projected for renewable energy sources.

The VSEC study and ABARE project similar growth in energy consumption in Victoria (27 and 29 per cent increases respectively). The ABARE business as usual scenario is however more hopeful than the VSEC base case regarding the carbon dioxide intensity of energy usage. The VSEC study projects more growth in carbon dioxide emissions (43 per cent) than does ABARE (23 per cent).

Table G10: **Comparison of ABARE and NIEIR (VSEC) results for Victoria**

		1988	*2005*	*Percentage change*
CO_2 emissions (Mt):	ABARE	82	100	23
	NIEIR	86	123	43
PJ of fuel:	ABARE	1051	1357	29
	NIEIR	1065	1352	27
NIEIR results only for CO_2 under Toronto target (Mt)		86	69	20

Source: ABARE results extrapolated from tables included in the statistical appendix, and figures should be taken as approximate estimates only.

In contrast to the CRA study, the VSEC study focused on the potential for privately profitable emissions abatement.

Besides the base case, the VSEC study examined an ‘efficient renewable’ energy scenario, and a ‘Toronto’ scenario. The efficient renewable energy scenario was designed to indicate the ‘maximum economic potential’ of energy conservation and renewable energy sources. Since these were insufficient by themselves for achievement of the Toronto target, the study also developed an additional scenario in which that target is met.

In developing the efficient renewable energy scenario, two conditions were applied. One was that the costs of energy conservation and introducing renewable energy should not exceed the long run marginal cost of the energy displaced. The other was that the renewable energy source should be capable of exploitation over the projection period `on less than an emergency policy basis'. Only those measures considered to satisfy both conditions were included in the scenario.

This does not mean that all measures included in the scenario are profitable. A renewable energy source that is economic from the point of view of a new purchaser may not be economic to a user with substantial investment in old technology. The most profitable course for such a user may be to continue with the old energy source until his existing equipment is ready for replacement. Such users were nevertheless assumed to adopt the new technology by VSEC within the forecast period.

The study states that no consideration has been given to the feasibility of introducing renewable energy within the specified period (except for the ‘less than emergency policy’ criterion), and that some assumed changes would be very difficult to implement. To meet the Toronto strategy, the assumed market penetration would be ‘almost impossible to achieve’. This review concentrates on the efficient renewable energy scenario, both because of its greater practicality, and because much more information was provided about this scenario in the VSEC study report.

The efficient renewable energy scenario reduced carbon dioxide emissions in 2005 by 21 per cent, compared with the base case. This is similar to the potential emission reduction estimated by ABARE (1991) for Australia as a whole, of 22 per cent, using what appears to be a similar criterion for adoption of emission abatement techniques.

The study reports annual energy cost savings from the efficient renewable energy scenario in 2005 of $3 billion (1988 prices), compared with the base case. Against these must be set higher equipment costs. The study reports (what appears to be) an estimate of first-round net economic benefits in 2005 of $900 million per year.

This does not appear to take account of any costs incurred in premature retirement of capital equipment to allow the adoption of new abatement techniques. Neither does it take account of any costs incurred by government to induce private users to make greater use of economically viable abatement technology. For these reasons, and because the study does not consider the feasibility of the assumed rates of market penetration of new techniques, these net economic benefits must be regarded as an upper bound rather than a realistic estimate of the potential economic gains from emissions abatement.

General equilibrium outcomes

It does not appear that differences in base cases in the CRA and NIEIR studies play any great part in explaining the differences in their conclusions. To a great extent the differences in the conclusions reached by the two studies seem to reflect differences in their emissions abatement scenarios. This section examines the extent to which the conclusions are affected by the characteristics of the general equilibrium models.

The CRA study takes as its measure of economic cost, the net present value of reductions in GDP over the forecast period. It reports two sets of estimates using different discount rates of 5 per cent and 10 per cent per year. Using the 10 per cent discount rate, the estimated cost is $19 billion (in 1989 prices). Of this, $13 billion is attributable to emission abatement in electricity generation, and $7 billion to road transport. Almost all of the $13 billion cost for electricity is attributable to higher generation costs, with less than $200 million being attributable to the levy.

The information provided in the study does not enable comparison of the first-round and general equilibrium costs of abatement. But a rough estimate can be obtained on a comparative-static basis, using data from the FH-ORANI database for 1980-81 (the same reference year as the database used in the study). In this database, electricity industry costs are equivalent to 3.6 per cent of GDP. So on a first-round basis, each one per cent increase in unit electricity costs is equivalent to a 0.036 per cent reduction in GDP. The appendix on the ORANI simulations, attached to the study, reports that a 1 per cent increase in electricity costs reduces GDP in general equilibrium by 0.039 per cent. Thus, ignoring dynamic effects, the first-round and general equilibrium costs of higher electricity generation are quite similar.

For the electricity levy, the first round cost is zero, while the general equilibrium cost is, as stated above, very small. So for emissions abatement in electricity generally, the economic cost estimates in the CRA study can be explained almost entirely by the costs and benefits incorporated directly in the scenarios, rather than on the general equilibrium modelling.

The general equilibrium modelling would, however, appear to be critical for the estimated economic cost of emission abatement in road transport achieved through higher taxes. This measure has no first-round cost, but its estimated general equilibrium cost is very high. Road transport costs are equivalent to only 4 per cent of GDP, but the general equilibrium results indicate that each 1 per cent increase in fuel prices brought about by higher fuel taxes reduces GDP by 0.009 per cent. Thus each dollar of taxation of road transport reduces aggregate output by about 20 cents. This indicates that in the model increases in fuel taxes cause severe allocative inefficiencies.

For the VSEC study, the first-round economic benefit of the efficient renewable scenario in 2005 is, as stated above, about $900 million per year (1988 prices). Taking gross state product as the welfare indicator, the general equilibrium economic benefit is $800 million per year. Thus the outcome of the general equilibrium modelling for the VSEC study appears to reflect the scenario modelled, rather than the characteristics of the model itself.

In summary, it appears that the very different outcomes of the modelling exercises reported in the CRA and VSEC studies are attributable mainly to the different scenarios modelled. The differences in the scenarios reflect partly the different objectives of the studies, and partly also different views on the likely scope for low-cost or zero-cost abatement strategies.

G4.2 The Tasman Institute and the CRA

The Tasman Institute (Sub. 55) provided some estimates of the welfare costs of introducing carbon taxes to meet the Toronto target. Although they did not use an explicit model, their estimates are based on Australian input-output data, and thus should be broadly comparable to the Commission's results using the ORANI model, which is also based on the input-output tables.

The Tasman Institute looked at the possible welfare costs in two ways. In the first, a carbon tax was introduced which would immediately reduce emissions to 20 per cent below 1988 levels, while in the second the introduction of the tax was delayed until 2000.

It was shown that the welfare losses of introducing a carbon tax could be considerably reduced by delaying its introduction. However, since the Commission's ORANI model can only model the introduction of a tax `now', rather than calculate the optimal time of introduction, only the Tasman Institute's results of introducing the tax to immediately reduce emissions are comparable with those presented by the Commission in Chapter 9.

The Tasman Institute used Nordhaus's estimate of the marginal cost of reducing carbon emissions, at the optimal level according to Nordhaus, of US$42 per tonne of carbon ($1989) (Nordhaus 1990). According to the Tasman Institute, this is equivalent to A$72 per tonne of carbon, or A$20 per tonne of carbon dioxide. The Tasman Institute thus used a tax rate which was slightly lower than the Commission's estimate of the required tax.

Using the tax rate of $72 per tonne of carbon, and the base case estimate of 76Mt of carbon emissions in 1990, the Tasman Institute estimated that the tax revenues in 1990 would equal $4.1 billion. To meet the target of reducing emissions to 80 per cent of 1988 levels would require a 24 per cent reduction in 1990, a reduction of 18Mt of carbon. The welfare cost was thus calculated as the tax rate times the forgone consumption of carbon divided by two (the area of a welfare triangle). This gives a welfare cost of $650 million in 1990.

In Chapter 9 the Commission estimated that the introduction of a tax of $22 per tonne of carbon dioxide for a larger emissions reduction (44 per cent, compared with Tasman's 24 per cent) would lead to a reduction in GDP, after the economy had adjusted, of about 2.1 per cent, equal to $7.75 billion in 1989-90. The revenues raised by this tax would equal $2.7 billion in 1988 values.

Thus while the Commission's estimate of the tax rate required is slightly higher, and the revenues raised almost two-thirds, of those estimated by the Tasman Institute, the Commission's estimate of the `welfare' loss -- assuming that GDP is a comparable welfare indicator -- is several times higher, mainly reflecting the larger cut in emissions.

CRA calculated the costs of reducing emissions by 80 per cent of the 1988 levels in the electricity and road transport sectors (CRA 1989), using the ORANI-F version of the model. While they looked at policies designed to improve fuel efficiency in these two sectors, rather than the introduction of a carbon tax applying to all sectors of the economy, the results can nevertheless be compared with those of the Commission as an estimate of the costs of two alternative ways in which to reduce emissions.

Since the electricity and road transport sectors account for 65 per cent of Australia's carbon emissions, CRA's estimate of forgone GDP should be roughly 65 per cent that of the Commission's estimate of the costs of an economy-wide carbon tax.

CRA estimated that the net present value of GDP forgone between 1988-89 and 2004-05 as a result of the price increases necessary to stimulate the required efficiency improvements, will be $32 billion (assuming a 5 per cent discount rate).

As already discussed, the Commission has estimated the cost, in terms of forgone GDP, of unilaterally meeting the target through a carbon tax, at 2.1 per cent, or $7.75 billion in 1989-90 values. Using ABARE's projections of GDP growth between now and 2004_05 (ABARE 1991) to forecast real GDP, and summing up a 2.1 per cent loss in each year, the net present value of GDP forgone represented by the Commission's results is $113 billion, again using a 5 per cent discount rate.

This assumes, of course, that the economy immediately shrinks by 2.1 per cent in response to a tax on carbon dioxide emissions, and that this 2.1 per cent loss is constant year after year. In reality the initial reaction of the economy may be to fall by less, subsequently rising to 2.1 per cent by the time the economy has fully adjusted. Alternatively, if adjustment costs are very severe, the economy may initially shrink by more than 2.1 per cent in the early years, with the reduction in GDP declining over time as the economy adjusts to the tax.

As ORANI is a static model it is unable to predict what sort of adjustment path the economy may take. Thus the assumption made that the economy shrinks by an immediate 2.1 per cent may either be an under- or overestimate of the short- to medium-term economic costs of introducing a tax on carbon dioxide emissions. If, for example, the economy adjusted in a linear fashion then the value of GDP foregone would fall to around $50 billion

G4.3 Different versions of the ORANI model

The general equilibrium results reported in the CRA study were generated by the Institute of Applied Economic and Social Research, using a forecasting version of the ORANI model, called ORANI-F. Considerable differences exist between ORANI-F and the version of the model commonly used by the Commission, FH-ORANI. It is therefore a matter of some interest to know whether the two versions of the model are liable to generate similar or conflicting results for abatement scenarios.

The main outcomes from the CRA report are reasonably robust with respect to the choice of version of ORANI. In particular, price increases arising from increases in costs of production are much more costly to the economy as a whole than price increases arising from taxation.

Results for changes in productive efficiency from the two versions of the model are also in general reasonably similar. Results for tax changes, on the other hand, differ more widely. This is to be expected, since the general equilibrium costs of changes in productive efficiency are usually dominated by the first round costs, whereas the results for changes in taxes and transfers reflect only changes in allocative efficiency, which depend critically on the characteristics of the model.

There is reason to suspect that differences in results between the two versions of the model arise largely from different investment outcomes. There are three reasons why these are likely to differ:

- different representation of initial investment flows in the database;
- different treatment of capital accumulation in the theoretical structure; and
- different treatment of rates of return on capital.

The different treatments of capital accumulation and rates of return arise partly because ORANI-F is designed for a shorter time horizon than FH-ORANI. In FH-ORANI, investment-capital stock ratios and rates of return are assumed to adjust completely to their normal values within the simulation period. ORANI-F, on the other hand, allows for partial adjustment, which is important in a shorter time frame. Although in the CRA study, the time horizon for the projections is fairly long (16 years), the projections are composed from shorter run ORANI-F simulations, with time horizons of 6 and 10 years.

To illustrate the effects of these model differences, results from several configurations of the model were obtained. Overall, the differences between results from different configurations appear to largely reflect different investment results. Changes in consumption results, for example, appear to arise mainly from crowding out by investment. Furthermore, it is clear that all three of the considerations listed above affect the aggregate investment results considerably.

Thus the major difference between ORANI-F and FH-ORANI would appear to be the representation of investment in the database. Investment in the electricity industry, for example, comprises 1.3 per cent of GDP in one of the databases used in these simulations, but only 0.8 per cent in the other. According to the database chosen, a 9 per cent increase in investment in the electricity industry is equivalent to either 4.5 or 2.8 per cent of aggregate investment, and 0.12 or 0.07 per cent of GDP. Thus the variation in the investment data is significant even on the scale of the whole economy.

Since the investment data are critical, and since they can be verified against external statistics, an accurate representation of investment in the database is important to the credibility of model results. On the other hand, agreement on the treatment of capital accumulation and rates of return, while also offering some benefits, appears less critical. To a large extent, the ORANI-F treatment is motivated by the desire to use the model for medium-run (say 5-year) simulations, which for the Commission, in the present inquiry, is not a consideration.

From the comparison of results from different versions of ORANI, it appears that divergences of moderate significance are liable to appear, especially in simulations of changes in taxes or transfers. The main source of divergence between model results appears to be the representation of investment in the database.

G4.4 Modelling undertaken for ESD Working Groups

ABARE and the Centre for Policy Studies, Monash University (COPS) were commissioned to undertake quantitative analyses of greenhouse abatement options for the Ecologically Sustainable Development (ESD) Working Groups. Their final estimates were presented in November 1991, but interim results were available for some time before that. The ABARE results were included in their final submission to this inquiry (Sub.ÿ132) while the work of COPS is set out in Adams et al. (1991). The objective of the ESD Working Groups had been to integrate the two bodies of work. ABARE were to undertake a detailed analysis of the costs of alternative energy options for meeting greenhouse gas emission targets, and COPS were to estimate the macroeconomic consequences of such actions. Lack of time, however, meant that this objective was not completely achieved.

ABARE's MENSA modelling

ABARE used the MENSA (Multiple Energy Systems Analysis) model to estimate the pattern of fuel usage that might be used in Australia's energy system to satisfy future demands for energy services. This study represents the most comprehensive Australian attempt to evaluate the costs of policies to limit carbon dioxide emission, even though it only relates to the energy sector.

MENSA is a multi-period linear programming model which estimates the cost minimising combination of technologies that would allow emissions of carbon dioxide from the energy sector to be reduced in accordance with the Toronto target. The model was run over successive five-year periods between 1990 and 2020. Carbon dioxide emissions were held constant at 80 per cent of their 1988 levels for the years beyond 2005. The energy sector is encouraged to switch to fuels emitting less carbon dioxide when combusted through the imposition of a carbon tax, which is introduced in 1997.

In MENSA, the analysis of energy demand begins with the specification of demand *for energy services* rather than for energy per se; that is, there is a demand for space heating instead of electricity, for example. Although energy service demands are exogenous, they are satisfied using a range of end-use technologies which in turn require a combination of supply technologies.

There are four types of technology that are used in sequence to satisfy final demands for energy services. These are extraction technologies, conversion technologies, process technologies such as coal liquefaction or combined cycle gas, and finally utilisation technologies.

The MENSA model also takes into account emerging technologies like renewable energy sources, energy efficient appliances and advanced coal or gas fired power stations. The interconnection of State electricity grids is also allowed for, as is the possibility of nuclear powered energy.

ABARE also enhanced the MENSA database by including information relating to projected capital and operating costs of emerging and existing widely used technologies. Carbon dioxide emissions coefficients were added to the database to enable the projection of emissions from energy use. These coefficients pertain to the carbon based fuels modelled, namely shale oil, black coal, brown coal, methanol, oil products, LPG and natural gas.

In the MENSA database, ABARE specifies technical assumptions regarding solar thermal and wind powered electricity generation. The limits imposed emphasise that there are a finite number of sites suitable for the location of wind and solar electricity generation facilities, and also that the availability of power will vary due to the nature of the techniques involved.

ABARE has recognised that alternative technologies still require development before they are a viable option for electricity generation. Thus, wind farms have an earliest start date of 1995 and solar thermal power is not allowed as an option until the year 2000. The cost levels ABARE use suggest that solar thermal power generation will face a significant cost disadvantage compared with conventional coal technology for some years to come.

Cross-price elasticities between alternative fuel sources are implicitly obtained in the optimisation process and substitution between alternatives tends to be discontinuous. That is, the cost-minimising combination of fuels may change suddenly with a small alteration to the relative price of the alternative fuels once a critical price is reached. (This is a well known feature of linear programming models.)

ABARE uses the difference between the costs of satisfying demand for energy services with and without the Toronto emissions constraint to represent the costs of compliance with the target. Because of the importance of future electricity generation costs, ABARE's forecasts of fuel usage patterns are pertinent.

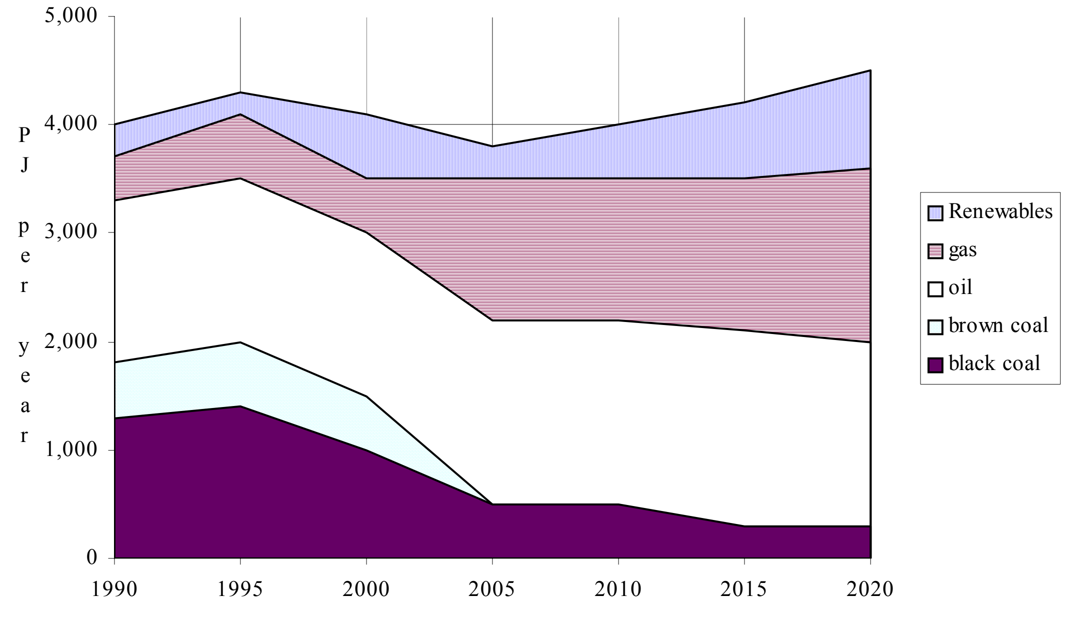
The introduction of a carbon emissions constraint will gradually make the ‘dirtier’ technologies less cost-effective. Under the constrained base demand scenario, increasingly stringent emissions reduction targets are achieved through interfuel substitution and energy conservation particularly in the post-2000 period (Figure G4). It may be realistic to assume that nuclear power is not permitted to enter calculations, reflecting community concerns about safety and disposal of waste.

ABARE also conducted projections which included the provision of baseload power by solar thermal technology. These results were heavily qualified, reflecting the experimental nature of the technology and the uncertainty surrounding the costs involved. In light of these considerations, the most realistic abatement scenario is the one where both nuclear and baseload solar power are excluded.

The ABARE study suggests that the Toronto target would be achievable by Australia but that considerable changes to the pattern of energy supply and demand would be required. The most striking result is that no black or brown coal would be 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 in those applications.

Combined cycle natural gas would supply the baseload in as many applications as possible in preference to other fuels up to 2005. To maintain emissions at their 2005 level in subsequent years, it would be necessary to use increasing amounts of renewable energy to generate electricity. Wind would become an important source of energy.

Figure G4: **Primary energy consumption by type of fuel used: Toronto target, standard demand scenario**



Source: ABARE (Sub. 132)

There tends to be an inverse relationship between the electricity and manufacturing sectors. That is, the lower the emissions from electricity, the higher the emissions from the residential sector and manufacturing. In the latter, oil would replace coal in as many uses as possible early in the simulation period and then in turn would be replaced by gas in the final five-year period.

Energy conservation rather than fuel substitution becomes more important in the commercial sector if nuclear and solar baseload technologies are excluded.

In residential applications, space heating would become serviced by heat pumps or oil with insulation. Wood, because of its low emissions coefficient, would become more attractive towards the end of the period despite its comparatively high costs. Water heating in all States would be dominated by solar with electric backup.

Although the use of coal would fall significantly, there are some areas in which substitution is technically impossible. For example, coal would still have widespread uses in steelmaking and metal smelting.

In the industrial sector of the economy, gas would replace coal and petroleum-based fuels wherever it is technically feasible.

As the Toronto target is approached, the marginal cost of further emissions abatement would rise rapidly although initial reductions could be achieved at low costs to the energy system.

The total system cost[1] under the unconstrained scenario is simply the expected cost of satisfying demands for energy services without any programs to reduce energy-based carbon emissions. The additional cost to the energy system of curbing carbon emissions is the difference between these two cost totals and proxies the loss to the whole economy.

ABARE predicts that high costs would be incurred in achieving the required level of emissions reductions by 2005. The costs would peak at $5.9 billion per year (discounted at 8 per cent) for the base demand growth case or about 1.1 per cent of GDP in 2005.

The cost would rise until 2005 mainly due to large amounts of investment in plant in the electricity generation sector. To attain the Toronto target, electricity authorities would need to adopt less carbon-intensive technologies.

The ABARE study implies that a carbon tax is levied to meet the Toronto target. The tax would be imposed at an initial level of $192 per tonne of carbon ($52 per tonne carbon dioxide) in 2000 and would rise to $539 per tonne of carbon ($147 per tonne carbon dioxide) in 2005. The tax would

1 Total system costs comprise building, operating and fuel costs and are minimised over the entire energy system, not merely the energy production and distribution sector.

need to rise over time to restrict emissions to their 2005 level. Under the base demand scenario, the carbon tax would rise rapidly beyond 2010.

These forecasts probably overstate the taxes that would be actually required. The taxes are those which would be necessary in the absence of a decline in demand for energy services. However, some fall in energy services consumption would follow from the imposition of such a tax.

COPS study

The Centre of Policy Studies used the ORANI-F model (the same model as was used in the early CRA study) to carry out three tasks for the ESD Working Groups:

- base case projections of prospects for the Australian economy through to 2030,
- evaluation of the sensitivity of the base case to environmentally motivated policies, and
- analysis of greenhouse issues via simulations drawing on the results from the energy sector produced by ABARE's MENSA/MARKAL modelling.

The two latter tasks are relevant to this inquiry. In terms of sensitivity analysis, COPS looked at the adoption of electricity-saving technical improvements which reduced each industry's requirements of electricity per unit output by 1 per cent per annum. Such a simulation illustrates the effects of achieving energy savings at zero cost. In practice this may not be possible. Rather, industries may have to increase their usage of other inputs if electricity usage falls. COPS were not able to make estimates of the likely extent of electricity saving. However, their elasticity estimate can be scaled to whatever level of electricity saving might be achieved.

The macroeconomic effects of adopting electricity-saving technologies are small, and depend on the assumed rate of technological improvement and the share of the costs of industrial usage of electricity in GDP. The main impact is on the output of the electricity industry. If more of other inputs are also required as electricity usage is reduced then the macroeconomic effects are close to zero, while output of electricity still falls. Industries that are important suppliers to electricity generation are also affected to some extent.

COPS interpreted the results from the MARKAL model as meaning an increase in real resource usage per unit of electricity. Electricity costs would increase because of switching from coal to gas inputs, additional capital costs, and the imposition of a carbon tax. The impact of such increases depends on whether alternative energy sources become available, eg nuclear power and whether there are alternative uses for the coal no longer required for electricity generation, eg exports. Electricity costs are estimated to rise by 4.8 per cent a year (net of any carbon tax) if nuclear power is possible and by 7.3 per cent a year if the nuclear option is precluded. The macroeconomic impacts of these scenarios are real GDP reductions of 0.2 or 0.3 per cent a year. This reduction would be largely borne by real wages. Whether or not surplus coal would be exported has little macroeconomic impact, but it is important to the coal industry.

Over 10 years the no nuclear power option would amount to a GDP loss of around 3 per cent. This is a higher estimate than that of the Commission. This largely reflects three factors. In ORANI-F there are no substitution possibilities between fuels or between energy in general and capital. This would tend to raise the cost of adjusting to an increase in electricity prices. Also the COPS analysis takes explicit account of increases in the costs of producing electricity over and above the effects of a carbon tax whereas the Commission only took account of a carbon tax. However, an offset to these factors in the Commission's analysis is the coverage of other energy sources in addition to electricity.

According to the COPS analysis, a carbon tax offset by lower direct taxes has little macroeconomic impact, though it does further reduce electricity usage, but details of the assumed carbon tax are not provided.

COPS also considered the impact of a reduced demand for Australia's exports of black coal, as might occur if there is an international consensus to reduce greenhouse gas emissions. Reduced demand would lead to a fall in the export price for coal. If the price of coal fell by 3.33 per cent a year, or 50 per cent over the 15-year period to 2005, there would be a significant effect on the Australian economy and on the coal industry, whose output is projected to decline by around 7 per cent a year. The price fall implies a deterioration in Australia's terms of trade of around 0.4 per cent per annum. To offset this would require a real exchange rate devaluation through lowering real wages by around 0.4 per cent a year. Although GDP is not projected to fall, the economy is worse off through cutbacks in imports and in investment spending. The main conclusions from this simulation are first that the overall impact on the Australian economy depends more on domestic action to reduce carbon dioxide emissions than on international action, but the prospects for the Australian coal industry depend more on overseas actions.

G4.5 NIEIR study for Commission for the Future

The Institute for the Commission for the Future and the Victorian Renewable Energy Authority commissioned the National Institute of Economic and Industry Research (NIEIR) and Energy Policy and Analysis Pty Ltd to undertake a study of the consequences of introducing fuel saving technologies. The study is not yet finalised or published, but a progress report (Brain et al. 1991) was provided at the Commission's workshop on ‘Modelling the Impacts of Greenhouse Abatement Strategies’ in October 1991.

The NIEIR's model contains an energy sub-model with detailed industry and energy end-use structures.

The model is used to generate baseline (business as usual) economic, demographic projections and an associated energy and carbon dioxide emission scenario. The scenario is then modified to take account of new and improved technologies for the more efficient use of energy and the supply of energy from renewable sources. The associated economic environment and energy demands are denoted as the 'maximum economic potential' scenario, where energy efficiency and renewable energy sources realise their full economic potential to displace non-renewable energy. Further details of these technologies and their associated costs are not yet available. The new technologies do not, however, enable the Toronto target for emission reductions by 2005 to be met. Further actions are needed to achieve the target.

The IMP model is used to estimate the macroeconomic implications of these emission reduction scenarios.

Incentives to reduce emissions are not taken into account explicitly in the modelling. However, it is estimated that adopting alternative technologies to lower emission rates would require $53 billion ($1990) of additional capital expenditure over the decade to 2005 (see Table G11). There would be a $10 billion increase in net annual industry costs to support this additional capital expenditure. But, in order to avoid balance of payments problems this additional expenditure would be incurred largely at the expense of private consumption which is projected to decline by $46 billion or around 2 per cent per annum. There would only be a marginal decline in GDP.

Table G11: **Additional capital expenditure[a] to 2005, Toronto versus base case**

Exploitation of maximum economic potential	
Households	10.1
Commercial sector	2.8
Industrial sector	3.9
Transport	15.5
Additional expenditure for Toronto target	
Gas fired electricity capacity	13.3
Gas distribution (pipelines)	4.0
Gas production (extraction facilities)	4.8
Renewables	3.1
Automobiles	2.4
Electricity infrastructure savings	-7.0
Total	52.9

[a] 1990 billion dollars.
Source: Brain et al. (1991).

The discounted cost of action to reduce greenhouse gas emissions is estimated to be $20 billion in 1990. The study notes in passing that adopting macroeconomic assumptions more akin to those used by ORANI modellers would halve these costs.

The preliminary results from this study are comparable with those generated from the Commission's ORANI model in terms of their estimated impact on private consumption (2 per cent and 1.6 per cent respectively). However because of the effects of investment, which are not taken into account explicitly in the Commission's analysis, the IMP model projects very little change in GDP, compared with the Commission's estimate of a decline of 2.1 per cent.

G5 Comparing results from different international models

Over recent years considerable efforts have been devoted to quantifying the possible economic costs of policies to reduce greenhouse gas emissions. Many studies have used global general equilibrium models to capture the implications of greenhouse policies on trade and financial flows between countries, since these are important in determining the economic consequences of such policies.

Many other models focus on a single country or region. While these models cannot capture trade flows, they do take into account the effects of unilateral action upon a country's trade competitiveness. They also can embody much greater sectoral detail than the global models, thus providing more detailed information about the implications of various policies upon a country's industrial structure.

A summary of the main results of some of these models was presented in Chapter 5 (Box 5.1). As noted there, variations in the scenarios modelled, the time frames over which the reductions were to be achieved, and the different regional coverages, make it difficult to compare results. Manne and Richels (1990) contains detailed coverage of the energy sector and the links between energy and output. That study does not, however, distinguish amongst different industrial sectors, nor are the regions linked via trade flows. Whalley and Wigle (1991) contains greater sectoral disaggregation and trade flows between regions, but is comparative static rather than dynamic. The OECD (1991) has a similar level of sectoral and regional detail to Whalley and Wigle, with regions linked via trade, but it also has a dynamic treatment of capital accumulation and resource depletion. Other models such as IEA (1990) are econometrically based rather than general equilibrium.

In addition to the different model structures, the scenarios modelled may have different baseline projections of output growth and future energy prices, as well as different assumptions regarding improvements in energy efficiency over future decades and the fossil fuel prices at which backstop technologies such as solar and nuclear will become competitive.

For example, Manne and Richels (1990) assume average annual GDP growth over the 1990-2100 period ranging from 1.6 per cent in the OECD countries, to 3.5 per cent in China, compared with Mintzer's (1987) estimate of 2 per cent. Edmonds and Barns (1990) project growth in energy efficiency of 1 per cent a year, compared with Manne and Richels (1990) whose estimates range from 1 per cent for China to 0 per cent for the rest of the world. The IEA (1990) projects fossil fuel prices will increase by 3.1 per cent annually, compared with Nordhaus and Yohe (1983) who project a 1 per cent annual increase.

Edmonds-Reilly model

One feature which most models have in common is that they do not attempt to forecast the distant future. Only Manne and Richels (1990) and Thorpe et al. (1991) look as far into the future as 2100. Thorpe et al. (1991) used the Edmonds-Reilly model (1985) to estimate the effects of an international carbon tax introduced in 2000 and applying for the following century. They employ a long run, partial equilibrium, non-linear, dynamic model in which the demands for fuels are derived from those for energy services and there are ad hoc feedbacks to the macroeconomy. In particular the possibility of convergence across countries in incomes, prices and technologies is allowed for.

One of the problems of comparing the results of Thorpe et al. (1991) with those of other studies is the definition of the regions that they model. Nine regions are distinguished, which are aggregated into five regions for reporting results. As in the OECD's GREEN model, Australia is included with Japan and New Zealand, which makes it difficult to predict the effects of emissions abatement for Australia alone.

Thorpe et al. use four sets of projections to illustrate the effects of varying degrees of consensus: first, a baseline scenario; second, a 100 per cent ad valorem tax on fossil fuels imposed only in OECD countries; third, a similar tax imposed in all countries except centrally planned Asia; finally, a global tax on fossil fuels is considered.

The effect of the carbon tax is to facilitate substitution of fuels; for instance, renewables for coal. There is less change in the level of income, consumption or total energy usage.

However, the size of the carbon tax required to attain any given emissions abatement target varies significantly if income levels between regions are allowed to converge. In contrast, the required tax falls if prices responses and energy technologies converge.

Most important, however, is the amount of cooperation in countries' attempts to reduce emissions. If the OECD alone were to impose a tax, world carbon dioxide emissions in 2100 would be 24 per cent below the base case. Under a global tax though, projected emissions would be 63 per cent below carbon dioxide emissions in the 2100 baseline scenario.

However, it is cumulative emissions of carbon dioxide which determines atmospheric concentrations and hence it is this variable which is vital. Cumulative emissions fall by 7 to 20 per cent below the base case in 2100, depending on the coverage of the carbon emissions tax. Clearly the effectiveness of tax measures will be enhanced if a truly global agreement can be reached.

Summing up

The available international studies are based on different models embodying sometimes quite different baseline scenarios, and often examining widely different greenhouse gas reduction scenarios. Nevertheless some general implications do emerge.

The *size of tax:* although there is considerable variation in the estimates of the tax rates required, it seems clear that the tax rates will rise sharply the greater the desired reduction in emissions. Small reductions may be achieved with relatively low tax rates, but these taxes rise more than proportionately as the reduction target is increased.

The *timing of the tax*: a sharp reduction in emissions in the short run is much more costly to achieve than an equivalent reduction in emissions over a longer time period. The shorter the time allowed in which to reduce emissions, the more of the existing capital stock must be scrapped prematurely. This adds considerably to the cost of achieving a given reduction in emissions.

Fuel substitution: the ease with which energy users can switch from one energy source to another will have considerable implications for the size of the required tax, and hence the costs of meeting a particular emissions reduction target. This substitution includes the ability to switch toward less carbon intensive fossil fuels (eg from coal to natural gas), and away from fossil fuels to carbon-free energy sources such as solar energy. The more easily this substitution can occur, the greater the reduction in emissions that can be achieved at a given tax. Again, the longer the time allowed in which to reduce emissions, the greater the substitution that can be achieved. Substitution possibilities will also differ between countries depending upon their industrial structure and regulatory framework.

Terms of trade effects: the regional distribution of carbon tax revenues can have an important impact on countries' balance of payments and hence on income flows around the world. Whalley and Wigle (1991) illustrated that taxes levied on the production of fossil fuels would benefit energy exporters, while developing countries and energy importers could lose considerably. Taxes levied on the consumption of fossil fuels, however, would be far less costly for energy importers, and could roughly halve the global economic costs of reducing emissions.

Regional costs: the costs faced by different regions in achieving a given emission reduction will depend significantly on their projected growth rates. For example, China and other developing countries are expected to experience high growth rates in the coming century. Simply requiring them to restrict their emissions in 2100 to twice those of 1990 could cost developing countries more in terms of forgone GDP, than a 20 per cent reduction in emissions in the developed countries (Manne and Richels 1990). Even if China's emissions were allowed to quadruple by 2100, its GDP would still be 6 per cent below the baseline projection. This highlights the potential difficulties in achieving a global consensus.

Global co-operation: the wider the coverage of any carbon tax agreement, the lower the tax will need to be to induce a given decline in emissions, other things being equal.

References

Adams, P.D., Dixon, P.B., Parmenter, B.R. and Peter, M.W. 1991, *Prospects for the Australian economy 1989-90 to 2029-30*, Final Report to ESD Working Groups, Centre of Policy Studies, Monash University, November.

ANZEC (Australian and New Zealand Environment Council) 1990, *A National Inventory of Greenhouse Gas Emissions,* July, Energetics.

Australian Inventory Preparation Group 1991, *Draft Australian Greenhouse Gas Emissions Inventory 1987-88,* Inter-governmental Panel on Climate Change, Working Group 1, Canberra.

Australian Bureau of Agricultural and Resource Economics (ABARE) 1989, *Quarterly Mineral Statistics,* June, AGPS, Canberra.

Australian Bureau of Agricultural and Resource Economics (ABARE) 1991, *Projections of Energy Demand and Supply,* Australia, 1990-91 to 2004-05, January, AGPS, Canberra.

Australian Bureau of Statistics (ABS) 1989, *Livestock and Livestock Products*, Australia, 1988-89 Cat. No. 7221.0.

Australian Institute of Petroleum (AIP) 1989, *The Greenhouse Effect - A Position Paper*, July, AIP.

Brain, P., O'Dwyer, T. and Saddler, H. 1991, `Quantifying the Macroeconomic Consequence of Introducing Fuel Saving Technologies', *Presentation to the Industry Commission Workshop on Modelling the Impact of Greenhouse Abatement Strategies*, National Institute of Economic and Industry Research, October.

Common, M.S. and Salma, U. 1991, *Accounting for Australian Carbon Dioxide Emissions,* Centre for Resource and Environmental Studies, Australian National University, Canberra.

CRA (CRA Limited) 1989, *Report to CRA Limited: The Feasibility and Implications for Australia of the Adoption of the Toronto Proposal for Carbon Dioxide Emission*, September.

Dee, P.S. 1989, *FH-ORANI -- a Fiscal ORANI with Horridge Extension*, preliminary working paper No. OP-66, March, Melbourne.

Dixon, P.B., Parmenter, B.R., Sutton, J. and Vincent, D.P. 1982, ORANI*: A Multisectoral Model of the Australian Economy,* North Holland, Amsterdam.

Edmonds, J.A. and Barns, D.W. 1990, *Estimating the marginal cost of reducing global fossil fuel emissions*, mimeo, August.

_______ and Reilly, J.M. 1985, *Global Energy: Assessing the Future,* Oxford University Press, New York.

Energetics Pty Ltd 1990, *Quantification of Victoria Energy - Related Greenhouse Gas Emissions*, Report for the Department of Industry and Economic Planning, Resources Policy and Planning, Victoria.

Galbally, I.E., Fraser, P.J., Meyer, C.P. and Griffith, D.W.T. 1990*, Biosphere/Atmosphere Exchange of Trace Gases Over Australia,* Paper presented at IGBP Workshop No. 14, Utilization of Renewable Biological Resources, Oct 3-5, Canberra.

Greene, D. 1990, *A Greenhouse Development Strategy: Sustainable Energy Development Strategy,* Report by Deni Greene Consulting Service to the Department of the Arts, Sport, the Environment, Tourism and Territories, February, Victoria.

Hargraves, A.J. 1990, 'Coal Seam Gas and the Atmosphere' in D.J. Swaine (ed*.), Greenhouse and Energy,* CSIRO, Canberra, pp. 147-156.

Helliwell, J., Sturm P., Jarrett, P. and Salou G. 1986, 'The Supply Side of the OECD's Macroeconomic Model', *OECD Economic Studies*, No. 6, pp 75-130.

IAC (Industries Assistance Commission) 1987, *A guide to the IAC's use of the ORANI model,* Information Paper, December, AGPS, Canberra.

IAC (Industries Assistance Commission) 1989, *Government (Non-Tax) Charges,* Vol. 4, Report No. 422, AGPS, Canberra.

IC (Industry Commission) 1991, *Issues Paper*, January, Canberra
.

International Energy Agency (IEA) 1990, Press Conference 31 Jan 1990, OECD, Paris.

Lesbirel, S.H. 1990*, The Political Economy of Substitution Policy: Japan's Response to Lower Oil Prices,* Pacific Economic Paper No. 162, Australia-Japan Research Centre, Australian National University, Canberra.

Manne, A.S. and Richels R.G. 1990, *Global* CO_2 *emission reductions - the impact of rising energy costs,* preliminary draft, February, Electric Power Research Institute (EPRI).

Mintzer, I. 1988, ‘Our Changing Atmosphere: Energy Policies, Air Pollution and Global Warming’ in *Toronto Conference Proceedings: The Changing Atmosphere: Implications for Global Security,* Secretariat of the World Meteorological Organisation, Geneva.

NIEIR (National Institute of Economic and Industry Research) 1990, *Efficient Renewable Energy Scenario Study for Victoria,* A study for the Victorian Solar Energy Council, May.

Naughten, B. 1991, *The Outlook for Oil Prices,* ABARE paper presented at the National Agricultural and Resources Quarterly Conference, 29-31 January, Canberra.

Nordhaus, W.D. 1990, *Economic Approaches to Greenhouse Warming,* Paper prepared for the conference `Economic Policy Responses to Global Warming', October 4-6, Rome.

Nordhaus, W.D. and Yohe, G.W. 1983, ‘Future Carbon Dioxide Emissions from Fossil Fuels’, in National Research Council (US) Carbon Dioxide Committee, *Changing Climate: Report of the Carbon Dioxide Assessment Committee,* Washington.

Organisation for Economic Co-operation and Development (OECD) 1990, ‘Walras -- a multi-sector, multi-country applied general equilibrium model for quantifying the economy-wide effects of agricultural policies’, in OECD Economic Studies, *Modelling the Effects of Agricultural Policies,* Special Issue No. 13 Winter 1989-1990, pp. 69-102, Department of Economics and Statistics, OECD, Paris.

Organisation for Economic Co-operation and Development (OECD) 1991a, *The Costs of Policies to Reduce Global Emissions of CO_2: Initial Simulation Results With GREEN*, Note by the Secretariat, Department of Economics and Statistics, OECD, Paris.

Organisation for Economic Co-operation and Development (OECD) 1991b, *Potential costs of adapting to sea level rise,* Environment Committee, Climate Change, Annex 3, pp. 50.

Pindyck, R.S. 1979, ‘Interfuel Substitution and the Industrial Demand For Energy: An International Comparison’, *Review of Economics and Statistics*, Vol. 61, pp. 169-179.

Prime Minister's Working Group 1989, *Reducing Greenhouse Gas Emissions*, Discussion Paper.

Steinberg, M., Cheng H.C. and Horn F. 1984, *A Systems Study for the removal, Recovery and Disposal of Carbon Dioxide from Fossil Fuel Power Plants in the US*, US Department of Energy, Washington.

Thorpe, S., Sterland, B., Jones, B.P., Wallace, N.A. and Pugsley, S. 1991, *World energy markets and uncertainty to the year 2100: Implications for greenhouse policy,* ABARE Discussion Paper 91.9, AGPS, Canberra.

Truong, T.P. 1985, ‘Inter-Fuel and Inter-Factor Substitution in NSW Manufacturing Industry’, *The Economic Record*, Vol. 61, pp. 644-653.

Turnovsky, M., Folie M. and Ulph, A. 1982, ‘Factor substitutability in Australian manufacturing with emphasis on energy input’, *The Economic Record*, vol. 58, pp. 61-72.

Walker, I.J. 1990, *Potential to Reduce Emissions of Greenhouse Gases in the Energy Sector*, EPD Discussion Paper No. 1, Energy Programs Division, Department of Primary Industries and Energy, Canberra.

Whalley, J. 1991, ‘The Interface Between Environmental and Trade Policies’, *Economic Journal*, vol. 101, pp. 180-190.

Whalley, J. and Wigle R. 1991, `The International Incidence of Carbon Taxes', *in Economic Policy Responses to Global Warming,* ed. by R. Dornbusch & J. Poterba, MIT Press, Cambridge, Mass.

Williams, D.J. 1989, *Greenhouse and Energy: Australia's Options*, paper prepared for the CSIRO conference held at Macquarie University, December.

Williams, D.J. 1990, ‘Australian methane fluxes’ in D.J. Swaine (ed.), *Greenhouse and Energy*, pp. 165-173, CSIRO, Canberra.

_ Total system costs comprise building, operating and fuel costs and are minimised over the entire energy system, not merely the energy production and distribution secto

APPENDIX H: MODELLING WORKSHOP

As foreshadowed in its draft report, the Commission arranged a modelling workshop to allow those with an interest in greenhouse abatement strategies to become familiar with the latest results of economic modelling. The one-day workshop was held in Canberra on Monday 21 October 1991.

About 75 persons attended the workshop, including representatives from State and Federal Governments, conservation groups, trades unions, universities, and private businesses.

For more information about the Commission's own modelling work, see Chapters 5, 8 and 9, and Appendix G.

Workshop program

INTRODUCTION: **Mr Mick Common**
Associate Commissioner
Industry Commission

SESSION 1: THE SCOPE FOR INTRODUCING FURTHER FUEL SAVING TECHNOLOGIES

Topic 1: *Evaluation of costs of energy use options to reduce greenhouse gas emissions*

Dr John Tilley
Department of Primary Industries and Energy

Dr Tilley presented a summary of the results of a number of studies evaluating the costs and savings of a range of options to meet the currently projected demand for energy services in the industrial, commercial and residential sectors. Market penetration of technologies was addressed together with an assessment of the costs and benefits of implementing options.

Topic 2: *Minimising the cost of providing Australia's future energy requirements*

Mr Barry Jones
Barry Naughten
Peng Zhao-Yang
Stephanie Belcher
Australian Bureau of Agricultural and Resource Economics

Mr Jones presented the results of an analysis with the 'Markal-Mensa' linear programming model which was used to analyse how Australia's projected energy demands could be met at least cost under alternative greenhouse gas abatement strategies.

Paper 3: *Quantifying the macroeconomic consequence of introducing fuel saving technologies*

Dr Peter Brain
Mr Tony O'Dwyer
National Institute of Economic and Industry Research
Dr Hugh Saddler
Energy Policy & Analysis Pty Ltd

The three speakers summarised the results of studies undertaken by the Institute for the Commission for the Future and the Victorian Renewable Energy Authority. The studies focused on the cost of meeting a 'Toronto Target' given the policy constraints likely to be faced by the Australian economy during the 1990s.

SESSION 2: BENEFITS OF GREENHOUSE GAS EMISSION CONTROL

Topic 1: *How large are the incentives to join subglobal carbon reduction? Initiatives*

Professor John Piggott
University of New South Wales
John Whalley
University of Western Ontario
Randall Wigle
Wilfrid Laurier University

Professor Piggott presented the paper which extended Whalley and Wigle's multi-country computable general equilibrium model. The extended model was used to investigate the extent to which major trading blocks might benefit from cooperation to control greenhouse gas emissions.

SESSION 3: IMPLICATIONS FOR AUSTRALIA OF CONTROLLING GREENHOUSE GAS EMISSIONS

Topic 1: *Controlling methane and carbon dioxide emissions: is there a trade-off?*

Mr Tony Lawson
Industry Commission

Mr Lawson reported on the use of the ORANI model in the Commission's draft report on greenhouse gas emissions. He explained how the model had been modified to better address this issue. The Commission examined taxes to reduce methane as well as carbon dioxide emissions.

This allowed comparisons to be made of the relative economic impacts of policies to reduce emissions of two important greenhouse gases, and enabled identification of the key factors determining those impacts.

Topic 2: *Prospects for the Australian economy 1990 to 2002: ORANI-F projections to support an enquiry into environmental issues*

Dr Phillip Adams
Professor Peter Dixon
Professor Brian Parmenter
Centre of Policy Studies, Monash University

The paper, presented by Professor Dixon, contained forecasts generated by ORANI-F to the year 2030. It showed how these forecasts were affected by the constraints the Australian economy would face if it was to unilaterally introduce Toronto-type restrictions on greenhouse gas emissions.

SESSION 4: GLOBAL CONSEQUENCES OF CONTROLLING GREENHOUSE GAS EMISSIONS

Topic 1: *World energy markets and uncertainty to the year 2100: implications for greenhouse policy*

Ms Sally Thorpe
Barry Sterland
Barry P Jones
Nancy A Wallace
Sally-Ann Pugsley
Australian Bureau of Agricultural and Resource Economics

Ms Thorpe presented estimates of the impacts on global and regional energy markets of introducing a range of greenhouse gas abatement strategies. The strategies were evaluated using the Edmonds-Reilly global energy model.

Topic 2: *Economic implications for Australia of global emission reductions programs: results from the WEDGE model*

Mr John Zeitsch
Industry Commission

Mr Zeitsch described in more detail results obtained from the WEDGE multi-country multi-commodity general equilibrium model developed by the Commission to examine the implications for Australian industry, and the Australian economy, of meeting various carbon dioxide emissions targets.