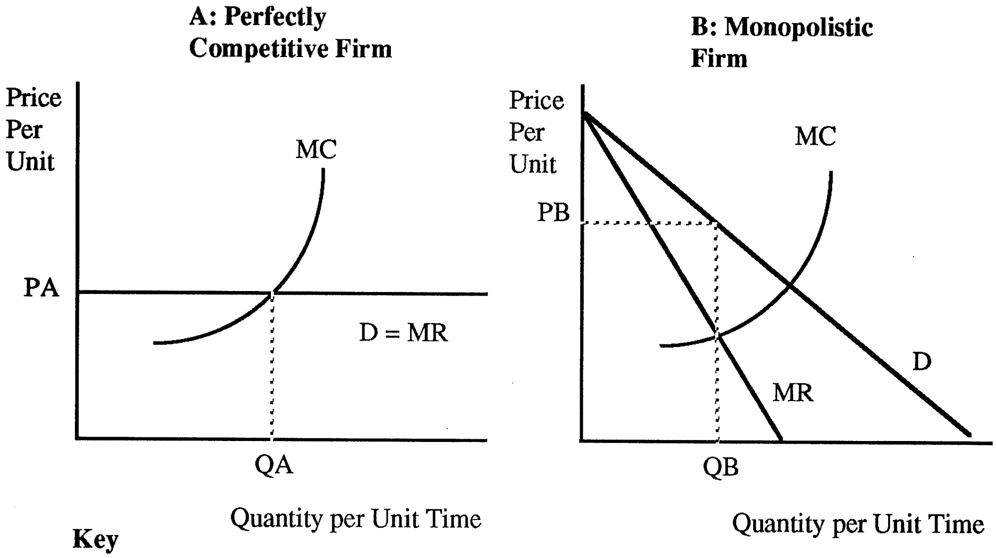
Figure 4.2
Demand Curves and Profit Maximising Strategy For Firms in Competitive and Monopolistic Markets



Key

D = Demand
MR = Marginal Revenue
MC = Marginal Cost
Pi = Profit Maximising Price within Particular Market Structure
Qi = Profit Maximising Quantity within Particular Market Structure

Source: Adapted from Tisdell 1982, p. 208

Proponents of different approaches to ESD would support the strategy of LCP for energy system planning, so long as the context of decision making was consistent with their approach. The remainder of this chapter describes different contexts for decision making that have traditionally characterised Australian energy systems, that are recommended by the *NSESD*, and that are advocated by economists and ecologists. It explains the likely impacts on Australian energy systems that would result from LCP's application in each of these contexts.

Traditional Australian Energy System Planning

LCP has not traditionally been a feature of energy system planning in Australia. Instead, the major actors in the Australian residential energy supply industry have planned energy systems largely on the basis of the conventional approach to energy described in Chapter Two. The electricity and gas industries essentially consist of public utilities operating in imperfectly competitive market structures. Public utilities have sought to optimise a range of values. They have traditionally aimed to meet anticipated energy demand, keep energy prices low (especially for disadvantaged customers), promote energy use, and avoid under-capacity. The coal and wood industries are both commercial and competitive. Suppliers of alternative energy hardware[2] too operate commercially in competitive markets. Commercial actors in Australian energy systems have aimed to maximise profits by maintaining and expanding markets. Externalities such as environmental damage from energy production and use have been internalised only to a limited extent, and only by regulations by actors in the energy industry.

Australian electricity and gas utilities have a number of community service obligations imposed on them to satisfy "government policies and social goals of an essentially non-commercial nature" (IC 1991:a, Vol. III, p. 119). For instance both industries are required to supply power to customers remote from existing systems on request, and/or to recover less than the full costs of making new connections (IC 1991:a, Vol. III, pp. 51-52, 76). Electricity is also supplied at subsidised prices to all domestic users, and both gas and electricity prices are reduced for low income groups (IC 1991:a, Vol III, pp. 51, 75). Significantly, electricity and gas users in areas connected to existing networks thus pay a subsidised marginal cost for power delivered by public utilities. As was stated in Chapter Three, solar energy is a viable alternative to electricity and gas for both water and space heating in Australia. However, in contrast to electricity and gas users, solar energy users pay the total cost up front for their energy hardware. Low initial costs and subsidised marginal costs encourage residential use of publicly supplied electricity and gas.

The central goal of energy forecasting and public utility provision in Australia has been to avoid under-capacity (Rosenthal & Russ 1988, p. 49-51). Once forecasts have been made, and utilities constructed, their output has tended to be sold "at any price to ensure the forecast is fulfilled and the capital is serviced" (Kellow 1986, p. 5). Thus Australian energy forecasts have tended to be realised, but only after demand has been stimulated by price reductions. Energy efficiency and demand management strategies undertaken recently by some Australian electricity authorities were described in Chapter Three. Measures such as these reflect a partial departure from the conventional approach of supplying quantities of energy, and toward a 'least-cost' approach focusing on energy service provision.

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[2] As noted in Chapter Three, 'alternative' energy sources include solar and wind energy, and systems that significantly improve energy efficiency or energy storage.

As was stated above, the key commercial actors in the residential energy supply industry are coal producers and wood merchants. The approach to energy system planning adopted by the Australian coal industry can be ascertained from the publications of the JCB and the QCB. In 1990, the JCB and the QCB reported "record" annual coal production, increasing levels of employment and labour productivity in the industry, increasing total and per unit returns on coal exports, and expanding exports and domestic consumption (JCB & QCB 1990, p. 1-2). These results are consistent with the published goals of the Joint Coal Board which include the "optimum development and utilisation of coal resources" and the "development of markets for coal" (JCB 1991, p. 4). The fuelwood, and alternative energy industries are commercial and decentralised and do not publish information on either their goals or progress towards them. It is therefore difficult to assess their approach to energy system planning. It is likely that planning in the fuel wood industry is minimal, but that wood merchants aim to meet demands for wood. Developers and suppliers of hardware for alternative energy use have promoted their products by stressing that their use is environmentally responsible, can result in cost savings, and will not reduce satisfaction of energy services (see Saddler 1990, pp. 7-9).

Competition between suppliers of energy from different power sources is determined largely by availability of infrastructure and by energy service type. Where electricity is available, it is used by many consumers for all residential energy service requirements. Where both electricity and gas infrastructure are in place, these power sources compete for the residential cooking, space and water heating markets (IC 1991, Vol. II, pp. 19-20). Where neither electricity or gas are available, fuelwood, alternative energy sources and petroleum products compete in the market for energy services to which they are applicable, although even in remote areas, energy users tend to prefer conventional to alternative energy systems (Saddler 1990, pp. 6-9). Fuelwood is also an important competitor for electricity and gas for space heating, even where these are both available (FTS & UT 1989), and solar energy competes with other energy sources for water heating throughout Australia (Taylor 1991, pp. 14-15).

Environmental costs associated with infrastructure provision, rehabilitation, conservation and alternative energy sources have traditionally been addressed to a limited extent in energy system planning decisions. In most states, electricity and gas authorities are required to consider environmental impacts of proposed developments. In Western Australia, New South Wales and the Northern Territory, authorities responsible for environmental protection are able to stop energy developments from going ahead on environmental grounds in some cases. In

Western Australia and the Northern Territory, energy system developers are required to rehabilitate land immediately after it has been damaged by developments, and in Tasmania rehabilitation costs (estimated at 1.5 per cent of total costs) are incorporated into the cost structure for new developments. In New South Wales and Victoria, rehabilitation of former gasworks and power station sites has been investigated. Australian energy conservation strategies have focused on facilitating efficient use of energy by removing constraints to market responses. The commonwealth government has supported renewable energy developments through funding for RD&D in preference to direct intervention to promote their use (IC 1991, Vol. II, pp. 243-51).

In summary, Australian energy system planners have traditionally promoted high levels of energy use and have ignored energy service provision. Specifically, they have promoted the use of electricity and natural gas from public utilities. Planners' preference for oversupply rather than under-supply of energy has produced a system where utilities are constructed in anticipation of future demand. When the demand does not eventuate, it is encouraged by subsidies and resultant increases in demand are considered to justify prior investments. Few provisions require that environmental costs of energy developments be addressed. These traditional approaches to energy planning have engendered a system that promotes high energy use in order to justify prior, and unnecessary energy expenditure.

National Strategy For Ecologically Sustainable Development Version of Least-Cost Planning

The context for LCP advocated in the *NSESD* is commercial, competitive, and would require energy suppliers to include a greater range of environmental costs in decision-making than has traditionally been the case. Specific recommendations involve "encouraging the development of commercially viable public and private sector energy service companies offering a wide range of demand and supply options and competing across electricity, gas, other energy forms, and energy efficiency measures" (ESDSC 1992:b, Section 2, p. 9). for internalising environmental costs, the *NSESD* recommends that urgent attention be given to "the establishment of effective mechanisms for setting and implementing national environmental protection principles, goals and standards" (ESDSC 1992:b, Section 2, p. 11). In addition investigation of "market mechanisms for achieving environmental protection in the energy sector" is recommended (ESDSC 1992:b, Section 2, p. 12).

The recent Industry Commission report on energy generation and distribution developed strategies for improving efficiency in Australia's electricity and gas supply industries (IC 1991, Vols. I, II, III). It proposed strategies for placing these public utilities into commercial settings and for encouraging their competition with each other, and with other energy forms. As far as commercialising the public utilities and increasing competitiveness are concerned, the *NSESD* and the IC report embrace equivalent objectives. The IC recommendations in these areas can therefore be considered indicative of the context for industry ownership and structure that would emerge from implementation of the *NSESD*.

Strategies proposed by the IC for commercialising public utilities include removing their community service obligations, establishing performance monitoring, placing public utilities on equal footing with private producers by removing legislative barriers to entry and obligations to supply new users at concessional rates, making public utilities liable for government taxes and charges, and adopting uniform commercial accounting practices. The IC recommends a two-stage process to restructure both gas and electricity supply industries and thereby increase competition. The process would involve ring fencing[3], and then separating generation, transmission and distribution authorities (IC 1991, V. I, p. 145).

In commercialising the energy supply industry, the IC recommend removing energy producers' obligation to supply energy to remote areas. Alternative energy systems compete more effectively for the energy market when electricity and gas are not available. In addition, subsidised connection to energy distribution grids has been one of the disincentives to alternative energy use in remote areas (Saddler 1990, p. 8). Commercialisation of the energy supply industry as proposed in the IC report would remove this disincentive, and encourage use of alternative energy sources in remote areas of Australia.

The manner in which Australian Governments have agreed to *NSESD* recommendations for incorporating environmental costs into energy system decision strategies is to continue implementing the Inter-Governmental Agreement on the Environment (IGAE[4]) (see ESDSC 1992:b, Section 2, pp. 10-11). The IGAE

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[3]'Ring fencing' is the term used to describe the process of forming separate accounting entities within the same enterprise to undertake logically separable tasks.

[4]The IGAE is an agreement between Heads of Government of the Commonwealth, States and Territories of Australia, and by representatives of Local Governments in Australia that was made at a Special Premier's Conference in Brisbane on 25th February 1992. The agreement aims to provide a

proposes introduction of a number of regulatory measures for improving recognition of environmental costs in decision making. IGAE principles for addressing social issues include i) adoption of a precautionary approach to environmental degradation; ii) promoting intergenerational equity; iii) conserving biological diversity and ecological integrity; and iv) improving valuation, pricing and incentive mechanisms that address social costs. The agreement proposes environmental impact assessment (EIA), carried out by development proponents (whether public or commercial) as a primary tool for assessing social implications of development proposals (see IGAE 1992, pp. 20-22).

An important limitation of EIAs undertaken by development proponents is that they are unlikely to fully address environmental costs of developments, or to recommend that a project not go ahead. This is because developers - and in particular developers operating commercially, and therefore seeking to maximise profits - have vested interests in projects' approval since their revenue is generated by successful projects, and because considerable resources are spent undertaking EIAs and companies will generally seek to recoup these costs (see Economou 1992, pp. 48-50). Since the IGAE recommends that development proponents remain responsible for undertaking EIAs, this pro-development bias of EIAs is likely to continue even after implementation of the *NSESD*. This proposed commercial context for LCP, in which environmental costs are discerned through developers' EIAs may not ensure that options such as alternative energy sources are adequately investigated in energy system planning. EIAs by development proponents are unlikely to be comprehensive in their investigation of alternative energy options, or to recommend that large projects (requiring expensive EIAs) not go ahead.

Despite this inherent bias of EIAs produced by development proponents, the regulations agreed to in the IGAE would go some distance toward ensuring that environmental costs were acknowledged in LCP decisions. Measures agreed to in the IGAE aim to reduce duplication of functions between different levels of government, ensure transparency in decision making, set up processes for cooperation between governments, and increase government accountability in developing and implementing environmental policy (IGAE 1992, pp. 2-3). To these ends, the IGAE commits governments to set up the National Environmental Protection Authority,

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cooperative national approach to the environment, a better definition of the roles of respective governments, a reduction in the number of disputes between the Commonwealth and the States on environment issues, greater certainty of government and business decision making, and better environment protection (IGAE 1992, pp. 1-2).

with powers and processes to establish a range of environmental standards. By clarifying governmental responsibilities and powers towards the environment, these measures would increase the incorporation of environmental costs into energy system planning decisions. One possible outcome of this, is that environmental impacts from installation of new, large scale generation and transmission plants could fall outside acceptable levels. The transparent EIA process recommended in the IGAE could allow interested parties to identify and expose unacceptable environmental impacts of proposed developments even if planners did not. This could reduce the attraction of large-scale energy systems for energy suppliers, and encourage them to undertake smaller scale, alternative energy initiatives.

It is likely that ring fenced and separate energy bodies would face difficulties in addressing a goal of providing energy services rather than quantities of energy. This is because neither generation nor transmission bodies would have direct contact with energy users so they could not design energy systems to specifically target the energy service requirements of their clients. Also, although energy distributors would have contact with customers, the energy transmitted to them for distribution would be provided in flexible, transportable forms, such as electricity and gas, since these would be attractive for generators and transmitters.

This discussion suggests that the context within which the *NSESD* recommends that LCP should be undertaken would limit the strategy's comprehensiveness. In particular, it could limit the ability of energy suppliers to target energy services, rather than quantities of energy. To a lesser extent, the strategy's reliance on EIAs for incorporating environmental costs into decision making could limit the range of environmental costs and options considered. Strengths of the strategy are that commercialising the energy industry, as recommended by the IC could remove some disincentives for alternative energy use in remote areas, and environmental standards set up under the IGAE could improve the attractiveness to energy suppliers, of small scale energy systems in relation to large scale installations.

Economic Versions of Least-Cost Planning

The following three sections describe the different contexts for LCP that would be recommended by FM, ME and RE economists, and suggests ways in which LCP applied within these contexts would impact on Australian residential energy use.

Free Market Economic Least-Cost Planning

According to FM economic theory, LCP would ideally be carried out by commercial firms, operating in competitive market structures, and accounting only for private costs. The first two elements of this context are consistent with the *NSESD* recommendations for industry ownership and structure, and with the IC report discussed above. The latter differs from the *NSESD*. This section explores the implications for Australian residential energy systems of LCP, applied in a commercial and competitive context, where no attempt is made to address environmental costs.

The IC report acknowledges that both gas and electricity transmission exhibit natural monopoly characteristics. To increase competition in energy supply industries they recommend increasing access to transmission grids, but no measures to remove monopoly power from transmission authorities. If transmission authorities were commercial monopolists, their profit maximising strategies would include attempts to block competition. Any energy supply system that did not require transmission through a grid would be a competitor. Solar hot water heaters are an example of just such a system. In the past, electricity supply authorities have "aggressively promoted off-peak pricing" largely to service debts incurred as a result of over capacity (Saddler 1990, p. 8). This has weakened the Australian solar water-heating industry. An absence of measures to account for environmental costs in energy LCP would allow strategies to block environmentally benign, small scale alternatives to large scale electricity supply to continue unchecked.

To not address environmental costs during LCP, energy suppliers would simply not carry out an EIA, and not be influenced by environmental standards. Without transparent EIA procedures, the separation of energy production, transmission and distribution (as was recommended by the IC for increasing competition in the energy industry) would leave energy users unaware of the ultimate source of their power, or of the environmental costs associated with energy produced for their use. Existing coal-fired power stations would remain economically viable, even when they have negative environmental costs. Synoptic LCP decision making in this context would have its comprehensiveness limited by an absence of incentives to apply novel planning techniques in developing new energy infrastructure. There would be no reason for energy producers to embrace energy alternatives and they would probably continue to use 'tried and true' methods of power generation.

This discussion suggests that application of LCP in a commercial, competitive environment, where environmental costs are not considered would result in continued exclusion of alternative energy sources from energy supply systems.

Mainstream Environmental Economic Least-Cost Planning

ME economists would recommend a commercial context for LCP, in which environmental costs were incorporated into decision making via economic instruments such as taxes or subsidies. ME economists are not necessarily in favour of either competitive or monopolistic market structures. They agree with FM economists that efficiency is likely to be higher in a competitive than a monopolistic industry, and that efficiency is environmentally sound since it leads to minimal resource wastage. On the other hand, since monopolists under-supply goods in relative to competitive industries they are more likely to conserve environmental resources than are actors in competitive contexts (Pearce & Turner 1990, pp. 284-86). Hence ME economists may recommend monopolistic market structures when resource conservation is a key issue, and competitive systems when efficient use takes priority. This section explains the implications for Australian residential energy systems of LCP applied in a context that differs from that endorsed by the *NSESD* in that environmental costs would be incorporated via economic measures, and where industry structure depends on the priority of efficiency or conservation for any resource.

ME economists would support the *NSESD* and IC recommendations to increase competition in electricity and gas supply industries, since the relative abundance of coal (the fuel for over 80 per cent of Australia's electricity) and gas mean that their conservation is of lower priority than their efficient use (see Chapter Three). In contrast, the shortage of fuelwood resources relative to current and potential demand in some areas, and the environmental costs associated with fuelwood use (see Chapter Three) would lead ME economists to recommend measures to promote conservation in the fuelwood supply industry. If all other factors remained constant, monopolisation of the fuelwood industry would lead to reduced availability of fuelwood, and its sale at higher prices. As well as leading to forest conservation this could promote increased efficiency in fuelwood combustion. Whereas fuelwood use is currently 10 to 60 per cent efficient in Australia (FTS & UT 1989, p. 36), higher prices and reduced availability would provide an added incentive for users to invest in efficient wood combustion hardware. Monopolisation of the fuelwood industry would also simplify government monitoring and control of fuelwood supply and demand.

The position taken by ME economists suggests that they would argue that environmental standards such as those proposed by the IGAE are unlikely to elicit optimal use of environmental resources. This is primarily due to difficulties in enforcing, monitoring, and applying adequate disincentives to exceed standards (Pearce & Turner pp. 103-107). The taxes that ME economists recommend instead of standards to incorporate environmental costs into energy decisions are set at levels that reflect the total economic value of social goods threatened by energy supply. Total economic value is the sum of private (or 'use'), option, and existence values (Pearce & Turner 1990, p. 131). Table 2.1 identified the major environmental impacts of various energy sources. Option values threatened by Australian residential energy production include the opportunity costs of losing farming or other land uses to coal mining, of damaging ocean resources due to oil spillage, of restricted scientific advance due to loss of habitats from mining or fuelwood harvest, and of clean waterways due to dam creation for hydro-electricity. Existence values threatened by energy systems include those associated with natural terrestrial and aquatic ecosystems.

Environmental taxes would increase the cost of fuelwood, since several option and existence values are associated with forest harvest and since no government charges are presently paid for fuelwood production or use. Since renewably grown fuelwood results in no net rise in atmospheric CO_2, no carbon tax would be applied to this fuel source. Since electricity use is currently subsidised due to utilities' community service obligations, and failure to charge users for infrastructure provision, the price of electricity would rise if these hidden subsidies were removed. It would rise significantly further with the imposition of environmental taxes. These price rises would provide an incentive for residential energy users to switch to alternative energy sources such as more efficient use of electricity and fuelwood, and solar energy, the cost of which would drop relative to the cost of its competitors since solar energy hardware would be subject to no new taxes. The use of these alternative energy systems could be further encouraged by funding RD&D initiatives from the revenue collected from environmental taxes.

In the context proposed by ME economists, LCP would be applied in an initial decision to use taxes rather than other measures to approach ESD in energy system planning, in subsequent decisions to select appropriate magnitudes for taxes, in monitoring the effects of taxes, and in selecting beneficiaries for revenue generated by environmental taxes. Actual adjustments to energy systems would be driven by market forces.

Radical Environmental Economic Least-Cost Planning

The context for LCP that RE economic analysis suggests would be non-commercial, decentralised and would explicitly and systematically recognise real environmental costs of energy systems. For RE economists, rejection of one extreme position for energy system contextual variables does not imply acceptance of the position at the other extreme for that variable. Thus, the non-commercial requirement would not be equivalent to endorsing public control of the energy system, but suggests simply that profit maximisation should not be a goal of energy system planners. Instead, energy planners would aim primarily to minimise the conversion of low entropy into high entropy in energy service provision. Similarly, a decentralised system would not be equivalent to a competitive system. Instead, RE economists would advocate cooperation between actors in a decentralised energy service provision system.

For RE economists, a central environmental cost of conventional energy systems is their wasteful and unnecessary conversion of valuable low entropy resources into high entropy waste. RE economists argue that low entropy is the world's sole truly scarce resource, and that everything of value has low entropy (although not all entities with low entropy are valuable). They describe low entropy resources in terms of two central characteristics. These are the quantity available, or stock, and its potential rate of harness, or flow.

RE economists distinguish between two sources of low entropy that are available for economic production purposes. One source is the minerals within the earths crust which exist in a strictly limited stock, but whose flow can be controlled by humans. The other is the energy available through the degradation of the sun. This is practically unlimited in its stock, but its flow rate of arrival to earth is limited (see Daly & Cobb 1989, pp. 194-99; Georgescu-Roegen 1971). Since RE economists consider low entropy as a fundamental determinant of value, it follows that they would recommend a decision strategy that ensured explicit recognition of low entropy, and encouraged minimal conversion of low to high entropy. Thus the costs that RE economists would seek to minimise in LCP would be the entropic changes associated with energy service provision, rather than an arbitrary monetary measure.

LCP in a context where cost was measured in terms of entropic changes would discriminate strongly in favour of alternative energy sources. Energy systems based on fossil fuel use would fail to minimise entropic costs since they operate by converting finite stocks of low entropy resources to high entropy heat and waste materials. An RE economic analysis exposes the ludicrousy of the Australian energy system in which fossil fuels can be burnt to produce electricity which can then be used to produce heat at an efficiency of around 1 per cent, when solar heating is available. In contrast, alternative energy systems such as those that harness solar and wind energies would minimise entropic costs since they concentrate the flow from the infinite stock of solar low entropy and thus increase the quantity of free energy available for human use. A decentralised energy system would be ideal for minimising entropic costs since it would allow free energy to be harnessed wherever and whenever it was available or needed (see Lovins 1977, pp. 38-46).

Ecological Versions of Least-Cost Planning

The following two sections describe the different contexts for LCP that scientific ecologists would argue were conducive to ESD in energy. It explains the impacts that LCP, applied in these contexts would have on Australian residential energy use.

Scientific Ecological Least-Cost Planning

Like RE economists, scientific ecologists would recommend a non-commercial, non-competitive context for LCP, which could not ignore environmental costs. For scientific ecologists, ecological rationality assumes a near-lexical priority, and must therefore underlie all human activities, including energy system planning[5] (Dryzek 1987, pp. 58-60). Ecological rationality is a form of functional rationality, or the ability to respond logically to changing conditions. Functional rationality differs from substantive rationality, which is the ability to move logically toward a pre-defined goal (Dryzek 1983, p. 6; Bartlett 1986, p. 224). Synoptic models are substantively rational decision strategies. They are used to identify optimal goals, and to develop strategies for moving logically and efficiently towards them. Clearly, the synoptic nature of LCP means that it could not be the ultimate basis for decision-making in an ecologically rational system.

Dryzek argues that ecologically rational decision making will be facilitated in social systems exhibiting negative feedback, coordination, either robustness or flexibility, and resilience during crises (Dryzek 1987, pp. 46-54). The model in Figure 4.1 indicated that once a strategy is developed within an LCP framework follow up work

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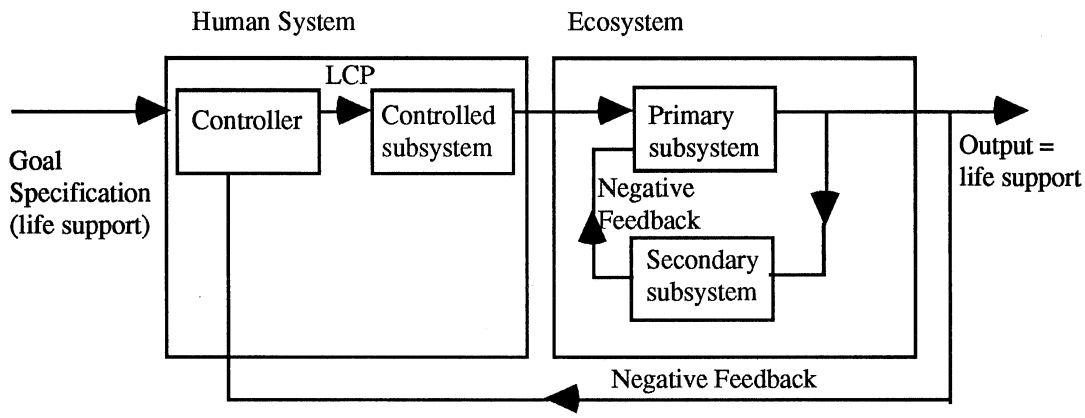
[5] Lexical priority means that lower values come into play only when designs in pursuit of a higher value are totally complete. When a value assumes near-lexical priority it means that other values can be accommodated when the higher value has been largely satisfied. For example, this could mean that ecological values could be considered less important than political values in a situation where a political crisis posed a threat to all other values (Dryzek 1987, pp. 58-60).

may be undertaken to refine it. Identification of necessary follow up work would require some mechanism for negative feedback, although such a mechanism is not identified in models for LCP. Figure 4.3 shows an ecologically rational model for social choice, in which LCP is placed within a decision strategy where negative feedback also occurs. What is notable about this model is that LCP plays a relatively minor role within a larger, iterative system, and is repeated regularly in response to changing conditions.

Figure 4.3
Teleological Social Choice with Least-cost Planning and Negative Feedback



Source: Adapted from Dryzek 1987, p. 48.

Conventional energy systems would not satisfy the criteria of ecological rationality. The conventional approach of responding to energy shortages by increasing production - as has traditionally been done in Australia - is a positive feedback loop, leading to ever increasing energy demand and supply. Coordination in conventional systems is also low, since these systems tend to displace problems rather than solve them. For example, the smog that once polluted London from coal combustion was reduced when coal and wood burning was banned in London houses. The demand for energy services of heat and cooking was met by energy utilities in outlying areas. This is an example of problem displacement over space, and not problem solution (Patterson 1990, pp. 51-52). The conventional system's reliance on finite resources also means that it is neither robust nor flexible, since conventional energy hardware cannot be used to provide energy services once fossil fuels are depleted, and nor could they be easily altered to utilise alternative energy sources (see Dryzek 1987, pp. 46-54).

In contrast, alternative energy systems would be ecologically rational. Such systems would use diverse hardware to harness renewable energy sources, such as solar and wind energies, and would thus be robust, since the use of these flow resources does not reduce their availability. They would use minimal, easily understood technology, and thus be flexible, since energy hardware could be rearranged easily in response to changing conditions. Coordination would be high, since the systems would be matched in scale, distribution, and energy quality, to energy services. The small scale of the systems would create negative feedback loops, since energy users would be personally affected by environmental damage resulting from their energy use (see Lovins 1977, pp. 38-9; Patterson 1990, Ch. 9).

Intuitive Ecological Least-Cost Planning

Intuitive ecologists attach intrinsic value to the integrity of natural ecosystems. Thus the cost that they would seek to minimise in LCP would be ecosystem damage. The context that they would recommend for this would not be defined by economic criteria, such as private costs or externalities, since according to intuitive ecologists, economic analysis is possible only through anthropocentrism. Ethical principles for environmental protection would provide the systematic imperative to minimise ecological costs of energy systems.

Arne Naess - who first articulated a distinction between shallow and deep ecology - argues that eight ultimate premises underlie the logical and intuitive decisions that deep ecologists make. This deep ecological platform places high value on i) human and non-human life, with the value of the latter independent of the former; ii) the richness and diversity of life; iii) no reduction in 'ii' except to satisfy vital needs; iv) the need for a substantial decrease in human population; v) reduced human interference with the natural world; vi) policies that allow societies to experience the connectedness of all things; vii) greater appreciation of life quality; and viii) an obligation to act on these premises (from Naess 1988, p. 130).

Thus, in a deep ecological context, the comprehensiveness of LCP would be restricted to the points raised by these premises. The resulting energy system would not harness energy from fossil fuels because this can result in high negative impacts on ecosystems and because its fossil fuel use allows humans to be out of touch with their natural surroundings. Fuelwood use too would be rejected except during crisis, since it involves biomass harvest, and therefore decreases the richness and diversity of life. A deep ecological energy system would utilise wind and solar energies.

Comparison of Approaches

It is clear from the arguments presented in this chapter that the effect of an LCP approach to energy system planning would be strongly dependent on the context in which it was applied. Key issues raised by the analysis include the implications of ring-fencing and separating elements of existing energy systems, and the degree to which different contexts will encourage a shift to alternative energy systems.

The *NSESD,* FM and ME economists would all recommend a competitive context for LCP. To increase competitiveness in the energy sector, the IC's recommendation to ring-fence, and separate energy production, transmission and distribution could plausibly find favour with those analysts endorsing increased competitiveness. But separation of these components of the energy system could reduce the ability of energy system planners to target energy services, and in so doing, undermine the primary goal of the least-cost approach. Thus, while separation of elements of Australia's energy system could increase economic efficiency, it may not be conducive to ESD.

The analysis in this chapter suggests that implementing a least-cost approach to energy system planning will not automatically result in increased penetration of alternative energy sources into residential energy systems. This would require additional measures to incorporate environmental costs of energy systems into decision strategies. The range of methods for incorporating environmental costs recommended by the different approaches examined here included regulations, price mechanisms, creating an accounting system based on real energy units, by strengthening negative feedback, and encouraging a conservationist ethic. The analysis does not show which of these systems would function better than any other. What is apparent however, is that the different methods are compatible, in that the use of one measure to incorporate environmental costs would not preclude the simultaneous use of other measures. For example, the effectiveness of regulations could be substantially increased if they were imposed alongside education programs that encouraged ecologically ethical use of energy resources. If price mechanisms to discourage conventional energy systems and encourage alternatives were also applied, the incentive for energy producers and users to embrace energy alternatives would be substantially enhanced.

A comparison of the context that the *NSESD* recommends for LCP, with those recommended by analysts from various disciplines, suggests that the model it most closely approximates is that recommended by free market economists. Both they, and the *NSESD* endorse a commercial, and competitive energy industry context for LCP. The key difference between these approaches is that the *NSESD* recommends some measures to incorporate environmental costs into energy system decision making, whereas the FM approach does not. ME economists suggest that regulations such as those proposed in the IGAE are inefficient in achieving environmental objectives. Certainly, this analysis suggests that the impact of IGAE environmental controls would be less incisive than other possible measures to incorporate environmental costs. Their effectiveness in practice remains to be seen.

Conclusion

The least-cost approach to planning residential energy systems is likely to find favour with a broad range of analysts. However LCP is clearly not a neutral strategy, since its comprehensiveness will always be negated by the context in which it is undertaken. Contextual variables that will affect the outcome of LCP include industry ownership and structure, and the extent and methods of inclusion of environmental costs into decision strategies. The *NSESD* version of LCP approximates that which would be recommended by free market economists.

CHAPTER 5: PERFORMANCE INDICATORS

Introduction

In Chapter Four it was argued that different energy analysts recommend different contexts for least cost energy system planning. This chapter argues that they would also favour the use of different performance indicators to determine the effectiveness of policies and strategies for ESD in energy. This comparison of factors used as indicators of energy system performance demonstrates the extent to which important data are overlooked by analysts with different approaches to energy. A key difference between the indicators is whether they measure performance in terms of physical, social, or economic units. Once again, this chapter focuses on the different strategies used traditionally in Australia, endorsed by the *NSESD* and proposed by economists and ecologists for assessing the success of residential energy systems.

Conventional Australian Performance Indicators

A suite of social, economic and physical indicators have traditionally been analysed to assess the performance of Australian energy systems. Systems have ultimately been considered successful if minimal social conflict or dissatisfaction are generated in response to energy issues. Occurrences that planners consider to be stimuli for conflict include physical shortfalls in energy provision or restrictions on energy use, and sudden price rises. These have traditionally been mitigated by energy system planners.

Planners' perception that energy shortages, or restrictions on energy use lead to dissatisfaction, and their desire to minimise such responses, is indicated in several ways. Firstly in their propensity to over-supply power, as was discussed in Chapter Three. Secondly, in their assurance that demand management will not detract from energy users' quality of life. This sentiment is emphasised by the Australian Minister for Resources, in the statement "energy conservation does not mean going without; it does not mean lowering our standards of living; it does not require fundamental changes in lifestyle" (Griffiths, 1991, p. iii). Thirdly, the perception is indicated in energy industry responses to power shortages. For example, on the 12th of December 1992 a fault at a Queensland electricity utility resulted in a loss of 38 per cent of Queensland's electricity supply. A press release explaining the fault emphasised its "rare and unusual" nature, and the effectiveness of the Queensland Electricity Commission's (QEC) responsive in minimising the detrimental effects of the cuts (QEC 1992).

Policies preventing sudden price rises for residential energy can be found in public utilities' publications. For example, the QEC's strategic plan expressly adopts goals of ensuring "stability in the pricing of electricity" and "not more than half-consumer price index retail price increases until 1996" (QEC 1991, p. 2).

National Strategy for Ecologically Sustainable Development Performance Indicators

The *NSESD* recommends that a number of physical, economic and social measures be used as performance indicators to assess Australia's progress toward ESD in energy. A physical measure identified in the report is Australia's annual level of greenhouse gas emissions. The key economic measure is efficiency in the energy sector, and the key social measure, the effect of ESD policies on the work force. The *NSESD* will be considered successful if it encourages a reduction of greenhouse gas emissions, increased economic efficiency in the energy sector, and no net negative effects on employment (ESDSC 1992:b, Sections 2 and 3). Data on the Australian energy systems performance in relation to these indicators is currently fairly scarce, so many of the *NSESD* recommendations focus on developing systems to monitor Australia's performance in these areas.

Systems proposed in the *NSESD* for monitoring physical performance indicators include a recommendation that energy utilities publish their contributions to greenhouse gas emissions in their annual reports. To assess economic efficiency, the Strategy recommends that governments identify appropriate rates of return for public utilities. The Strategy recommends that "market behaviour should be subject to external scrutiny under an appropriate general competition policy framework" (ESDSC 1992:b, Section 2, p. 8). The form which such a framework would take is not further examined in the *NSESD*. The *NSESD* acknowledges that raising the efficiency of the energy sector could result in some job loss. The strategy proposes that these effects be measured in terms of "skills development, career paths, equal employment opportunity and wage levels rather than simply as net job losses" ESDSC 1992:b, Section 2, p. 28). While many of the *NSESD's* recommendations focus on increasing the potential for renewable and alternative energy sources to compete effectively with conventional ones, no performance indicators are proposed for assessing the success of these measures.

Economic Performance Indicators

The following three sections describe performance indicators that would be recommended by proponents of FM, ME and RE economic approaches to ESD in energy.

Free Market Economic Performance Indicators

FM economists measure the performance of economic systems using economic and social units. National accounts such as GNP, and national employment levels are common economic performance indicators for FM economists. Thus to assess the success of the ESD strategy, FM economists may compare the energy industry's contribution to GNP and employment before the Strategy's implementation to its post-implementation levels.

As was mentioned above, one of the Strategy's goals is to increase the potential for renewable energy sources to compete with conventional energy sources. If energy systems became more oriented toward energy alternatives than is now the case it is likely that the contribution of the energy sector to GNP and employment would be reduced. This is because many alternative energy systems (such as increased efficiency and solar hot water and photovoltaic systems) reduce their users' reliance on conventional energy networks in achieving their energy services. Energy systems that are external to conventional networks are not accounted for in measures such as GNP. For example, Australia currently makes use of solar energy for solar salt-drying, outside laundry drying, and passive building heating (ABARE 1991, p. 3). No contribution to GNP from the energy used in these systems is registered in national accounts. Thus increased use of alternatives such as these would reduce the magnitude of the contribution of the energy sector to Australia's national accounts.

Increased use of alternative energy sources could reduce the contribution of the existing energy systems to employment because the reduced demand for electricity and other conventional power sources would mean that fewer workers were required in conventional energy provision. Jobs in the manufacturing sector may increase due to increased demand for solar cells, insulation, or wind generators. An employment displacement effect such as this occurred in Denmark when wind energy was vigorously promoted. 28 jobs in the existing Danish power industry were lost, and 3071 were created as a result of the policies (Diesendorf & Kinrade 1992, p. 7). National accounting systems based on GNP could mask the real benefits of a switch to alternative energy sources. Increases in employment, such as those that were experienced in Denmark are likely to be recorded in the manufacturing sector rather than the energy sector and thus not show up as a rise in productivity in energy. That traditional FM economic indicators could interpret a switch to alternative energy sources as detrimental to the Australian economy, or to the energy sector suggests that these performance indicators may not be useful if increased use of energy alternatives is a goal of the *NSESD*.

Mainstream Environmental Economic Performance Indicators

ME economists advocate the use of monetary performance indicators that reflect the total value of physical resources. They argue that the FM economic use of GNP as a measure of the standard of living of the population is problematic since it can fail to register social benefits of economic activity (such as employment changes in economic sectors due to a shift to alternative energy sources described above), and it will register many real social costs as beneficial additions to GNP. For example, when pollution from fossil fuel combustion damages health, and health care expenditures rises, this is measured as addition to GNP even though it clearly involves a real cost to society. ME economists recommend that national accounting systems, such as GNP should be augmented so that they will measure the total economic value of environmental assets and register real costs and benefits of economic activities accordingly. Unlike GNP, ME national accounts would register environmentally damaging activities as costs, rather than benefits (Pearce, Markandya & Barbier 1989, pp. 22-23).

In *Blueprint for a Green Economy,* Pearce, Markandya and Barbier (1989) state that they would support the measurement of sustainable income as a performance indicator for an economy. They define sustainable income as "the flow of goods and services that the economy could generate without reducing its productive capacity" (Pearce, Markandya & Barbier 1989, p. 108). The key difference between this system and the FM measure of GNP is that calculating sustainable income involves subtracting real environmental costs (measured in monetary terms) from the figure that FM economists would calculate for GNP. Environmental costs accounted for in a measure of sustainable income include i) household defensive expenditures, calculated as the sum of expenditures paid by householders to "protect themselves against the adverse consequences of the production process" (Pearce, Markandya & Barbier 1989, p. 105); ii) monetary value of residual pollution, or the cost of negative production externalities; iii) depreciation of human-made capital, and iv) depreciation of natural capital, including loss of ecosystem function damage, renewable capital and exhaustible capital (Pearce, Markandya & Barbier 1989, p. 108).

If this measure of sustainable income was used to analyse Australian energy systems and the changes they may undergo as a result of the *NSESD*, the success of the Strategy would be quite differently interpreted than by its impact on GNP. Extending the example used in the previous section, if the *NSESD* encouraged a shift away from conventional energy and toward alternative energy systems, the change would be reflected as a net benefit in a measure of sustainable economic welfare. Since energy alternatives are less polluting, and result in emission of fewer greenhouse gas emissions than do conventional systems, the monetary value of residual pollution would be greatly reduced as a result of the Strategy[1]. Similarly, since conventional energy systems have profound negative impacts on environmental capital (such as when oil spills pollute oceans, or ecosystems are destroyed due to flooding for large-scale hydro-electric schemes), a system based on alternative energy sources would be measured as beneficial to environmental capital under a sustainable income accounting system.

Radical Environmental Economic Performance Indicators

RE economists are fundamentally opposed to any measure of the well-being of an economy that identifies growth of that economy as a goal. Their opposition is based on their interpretation of the implications of the second law of thermodynamics (the entropy law) for economic systems. As was stated in Chapter One, the entropy law demonstrates that the costs of economic activities always outweigh the benefits, so any system that records net benefits from economic activities is clearly misinformed (see Georgescu-Roegen 1973, pp. 41-42). RE economists tend to recommend performance indicators based on real units, and economic units that reflect environmental concerns.

In his paper "On Sustainable Development and National Accounts", Daly (1988) proposes a system to measure the performance of an economy that would measure qualitatively different aspects of economic systems in three separate accounts. Like GNP, the value of these could be calculated at regular intervals and compared over time to assess an economy's ongoing performance. The first account would be a *Benefit Account,* and would measure the value of the services provided within a particular time period. The ultimate objective for this account would be to optimise the values recorded within it, so that services were provided effectively, but not

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[1] As was indicated in Table 2.1, environmental costs are also associated with alternative energy sources. The environmental costs from energy alternatives however, are generally less serious than those associated with conventional energy systems.

wastefully. Daly suggests that in practice, optimising accumulation would be difficult, and that 'satisficing' would probably be attempted instead. The second account, the *Cost Account,* would record the value of all disutilities, such as those derived from pollution, depletion, and the throughput of resources. Economic policies would focus on minimising the values recorded in this second account. The third and final account would be a *Capital Account.* This would be an inventory of the accumulation of stocks and funds and their ownership and distribution. Both natural and human-made capital would be represented in this account, and policies would seek to maximise the accumulation of capital (Daly 1988, pp. 52-53).

As with the ME economic approach, this set of performance indicators would interpret the effect on the Australian economy of a shift toward alternative energy sources as extremely positive. Although the present system would record quite high values in a benefit account, its performance in the cost and capital accounts would be less impressive. High costs would be recorded since current energy systems are highly polluting, and intrusive into ecological systems. The net additions to capital would be extremely low, since additions to capital from extensions to conventional energy networks would be off-set by excessive use of non-renewable energy resources. Alternative energy systems on the other hand, would result in appropriate energy service provision, and so would satisfice benefits. They would reduce costs, since their environmental impacts would be far less serious, less likely to occur, and more able to be mitigated than those associated with conventional systems. Finally, the accumulation of capital would also be improved in relation to conventional systems, since the use of energy alternatives such as solar and wind energies does not result in any loss of natural capital.

Ecological Performance Indicators

Performance indicators endorsed by ecologists differ from economic ones in that ecologists focus almost entirely on 'real' units to the exclusion of economic ones. The next sections sketch out the type of performance indicators that would be recognised by ecologists.

Scientific Ecological Performance Indicators

Scientific ecologists would test an energy system against a set of real indicators to assess the degree to which the system was consistent with the goals of ESD. The central ecological indicator is the extent to which a system operates to maintain safe minimum standards for environmental assets (Foy 1990, p. 775). Ensuring that safe minimum standards are maintained requires avoiding irreversible actions to preserve future options, and acknowledging limits to growth, especially when growth is based on exploitation of non-renewable resources (Goodland & Ledec 1987, pp. 26, 30, 38-39).

Scientific ecological performance indicators would interpret conventional systems as not conducive to achieving the goals of ESD. Fossil fuel use is clearly irreversible and certainly reduces future options. This fact is starkly demonstrated in the case of crude oil. This is a non-renewable fuel whose reserve-production ratios suggest extreme scarcity in Australia. Depletion of oil will restrict future options both in energy and non-energy areas. Petroleum products are valuable not only as fuels, but also as inputs into production of products such as plastics. Whereas alternatives for petroleum products as fuels are plentiful in the provision of many energy services, they are less so for the other uses to which these products are put. Conventional energy systems also fail to acknowledge limits to growth. This is indicated by the propensity of conventional energy planners to construct power stations in anticipation of future supply and to then sell the energy at any price so as to justify expenditures (as was discussed in Chapter Four).

Alternative energy systems would fare better under scrutiny of scientific ecologists than conventional systems. Use of renewable, ambient energy sources such as solar and wind energies does not detract at all from future options, since this energy flows from the sun regardless of whether or not it is used. Alternative energy systems acknowledge limits to growth by directly lining energy provision to energy service requirements and by demonstrating that energy needs are not subject to exponential, or continued growth, but instead are likely to have a definite upper limits (see Diesendorf 1992, pp. 6-7).

Intuitive Ecological Performance Indicators

Intuitive ecologists identify ethical principles, based on social and real units that could indicate the performance of energy systems. These principles focus on ensuring reversibility of actions, comparing alternatives, protecting the vulnerable, maximising sustainable benefits and avoiding harm (Goodin 1983, pp. 6-15). The performance of an energy system would be considered good if these principles were upheld. Instead of measuring the effectiveness with which the principles were being undertaken, intuitive ecologists would assess an energy system's performance on the basis of individual judgements. Intuitive ecologists would be likely to draw similar conclusions about optimal energy systems for Australia than would scientific ecologists.

Comparison of Performance Indicators

The above discussion suggests that the degree to which the *NSESD* is considered successful will largely depend on the performance indicators used to assess it. These in turn will depend on the approach to ESD endorsed by those assessing energy systems. Many of the recommendations in the *NSESD* target alternative energy sources, aiming to increase their use in Australia. The performance indicators endorsed by the *NSESD* would not specifically register a move toward use of alternative energy sources, while FM economic indicators would record such a shift as a net cost to society. In contrast, ME and RE economic, and ecological performance indicators would record a shift to alternatives as a major benefit to society.

The discussion suggests that there are certain advantages associated with physical, economic and social performance indicators. Physical indicators are useful since they can allow comparison of similar entities, such as is recommended in RE economic analysts, and militate against the risk of interpreting real costs as benefits as is done in the FM approach. Economic performance indicators have the advantage that they are flexible enough to be applied to a wide range of issues. Social indicators are valuable since they can indicate how well energy systems fulfil service requirements, and how well they address other social goals such as employment.

Conclusion

The *NSESD* recommends adoption of a number of new indicators to assess the performance of the Australian energy system. These represent a change from the conventional Australian approach, which reflected a key goal of decision makers in the energy sector to minimise conflict deriving from energy. Although the Strategy recommends policies to increase the use of alternative energy sources, it does not recommend adoption of any performance indicators to assess progress toward this goal, or the costs and benefits associated with it. The absence of such indicators could be problematic, since FM economic analysis would be likely to interpret a shift to alternative energy systems as a net cost to society. The environmental benefits of a switch to energy alternatives that are highlighted in performance indicators from other economists and ecologists suggest that such a switch would be beneficial for Australia. It would therefore be logical if the *NSESD* recommended adoption of performance indicators that more adequately reflected these benefits.

CHAPTER 6: RESPONSES TO GLOBAL WARMING

Introduction

Chapter Three described global warming as an environmental impact of energy systems with important international implications. This chapter describes the responses to global warming that are conventionally advocated in Australia, that are recommended as part of the National Greenhouse Response Strategy and that are endorsed by economists and ecologists. It focuses on ways in which policies derived from each set of responses would affect residential energy use in Australia.

Global Warming Benchmarks

The global warming issue has received much international scientific and political attention. One international body (the Inter-Governmental Panel on Climate Change), and three multilateral initiatives (the Montreal Protocol on substances that Deplete the Ozone layer, the Toronto Target and the United Nations Framework Convention on Climate Change) focus on the causes and likely consequences of, and appropriate responses to global warming at an international level. This section sketches out global warming benchmarks derived from scientific assessments and international agreements. Australian responses to global warming will be measured against these benchmarks in the remainder of the chapter.

As was stated in Chapter Three, there is continuing uncertainty within the scientific community about the likely consequences of rising concentrations of atmospheric greenhouse gases (GHGs). The worst case scenario for global warming involves a runaway greenhouse effect where positive feedbacks are initiated between atmospheric GHG concentrations and temperature increases. One example of a chain of events that could lead to a runaway greenhouse effect is that rising temperatures in the arctic oceans could melt the huge expanses of permanently frozen peat, releasing CO_2. This would stimulate a positive feedback cycle in which increasing global warming would lead to increasing concentrations of atmospheric GHGs, which in turn would increase global warming. If this occurred, the temperature regime on Earth could eventually rise to a range similar to that of Venus: far too hot to support any life (Gribbin 1991, pp. 230-232). While the atmospheric concentration of GHGs needed to initiate a runaway greenhouse effect is not known, it is certain that no adaptive measures would be sufficient to ensure human survival in this event. If a runaway greenhouse effect does not occur, it is most likely that the degree and rate of global warming will be positively related to anthropogenic GHG emissions. If this is the case, then global warming can be mitigated by action to control emissions. Higher emission reductions in the present are likely to reduce global warming in the future relative to a 'business as usual scenario' (Shine et. al. 1991, pp. 41-68). The most optimistic scenario is that increased concentrations of GHGs will not bring about global warming, and therefore that no action to reduce GHG emissions is necessary (see Moran, Chisholm & Porter 1991, pp. 246-249). This high degree of uncertainty about the effects of increasing atmospheric GHG concentrations means that the trade-off between emission reductions, and future benefits is indeterminate. Given these difficulties, policy formulation in response to global warming will be based on a range of factors, including scientific, economic, and political considerations.

The IPPC was established in 1988 to assess the scientific information on global warming and formulate realistic response strategies for managing climate change (IPCC 1991, p. i). On the basis of its scientific research, the IPCC has calculated with confidence that CO_2 has been responsible for over half of global warming in the past, and that it is likely to remain responsible for this proportion of warming in the future. Present emissions of long-lived gases will result in increased atmospheric GHG concentrations for several centuries, and immediate reductions of 60 to 80 per cent of emissions of the long-lived gases (such as CO_2) is necessary to stabilise their concentrations at today's levels (IPCC 1990, p. xi).

The Montreal Protocol on Substances that Deplete the Ozone Layer was adopted in September 1987. It specifies measures to be taken by countries that had ratified the earlier Vienna convention for the Protection of the Ozone Layer, in carrying out their obligations to reduce use of ozone depleting substances under that agreement. This is an important global warming benchmark since ozone depleting substances are also powerful greenhouse gases, and thus their reduction will reduce anthropogenic contributions to global warming. That the Protocol will reduce anthropogenic contributions to global warming as well as reducing ozone depletion is largely an unintended side-effect of the agreement (Rummel-Bulska & Osafo 1991, pp. 309-323).

The Toronto target was set at a conference in Toronto on "The Changing Atmosphere: Implications for Global Security" in 1988. The conference called for countries to "reduce CO_2 emissions by approximately 20 per cent of 1988 levels by the year 2000" ("The Changing Atmosphere: Implications for Global Security" 1988, p. 5). The level of reductions specified in the target were arbitrary, rather than being derived from scientific assessment of global warming, and their usefulness as a target has been questioned on this basis (see NGSC 1992, p. 83).

The United Nations Framework Convention on Climate Change aims to stabilise "greenhouse gas concentrations in the atmosphere at a level that would prevent serious anthropogenic interference with the climate system" (United Nations Framework Convention on Climate Change 1992, Article 2). The convention must be ratified by fifty countries before it comes into effect. The Commitments contained in the convention are stated in the form of legally binding obligations, and include preparation of inventories of greenhouse gas emissions, cooperation on technology related to greenhouse gas sinks and sources, sustainable management of greenhouse gas sinks and reservoirs, integration of climate change policies with other policies, research to reduce uncertainties about global warming, exchange of information, education, training and public awareness raising, and communication of information on implementation (IEA 1992, p. 12). The convention has not set concrete targets with timetables for greenhouse gas emissions stabilisation, but developed countries that signed the Convention "have agreed in essence to adopt national policies and take measures consistent with the objective of returning their anthropogenic emissions of CO_2 and other greenhouse gases to 1990 levels by the end of this decade" (IEA 1992, pp. 13-14).

Conventional Australian Responses to Global Warming

The suppliers of Australia's residential energy have responded in various ways to global warming. The variation can be explained in terms of the implications that global warming responses hold for different industries. Those industries that are likely to feel significant negative effects have been less active in responding to global warming, and those that could benefit have been more active.

Since coal is the highest contributor to global warming of all fossil fuels, the demand for coal, and electricity produced in coal-fired power stations is likely to decrease as a result of policies to reduce CO_2 emissions. The 1992 *Coal Industry Policy Statement* includes a section on 'climate change'. The discussion emphasises the economic losses that would be imposed on the coal industry from Australia's response to global warming while never mentioning the environmental benefits that would also result (Crean & Cook 1992, p. 29). Another body with vested interests in coal production, the World Coal Institute is similarly unenthusiastic about reducing CO_2 emissions from coal combustion. It argues that coal combustion is a minor contributor to global warming, which in any case is an unproven scientific theory with uncertain effects (World Coal Institute 1991, pp. 9-13). Neither body endorses any actions to reduce coal combustion in response to global warming.

At the other end of the spectrum for fossil fuels, the natural gas industry stands to benefit from responses to global warming since natural gas has the lowest level of greenhouse gas (GHG) emissions of any fossil fuel. Gas suppliers have responded pro-actively to global warming, for example by investigating and endorsing options such as increased use of natural gas in electricity generation. Energy efficiency and demand management strategies undertaken by some Australian electricity utilities (that were mentioned in Chapter Three) represent a response to global warming as well as a move toward economic efficiency (DPIE 1991, p. 4, IC 1991:a Vol. I, pp. 8-9, 12-13, 19-20).

Since the Australian fuelwood industry is decentralised and poorly coordinated, the industry itself has produced no response to global warming. Work in progress by this author suggests that strategies to reduce GHG emissions could lead to an increase in fuelwood use in Australia[1]. This is because no strategies to reduce GHG emissions have targeted fuelwood consumption, and since proposed policies to reduce emissions may increase the attractiveness of wood in relation to other fuels. In particular, wood is likely to be less expensive, and therefore more attractive than electricity produced in coal-fired power stations for residential space heating. Substitution of wood for electricity in space heating appears justifiable in terms of CO_2 emissions since under existing conditions, "the net CO_2 release from fuelwood is an order of magnitude less than doing the same tasks with fossil fuels" (FTS & UT 1989, p. 179) and (as was stated above) combustion of renewably grown wood results in no net emissions of CO_2. Fuel merchants could therefore be expected to support policies to reduce CO_2 emissions.

Three types of responses to global warming have been put forward by producers and proponents of alternative energy sources[2]. Firstly, they have emphasised the lower CO_2 emissions associated with alternative, rather than conventional energy systems. Secondly, they have demonstrated the potential for many alternative energy sources to compete economically with fossil fuels in Australian energy

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[1] Work is in progress on a paper entitled "The Effect on Australian Forests of Policies to Reduce Greenhouse Gas Emissions: A Neglected Issue".

[2] As noted in Chapter Three, 'alternative' energy sources include solar and wind energy, and systems that significantly improve energy efficiency or energy storage.

provision (see for example Taylor 1991; Lowe, Backhouse & Sheumack 1984; Diesendorf 1991; Saddler 1990). Thirdly, they have stressed the imperfection of energy markets, and in particular the inherent, and contextual constraints on commercialisation of alternative energy systems that were described in Chapter Three.

The overall response to global warming from major players in the Australian residential energy industry has been limited. The natural gas industry, the electricity industry, and alternative energy industries have each endorsed some strategies, and taken action that simultaneously entail economic benefits and reduce Australia's CO_2 emissions. No industry appears to have undertaken any responses beyond these 'no regrets' measures.

Australia's National Greenhouse Response Strategy

The Australian *National Greenhouse Response Strategy (NGRS),* is linked to, but separate from the *NSESD*. Its origins are with the United Nations Framework Convention on Climate Change, which Australia has ratified. In October 1990, Australian Federal, State and Local Governments agreed to jointly develop a national greenhouse response strategy. During the initial step of the Strategy's development, the heads of each of the ESD Working Groups reported on costs, benefits and options for reducing GHG emissions. Following those reports, the NGSC developed the *NGRS* which they describe as "an important plank of the national commitment to ecologically sustainable development" (NGSC 1992, p. 5). The *NGRS* and the *NSESD* together identify ways in which Australian energy systems could be altered to reduce GHG emissions. Recommendations pertaining to this discussion include those focusing on energy supply, household energy use, and the natural environment (NGSC 1992, Parts 3.1, 3.2, 3.7; ESDSC 1992:b, Objective 8.1).

The objective of energy supply policies recommended in the *NGRS* is to

> "limit greenhouse gas emissions arising from energy production and distribution wherever economically efficient by minimising greenhouse gas emissions per unit of each type of energy supplied to end users, and by promoting alternative energy sources that have the potential to lower greenhouse gas emissions per unit of energy supplied" (NGSC 1992, p. 16).

The strategies and response actions arising from this objective focus firstly on strategies to increase competitiveness of existing energy systems by promoting thirdparty electricity generation and free and fair trade in natural gas. A second strategy requires energy agencies to develop an integrated least-cost approach to energy system planning (discussed in Chapter Four of this dissertation). A third strategy requires that public energy utilities move toward achieving commercial rates of return. To these ends, "issues affecting the incorporation of externalities in the energy sector to better understand the full cost of energy service provision" will be investigated and "a methodology for the identification and costing of subsidies, cross-subsidies and community service obligations" will be developed (NGSC 1992, p. 18). It should be noted that although the *NGRS* thus commits Australia to investigate the merits of a carbon tax and tradeable emission permits, the Australian Government has stated that it is not considering a carbon tax (ESDSC 1992:b, section 3, p. 19). Fourthly, energy sources will be diversified to include co-generation, increased use of natural gas, and expanded use of renewable energy sources in electricity generation in remote and rural areas.

Two objectives for household energy use are identified in the *NGRS*. These are to "improve energy efficiency of residential buildings and domestic appliances" and to "influence householders to become more economical in their use of energy, and to switch to energy sources with lower greenhouse gas emissions" (NGSC 1992, p. 20). Educational, regulatory and economic strategies are recommended for achieving these objectives. Educational strategies include improving access to information to householders about energy use. Regulatory strategies include development and implementation of national schemes for mandatory energy labelling and energy performance standards for major household appliances. Economic strategies will require public utilities to price energy so as to influence the behaviour of householders (NGSC 1992, pp. 20-21). A study "to determine the most effective way of achieving improvements in energy efficiency in existing dwellings and of complementing initiatives being taken in the new housing market" is also recommended (NGSC 1992, p. 22).

Objectives regarding natural environments aim to conserve and enhance the sink capacity of Australia's natural environment and minimise greenhouse gas emissions from the natural environment caused by human activities. Strategies involved in meeting these objectives focus on developing an understanding of natural greenhouse sinks and reservoirs, adopting land use and management measures to conserve sinks, increasing the amount of vegetation in forests or elsewhere, maintaining soil quality, and promoting efficiency of conversion of harvested timber by recycling and greater use of wood products in preference to higher energy alternatives (NGSC 1992, p. 32). As with household energy use, education, regulation and economic tools are to be used in achieving these strategies.

In summary, *NGRS* objectives for altering energy systems to reduce atmospheric GHGs focus on increasing economic efficiency and competition in energy supply industry, removing barriers to natural gas and renewable energy use, and enhancing Australia's GHG sink capacity. Economic, educational and regulatory measures are recommended for achieving these objectives.

Economic Responses to Global Warming

Free market, mainstream and radical environmental economists all accept certain scientific facts about the greenhouse effect. They acknowledge that GHGs are present in the Earth's upper atmosphere, that these modify the temperature of the Earth, making it hospitable for human life, and that human activities over the last 200 years have raised the concentration of atmospheric GHGs. As well, each group of economists considered in this chapter interpret global warming as a result of market failure. Since the atmosphere is a public good, its users do not pay for the services they derive from it. This leads to over-use of the atmosphere as a sink for CO_2 emitted during combustion of wood and fossil fuels. Consensus among different groups of economists ends at this point. They each place different emphasis on the interpretation of data on climate change, the economic, social and ecological implications of climate change, and the appropriate policy responses to the phenomenon.

Free Market Response to Global Warming

Free market economists tend to favour adaptive, rather than pre-emptive policy responses to global warming. They emphasise that, although there is a theoretical basis for expecting global warming to result from increased GHG concentrations, observed temperatures on land and in oceans do not confirm the predicted relationship (Moran, Chisholm & Porter 1991, pp. 242-249). Furthermore, they argue that even if global warming does result from GHG emissions, its predicted effects are predominantly beneficial. For example, since temperature rises are likely to be higher near the poles and lower near the equator, the effect will be to increase comfort in the coldest climates without decreasing it in hot areas. Precipitation is also expected to increase in countries such as Australia, India and North Africa which currently have extremely dry climates (Moran, Chisholm & Porter 1991, pp. 249-251)[3].

FM economists also argue that policies to decrease CO_2 emissions, and thus mitigate its possible future costs will be more expensive than adaptive measures undertaken when necessary in the future (see "Energy and the Environment 1991, p. 26; Moran, Chisholm & Porter 1991, Ch. 10; "Environmentalism Runs Riot" 1992, p. 11). To emphasise this point, Moran, Chisholm and Porter propose, by analogy that an occasional band-aid and runny nose may be preferable to perpetual hospitalisation of the healthy (1991, p. 252).

Some FM economists argue that even 'no regrets' policies, that by definition involve no net costs to society but may result in some benefits, are not worth pursuing since difficulties associated with predicting their effects mean that there are no compelling reasons to adopt them (see Moran, Chisholm & Porter 1991, p. 254). Other FM economists endorse 'no regrets' strategies such as the removal of barriers to energy conservation and fuel-switching to low GHG emitting energy sources. For example, the authors of a recent 'survey' in *the Economist* endorse fiscal reforms to encourage use of natural gas and oil by removing hidden subsidies for coal use ("Energy and the Environment" 1991, p. 26).

In the Australian context, an FM economic greenhouse response strategy would promote economic efficiency in the energy sector. It would specifically seek to reduce GHG emissions to the extent that this also promotes economic development. The recent Industry Commission study on *Energy Generation and Distribution* (IC 1991:a, Vols. I, II, III) which "identifies policies that will promote efficiency and ensure that the electricity and gas supply industries in Australia perform to their full potential" provides an example of a greenhouse response strategy that would find favour with FM economists. The study recommends promotion of competition in energy supply industries, corporatisation of public utilities, regulatory changes to increase private sector representation in energy markets, and that energy conservation strategies should be undertaken by public utilities only when "they

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[3]Note that what is omitted from this argument is a recognition that overall increases in precipitation will not necessarily be positive. As was stated in Chapter Three, these countries may experience higher annual rainfall, but also increases in extreme events such as floods and droughts. Soil moisture - the driving force behind agricultural productivity - is likely to be lower overall in these countries than prior to the enhanced greenhouse effect. See Lins, Shiklomanov & Stakhiv 1991, especially pp. 92-93, and Sinha 1991, especially p. 102-103 for further discussion of these issues.

enhance utility revenues or reduce revenues to a larger extent than they reduce supply costs" (IC 1991:a, Vol. II, p. 203). The IC does not recommend "provision of energy information to consumers, labelling of appliances, energy rating of buildings or imposition of minimum energy efficiency standards ... [due] to the difficulty of taking into account the indirect costs of these initiatives" (IC 1991:a, Vol. II, p. 204).

Mainstream Environmental Economic Response to Global Warming

ME economists recognise that there are costs associated both with reducing GHG emissions, and with militating against the consequences of global warming. They argue that these costs are inversely related, since limited current reductions will lead to higher future mitigation costs and higher current reductions will reduce future costs. The global warming response strategies recommended by ME economists propose to augment economic systems so that both sets of costs, not just those associated with reducing emissions, are recognised. An ideal strategy would minimise the net costs of reducing emissions and mitigating the effects of climate change (see Pearce & Turner 1990, Chs. 6-8; Barrett 1991, pp. 31-35). ME economists recommend worldwide application of either a carbon tax, or tradeable emission permits to reduce CO_2 emissions while encouraging economic development.

A carbon tax is a charge on use of the atmosphere as a dump for GHG emissions. The level of tax charged would reflect the damages imposed on others by a tax-payer's CO_2 emissions (Barrett 1991). Tradeable permits would entitle their owners to emit CO_2 up to, but not beyond a specified limit. Following their initial allocation, these permits could be traded within and between countries depending on each country's willingness and ability to pay for emission rights (Markandya 1991). Although a carbon tax and a tradeable permit system would operate quite differently, they address the same goals. Both strategies (if successful) would reduce CO_2 emissions either by i) changing demand patterns and technology towards less use of energy; or ii) changing the mix of fuels so that those with low emissions per unit of energy were preferable to those with high emissions (Hoeller & Wallin 1991, p. 9).

It is beyond the scope of this study to predict the exact impacts of ME economic strategies to reduce Australian CO_2 emissions. It is possible however to suggest likely trends in residential energy use. Chapter Three stated that 80 per cent of Australia's electricity is produced in coal-fired power stations. A uniform carbon tax, projected to reduce total world CO_2 emissions by 12.7 per cent of their expected levels under 'business as usual' conditions in 2005, would raise the price of electricity produced in these power stations by about 55 per cent. A uniform carbon tax to reduce emissions by 20 per cent would raise prices by around 130 per cent per unit of electricity (see Appendix Five)[4].

According to economic theory, a carbon tax such as that described above would increase the costs of energy (especially electricity produced by coal combustion), relative to the costs of other goods and services used in the residential sector. In the short term, this would have little impact on total energy demand, since initially, consumers would have little choice but to use their existing energy hardware as they did prior to imposition of the tax. In the long term, high energy prices would influence energy users to demand efficient energy hardware, and this would encourage suppliers of energy hardware to improve the efficiency of their products. These measures would result in energy conservation and a switch to environmentally benign energy sources (see Tisdell 1982, pp. 55-60).

Radical Environmental Economic Response to Global Warming

Two central aspects of radical environmental economic responses to global warming are their focus on the historical responsibility for, and support for equity in contributions to global warming. An RE economic response to global warming in Australia would involve significantly greater reductions to CO_2 emissions than either FM or ME economists recommend.

One concern expressed by researchers on global warming, is that the contributions from underdeveloped countries to global warming are likely to increase substantially in the future. This will be due to population growth, urbanisation and industrialisation in those regions (see for example Norse 1991, pp. 363-365, Ripert 1991, p. 145). RE economists argue that this emphasis on probable future CO_2 emissions allows decision makers in developed countries to avoid responsibility for their countries' past contributions to global warming (Krause, Bach & Kooney 1990, p. I.5-2 quoted in McCully 1991, p. 163). It also distracts attention from the colonial and neo-colonial influence of developed countries in the economic activities of underdeveloped countries. This influence is often a driving force behind ecological damage in underdeveloped countries[5].

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[4] These estimated values for a carbon tax are based on certain assumptions about elasticities of demand for energy. See Appendix Five for a discussion of these assumptions.

[5] For detailed discussions on the influence of developed countries in economic activities of underdeveloped countries see Trainer 1989, George 1988, Caufield 1985, Frank 1975.

The 1988 climate change conference in Toronto suggested that countries should aim at a 20 per cent reduction of CO_2 emissions from their 1988 levels by the year 2005, and a reduction of 50 per cent in the long run (Hoeller 1991, p. 8). An RE economic critique of the target states that its apportioning of GHG emissions among countries on the basis of how much each polluted in 1988 is inequitable. This is because per capita emissions from developed countries are far higher than those for underdeveloped countries (as was shown in Figure 3.8). The ability of residents in underdeveloped countries to improve their standards of living would be diminished if they were required to reduce already minimal emissions of GHGs[6]. An alternative global warming response strategy based on per capita emissions would not similarly discriminate in favour of developed counties (McCully 1991, p. 160). Both the historical responsibility and equity in CO_2 emissions endorsed by RE economists seem particularly appropriate when the projected effects of global warming are considered. As was stated in Chapter Three, underdeveloped countries are expected to experience more extreme, and more socially and environmentally damaging impacts of climate change than are developed countries.

The reduction in Australian CO_2 emissions recommended by RE economists in response to global warming can be quite easily calculated. Australia supports 0.3 per cent of the world's population (ABS 1991, p. 123; UN 1992, p. 141). It would therefore be equitable and responsible for Australia to emit 0.3 per cent of total global GHGs. Immediate reductions of 60 per cent of global anthropogenic CO_2 emissions are necessary to stabilise GHGs in the long term (IPCC 1990, p. 5)[7]. To

[6]This is not equivalent to recognising a direct relationship between economic development and energy use. Energy use is essential for human survival. In many developing countries, most individuals use extra-somatic energy only for cooking. Increases to the efficiency of stoves and other energy hardware in developing countries could decrease energy use without resulting in a reduction in quality of life (see Harrison 1983, pp. 143-146). But to limit developing countries' total energy consumption to below their current levels would remove many opportunities for residents to improve their livelihood. This is especially the case when population growth increases the number of individuals requiring energy services.

[7] The difference between the 20 per cent greenhouse gas reductions recommended in the Toronto target, and the 60 per cent reductions of CO_2 emissions recommended by the IPCC is explained by the different atmospheric lifetimes of greenhouse gases, their absorption characteristics, and the different criteria used to set the targets. CO_2 remains in the atmosphere for up to 200 years; longer than any other greenhouse gas . This means that reductions to CO_2 emissions will reduce atmospheric concentrations of CO_2 only after a substantial time lapse. Absorption characteristics determine the radiative forcing potential of greenhouse gases. While CO_2 has less radiative forcing potential than

stabilise GHGs, and to ensure equity between the developed and underdeveloped countries it is necessary for Australia to immediately reduce its CO_2 emissions to nine per cent of their 1990 levels. A sense of the implications of such significant CO_2 reductions can be gained by estimating energy price rises required if economic tools were employed to induce changes. If an economic tool such as a carbon tax was applied to OECD countries (rather than underdeveloped countries) to achieve only a twenty per cent reduction it would raise the price of electricity produced in coal-fired power stations by around 932 per cent (see Appendix Six)[8].

Ecological Responses to Global Warming

Both scientific and intuitive ecologists have produced detailed interpretations of the causes of global warming, and its relevance for human populations. For both scientific and intuitive ecologists, global warming is the result of humans maintaining unnatural lifestyles and failing to respond to ecological signals warning of associated dangers. Both groups of ecologists emphasise that global warming is likely to create greater stresses for ecosystems than those experienced during the geological time period in which modern life forms evolved. Intuitive and scientific ecologists agree that climate change beyond the limits set by these 'natural' bounds will threaten the integrity of modern ecosystems. The exact nature of the changes cannot be predicted, and neither can the success of strategies for mitigating environmental problems derived from climate change. Both groups of ecologists endorse policies to minimise, and to slow the rate of global warming. The fundamental difference between different ecologists' interpretations of global

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some of the other greenhouse gases, this characteristic, combined with its atmospheric concentration mean that CO_2 is likely to be responsible for 65 per cent of future global warming (Siegenthaler & Sanhueza 1991, pp. 48-56). Because of CO_2's atmospheric lifetime and absorption characteristics, a reduction of, say, 20 per cent of the atmospheric concentration of greenhouse gases requires a larger than 20 per cent reduction in CO_2 emissions. The Toronto target of 20 per cent reductions was informed by scientific data, but set by international agreement. In contrast, the IPCC figure of more than 60 per cent reductions of CO_2 emissions reflects a scientific assessment that has not been politically endorsed. A reduction goal as high as that stated by the IPCC would probably receive less international support than the lower Toronto target figure was able to. The 60 per cent figure for CO_2 reductions is used in the calculation above because it relates specifically to carbon, and because the discussion is on the ideal RE economic response and not one that has been influenced by a political process.

[8]The assumptions about price elasticity that were described in Appendix Five also apply to this estimate.

warming is their justification for global warming response strategies. For scientific ecologists, global warming should be slowed because it threatens human societies. For intuitive ecologists, global warming is unethical because it threatens Gaia's survival.

Scientific Ecological Responses to Global Warming

For scientific ecologists, the major direct threat from global warming is its potential to cause irreversible damage to world ecosystems on which humans ultimately depend. While scientific ecologists are not opposed to economic responses to global warming, they consider that these would not be sufficient to solve ecological problems caused by global warming.

In scientific ecological terms, anthropogenic CO_2 creates a stress whose likely impacts include minor direct and beneficial effects on some plant systems and significant indirect and detrimental effects on other plant and animal systems. The direct effect of anthropogenic CO_2 will be to stimulate photosynthesis by CO_2 fertilisation. This would increase plant productivity as long as shortages of other important nutrients or water were not limiting (Freedman 1989, pp. 43-52). Indirect effects of anthropogenic CO_2 emissions include global warming, and a range of associated changes to climatic systems. In turn, these changes will cause a "fundamental restructuring of the vegetation mosaic on the landscape" (Freedman 1989, p. 50).

Two examples of issues of particular concern for human societies are that habitats of rare and endangered species will be threatened, and the ability of many areas of agricultural land to support crops will be reduced due to increases in extreme events (Freedman 1989, p. 50). These impacts are undesirable since the former will lead to losses of biodiversity and species richness. Effects of this include reductions in ecosystem resilience, and loss of option values associated with unexploited natural resources (Ehrlich & Ehrlich 1981). The latter will directly limit human food production, and thus directly threaten human survival.

Scientific ecologists would support economic measures to reduce CO_2 emissions, but would argue that alone, these measures are too simplistic to deal effectively with a complex ecological problem such as global warming. For example (as was stated above), environmental economists have suggested carbon taxes as a means to reduce CO_2 emissions. Ecologists may question whether these taxes would be applied only to old time, or to real time CO_2 emissions as well. If they are applied only to old time CO_2 emissions, then their effect in Australia may be to provide an incentive for increased use of fuelwood, and increasing deforestation since other fuel sources would become more expensive in relation to wood[9]. Alternatively, if carbon taxes were applied to real time CO_2, the decentralised structure of, and lack of government control of the Australian wood industry (described in Chapter 3) could create a black market for fuelwood, again with increasing deforestation. Clearly, these unintended consequences of an Australian carbon tax warrant investigation, and may make such a tax unacceptable.

Dryzek's formulation of characteristics of ecologically rational social systems (discussed in Chapter Four) is once again useful here. A society using social choice mechanisms involving negative feedback, coordination, robustness or flexibility, and resilience would be likely to develop effective responses to global warming (see Dryzek 1987, pp. 46-54). Problems such as increasing deforestation in response to application of a carbon tax would automatically be recognised and responded to in such a system. Unfortunately, since the exact nature of such a system, or ways of moving to such a system from existing social systems are not explained by scientific ecologists.

Intuitive Ecological Responses to Global Warming

Intuitive ecologists focus on effects on natural ecosystems of human activities such as GHG emission. They argue that destruction of natural ecosystems is unethical since non-human entities are inherently valuable (see Goodin 1992, Ch. 2). Thus human activities that could stimulate global warming, and thereby harm ecosystems are not acceptable to intuitive ecologists. Intuitive ecologists tend to favour responses to global warming that minimise the risk of ecologically damaging global warming.

Intuitive ecologists would view the phenomenon of global warming as resulting from the internal relatedness of all organisms (Eckersley 1992, p. 49). Some of the ways in which natural, dynamic relationships between organisms serve to stabilise the natural greenhouse effect are as follows. Liquid water on the surface of the earth evaporates and dissolves CO_2 to form carbonic acid, thus removing CO_2 from the atmosphere and reducing global warming. Carbonic acid deposited on the surface of the earth as rain dissolves calcium, silicon and oxygen rich rocks. This releases calcium and bicarbonate which living organisms such as planktons use to build their

[9] Increased deforestation may not result if all environmental costs of energy were incorporated into energy prices since the costs of deforestation would also be included in the price of fuelwood. A tax on carbon emissions alone however would not provide a disincentive for deforestation.

shells. Shells collect on the sea floor, are shifted by the action of plate tectonics, and eventually expelled into the atmosphere by volcanic activity. This system regulates temperatures by negative feedback mechanisms. If the Earth cools, less water evaporates, and less CO_2 is removed from the atmosphere. Volcanic activity continues to increase atmospheric CO_2 concentrations, causing global warming, and increased evaporation of water vapour. This dissolves CO_2 and the cycle is repeated (Gribbin 1990, pp. 35-37). Other, related carbon cycles involving organisms such as photosynthesising plants and bacteria operate together with this macro carbon cycle to maintain nearly constant temperatures by negative feedback (Gribbin 1990, pp. 40-46). Modern human activities are dangerous because they supply large and increasing quantities of CO_2, methane and other effective GHGs to an already warm inter-glacial atmosphere.

Intuitive ecologists predict only two possible scenarios if human activities continue to disrupt these important processes. The first is that global temperatures will rise beyond a point where human societies can be maintained, and that life forms such as bacteria, that are able adapt quickly to, and also moderate climate change will survive, and perhaps eventually lower temperatures in the long run (Lovelock 1988, pp. 225-237). The second is that human activities may initiate a runaway greenhouse effect, eventually leaving Earth with a climate similar to that of Venus, far too hot to support any life (Gribbin 1991, pp. 230-232). Both scenarios culminate (for people) in the extinction of the human species as a direct result of human activities (see Bunyard 1988, p. 206).

Intuitive ecologists argue that to avoid extinction as a result of global warming, humans must abandon economic development as a policy goal, and wherever possible reconstitute the natural world (Goldsmith 1989, p. 75). For Australian residential energy suppliers and users this would mean disposing of economic indicators as determinants of energy choices, and stopping all fossil fuel combustion. Acceptable energy sources would include human muscle power, the sun and wind. Hydrological energy would be acceptable if harnessed from ecologically benign systems, and fuel wood would be acceptable from biomass was grown from seedlings for energy purposes and replaced after harvest. Along with changes to energy systems, intuitive ecologists recommend population reduction, alternative agricultural practices, and other measures to elicit harmony between humans and their natural environments (see Bunyard 1988 p. 206, Lovelock 1988, pp. 225-237, Naess 1988, pp. 130-131). Intuitive ecological discourse suggests that these substantial changes to Australian energy and social systems would emerge fairly naturally if energy systems were organised in ways suggested in Chapter Four's discussion on intuitive ecological energy system planning.

Comparison of Responses

In comparing Australia's *NGRS* to responses endorsed by proponents of conventional Australian, economic and ecological approaches to this issue, it is worth distinguishing between greenhouse response actions that the National Strategy *commits* Australia to, actions that are recommended for *investigation,* and actions that are not considered at all. The first category includes mandatory energy labelling, minimum efficiency standards for appliances, and development of a least-cost approach to Australian energy system planning (discussed in Chapter Four of this dissertation). In the second category are strategies to increase the efficiency of existing and future dwellings, inclusion of environmental costs into energy prices. In the third category are measures to phase out fossil fuel use (as recommended by ecologists), and measures to encourage global equity in responses to global warming (as recommended by RE economists).

FM economists would not favour any of the measures set out in the *NGRS,* since the benefits of each would be unsupported by FM analysis of global warming issues. The *NGRS's* commitment to apply mandatory energy labelling and efficiency standards is an example of their willingness to adopt measures that are contradictory to those advocated by FM economists. Energy labelling and efficiency standards would be consistent with scientific ecological recommendations to increase co-ordination in social choice. This is because these measures would provide a link between energy hardware producers and users that currently does not exist. The measures would not be sufficient however to create an ecologically rational energy system since negative feedback, robustness or flexibility, and resilience would still not be assured. Energy labelling and efficiency measures would also be consistent with ME economic recommendations. Such measures would aid replacement of inefficient appliances with efficient ones. However, ME economists would doubt whether such measures would be sufficient to reduce CO_2 emissions, unless applied in conjunction with a carbon tax. The carbon tax would provide the incentive for energy users to utilise the energy rating system while purchasing energy hardware.

Strategies in the second category - measures to be investigated - would find more favour with ME economists and scientific ecologists than with RE economists or intuitive ecologists. If measures to increase energy efficiency of buildings, and include environmental costs in energy prices were applied simultaneously with mandatory energy labelling and minimum efficiency standards it could increase the effectiveness of each measure relative to how each would operate in isolation. Scientific ecologists would support this suite of measures since the mix of market, legal and persuasive mechanisms could increase the negative feedback and coordination (see Dryzek 1987, Chs. 7, 10, 11). One example of how this could work is that rising electricity prices due to incorporation of environmental costs, coupled with increased building efficiency would reduce the risk that energy users would switch from electricity to fuelwood for residential space heating since the latter measure would reduce the need for space heating. Once again, the measures would be insufficient to ensure ecological rationality since this would also require robustness or flexibility and resilience. ME economists too would favour the simultaneous introduction of all four measures since this would provide energy users with a stimulus to reduce energy use, as well as information on how to achieve it. ME economists' central concern regarding the measures would be to monitor the degree of emission reductions relative to benchmarks such as the Toronto target.

RE economists would argue that the *NGRS* totally fails to acknowledge Australia's inequitable share of global CO_2 emissions. The emission reductions that would be achieved, even if both categories of measures were enacted would fall well short of the 91 per cent reductions necessary to ensure equity, and to keep atmospheric concentrations at their current levels. Intuitive ecologists would also be dissatisfied with the *NGRS* since it would encourage reductions in emissions, but not active replacement of fossil fuels with more ecologically acceptable alternatives. The *NGRS* would also do nothing to promote ecological ethic or recognition of the internal relatedness of human and non-human elements of global ecosystems.

Conclusion

Conventional Australian responses to global warming would be insufficient to achieve the Toronto Target of 20 per cent reductions of GHG emissions by the year 2020. They would certainly fall well short of the IPCC recommendation of immediate 60 to 80 per cent reductions of CO_2 emissions. The interdisciplinary analysis presented in this chapter suggests that while strategies proposed in the *NGRS* would reduce CO_2 emissions relative to their 'business as usual' levels, it would be unlikely to ensure achievement of the Toronto target. The effectiveness of the strategy would be increased if commitments were expanded to encompass measures that at present are only being investigated. Some important issues are completely omitted from the *NGRS*. Among those that have been identified in this economic and ecological analysis are the inequity of Australia's CO_2 emissions in comparison to those of underdeveloped countries, a failure to address the possibility that emission reductions may need to be far greater than the Toronto target to stabilise atmospheric GHGs.

CONCLUSION

Australia's *National Strategy for Ecologically Sustainable Development* represents a limited shift from traditional, to more ecologically responsible development goals. In its analysis of Australian residential energy systems, the Strategy does not address the cognitive dissonance that characterises current ESD debates. Instead, the Strategy's analysis and recommendations largely reflect a free market economic approach to ESD. This 'economically rational' perspective is augmented to a limited extent by some recommendations that mainstream environmental economic analysis be undertaken for certain energy issues. Radical environmental economic, and scientific and intuitive ecological approaches to ESD are not represented in the Strategy. This dissertation has demonstrated the contributions that these neglected disciplinary perspectives could have made to the Strategy's recommendations for least-cost planning, performance indicators and global warming.

Conventional Australian residential energy systems are not ecologically sustainable. The bulk of energy used in residential settings is from fossil fuel sources and is produced, transmitted and distributed by public utilities. These typically subsidise residential energy users, for example by not charging customers for infrastructure provision. By undercharging energy users, these utilities encourage excessive and inefficient energy use. In the residential sector, fuelwood is the most widely utilised potentially renewable energy source. However forest harvest for fuelwood in many parts of Australia is carried out beyond natural replenishment rates and is therefore unsustainable in practice. Small scale energy systems, and ones relying on flow resources such as solar energy are relatively rare, even where they are economically viable compared to conventional power sources. Environmental damage resulting from energy provision is mitigated by some regulations requiring energy producers to minimise environmental damage from energy systems. These traditional patterns of energy production have altered marginally in recent years. Some energy utilities have adopted demand management strategies, and some have set up energy systems that utilise ambient flow energy in electricity generation. Different groups of economists and ecologists have suggested a range of further changes that could be made to existing Australian energy systems to increase their sustainability.

The free market approach to ESD is based on the view that the goals of ESD can best be achieved within a perfectly competitive economic system. Thus free market economists argue that by maximising economic efficiency in its energy industry Australia will achieve sustainability in energy production and use. Energy policies endorsed by free market economists therefore include those 'no regrets' actions that entail no economic costs but are likely to deliver benefits. According to free market economists, residential energy suppliers should operate in competitive and commercial settings. Environmental costs, such as potential damage from global warming should be incorporated into decision making only when the benefits associated with mitigating damage clearly outweigh the associated costs. Free market economic analysis suggests that the effectiveness of Australian residential energy systems should be evaluated on the basis of their contribution to GNP.

Mainstream environmental economists argue that pervasive market failure within competitive economic systems limits their ecological sustainability. They propose a range of measures to augment economic systems in order to internalise environmental costs and ensure that these are recognised in decision making. For instance mainstream environmental economists recommend imposition of either carbon taxes, or tradeable greenhouse gas emission permits to militate against possible future costs of global warming. These measures would include 'no regrets' actions and may move beyond these into 'insurance' options when there is uncertainty about the magnitude of potential environmental damage. Mainstream environmental economic analysis suggests that energy systems should be predominantly commercial, and competitive except when resources are particularly scarce. An augmented version of gross national product that registers environmental damage as a net social cost is recommended by mainstream environmental economists as an indicator of the performance of energy systems.

Radical environmental economists argue that no energy system can be indefinitely sustained since all ultimately depend on energy from the sun, and this will eventually burn out. Radical environmental economic policies for ESD aim to create a social system that will allow humans to survive equitably, up to the time when solar sources of low entropy are no longer available. Radical environmental economists recommend that energy systems should be small scale and decentralised to ensure that they are appropriate for the energy services they address. Proponents of this approach to ESD argue that environmental costs of energy systems should be explicitly recognised in decision making. This could be achieved by replacing gross national product with separate accounts for changes to the real costs, benefits, and accumulated capital of energy systems over time. Strategies recommended by radical environmental economists to address global inequity include limiting total global greenhouse gas emissions to 'natural' levels and allocating emission permits to countries on a per capita basis. This response to global warming would require Australia to immediately reduce its annual CO_2 emissions to around nine per cent of their 1990 levels.

Scientific ecologists' recommendations for ESD in energy focus on maintaining the integrity of ecosystems. Scientific ecologists argue that humans are ultimately dependent on natural ecosystems, and that too little is known about ecosystem functions to risk disturbing natural equilibria unnecessarily. They therefore advocate adoption of a social system that automatically responds to ecological problems by way of negative feedback, coordination, robustness, flexibility and resilience. An energy system would be ecologically rational if it maintained safe minimum standards for environmental assets by avoiding irreversible actions and acknowledging limits to growth. For example, an energy system that risked a possible runaway greenhouse effect would be ecologically irrational.

Proponents of intuitive ecological approaches to ESD claim to be spiritually attuned to ecological systems. They argue that decisions regarding environmental objectives should be based on ecocentric ethical principles such as recognition of intrinsic values of ecosystems. Intuitive ecologists argue that energy services should be achieved at least ecological cost. As a response to global warming, this principle would require an almost complete shift to flow energy sources. Even burning renewably grown biomass for energy would be discouraged since this requires that trees and other living things be killed.

Australia's *National Strategy for Ecologically Sustainable Development* recommends that Australian energy system planners should aim to satisfy energy services on a least-cost basis. It proposes that least-cost planning should occur within a commercial and competitive setting, and that environmental impacts of energy systems should be addressed by way of regulations requiring conservation of important ecological resources. This context for least cost planning closely resembles that recommended in a free market economic approach to ESD in energy. The major difference is that the Strategy recommends that major environmental impacts of energy systems be assessed whereas free market economists would advocate this only if associated economic costs were offset by economic benefits.

A possible problem with least cost planning in a commercial and competitive context is that energy system planners may not be able to effectively target energy services. This is because proposals for increasing competition in the energy industry recommend a separation of energy producers, transmitters and distributors. This separation would reduce contact between energy producers and end users. Without direct contact with energy users, producers would be likely to continue to supply power in highly flexible forms and especially as electricity. Since electricity is a highly inefficient energy source for most residential energy services this would mean that the goal of satisfying energy services at least cost could not be achieved.

The Strategy recommends adoption of a range of physical, social, and monetary indicators for assessing energy system performance in relation to the goals of ESD. It recommends that energy suppliers report regularly on the physical quantity of their greenhouse gas emissions so that reductions to these can be documented and Australia's progress toward emission reduction targets be assessed. It further proposes that changes to employment in the energy industry resulting from implementation of the Strategy be assessed in broad social rather than purely economic terms. The Strategy also recommends that Governments identify appropriate monetary rates of return for public utilities that encourage efficient energy supply. This set of performance indicators recommended in the Strategy differs from those recommended by any of the economic or ecological approaches to ESD described in this dissertation.

The dissertation has suggested a possible shortfall of the Strategy's performance indicators. This is that none of the indicators proposed will register Australia's progress toward adoption of alternative energy systems. It is possible that adoption of energy alternatives will reduce the contributions from the energy sector to gross national product since the benefits from such a change could be registered in these national accounts as additions to the manufacturing sector and the overall contribution from the energy sector could decline. To assess the real social benefits resulting from a switch to energy alternatives it would be necessary to adopt performance indicators that explicitly registered the total impact across the economy of such a switch. Radical environmental economic Cost, Benefit and Capital accounts could be a useful tool for assessing the real effects of a shift to energy alternatives.

The *National Greenhouse Response Strategy* commits Australia to a 20 per cent reduction in greenhouse gas emissions on 1990 levels. The most striking aspect of the Greenhouse Response Strategy explored in this dissertation is the degree to which it fails to address issues of global equity or ecological rationality in its emission reduction targets. The 20 per cent reduction in emissions to which Australia is committed having ratified the United Nations Framework Convention on Climate Change falls well below the 60 to 80 per cent reduction of global CO_2 emissions required to stabilise atmospheric greenhouse gases. In addition, since Australian per capita CO_2 emissions are among the ten highest in the world, even a 20 per cent reduction would maintain global inequities in contributions to global warming. The magnitude of reductions necessary to stabilise atmospheric greenhouse gases, and the inequity of Australia's emissions suggests that a 20 per cent reduction should be considered a bare minimum and that an ultimate objective for emission reductions should be far greater.

The interdisciplinary approach to ESD taken in this dissertation has also suggested a potential problem derived from policy responses to global warming. This is that strategies to reduce CO_2 emissions could result in increased use of fuelwood for space heating in the residential sector, which in turn could lead to forest loss. This is because adoption of measures such as carbon taxes and the removal of hidden subsidies for electricity to reduce CO_2 emissions, would result in a rise in the price of electricity relative to other energy sources. Although fuelwood is a particularly important energy source in the residential sector it is not addressed at all in the energy sections of the Strategy. Its price would not rise following implementation of the Strategy. Because of this, the real price of space heating from fuelwood would decrease relative to that of electric heating, and this could encourage energy users to switch from electric to wood heating. Present rates of fuelwood harvest already exceed natural replenishment rates in many parts of Australia. A net increase in fuelwood use would therefore further increase forest loss. Table I below presents a summary of the dissertation's findings.

It is clear from the table and from the discussion above that a range of possible approaches to ESD exist, and that the consequences of adopting ESD as a policy goal will depend on which approach is taken. It is therefore misleading for decision makers to identify ESD as a policy goal without also specifying the approach they intend to adopt in achieving this goal. The recommendations in Australia's *National Strategy for Ecologically Sustainable Development* propose a significant shift from conventional residential energy systems. The direction of this shift is towards a free market approach to ESD with investigation of some measures from a mainstream environmental economic approach. The strategy makes no use of radical environmental economic, scientific ecological and intuitive ecological analysis of ESD issues. This may well limit the degree to which the Strategy encourages simultaneous achievement of ecological integrity, social equity and economic development.

Table I
Summary of Findings

	Versions of Least-Cost Planning	Performance Indicators	Response to Global Warming
Conventional Australian Approach	•Public control of utilities •Monopolistic industry structure •Private costs accounted for	•No social conflict or dissatisfaction •No shortfall in energy supply •No sudden price rises	•Highly threatened suppliers: no response. •Advantaged suppliers: positive response
NSESD Approach	•Commercialised setting for energy planning •Competitive industry recommended •Investigate social costs	•Report on greenhouse gas emissions • Assess employment in broad terms •Identify appropriate rates of return	•Reduce emissions by 20% 1988 levels by efficiency labelling of appliances, education, removing barriers to natural gas and renewable energy use.
Free Market Economic Approach	•Commercial setting for energy planning •Competitive industry recommended •Account for private costs	•High contributions to GNP and employment from energy sector	•Increase economic efficiency of energy production
Mainstream Environmental Economic Approach	•Commercial setting for energy planning •Competitive or monopolistic setting •Account for social costs	•Indicate physical costs and benefits using monetary measures	•Carbon tax or tradeable emission permits
Radical Environmental Economic Approach	•Non-commercial energy planning. •Encourage small scale •Account for social costs	•Compare qualitatively similar variables through Cost, Benefit and Capital accounts	•Ensure equitable global CO_2 emissions •CO_2 emissions determined by ecological limits (60 to 80% reductions)
Scientific Ecological Approach	•Ecologically rational decision strategy •Should automatically respond to environmental issues by negative feedback, coordination, robustness or flexibility and resilience	•Maintain safe minimum standards by avoiding irreversible actions and acknowledging limit to growth	•Ecologically rational approach •CO_2 emissions to ecologically defined limits (60-80% reductions) •Response strategies must be co-ordinated
Intuitive Ecological Approach	•Supply energy services at least ecological cost	•Use ecocentric ethical principles to assess performance.	•Emissions should be reduced to only real time CO_2.
Comparison	•NSESD = FM with consideration of ME	•NSESD = various approaches	•NSESD = FM with consideration of ME, and scientific ecological approaches.

APPENDIX 1

List of Acronyms and Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
AGPS	Australian Government Publishing Service
AMEC	Australian Minerals and Energy Council
ANZMEC	Australian and New Zealand Minerals and Energy Council
ANZECC	Australian and New Zealand Environment and Conservation Council
BMRGG	Bureau of Mineral Resources, Geology and Geophysics
CBA	Cost-benefit analysis
CFC	Chlorofluorocarbon
CO_2	Carbon Dioxide
CSO	Community Service Obligations
DPIE	Department of Primary Industries and Energy
ECNSW	Electricity Commission of New South Wales
EIA	Environmental Impact Assessment
EPAWA	Environmental Protection Authority: Western Australia
EPWG	Energy Production Working Group
ESD	Ecologically Sustainable Development
ESDSC	Ecologically Sustainable Development Steering Committee
ESDWG	Ecologically Sustainable Development Working Group
ESI	Electricity Supply Industry
EUWG	Energy Use Working Group
FM	Free market
FTS	Forestry Technical Services
GHG	Greenhouse gas
GNP	Gross National Product
IC	Industry Commission
IEA	International Energy Agency
IGAE	Intergovernmental Agreement on the Environment
IPCC	Inter-governmental Panel on Climate Change
IUCN	International Union for Conservation of Nature and Natural Resources
JCB	Joint Coal Board
kWh	Kilo watt hour
LCP	Least-Cost Planning

ME	Mainstream environmental
NGAC	National Greenhouse Advisory Committee
NGI	Natural Gas Industry
NGRS	National Greenhouse Response Strategy
NGSC	National Greenhouse Steering Committee
NIC	Newly industrialised country
NSESD	National Strategy for Ecologically Sustainable Development
NSW	New South Wales
NT	Northern Territory
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of Petroleum Exporting Countries
QCB	Queensland Coal Board
QEC	Queensland Electricity Commission
QLD	Queensland
RD&D	Research, Development and Demonstration
RE	Radical environmental
SA	South Australia
SEQEB	South East Queensland Electricity Board
T	Tonnes
t	Tons
TAS	Tasmania
UN	United Nations
USA	United States of America
UT	University of Tasmania
VIC	Victoria
WA	Western Australia
WCED	World Commission on Environment and Development

APPENDIX 2

Glossary

Anthropogenic: human induced or human caused.

Conversion: the process of transforming one form of energy into another.

Cost-benefit analysis: A means of setting out the economic and social costs and benefits of an investment project and evaluating whether the project should be undertaken (Bullock, Stallybrass & Trombley, p. 184)

Demand: The demand for a particular good or service is total quantity of a product that purchasers of the commodity are willing to purchase at various prices. Demand is generally represented as a downward sloping curve on a graph whose generic 'x' axis is 'price per unit' and whose 'y' axis is 'quantity per unit of time'. This indicates that there is a trade-off between price and quantity, and that purchasers are willing to buy less of a product at higher prices than at lower prices.

Depletable resources: There are two categories of depletable resources. These are renewable-depletable and stock resources. A renewable-depletable resource is one which can be used at a rate that exceeds its capacity for regeneration. For example trees represent a renewable energy resource but can be depleted through harvest beyond the rate of reforestation. A stock resource is one that cannot be regenerated in 'real time'. Such resources include fossil fuels since these are only formed after many millions of years.

Developed countries: Those countries that are variously referred to in other papers as the North, overdeveloped countries and industrialised nations, among other terms.

Elasticity: In economics, the proportional change in one variable in response to a proportional change in another.

Energy hardware: Equipment that utilises energy to produce work.

Energy production: The term energy production is a misnomer since energy can neither be created or destroyed. It is used in this dissertation to avoid confusion, in its generally accepted sense. It thus refers to the release (for example from fossil fuels) or harness (for example from ambient sources such as solar rays) of energy by humans for the purposes of doing work.

Energy system: A set of energy infrastructure. For example one energy system is the coal mines, operation of coal mines, railway lines, power plants, electricity grids, and electric wiring within houses in Queensland. Another is the solar energy, solar cells, batteries and wiring of an isolated house.

Existence value: Value which is unrelated to humans altogether (Pearce & Turner 1990, p130)

Externality: A real cost or benefited which is not paid for within an economic system.

Global warming: The impact of the enhanced greenhouse effect

Greenhouse effect: The term 'greenhouse effect' as used in this dissertation refers to the enhanced greenhouse effect, or global warming that is forecast as a result of human activities such as the burning of fossil fuels. This is distinct from the natural greenhouse effect that keeps the earth at a habitable temperature

Greenhouse gases: Gases that accumulate in the atmosphere and contribute to global warming. They include carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons and water vapour.

Gross national product: An aggregate used to measure the well-being of an economy. It refers to the output produced by the residents of a country in a year (Jackson & McConnell 1985, p. 126)

Joule: (J) A unit of energy. One Joule is the amount of heat required to raise the temperature of water by one degree Celsius.

Kilowatt-hour: (kWh) A unit of power, or the rate of doing things. One kilowatt-hour equals 3,600,000 joules.

Marginal cost: The change in total cost that results from a small change in output.

Marginal revenue: The extra unit of revenue obtained by selling an extra unit of the product.

Natural gas: Fossil fuel occurring in conjunction with petroleum deposits. Includes commercial quality sales gas, ethane, methane and plant and field use of non-commercial quality gas (ABARE 1991, p. ix).

Option value: Value of the option to use a resource which may be used by the valuer, by the valuers descendants, or by others (Pearce & Turner p.131)

Petroleum products: "consist of crude oil and condensate used directly as fuel, liquefied petroleum gas, refined products used as fuels (aviation gasoline, automative gasoline, power kerosene, aviation turbine fuel, lighting kerosene, heating oil, automotive diesel oil, industrial diesel fuel, fuel oil, refinery fuel and naphtha), and refined products used in non-fuel application (solvents, lubricants, bitumen, waxes, petroleum coke for anode production, and specialised feedstocks)" (ABARE 1991, p. ix).

Public good: A good that is not marketable because access to them can not be made dependent on a price payment and because they can be jointly consumed. Individuals benefit from the supply of public goods whether or not they pay for, or contribute to them (Tisdell 1982, p. 420).

Primary fuels: Those forms of energy obtained directly from nature. They include non-renewable fuels such as coal and oil. (ABARE 1991)

Property rights: Ownership, the right to use a resource or extract a payment from others who use it, or restrict usage to it in order to conserve it.

Renewable resources: Resources whose natural replenishment rate is non-negligible. There are two types, renewable-depletable (see depletable resources above) and flow resources. The availability of flow resource is unaffected by their use.

Ring fencing: The process of forming separate accounting entities within the same enterprise to undertake logically separable tasks.

Sink: A biological or other process that removes a greenhouse gas from the atmosphere. For example the absorption of CO_2 by forests.

Supply: The supply for a particular good or service is total quantity of a product that traders of the commodity are willing to sell at various prices. Supply is generally represented as an upward sloping curve on a graph whose generic 'x' axis is 'price per unit' and whose 'y' axis is 'quantity per unit of time'.

This indicates that there is no trade-off between price and quantity, and that traders are willing to supply more of a product at higher prices than at lower prices.

Units: Standard metric prefixes used are as follows:

kilo	(k)	=	10^3 (thousand)
mega	(M)	=	10^6 (million)
giga	(G)	=	10^9 (billion)
tera	(T)	=	10^{12}
peta	(P)	=	10^{15}

Underdeveloped countries: This refers to countries otherwise known as 'the south' or 'the third world'.

APPENDIX 3

Methodologies Used in Australian Fuel-Wood Studies to Estimate Quantities of Final Energy Derived from Wood

The Australian Bureau of Agricultural and Resource Economics Study.

Information on the methodology used to estimate the quantity of fuel wood used in the residential sector in Australia was obtained by personal communication with Shane Bush, March 26th 1993. Bush is the author of ABARE's annual publication *Projections of Energy Demand and Supply.* Regarding the sources of the data for final energy from wood, Bush explained the following:

> i) Little data are available regarding wood as an energy source. Therefore an estimate, based on the best available data was made. The estimates were calculated on the basis of data from two separate sources;
>
> ii) The first data source was wood merchants, who were asked to estimate the average quantity of wood used yearly per wood-burning household;
>
> iii) The second data source was the Australian Bureau of Statistics survey of domestic appliances. This gives a figure of the number of households in each state using particular sorts of appliances, including wood-burning space and water heaters;
>
> iv) The final estimate was obtained by multiplying the household average quantity of wood used for energy, by the number of households using wood-burning appliances. This was done for each state, and then summed for an Australian total;

Bush commented that energy analysts from Victoria have suggested that the data may be an over-estimate. He also stated that different states, and different areas within states use very different quantities of wood for energy purposes. Tasmania has the highest per household fuel-wood consumption, with Victoria, New South Wales and the Australian Capital Territory also showing high usage rates. In New South Wales, wood burning is noticeably higher in areas outside the South-East region where natural gas is available.

Bush was reasonably confident about the accuracy of the estimates.

The Forestry Technical Services Pty. Ltd and University of Tasmania Study.

The study by Forestry Technical Services Pty. Ltd and University of Tasmania also combined several data sources. Firstly, the study involved telephone surveys in Canberra, Hobart, Melbourne, Ballarat and Adelaide in August/September 1988. This provided data on household fuel-wood demand and characteristics of fuel-wood using households. Secondly, the consultants inquired to wood-heater manufacturers in Victoria, New South Wales and South Australia and retailers in Tasmania and Victoria. This provided data on sales trends, effects of regulations and customer attitudes. In addition, the study made use of data from the Australian Bureau of Statistics survey of domestic appliances (also used in the ABARE study), and a study of wood and wood-waste use in domestic appliances conducted by the Department of primary Industries and Energy (Forestry Technical Services Pty. Ltd and University of Tasmania 1989, pp. 29-30).

APPENDIX 4

Methodology used to Estimate Energy Services by Fuel Source.

The table presented in this appendix contains the data that were used in Figure 3.7. The methodology used to derive the data is described below.

Table A1

Energy Sources by Fuel Type

(PJ)	Wood	Pet. Prod.	Nat. Gas	Elect.	Other	Total
Water Heating	(A1) 5.0	(A2) 4.7	(A3) 35.9	(A4) 30.2	(A5) 2.6	(A6) 78.4
Space Heating	(B1) 60.0	(B2) 7.5	(B3) 29.9	(B4) 25.2	(B5) 4.5	(B6)127.1
Space Cooling	(C1) 0.0	(C2) 0.2	(C3) 0.0	(C4) 2.4	(C5) 0.0	(C6) 2.6
Cooking	(D1) 5.6	(D2) 1.4	(D3) 9.0	(D4) 7.6	(D5) 0.0	(D6) 23.6
Refrigeration	(E1) 0.0	(E2) 1.6	(E3) 0.0	(E4) 24.8	(E5) 0.0	(E6) 26.4
Appliances	(F1) 0.0	(F2) 0.7	(F3) 0.0	(F4) 11.4	(F5) 0.0	(F6) 12.1
Lighting	(G1) 0.0	(G2) 0.7	(G3) 0.0	(G4) 10.1	(G5) 0.0	(G6) 10.8
Other	(H1) 0.0	(H2) 1.1	(H3) 0.0	(H4) 16.3	(H5) 0.0	(H6) 17.4
Total	(I1) 70.6	(I2) 17.9	(I3) 74.8	(I4) 128.0	(I5) 7.1	(I6) 298.3

Comparability

The two main data sources (ABARE 1991, p. 60; and Wilkenfeld 1991; pp. 211-244) cite slightly different total energy use in the domestic sector. ABARE 1991 cite a total figure of 298.3 PJ, while Wilkenfeld 1991 cites 294.8. There is no indication as to where the differences may have originated. In the absence of such information, the two data sets were made comparable by scaling up of Wilkenfeld's data, so that the proportions of each fuel are the same, but the totals are equal to those of ABARE 1991.

Column 1: Wood.

Australian fuelwood is used primarily for space heating, and to a lesser extent for water heating and cooking. Todd (1986) provides an estimate of the proportions of wood used in Tasmania for each of these three purposes. In Tasmania in 1986, space heating accounted for 85 per cent, cooking for eight per cent, and water heating for seven per cent of total fuelwood used (Todd, 1986, p. 6). The national fuelwood study by Forestry Technical Services and the University of Tasmania (1989) estimated the number of households in Australia using fuelwood for each of these purposes. In Australia in 1988, 88 per cent of fuelwood used nationally went to space heating, four per cent to cooking, and seven per cent to water heating (Forestry Technical Services and the University of Tasmania 1989, p. 92). The discrepancies between the estimates of quantities of wood burnt in Tasmania and the number of households burning wood in Australia for these energy services are very slight, suggesting that the proportions of fuelwood used for each purpose across Australia are fairly consistent. Column 1 of the table was completed by allocating the total quantity of fuelwood used in Australia to each energy service in the same proportions as was estimated for each service in Tasmania.

Column 2: Petroleum Products.

Petroleum products include power kerosene, lighting kerosene, and heating oil among other fuels. They are used particularly in rural areas as substitutes for electricity and gas where these are not publicly available. It is assumed here that the proportions of petroleum products used for each energy service are the same as the overall proportion used in that service. These proportions were calculated from Wilkenfeld's data.

Rows C, E, F, G: Space Cooling, Refrigeration, Appliances, Lighting.

It is assumed that the remaining provision of energy services of space cooling, refrigeration, appliances and lighting are performed by electricity, since this author is not aware of commonly utilised means for achieving these services using any other listed fuel.

Column 5: Other Energy Sources.

The 'other' energy sources include black coal, briquettes, town gas and solar. The solar energy included in ABARE's data is used for water heating and is allocated to this energy source in the table. All of the remaining fuels are assumed to be used for space heating.

Row H: Other Energy Services.

Since there is no indication of what the 'other' energy services are, they are assumed to be fuelled by electricity, since that is the most flexible energy source.

Cells A3, A4, B3, B4, D3, D4: Natural Gas and Electricity for Water Heating, Space Heating and Cooking.

To complete the final six cells it was assumed that the proportions of natural gas and electricity spent on each service was equivalent to the remaining proportion of those fuels. 74.8 PJ of natural gas and 63 of electricity were still to be allocated to services. Thus 54 per cent of the remaining energy was from natural gas and 45 was from electricity. For each of the energy services, the remaining quantity of energy was split in these proportions between natural gas and electricity.

APPENDIX 5

Calculation of the Effect of a Carbon Tax on the Price of Electricity for Residential Consumers

IEA and OECD studies on the effects of carbon taxes on OECD primary energy consumption and energy related CO_2 emissions concluded that for a tax to be effective in the long term, it would have to be very substantial. According to the IEA, a tax of $130 per ton of carbon emitted would result in a 12.7 per cent reduction of CO_2 emissions, on 2005 business as usual projections. Under this tax, total emissions in 2005 would still be 7 per cent higher than their 1991 emissions levels (IEA 1991:b, quoted in IEA 1991:a, pp. 173-174). According to the OECD, to cut the output of carbon dioxide by 20 per cent between 1990 and 2010 and stabilise it thereafter would require a tax in 2020 of $300 per ton of CO_2 emissions in OECD countries (OECD, June 1991, quoted in "Energy and the Environment" 1991, p. 28).

The relationship between the size of a carbon tax, and the resulting GHG emission reductions will vary between countries depending on each country's price elasticity of demand for carbon-based energy, and a range of other factors. Price elasticity refers to the degree to which changes in price will affect changes in demand for a good or service. In countries where alternative energy systems are readily available, for instance where solar technology is cheap and accessible, the price elasticity will be high, and imposition of large carbon tax will lead to a correspondingly large reduction in CO_2 emissions. In countries where alternatives are not readily available, price elasticities will be low, and a large carbon tax will increase the proportion of incomes spent on energy, without greatly influencing total demand. Price elasticities are always higher in the long term, since high costs of a commodity should stimulate development of cheaper alternatives. Thus in the long term, a carbon tax would reduce CO_2 emissions even in countries with few alternative energy sources. Differing price elasticities for energy between countries would mean that a uniform global carbon tax would result in differing emission reduction levels between countries, especially in the short term. Other factors that will influence the emission reductions associated with a certain level of carbon tax include the slope and position of the demand curve for carbon-based energy and the pre-tax price of energy. Calculations of the degree of reductions that will result from any particular carbon tax (such as those specified above) rely on an assumption that these variables are held constant while the price of carbon emissions alone is altered. This assumption is not upheld in practice (see Tisdell 1982, pp. 54-61). With this many variables involved, it is highly unlikely that the predicted reductions will in fact result from the specified taxes. This means that while the effect on residential electricity prices of carbon taxes of the levels identified in the IEA and OECD studies can be calculated with some accuracy, the actual CO_2 emission reductions that will result from this tax in the short and long term cannot.

The reductions achieved under both tax scenarios fall well short of the immediate 60 to 80 per cent reductions that the IPCC calculate would be required to stabilise greenhouse gases at their 1992 levels (IPCC 1990, p. 5). To achieve more substantial reductions, a much higher tax would have to be levied, since the marginal cost of reducing CO_2 emissions would increase with total reductions. The IEA figure is used here to calculate the effects of a carbon tax on Australian residential electricity prices since it was calculated recently, and applies to OECD countries (such as Australia). A tax of $130 per ton of carbon would be equivalent to one of $132 per tonne of carbon and a tax of $300 of $305. The IEA prices are presented in American dollars. Converted into Australian dollars (to represent a uniform tax) this is equal to $169 or $391 respectively per tonne of carbon emitted in 1990 Australian dollars (ABS 1992, p. 116).

In 1988, Australia sold 131.2 PJ of electricity to domestic markets (ABARE 1991, pp. 61-62). A total of 10.46 Mt of carbon was emitted as a result of electricity produced for residential sales. This is a total of 10.63 MT of carbon (since one tonne is equal to 1.016 tons). This means that in 1988 Australia emitted 81, 021 tonnes of carbon per petajoule of energy, supplied as electricity to the residential sector. This is equivalent to 0.00029 tonnes of carbon per kilowatt-hour.

In 1990, Australia sold 138.6 PJ of electricity to domestic markets (ABARE 1991, pp. 63-64). Assuming that the proportion of carbon emitted per unit of energy was constant between the two years, total carbon emissions from residential electricity sales would have been 11.23 MT.

If the total cost of the carbon tax was transferred to consumers, (which it actually would not be) then electricity prices would rise by either $169 or $391 per tonne of CO_2 depending on whether 12.7 or 20 per cent reductions were targeted. This would mean a price rise of 4.9¢ or 11.34¢ per kilowatt-hour of electricity (multiplying 0.00029 tonnes of carbon per kilowatt-hour by the carbon tax).

In Queensland in 1990, residential electricity sales per capita totalled 6332 kilowatt-hours at an average cost of 8.86¢ per kilowatt-hour. The total price of residential electricity sold per capita in Queensland in 1990 was $589.45 (QEC 1991, p. 43).

Thus, the carbon tax investigated here would raise the price of electricity in Queensland to 13.76¢ or 20.2¢ per kilowatt-hour. The percentage increase in price would be 55 or 128 per cent per unit of electricity. The figure of 128 per cent is rounded up to 130 per cent in the main text.

The discussion in the main text assumes that this proportion of price increases would be fairly consistent across Australia. The justification for this assumption is as follows. The Queensland Electricity Commission boasts low electricity prices compared to other states (QEC 1991, p. 4). This would mean that the proportion of price rise per unit of CO_2 emissions in Queensland would be slightly lower than in other states. Victoria uses brown coal for 87, and South Australia for 40 per cent of their electricity production (IC 1991:b, p. 25). The price increases due to a carbon-tax, per unit of electricity would be higher in these states than for Queensland, due to the additional greenhouse gas emissions associated with brown coal combustion. This means that Queensland's price increase due to CO_2 emissions would lie somewhere between those for other states.

APPENDIX 6

Methodology Used to Estimate 1990 Carbon Dioxide Emissions

Complete data on 1990 world and Australian CO_2 emissions and energy use are not available[1]. The United Nations *Energy Statistics Yearbook* includes figures for total world energy use by country, but at the time of its publication the data are two years out of date, and editions beyond 1990 could not be located. The International Energy Agency (an autonomous body within the framework of the OECD) publish detailed energy statistics, including estimates of CO_2 emissions by sector for OECD countries. Their most recent published data for these indicators is for the calendar year 1988 (IEA 1991). The IEA do not publish these statistics for underdeveloped countries. The methodology was used to estimate 1990 CO_2 emissions is detailed below

The data available were:

- Total world energy use from 1985 to 1988 (UN 1990, p. 90)
- 1985 world and regional carbon emissions (Tegart 1991)
- 1988 Australian CO_2 emissions (IEA 1991, p. 199)

I assumed that:

- The global mix of energy did not alter significantly during the period 1985 to 1990, therefore CO_2 emissions per unit of energy did not change significantly.
- World energy consumption between 1985 and 1990 approximated a linear growth curve. (Although the long term rate of change of energy use followed a logarithmic, or even an exponential growth curve, over the short time period considered, the slope of the linear and exponential curves are very close. See Figure A.1 below)

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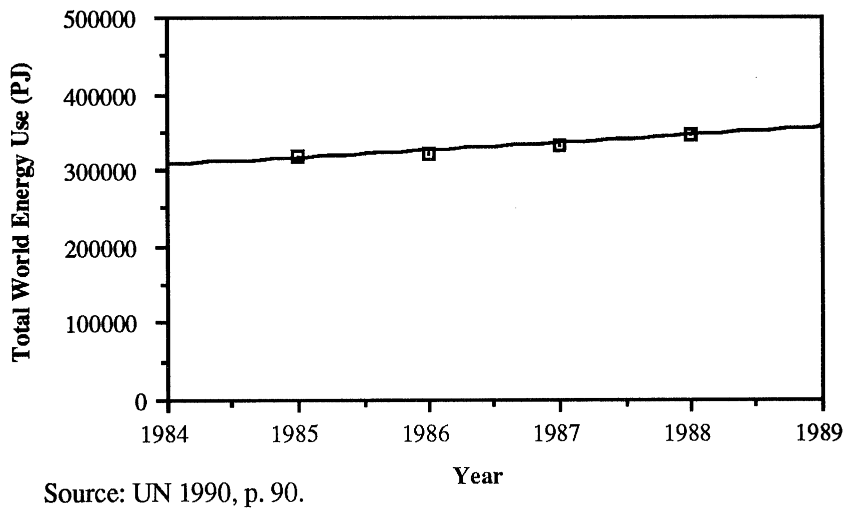
[1] This author searched extensively for the data in libraries throughout Brisbane, and also arranged a search in the library at the Department of Environment, Sport and Territories. This Department was responsible for organising information for Australia's input to the United Nation's Conference on the Environment and Development in 1992, where global warming issues were a major agenda item, and also has an extensive library. Because of this, the Department could reasonably be expected to have had the information if it were available anywhere.

Figure A5.1
Total World Energy Use, 1985 to 1988



Source: UN 1990, p. 90.

Table A6.1
World Energy Use and Carbon Emissions, 1985-90 (Estimated)

Year	World Energy Use (PJ)	World carbon Emissions (GT carbon/year)
1985	317,053	5.15
1986	323,200	5.25
1987	333,732	5.42
1988	345,793	5.62
1989	342,860	5.57
1990	348,680	5.66

A reduction of 60 per cent of carbon emissions on their 1990 levels would allow for total annual emissions of 2.27 GT of carbon.

Since Australia supports 0.3 per cent of the world's population, it would be equitable for Australia to emit 0.3 per cent of carbon. 0.3 per cent of total allowable carbon emissions would be 6.80 MT of carbon per year. In 1988 Australian carbon emissions totalled 69.98 MT. Between 1988 and 1990, Australian energy supply rose by 7.6 per cent. Assuming no change in energy mix over that time period, carbon emissions would also have risen by 7.6 per cent to a total of 75.30 MT. Therefore to achieve a level of emissions that would satisfy the requirements of maintaining greenhouse gases at their 1990 levels, and ensuring equitable carbon emissions throughout the developed and underdeveloped world, Australia would need to cut back carbon emissions to nine per cent of their 1990 levels.

One way of achieving reductions in carbon emissions (discussed in Chapter Six and Appendix Five) is to apply a carbon tax. The carbon taxes that were used in the calculations in Appendix Five were uniform carbon taxes that would be applied equally in all countries. The OECD estimates that a carbon tax to reduce CO2 emissions to 20 per cent of their 1990 levels by 2020, but which was applied only in OECD countries would need to be $2,200 per ton. The method used in Appendix Five to estimate the coal-fired electricity price increase suggests that such a tax would raise residential electricity prices by 932 per cent. This figure is rounded to

930 in the text. ($2,200 per ton equals $2,222 per tonne, $2,222 American equals $2849 Australian, suggesting a price rise of 82.62¢ per kilowatt-hour of electricity). To achieve 60 to 80 per cent reductions should require a far larger tax. The same assumptions about price elasticity that were described in Appendix Five also underlie this estimate.

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