ECOLOGY, ECONOMICS AND ENERGY: AN INTERDISCIPLINARY ANALYSIS OF AUSTRALIA'S NATIONAL STRATEGY FOR ECOLOGICALLY SUSTAINABLE DEVELOPMENT

Dissertation by
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Synopsis

Ecologically sustainable development (ESD) requires that ecological integrity, social equity, and economic development be simultaneously achieved. Analysts from various disciplinary perspectives have suggested different ways in which ESD can be approached and different strategies for assessing progress toward ESD. This dissertation describes approaches to ESD recommended by free market, mainstream environmental and radical environmental economists and those recommended by scientific and intuitive ecologists. It compares these to the approach to ESD that is proposed in Australia's *National Strategy for Ecologically Sustainable Development.* The dissertation focuses on Australian residential energy issues, and the likely impacts on residential energy systems that would result from implementation of the Strategy. Three energy issues that are analysed in the Strategy are investigated from an interdisciplinary perspective in this dissertation. The issues are the contexts for least-cost planning, performance indicators and responses to global warming. The dissertation discusses Australia's conventional approach, that recommended in the *NSESD,* and economic and ecological approaches to each issue.

The dissertation concludes that implementation of Australia's *National Strategy for Ecologically Sustainable Development* represents a limited shift from traditional to more ecologically responsible development goals. The effectiveness of the strategy would be vastly improved if Australia committed itself to implementing the numerous measures that are recommended only for investigation in the strategy. In addition, to achieve all the goals of ESD, Australia would have to commit itself to a range of measures that were excluded from the strategy's analysis .

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Statement of Originality

This work has never previously been submitted for a degree or diploma in any University. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the dissertation itself.

Su Wild River

INTRODUCTION

The 1987 publication of *Our Common Future* (World Commission on Environment and Development (WCED)), focused and popularised ongoing debates about ecologically sustainable development (ESD). *Our Common Future,* or the Brundtland Report as the publication is more commonly known, states that most analysts have interpreted major global problems such as inequality, poverty, and environmental degradation as separate issues. It argues that in reality these problems constitute interlocking crises, and proposes ESD as a framework within which joint solutions for economic, social and ecological concerns can be engendered (WCED 1987, pp. 4-9).

ESD as defined in the Brundtland Report has received intellectual support from a highly varied array of interest groups, academics and policy makers. Yet despite the broadly based support for ESD, there is continuing debate about ways in which to achieve the ideal. This dissertation develops and applies a framework for understanding these debates. It observes that ESD requires that economic development, social equity and ecological integrity be simultaneously achieved (see WCED 1987, p. 17). It concurs with the Brundtland Report's claim that analysts from various disciplines have traditionally differed in their interpretation of these normative goals, and their conception of ways to achieve them. It compares and contrasts different interpretations of ESD suggested by analysts from two disciplines, economics and ecology. These disciplines are selected for comparison since they have both contributed substantially to ESD debates. Economics and ecology utilise very different theoretical bases, data sources and methodologies. This means that there is great potential for contradictory recommendations for ESD to emerge from analysis within each discipline.

The dissertation argues that ESD literature does not provide a framework for transcending disciplinary boundaries and that this results in cognitive dissonance between recommendations for ESD. In addition, ESD literature offers no framework for resolving inter-disciplinary conflicts. This results in covert orientation of decision makers toward a particular disciplinary perspective. This perspective is likely to reflect traditional Governmental biases rather than the broad goals of ESD.

The dissertation takes the Australian Federal Government's recently released *National Strategy for Ecologically Sustainable Development (NSESD)* (Ecologically Sustainable Development Steering Committee (ESDSC) 1992: a and b) as a case study in the application of ESD to public policy. It focuses on the

strategy's discussion of, and recommendations for, energy production and use in Australia. The focus on energy narrows the scope of the research and makes the project manageable and the results meaningful. The dissertation shows that the Australian *NSESD* exhibits a bias toward economic development in its approach to ESD. It argues that the Strategy's economic bias discriminates against ecological priorities.

The dissertation is in two parts. Part One, containing chapters One, Two and Three, is necessarily broad. It examines the wide range of issues associated with ecologically sustainable development and with energy production and use. Chapter One describes economic and ecological perspectives on ESD debates, and discusses the potential for contradictory interpretations of issues to emerge from different disciplinary perspectives. Chapter Two outlines energy issues, the dimensions of energy policy and various approaches to energy analysis. Chapter Three describes Australian energy issues that are central to ESD debates.

Chapters Four, Five and Six from Part Two integrate and focus the information presented in Part One by describing economic and ecological approaches to three key issues for ecologically sustainable energy use in Australia. Each chapter in Part Two discusses conventional Australian, economic, and ecological approaches to one of the energy issues, and compares these to the recommendations from the *NSESD*. Chapter Four compares different versions of least-cost planning; an approach to energy system planning that is endorsed by analysts from each disciplinary perspective. The chapter discusses the implications for Australian residential energy systems of the different contexts for least cost planning that are recommended by proponents of different approaches to ESD. Chapter Five describes the performance indicators used by different analysts to judge the effectiveness of policies and strategies for ESD in energy systems. The implications of different analysts' use of a range of physical, social and economic units to assess the performance of energy systems are analysed in this chapter. Chapter Six explains the range of policy responses to global warming that are endorsed by analysts from the different perspectives.

The conclusions from this study are that, for the energy measures considered in this dissertation, the *NSESD* proposals would change Australian energy systems significantly. What is notable about the recommendations however is that they propose changes that are more consistent with a free market economic approach to energy, than to environmental economic, or ecological approaches. This economic

rationalist focus may render the *NSESD* recommendations insufficient to engender development that is truly ecologically sustainable.

Objectives, Focus and Limitations

The dissertation has three objectives. The first is contribute to conflict resolution in ESD debates. To achieve this objective it examines the implications of different disciplinary perspectives on policy recommendations for ESD. The second objective is to identify some specific differences between economic and ecological analyses of key issues concerning ESD. The third objective is to apply the results of the research to a practical policy issue. This involves developing a set of recommendations to augment those proposed in the *NSESD*.

The dissertation focuses its discussion on domestic, non-transport energy issues. This focus was selected so that the analysis could easily be compared with that performed by the Energy Production and Energy Use working groups and published in their respective working group reports (Energy Production Working Group (EPWG) 1991, Energy Use Working Group (EUWG) 1991).

The study has two major inherent limitations. Firstly, although it critically assesses various approaches to ESD, it does not question the overriding usefulness of ESD as a policy objective. This is significant since debates about whether ESD is a realistic, or beneficial policy goal remain unresolved in the relevant literature. This limitation is considered acceptable by this author since a conclusion that ESD is realistic is contingent upon the resolution of inter-disciplinary conflicts explored in this dissertation. Hence the issues identified have relevance for the overriding debates about ESD. The second limitation is that the focus on domestic, non-transport energy excludes analysis of important areas of energy production and use, in particular, of transport and manufacturing energy. This limitation is justified on practical grounds, due to time constraints.

Terminology

It is necessary to define a number of terms that are used in specific ways throughout this dissertation. The term 'energy' is generally used to describe all forms of energy (including ambient energy) that are used in addressing residential, non-transport energy services, since the bulk of the discussion deals with energy used for these purposes. 'Fuel' is the subset of energy that is produced, stored and distributed for provision of energy services. It does not include ambient energy. 'Gas' is used to describe natural gas unless otherwise specified. Similarly, unless otherwise

specified, 'state' refers to either states or territories in Australia. The discussion in the dissertation does not differentiate between the *National Strategy for Ecologically Sustainable Development,* and the *Compendium of Ecologically Sustainable Development Recommendations* that was published in conjunction with it. A list of acronyms and abbreviations used in the dissertation appears in Appendix One, and a glossary of technical terms appears in Appendix Two.

PART I: OVERVIEW OF ISSUES

The interdisciplinary approach taken in this dissertation, and the breadth of topics covered by the subject areas of both ESD and energy mean that it is unlikely that those who read this work will have expertise in all issues covered. The purpose of Part I of the dissertation is to introduce each of the issues covered in this study, and to explain their importance, and current status in Australia.

CHAPTER 1: DISCIPLINARY APPROACHES TO ECOLOGICALLY SUSTAINABLE DEVELOPMENT

Introduction

The possibilities for encouraging development that enhances the quality of life now, and that is sustainable far into the future have been debated by scholars for many decades. The recent publication of *Our Common Future* by the World Commission on Environment and Development (1987) focused ESD debates and placed ecologically sustainable development (ESD) onto public policy agendas in many countries.

There is significant disagreement among analysts and policy makers regarding how ESD is to be realised. The disagreement is derived in part from the different disciplinary perspectives involved in ESD debates. This chapter describes three economic and two ecological approaches to ESD. It discusses the data, methodologies and theoretical perspectives of practitioners from each approach. It describes the contributions that advocates of each approach claim that their approach can make to addressing the goal of ESD. It also discusses the translation of knowledge gained through each approach into public policies and decision strategies. This provides a framework within which sustainable energy use, and the conflicts involved in its achievement, will be discussed in later chapters.

The *National Strategy for Ecologically Sustainable Development* and its supporting documents provide definitions of ESD and explanations of strategies for approaching it (see ESDSC 1992:a, pp. 6-7; EPWG 1991, Ch. 1; EUWG 1991, ch. 5). This chapter does not draw on those discussions. Instead, the *NSESD* is discussed in Part Two of this dissertation, where specific recommendations from the strategy are compared to recommendations for ESD in energy that are proposed by analysts from the various disciplinary perspectives described in this chapter.

Defining Ecologically Sustainable Development

Many scholars have proposed definitions for ESD. Pearce, Markandya and Barbier (1989) for example, identify twenty-four different definitions. The absence of a single operable definition creates problems for decision makers wishing to implement ESD. However despite the various definitions there is much common ground. There is consensus among analysts that the central goals of ESD are to ensure a high quality of life for both present and for future generations.

There is significant disagreement about the ways in which ESD can be achieved. The source of much of this disagreement can be traced to the disciplinary focus of ESD analysts. Two disciplines in particular, economics and ecology, have contributed substantially to the literature on ESD. Several fundamental issues for ESD remain controversial both within and between these two disciplines, yet distinctive approaches to ESD have emerged from each. These approaches are described in the following two sections of this chapter.

Before describing economic and ecological approaches to ESD it is worth noting the inter-relationships between these disciplines. Ecology is a broad discipline, whose practitioners study life in all its forms. Ecologists study how, where, and why organisms live, how they interact, how their populations change and how they survive over time (Ehrlich 1986, pp. 1-18). Humans are one of the myriad of species that ecologists study. Social ecology and human ecology for example posit that ecological laws underlie many human activities (Starr & Taggart 1987, pp. 773, 776).

In addressing the *problematique* of ESD, ecology's strengths lie in its insights into the fundamental biological needs of humans and the ecological processes that contribute to human survival. As animals, humans have needs for resources such as clean air, water, food, and shelter. While humans can develop these artificially they are reliant on their physical environment, and surrounding ecosystems for raw materials. Also, the sheer complexity of ecosystems throws doubt onto any notion that humans may ever be able either to fully comprehend all that they get from natural ecosystems, or to replicate the natural ecosystems they evolved alongside should anything destroy these (Dryzek 1987, pp. 14-24). Ecology's weakness for ESD analysis is in its inability to account for human cultural behaviour and unique potential for adaptation by exosomatic means.

The social sciences offer different ways of interpreting human phenomena that overcome many of the limitations of the ecological perspective. The social sciences involve practitioners in the study of human nature, social structures and social change (Wright Mills 1959, p. 6). Economics is a social science that investigates societies' organisation and administration of resources. The central problem for applied economics is the allocation of resources amongst competing wants to reduce poverty and scarcity (Tisdell 1982, p. 3). The economic approach is useful since economic models clearly and concisely explain patterns, and expected outcomes of social choice. Its clearly defined scope has meant that economic analysis offers a comprehensive range of implementable policy recommendations for ESD.

Weaknesses of the economic approach derive from its comparatively narrow scope, and its reliance on models which invariably oversimplify reality.

The following sections describe the contributions to ESD debates of three economic and two ecological schools of thought. Each school of thought provides a different model of how the goals of ESD can be achieved. The models are based on different data and analysis, and each suggests different normative goals and decision strategies for ESD.

Economic Approaches to Ecologically Sustainable Development

There is considerable debate among economists about the economic policy mix required to achieve ESD. Three schools of economic thought in particular have contributed greatly to discussions on ESD. These have received various labels[1], but are referred to here as 'free market', 'mainstream environmental economic' and 'radical environmental economic' approaches to ESD. Each of these perspectives is described briefly below.

The Free Market Approach

Free market (FM) economists argue that the goals of ESD will automatically and best be achieved within a perfectly competitive economic system. They argue that within such a system, scarce resources will be efficiently allocated both among and between generations, and that the free market responds effectively to changing resource availability. From a free market perspective, economic development for ESD is equivalent to economic growth, defined as a rise in gross national product (GNP) over time.

The FM approach is based on a model that sees society as consisting of rational individuals who allocate resources so as to maximise their personal utility. They take

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[1] For example, Pearce and Turner (1990, p. 14, adapted from O'Riordan & Turner 1983) use a similar distinction in identifying 'extreme cornucopian', 'accommodating', 'communalist' and 'deep ecology' environmental ideologies. These categories coincide broadly with the groupings used in this dissertation. The main difference is that their 'communalist' category has been split into radical environmental economists and scientific ecologists. This distinction aids examination of economic versus ecological approaches to ESD and reflects very real differences between different groups of ecologists and economists. These differences are examined throughout the dissertation. The distinction between intuitive and scientific ecological perspectives in relation to more technocentric (and economic) ideologies is explored by Pepper (1984).

account of anticipated future gains and losses in utility by discounting the value of these back to the present. Maximum utility is achieved by maximising the net present value of resources. Transactions in a free market are uncoerced, so each transaction is mutually beneficial and moves society to a more socially optimal state. If market failures do not occur, the system should continuously develop towards economic efficiency and maximum utility (Tisdell 1982, pp. 114, 544-549, 419).

The development occurring within a free market is argued by FM advocates to be ecologically sustainable since the total productive capital within a free market system theoretically increases over time. As development occurs, natural resources are brought into the production process and either consumed, or transformed into human-made capital. In many cases, human-made capital can be substituted for and even improve on natural capital in providing consumers with a high quality of life. If resource shortages occur, or if damage to natural environments threatens economic development this will be recognised by decision makers through the price mechanism. Rising costs associated with environmental degradation should thus induce economic agents to alter activities so as to maintain development opportunities (Kahn, Brown & Martel 1976, pp. 10-17).

Advocates of FM's argue that markets have several positive attributes which other systems of resource allocation lack. Their basis in mutually beneficial and uncoerced exchange makes them self administering. Their responsiveness to wants makes them flexible, open and adaptive to changing demands. Maximisation of net present value leads to complete allocation of resources in the economy to their most valuable use. Markets give automatic signals of resource scarcity which encourage technological advancement in important areas. Finally, FM's tend toward a state of maximum efficiency, defined by the achievement of Pareto optimal production, consumption, and distribution within an economy. Pareto optimality refers to "an environment in which it is impossible by any economic reorganisation to make any person better off (in his [*sic*] estimation) without making another worse off (in his [*sic*] own estimation)" (Tisdell 1982, p. 68). Pareto optimality is used by economists as a rough measure of the efficiency of and economic system. (Tisdell 1982, pp. 394-396; Page 1977, pp. 190-198; Kahn, Brown & Martel 1976, pp. 11-14).

FM economists strongly support the traditional development aspect of ESD, where development is defined as growth in GNP per capita over time. They argue that growth is necessary to reduce poverty and its negative environmental and social impacts. Poverty is considered a causal factor in environmental problems since the desperately poor usually choose to utilise resources at hand for short term survival

rather than opting to conserve them. This leads to over-utilisation and severe depletion of resources (WCED 1987, pp. 29-32). Economic growth reduces the environmental impacts of poverty by generating a general rise in standards of living. FM economists argue that it is unrealistic to expect the rich to redistribute their wealth to the poor if it means accepting a lower standard of living for themselves. Economic growth raises total income distribution allowing the poor to increase their standards of living without taking resources from the rich (Jackson & McConnell 1985, p. 358).

Policy prescriptions for ESD arising from the FM perspective are consistent with those which they endorse for the economy as a whole. Micro-economic reform, deregulation, no regrets policies and improvements in structural efficiency are each considered to be consistent with the goals of ESD (Clark 1991, pp. 143-155). Strong evidence of the economic costs resulting from environmental problems is required by FM economists before they are likely to suggest any policies geared specifically toward ecological sustainability. When policies for ESD are proposed by FM economists, they strongly favour economic instruments (such as taxes) over regulatory measures (such as standard setting) and reject policies which would impede business productivity and performance by imposing extra costs on developers (see Business Council 1990, p. 10).

In Australia, in the 1980's and 90's, the FM economic perspective became the basis of the dominant ideology of powerful Australian politicians and bureaucrats (Pusey 1991; Carroll & Manne 1992). Many analysts of Australian political economy have criticised key decision makers' 'economically rationalist' approach to policy formulation in Australia. Critics of economic rationalism argue that its consequences in Australia have included the high and rising external debt, closure of several Australian manufacturing groups, excessively high interest rates, high unemployment, unproductive investment, and a general threat to Australia's way of life (Carroll 1992, pp. 14-26). Part II of this dissertation demonstrates that the economic rationalist ideology is strongly represented in Australia's *NSESD,* often to the exclusion of other theoretical perspectives.

The Mainstream Environmental Economic Approach

The mainstream environmental (ME) economic approach to ESD is based on the argument that market failure is both pervasive and problematic in the FM system. The FM is argued to lack an existence theorem which would "guarantee that any economic optimum is associated with a stable ecological equilibrium" (Pearce &

Turner 1990, p.24). The recommended solution to this problem is to ensure that the total economic value of environmental resources is fully recognised in decisions affecting their allocation (Pearce & Turner 1990, Ch. 9). Current work by ME economists focuses on methodologies for augmenting the market to ensure that environmental values are incorporated into economic decisions.

The lack of an existence theorem in the FM conception of production is evidenced by its model of a closed system through which goods, services and money flow during economic activity (Jackson & McConnell 1985, p39). Through its normal operation, this system expands to produce the economic growth that was discussed in the previous section. Environmental economists explain the apparent contradiction of growth within a closed system by thermodynamic analysis of economic activities. The first and second laws of thermodynamics state that:

1. Matter and energy cannot be created or destroyed (the law of conservation of matter and energy)

and

2. The entropy of a closed system always tends toward a maximum (the entropy law)

Introduction of the first law to economic analysis indicates that the economy is not closed, but rather requires the input of resources. The cost of these inputs is systematically undervalued in the free market since natural resources are treated as "free gifts" which need not be paid for (Jackson & McConnell 1985, p.18). The implication of the second law is that economic activity leads to degradation of inputs. Full recycling of resources is not possible, and the production process leads to the generation of polluting, high entropy wastes (Pearce & Turner 1990, p38). These are usually transferred back into the environment at no cost to the polluter since environmental 'sinks' for wastes are usually common property resources. Since no individual owns common property resources, no-one is reimbursed for their degradation. This leads to over-utilisation and inefficient utilisation of environmental resources (Baumol & Oates 1988, Ch. 3).

ME economists consider that the absence of an existence theorem in the FM is off-set by several major advantages of the FM over other social choice systems. FM characteristics of self-administration, flexibility, technological advancement, and efficiency are acknowledged and considered to be valuable attributes. ME economists share the FM optimism that technological advance creates potential for greater efficiency in resource use and substitution of scarce resources for plentiful ones. ME economists add to the discussion the dimension that in some cases human

made may be substitutable for natural capital (Pearce & Turner 1990, Ch. 3). Implicit in writings by ME economists is broad agreement with the notion that the FM system may promote economic development in currently underdeveloped countries (Pearce & Turner 1990, Ch. 22). Another advantage of the FM system is that it is the dominant social choice system determining resource allocation in the modern world. If the goal of ESD is to be achieved it is likely to be advanced by application of an already accepted system of social choice (WCED 1987, pp. 1-26).

ME economic analysts have proposed the following decision rules for approaching ESD using an augmented FM. Achieving ESD will involve ensuring that the rate at which renewable resources are used is less than their rate of renewal. The flow of wastes into the environment should be less than the assimilative capacity of the environment. Non-renewable resources would be used at the rate at which they can be compensated for by recycling and an increase in the quantity of renewables. A given standard of living can be sustained with a declining resource base if technological advances allow for the substitution of human-made for natural capital. If the world's population continues to grow, a given standard of living may be maintained by depletion of resources or increased efficiency in resource use. Finally, irreversible decisions should be treated with caution since irreversible mistakes may be disastrous (Pearce & Turner 1990, Ch. 3).

Several methodologies have been recommended by ME economists to move economic activity towards ESD. Firstly, cost-benefit analysis (CBA) could be extended to include 'option' and 'existence' as well as 'use' value of environmental resources. Secondly, the problems associated with externalities could be overcome by strategies such as assigning property rights, taxing for pollution, subsidising pollution abatement, zoning of polluting industries, selling marketable pollution permits, or making the users of environmental resources pay for that use. Environmental objectives could be automatically endorsed as policy goals if GNP were changed so that environmental costs were measured as reductions, rather than additions to GNP (see Pearce, Markandya & Barbier 1989).

The Radical Environmental Economic Approach

The radical environmental (RE) economic approach derives from a large and influential body of literature which criticises many of the arguments of both the free market and mainstream environmental economic approaches. Many of the scholars who have published radical environmental economic arguments are not trained as economists. For example, many are trained, or work as ecologists or demographers

(see Paul Ehrlich and Dennis and Donella Meadows) The limited political-economic training of scholars working within this school of thought may explain why fewer implementable policy prescriptions are suggested than by writers from either of the other schools.

The fundamental RE critique of other economic schools of thought is that they do not award sufficient priority to environmental or social objectives to the extent necessary in order to achieve ESD. RE economists either reject the argument that technological solutions will be found to environmental problems (Ehrlich & Ehrlich 1991, pp. 30-32), or recommend that resources be conserved within sustainable limits until technological fixes have been developed and tested (Georgescu-Roegen 1982, p22). RE economists maintain that the FM is biased toward current generations at the expense of future generations since humans are currently operating above the Earth's carrying capacity (Meadows et. al. 1972, Ch. 2). Neither do RE economists agree that FM based ESD will lead to intra-generational equity, since existing economic relations operate so as to maintain inequalities between developed and underdeveloped economies (George, 1992).

The 'existence theorem' proposed by RE economists is that economics must recognise the absolute limits on development that are imposed by physical and biophysical realities. The significance of the entropy law is emphasised, since it means that "in entropy terms, the cost of any biological or economic enterprise is always greater than the product" (Georgescu-Roegen 1973, pp. 41-42). Hence even the most technically sophisticated economic activity will always result in a surplus of high entropy. The usual conclusion arising from this observation is that the rate of economic development and the associated use of low entropy should be drastically slowed down, and that renewable sources of low entropy should be substituted for non-renewables wherever possible (Georgescu-Roegen 1973, p.48).

RE economists argue that the potential for substitution of human-made for natural capital is extremely limited due to the extreme complexity of ecosystem functions. For example, agricultural systems are an attempt by humans to substitute human-defined systems for natural ecosystems. Modern agricultural systems are highly productive, but require extensive inputs of nutrient enriching fertilisers to overcome nutrient deficits caused by cropping. Despite the regular input of fertilisers, agricultural soils tend to degrade significantly over time. Modern high-technology, high-input agricultural systems are also highly susceptible to attack by insects or disease. They must therefore be protected by regular application of insecticides. These usually have the disadvantage of increasing the resistance of insects to the

insecticide. Reliance on the products of unsustainable agriculture is one factor allowing humans to operate beyond the carrying capacity of the world to support them (Ehrlich & Ehrlich 1991, Ch. 7).

RE criticisms of the free market go beyond identification of market failures. The goals inherent in the FM system are also rejected as allowing for possible transition to ESD. Among the economic goals that are questioned are economic growth, efficiency, and individual want satisfaction. RE economists argue that economic growth is a flawed goal since it creates new wants within society. This leads consumers to constantly increase their efforts to obtain previously unavailable goods and services, increasing social discontent and pressure on resources (Zolotas 1981, pp. 8-14). Economic efficiency is also criticised since it ignores such social goals as "universal satisfaction of truly basic needs, equitable income distribution, [or] preservation of civil liberties" (Goodland & Ledec 1987, p.24). The free market identification of human wants as adequate bases for deriving social welfare functions is criticised due to the divergence of private and social wants (Self 1975, pp. 133-139). These factors are argued to systematically limit the sustainability of FM economies.

RE economists support the ESD goal of reducing intra-generational inequities, but argue that intragenerational equity is an impossible outcome from either FM or ME economic development since markets require inequality in order to operate effectively. International markets necessarily operate by expropriating real wealth from economies on the 'fringes' of development and appropriating it to those in the 'core' (Frank, 1975). The inequalities resulting from this are only exacerbated by aid and technological transfer from developed to underdeveloped countries (Hayter, 1989).

Thus RE economists recognise that achieving a sustainable society is an impossibility since the entropy of the universe always rises and even the sun will burn itself out eventually. Their policy prescriptions seek to engender a social system that would allow humans to survive equitably, up to the time when this ultimate source of low entropy no longer exists. Policy prescriptions arising out of RE economic analysis are essentially a call to "reduce the scale of human enterprise" (Ehrlich & Ehrlich 1990, p37). Daly proposes that economic development would be as sustainable as is possible within a steady state economy. In such an economy, "the total population and the total stock of physical wealth are maintained constant at some desired levels". A second requirement for ESD would be to reduce intra-generational inequality. To achieve this goal George recommends a negotiated

settlement and creative reimbursement of international debt within a democratic and development oriented framework (George 1988, Ch. 14).

Ecological Approaches to ESD

As with economic and social approaches to ESD, a breakdown of ecological approaches into different types will increase the clarity of the discussion. A judicious analysis can be achieved by investigating ecological approaches from the perspectives of intuitive ecology and scientific ecology.

Scientific Approaches.

Scientific ecological approaches to ESD are characterised by a profound distrust of its 'development' aspects. Ecologists agree however with the assertion in the Brundtland Report that maintenance of the integrity of ecological systems is vital for human survival (WCED 1987, p. 17). Ecology is a fairly new science dealing with infinitely complex subject matter, and because of this has answered very few of its own fundamental questions (Ehrlich 1986, pp. 11-18). Thus policy recommendations from an ecological perspective are characteristically based on uncertainties. For this reason, ecologists have been unable to provide positive answers to questions regarding the outcomes of ecological changes from development. They tend to argue that until the ecological consequences of particular development activities are understood it is irrational to threaten ecosystem functions.

Ecological arguments supporting the maintenance of ecosystems focus on the functions of ecosystems which cannot be reproduced by human ingenuity. Ecosystems exhibit the characteristics of complexity, non-reducibility, variability, uncertainty and spontaneity and collectiveness (Dryzek 1987, pp. 28-33). As a result of these characteristics, alteration of ecosystems by humans leads to unpredictable consequences which may be far greater than expected, and which may seriously threaten human survival (Commoner 1972, Ch. 11).

In *Rational Ecology,* Dryzek derives benchmarks for ecologically rational social systems from ecological principles. He argues that an ecologically rational social system would exhibit the qualities of negative feedback, coordination, robustness or flexibility and resilience. Negative feedback in this sense is the "presence of a deviation-counteracting input within a system" (Dryzek 1987, p. 47). Such an input would promote stability even within a complex and dynamic system. Coordination occurs both among actors, and within particular collective actions. It ensures that action taken in response to a stress in one part of a system does not simply displace

the stress to another part of the system. Problems can be displaced across time, space or media when coordination is lacking. Robustness is the ability of a mechanism to "perform well across a wide variety of conditions" (Dryzek 1987, pp. 51-52). A system may be equally ecologically rational if it is flexible rather than robust. Flexibility allows a system to "adjust its own structural parameters as changing environmental conditions demand" (Dryzek 1987, p. 52). Resilience is a quality that would only be required if a stress had moved a social system outside its equilibrium range. Resilience would steer the system back to its normal operating range (see Dryzek 1987, pp. 46-54).

Scientific ecologists would argue that an ecologically rational social system would encourage ESD since human systems are ultimately dependent on ecological systems, and cannot be sustained without effective maintenance of these. Hence human systems must respond appropriately to indicators of ecological problems if they are to survive into the future. Thus, the sentiment expressed in the Brundtland Report that the "sustainability of ecosystems on which the global economy depends must be guaranteed" is clearly supported by scientific ecologists.

Intuitive Approaches

Intuitive approaches to ecology are typified by the deep ecological perspective. The term 'deep ecology' was coined by the Norwegian philosopher Arne Naess in 1973 to describe a world view in which individuals become spiritually attuned to ecological systems and their needs and direct their actions in response to their intuition. Deep ecologists are sceptical of information gained through scientific research, arguing that such information is based on anthropocentric philosophical bases that systematically disregard non-human priorities (Grey 1986, p. 211).

Deep ecologists have not extensively discussed ESD. However it is possible to derive a deep ecological stance on ESD by extrapolating from ethical positions which deep ecologists usually endorse. Deep ecologists argue that the world views of those from 'traditional' (non technological) societies enable a better response to environmental crises than do those of modern developed societies. For instance Taoism is argued to offer much to deep ecological theory and understanding (Sylvan & Bennett 1988). Deep ecologists may conclude that ESD could be achieved by a return to Taoist, Gaian or other traditional lifestyles (Bunyard 1988). The deep ecological distrust of all things technological would lead to policy recommendations for ESD in direct contradiction to those endorsed by free market economists and environmental economists. They would see no role for technological solutions to

environmental problems. Instead they would advocate societal activities with low environmental impact which may reduce the need for technological intervention (Naess 1988, p130).

Eco-feminism is an ecological philosophy related to deep ecology, but which identifies patriarchy, not anthropocentricism as the main cause of environmental problems. There can be little debate that a relationship exists between patriarchy and environmental problems, since all people live in patriarchies (Bamberger 1974). The utility of this observation could well be disputed since such a relationship implies no causality. Eco-feminists aim to change environmental impact of human activities on a grand scale. Yet their ideologies often result in a focus on individual liberation and not the liberation of all women or the global environment (Oakley 1981:310).

Both deep ecology and eco-feminism promise more than they appear able to offer in terms of solutions to environmental problems and aid in a transition to ESD. They both lack sound theoretical backing, they reject much potentially valuable input from science and scientific thought, and they can provide limited policy recommendations for ESD (see Grey 1986).

Conclusion

There is considerable disagreement among advocates of different approaches to ESD regarding policy measures appropriate for its achievement. The free market approach suggests that the primary role of the government is to ensure the smooth operation of the market. The mainstream environmental economic approach recommends a more interventionist role for government in ensuring that environmental values are incorporated into economic analysis. Radical environmental economic analysts suggest an even greater role for government in purposely counteracting market forces where they distort environmental issues, and create inequities. The economic approaches have in common that they take a utilitarian view of the natural environment and are anthropocentric regarding its uses.

Ecological approaches to ESD are both less utilitarian and less anthropocentric than economic views. According to their advocates, both the scientific and the intuitive ecological approaches see the non-human environment as having value beyond its usefulness to humans. Both conceive of humanity as part of a global ecological system that humans have inadequate knowledge of to justify altering global processes beyond limits set by natural variations within ecosystems themselves. The

key difference between ecological approaches is in their inquiry methodologies, these being science and intuition-based respectively.

There is fundamental disagreement both within and between economic and ecological approaches regarding the role of technology, the relevance of individual opinion, approaches to optimising resource allocation among and between generations, and the nature of interactions between humans and their environments. The perspectives discussed above are so different that to attempt to derive a single approach to ESD would be to marginalise views which may yet provide valuable insight into issues of ESD. The discussion of ESD that follows will use the framework developed above to investigate the question of achieving ESD in energy production and energy use.

CHAPTER 2: ENERGY POLICY ISSUES

Introduction

This chapter introduces issues about the utilisation of energy resources that are central to the discussion of ecologically sustainable development. It defines energy, explains its prominent role in modern societies, sketches out the dimensions of energy policy and explains three approaches to energy analysis.

The Importance of Energy

The first law of thermodynamics states that matter and energy cannot be created or destroyed but merely changed in form. Therefore the quantity of these is always constant throughout the universe. The nature of qualitative changes to matter and energy are described by the second law of thermodynamics which explains that all change or work, is accompanied by a net rise in entropy. Such a rise in entropy can also be described as a degradation of free into bound energy. Forms of free energy include kinetic, matter and the potential energies from gravity, electromagnetic fields and forces between elementary particles. Bound energies include heat, light and chemical energy. By definition, free energy is available to do work. Bound energies can also be harnessed to do work under certain conditions. For example chemical energy can often be converted to heat energy after an initial input of low entropy, such as occurs when wood is ignited and then burns on its own. Heat energy can also be concentrated and used to produce steam, which can then be compressed to produce movement, or kinetic energy. This does not break the second law of thermodynamics, since creation of low entropy from high entropy occurs only within a fixed area, and the overall entropic change within the system is always positive (Bullock, Stallybrass & Trombley 1988, pp. 271, 859).

Energy is a social necessity. The set of needs that is generally accepted as the most fundamental for human survival includes the needs for air, water, food, shelter and sleep (Maslow 1970, Ch. 11). Energy beyond simple human muscle power is used in satisfaction of most of these needs in all industrialised and developing nations. Energy is used in production, storage and preparation of food, in erecting, and achieving comfortable temperatures within shelters, and in developing and often in maintaining water supply systems. Energy is also used in providing many other services to humans. For example fossil fuels are used to power vehicles such as cars and aeroplanes.

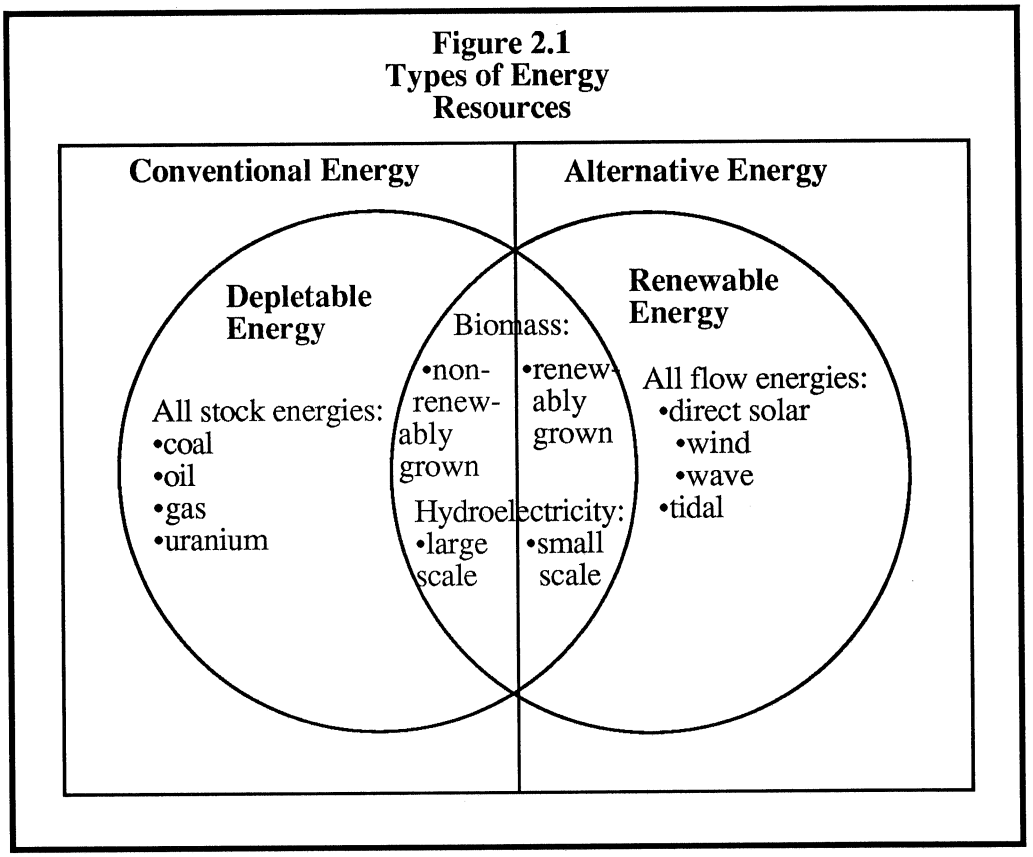
The development of modern industrial society has parallelled human ability to harness energy as fuel to do work. In early pre-industrial societies the only energy source available to humans was the mechanical energy derived from human muscle power. Later, humans learnt to ignite and control fire and thus burn wood to produce heat from stored chemical energy. This allowed them to cook food, heat dwellings and extract metals such as copper and iron from ores. They began to use the muscle energy from draft animals and kinetic energy from wind and river water for agricultural and other purposes. Perhaps the most significant technological achievement in human history was the development of the steam engine that transformed 'bound' heat energy into 'free' kinetic energy (with an associated net increase in ambient heat, light and noise energies). Since the invention of the steam engine, energy technologies have developed dramatically. Highly concentrated fossil fuels such as coal, oil and natural gas derived from biotic conversion of solar energy hundreds of millions of years ago have become conventional sources of chemical energy. These can be transported, stored and put to a wide variety of uses ranging from conversion to mechanical energy for transport to electrical energy giving highly flexible and portable power (Goldemberg et. al. 1988 pp. 2-3; Patterson 1990, pp. 7-16). Technological advances in energy utilisation such as those described here have vastly increased the amount of energy available to humans. This has allowed the development of unprecedented forms of social organisation such as those occurring in industrial societies and urban centres (Harris 1980, pp. 184-185, 200-201; Jones, 1990, pp. 214-216).

There are important differences between the sustainability over the long term of different energy sources used by humans. These differences derive from the capacity and rate of renewal of stock, flow, renewable and non-renewable energy sources. Stock resources are those "for which the natural-replenishment feedback loop can safely be ignored" (Tietenberg 1988, p. 117). Stock energy resources include fossil fuels and uranium[1]. Depletable energy resources are those whose potential supply is reduced on use. These include all stock energy resources as well as biomass (which is depleted by over-harvesting) and hydrological energy (which is depleted by siltation of dam sites). Renewable energies are those whose natural replenishment can augment its potential supply at a non-negligible rate. Flow energies are the subset of renewable energy sources whose supply is not reduced by use. Resources displaying flow qualities include solar, wind, wave and tidal energies. Figure 2.1

[1]Even fast breeder reactors, or those that rely on depleted uranium-238 to 'breed' plutonium as an energy source would eventually deplete world reserves of their primary fuel. Energy supply from such reactors would be 'almost', but not completely indefinite (Moss 1981, p. 60).

shows the relationships between these different types of energy sources. It also indicates those that are generally classified as conventional and alternative energy resources. Conventional and alternative energy sources are discussed in more detail below.

Figure 2.1
Types of Energy Resources



There are important differences between the potentials for renewal and depletion of the various energy sources used by humans. Renewable resources are those whose natural replenishment can augment its potential supply at a non-negligible rate (Tietenberg 1988, p. 118). In other words, renewal occurs in 'real' time. Renewable energy resources include all forms of solar energy including direct solar, wind, and wave energies in addition to lunar tidal energy. The use of each of these resources has no impact on their potential supply, and for this reason, these are known as 'flow' resources. use has no impact on potential supply. A depletable resource is "one for which the natural-replenishment feedback loop can safely be ignored" (Tietenberg 1988, p. 117). Depletable energy resources include all fossil fuels and the uranium used to release nuclear energy in a thermal reactor. It is worth noting that the terms 'depletable' and 'renewable' are not opposites and that a significant

set of energy resources are simultaneously both renewable and depletable. The renewal rates of both chemical energy stored in biomass, and kinetic energy of river water are non-negligible. However, unlike those energies defined as renewable above, these energy sources can be depleted, biomass by over-harvesting and hydrological energy by siltation of dam sites.

It is important to recognise the distinction between *energy* and *energy services*. For domestic purposes energy services include heating and cooling over a range of about one-hundred degrees Centigrade, lighting, mechanical effort, and electronics. In industry the services are similar, but heating and cooling occur over a wider temperature scale and the additional category of electrochemical services is introduced (Patterson 1990, Ch. 6). The demand for energy is driven by the demand for energy services but these can be provided by a variety of technological, and infrastructural means whose efficiencies vary substantially. Decisions regarding which energy services society should be prepared to provide, what means are used to meet these demands and in particular how much energy is used in the process are questions of energy policy (Saddler 1981, p. 5). The issues involved in these decisions are discussed in the following section.

Dimensions of Energy Policy

The previous section stressed that energy use is involved in all facets of life in modern societies. The optimal provision of energy resources requires government intervention because of the wide ranging uses for energy, and the nature of energy resources and systems for energy provision. The discussion in this section describes the dimensions of important energy policy areas that both historically, and currently generate sharply conflicting viewpoints from different energy policy writers and analysts. For the purposes of the discussion these are grouped into the three areas of policies addressing energy supply, energy demand management and the compatibility of supply and demand.

Energy Supply

The goal of energy supply policies is generally to ensure the maintenance of a supply of energy sufficient to satisfy national goals. Goals that are generally considered to be affected by energy supply policies include economic development, social justice and national security. Energy supply policies address issues such as the i) the total quantity of energy supplied to a nation; ii) the ownership and control of energy supply systems; iii) the optimal rate of depletion of non-renewables; iv) the environmental impact of energy supply systems; v) the reliability of supply; and vi)

the strategic significance of energy materials. These issues are discussed in turn below.

An historical relationship exists between the levels of activity in an economy and energy consumed within it. Generally, higher rates of growth of economic indicators such as GNP have corresponded to higher energy consumption. This relationship has weakened over the past century and increasingly since the energy crises of 1973 and 1979 when a group of countries, largely within the Persian Gulf formed the OPEC (Organisation of Petroleum Exporting Countries) cartel and significantly raised the price of oil (Goldemberg et. al. 1988, pp. 7-11). Since the oil price rises, the energy to GNP ratio has been reduced in industrialised countries due largely to increased efficiency in energy use, and shifts from high to low energy intensive activities. In newly industrialised countries (NIC's) and underdeveloped countries the energy to GDP ratio has increased. In the NIC's this has been due to their dominant petroleum reliant, export driven industrial sectors and inefficiencies due to poor design and maintenance of energy hardware. In underdeveloped countries the increase has followed a structural economic shift from agricultural to industrial activities (Australian Bureau of Agricultural and Resource Economics (ABARE)1991, pp. 16-18). The relationship between energy and GDP has meant that governments aiming to stimulate development have traditionally endorsed policies that encourage a constantly increasing supply of energy. More recently energy analysts in some OECD (Organisation for Economic Co-operation and Development) countries have responded to the changing energy to GDP ratio by investigating policies for improving the efficiency of energy use (Patterson, 1990, pp. 79-84).

Policies regarding the ownership and control of energy resources often focus on reducing social costs that derive from energy market structures. Energy markets are often imperfect. For example, electricity, the dominant energy carrier in industrialised countries is a natural monopoly when generated in central power stations, since "to have two or more competing electricity suppliers laying cables and fighting for customers in the same street makes no technical or economic sense" (Patterson 1990, p. 26). Monopolies in any markets, including those for energy can cause a range of negative social consequences such as misallocation of resources, inefficiency in production, the gaining of unearned income or exercise of political power (Tisdell, 1982, pp. 209-238). Policies that address these problems either to regulate monopoly power, or nationalise monopolised industries. Specific strategies in the first category include controlling prices by setting price ceilings, using taxes or subsidies to achieve a target price, and funding research, development and demon-

stration (RD&D) to encourage technological improvements (Benvensite 1985, pp. 93-96).

An optimal rate of depletion would maximise the benefits to society accruing from the use of non-renewable energy resources in the short and long term[2]. Achieving this goal would ensure that resources that become scarce can be readily replaced by alternatives and that the transition to these will be smooth and unproblematic. According to neo-classical economic theory, depletion rates are optimised under conditions of perfect competition. This is because scarcity of energy resources would gradually increase production costs, thus reducing the quantity demanded and creating incentives for research into alternatives. When the costs of harnessing energy using traditional fuels reaches the cost of alternatives energy user's utility-optimising strategies will lead them to replace traditional fuels with alternatives. According to these principles a possible future for energy supply is that oil will become uneconomic over the next few decades, followed several decades later by natural gas. Energy from coal and nuclear sources will replace these as the major global fuel sources during a lengthy transition to renewable energy sources such as solar and wind energy (Tietenberg 1988, pp. 119-127, 137-138; Simon & Kahn 1984, p. 25)[3]. Policies addressing problems associated with depletion include those that encourage RD&D into non-depletable energy sources.

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[2]There is considerable ongoing debate in academic literature regarding decision strategies for inter-temporal allocation of non-renewable resources. The most widely accepted decision strategy involves 'discounting' future costs and benefits of present resource use, and selecting a course of action that maximises the net present value of resources. Critiques of discounting have questioned its logic, ethics, and likely social, and ecological impacts. In particular, critics have focused on ways in which discounting deals with issues associated with pure time preference, risk and uncertainty, diminishing marginal utility of consumption, opportunity costs and future generations. See Pearce & Turner 1990; Ch. 14, Dryzek 1987 pp. 74-75; Page 1977, Ch. 7; Pearce, Markandya & Barbier 1989, Ch. 6; Solow 1974, for the debate on discounting.

[3] The likelihood of the ideal scenario being achieved has been questioned on several grounds. Firstly, it relies on the existence of a perfectly competitive market system, since without such a system, changes in resource availability would not be accurately reflected in resource prices, and could not provide the required impetus for technological advance. Secondly, environmental impacts of energy resource use (such as global warming from emission of greenhouse gases) may have negative economic effects that inhibit use of particular fuels. Thirdly, resource depletion tends to be 'lumpy' rather than smooth as is assumed under an ideal scenario. For further discussion of these issues see Pearce & Turner; Part II.

A range of environmental problems are associated with energy supply. For example, electricity's cleanliness at the point of use of belies the fact that all methods of generating and using electricity on a large scale produce environmental impacts associated with generation, transmission and distribution (Roberts, Liss & Saunders 1990, pp. 10-12). Particular impacts include visual intrusion and land use. As well as these impacts, different energy sources are associated with specific environmental problems. These can be grouped into impacts occurring at three stages; the pre-harness stage, during harness, and post-harness. Table 2.1 lists the dominant energy sources used in Australia together with some less common energy sources that show some potential for expansion. Major environmental impacts of less common sources at various stages of harness are indicated. The impacts vary in magnitude, likelihood of occurrence, seriousness and potential for mitigation. For example, coal production from surface mining always causes local degradation of soils and habitats. This is unlikely to be immediately life threatening, and satisfactory rehabilitation has been achieved in many cases (Roberts, Liss & Saunders 1990, p. 19-20). In contrast, significant uncertainty exists regarding the likelihood that the enhanced greenhouse effect is occurring. Many scientists predict that this may result from fossil fuel burning and the associated release of carbon dioxide (CO_2) and other gases into the atmosphere. If global warming from the enhanced greenhouse effect does occur, it is likely to cause global environmental disruption with slim chance for mitigation of effects (National Greenhouse Steering Committee (NGSC) 1992, p. 8). A few of the myriad of policies for mitigating environmental impacts of energy supply include requirements that mining companies undertake rehabilitation of vegetation at mined sites, encouragement of fuel switching from more to less greenhouse gas emitting fuels, safety standards for oil tankers and requirements for careful disposal of nuclear wastes.

The low environmental impact of renewable energy sources, and in particular solar, wind, tidal and wave flow energies is indicated in Table 2.1. For energy supply purposes, the environmental advantages of these energy sources is to some extent off-set by the low concentration of energy derived from them and the inconsistency of its supply. Solar energy can only be harnessed during the day, and is most concentrated when there are few clouds. The intensity of wind energy is time and season dependent. The timing of peaks and troughs of tidal energies can be accurately predicted, but this variation in available energy and a deficiency of suitable sites present inherent limitations for large scale energy supply from tides (Patterson 1990, pp. 137-139). In contrast, if fuel is available, the timing and quantity of energy harnessed from fossil, nuclear and large-scale hydro-electric

sources can easily be controlled. For large scale electricity supply the additional control associated with these energy sources is highly advantageous. Electricity is an energy carrier not an energy source, and conversion of other energies to electricity must occur at the time of electricity use. Energy that is harnessed prior to use as electricity must be stored as chemical energy in batteries until it is used, and free energy is lost in the conversion process (Patterson 1990, pp. 92-93). Essentially what this means is that if renewable energy sources were to replace depletable ones in industrialised countries then the timing and quantity of energy use would be governed more by environmental factors, such as predominant weather patterns, than is now the case.

A final policy issue for energy supply concerns the strategic aspects of various fuels. Nuclear energy in particular confers strategic power onto its suppliers since its fuel, uranium, is both a source of power and the most destructive explosive ever invented. The technologies involved in achieving these two ends is similar and nations producing nuclear energy can generally also develop a nuclear arsenal (Moss 1981, pp. v, 21). There are significant difficulties associated with energy harness from nuclear sources. Firstly, the cost of nuclear power appears high compared to other fuel sources and energy strategies (Keepin & Katz 1988). Secondly, nuclear power is politically dangerous since accidents in nuclear power plants such as those at Three Mile Island in 1979 and Chernobyl in 1986 have fuelled opposition to nuclear energy in communities near proposed or existing nuclear power plants (Burton 1990, pp. 211-221). Thirdly, although much research into nuclear energy has been undertaken many technological barriers to nuclear energy remain. For example, inherently safe nuclear reactors have neither been, nor are likely to be developed in the foreseeable future (Barkenbus 1988). Since energy harness from nuclear sources has such significant drawbacks in comparison to other energy strategies it seems likely that policies encouraging nuclear power link strongly to defence policies for many nations.

The strategic value of petroleum products was graphically demonstrated by the oil crises and more recently by the Gulf War. The oil crises showed oil importers that their national economies and security were unstable due to their reliance on resources beyond their direct control (Patterson 1990, p. 45). The strong response by the United Nations (UN) and countries such as the United States of America (USA) to Iraq's invasion of Kuwait in 1991 were partly motivated by those bodies' desire to maintain access to petroleum products from the Middle East. The strategic role of energy may not be explicitly addressed by energy policies but is likely to be a factor contributing to the choice of energy sources used by many nations.

Table 2.1

Major Environmental Impacts of Various Energy Sources

	Pre-Harness	Harness	Post-Harness
Coal	Mining damages soil, water and habitats and produces spoil (1, pp. 18-20)	Release of CO_2 and other greenhouse gases. Highest of all fossil fuels. (2)	Pulverised fuel ash produced. Some used commercially. Remainder buried with loss of land, amenity and potential water pollution. (1, pp. 21-22)
Oil	Fraction lost by spillage or accident. Major losses of marine wildlife. (1, p. 16)	Release of CO_2 and other greenhouse gases. Risk of large scale accidents.(1, p. 16)	Liquid wastes usually emitted to waterways. (1, p. 17)
Natural Gas	High risk of accident associated with transportation. (1, pp. 17-18)	Lowest release of CO_2 of all fossil fuels. Risk of large scale accidents. (1, pp. 17-18)	#
Nuclear	Production of large quantities of low level nuclear wastes. Must be permanently stored. (3, pp. 112-115)	Small risk of catastrophic accidents. (1, pp. 113-117)	Production of radioactive wastes. difficult and expensive to contain (1, pp. 134-140)
Hydro-Electric	Loss of land to flooding, reduction of fertility and increase in erosion downstream, loss of water to evaporation, transpiration and seepage. (4, pp. 49-66)	Spread of disease, loss of fisheries in long term, risk of earthquake and flood. (4, pp. 72-134)	Eventual loss of dammed area to siltation and other detritus. Compacted, uncultivatable area remains. (4, pp. 226-230)
Solar	Some impacts from mining for minerals for construction.	#	#
Wind	Visual impact and land alienation (relatively minor) (6, pp. 11-15)	Manageable risk of blades disconnecting, noise, electromagnetic interference (7)	#
Biomass	Possible loss of agricultural land or wilderness to fuel crops (7, pp. 213-232)	Contribution to acid rain in some conditions (8, pp. 271-278). Possible soil degradation (7, p. 251-253)	#

*A hash (#) indicates no major associated environmental problems

1. Roberts, Liss & Saunders 1990. 2. Edmonds & Reilly 1983. in Barrett 1991, p. 37
3. Brain & Schuyers 1981 4. Goldsmith & Hilyard, 1984.
5. Watt & Harrington 1985. 6. Barker et. al. 1983.
7. Newman & Hall 1990. 8. Chadwick 1990.

Energy Demand Management

An increasing number of energy policies aim to minimise the quantity of energy used in providing energy services. Successful adoption of these energy demand management policies would confer significant benefits to society. These would include reductions of greenhouse gas emissions, a lowering of demand for new

energy hardware such as hydro-electric dams and coal or nuclear-fired power stations, reduced costs of production and an extension of the lifetime of non-renewable energy resources. Four areas of focus for demand policies include i) improving the technical efficiency of energy hardware; ii) encouraging the use of energy efficient technologies and practices; iii) altering energy use patterns so that the services obtained from existing hardware are increased; and iv) encouraging activities that require minimal energy inputs. The dimensions of energy demand policies surrounding these areas are discussed in this section.

The efficiency of energy hardware can be defined as:

$$\frac{\text{Theoretical Minimum Energy Consumption for a Particular Task}}{\text{Actual Energy Consumption for a Particular Task}}$$

(Goldemberg et. al. 1988, p. 104)

Currently, efficiencies of around one per cent are common for most household and industrial activities. However a reasonable long-term goal for energy efficiencies would be between 20 and 50 per cent for "typical practical systems" (Goldemberg et. al. 1988, p. 104).

There is great potential for increasing the technical efficiency of both active, and passive components of much energy hardware. Increasing the technical efficiency of an active component means getting more work out of each unit of energy used. Heat pumps are examples of highly efficient energy hardware. These are devices that transfer heat from one area to another thus cooling the former and warming the latter. They are far more efficient at raising temperatures than are conventional heaters, and a single unit is multi-functional since it can be used as either a heater or air conditioner and thus reduce total demand for energy hardware (Patterson 1990, pp. 92, 99; Goldemberg et. al. pp. 103-106). Increasing efficiency by altering passive components of energy hardware means augmenting the services rendered per unit of work done. For example, insulation can be used to passively increase technical energy efficiency since less energy is required to heat or cool an insulated building than an uninsulated one.

Highly efficient energy technologies have been developed, and are commercially available for many energy services. However energy users have been slow to adopt them for several reasons. Firstly, energy efficient technologies usually incur extra initial expenditure, but savings during operation when compared to energy wasteful technologies (Goldemberg et. al. 1988, pp. 105-106). Secondly, the structure of Australian energy supply systems is such that the costs of moving to energy efficient

technologies are borne privately while existing inefficient systems are maintained publicly and are available to most Australians for low initial costs (Saddler 1981, p. 163). Thirdly, in Australia, and in many other countries there is no national system indicating the efficiency of appliances[4] and no energy performance standards, so wasteful energy hardware is widely available and indistinguishable from efficient hardware at the point of sale (Diesendorf & Kinrade 1992, p. 4). Fourthly, it is difficult for consumers to relate the marginal cost of energy to the services rendered by it via particular appliances so opportunities for reducing energy use and energy costs are hard to discern (Saddler 1981, pp. 159-161). Finally, a range of social and psychological factors are involved in energy use decisions and these have been poorly addressed in strategies for reducing energy use. For example, energy users are likely to act more on information showing benefits of energy savings than costs of energy waste, but many energy conservation strategies have taken the latter approach (Coltrane, Archer & Aronson 1986, p. 138). Together these factors create disincentives for energy users to invest in expenditure or activities that reduce energy consumption. Policies aimed at increasing the use of energy efficient technologies and practices have endorsed subsidies for, and information about efficient appliances, education packages about efficient practices, free or subsidised energy audits, and a range of other services (for example see South East Queensland Electricity Board (SEQEB)1992:a).

The size and form of many energy systems correspond to the peak demand that is likely to be placed on them. For example, if the demand for electricity at any time exceeds the capacity of the electricity supply system then blackouts will occur, causing significant social disruption (Rosenthal & Russ 1988, pp. 67-69). Similarly, road networks must be designed to cope with a peak capacities if time and energy wasting congestion is to be avoided. Unfortunately, energy demand exhibits significant time and season dependent peaks and troughs. For example, the demand for electricity is significantly higher between 6 and 9pm on winter nights when many electricity users are cooking, heating their homes, drying clothes and running dishwashers than it is between 2 and 5 am on summer mornings when few of these activities are performed (SEQEB 1992:a, p. 2). The utility derived from a given energy system is optimised when demand is spread evenly over time and remains

[4] Although there is no national system indicating energy efficiency of appliances, an energy labelling system is in place in some states for some appliances. South Australia, New South Wales and Victoria operate energy labelling systems that cover five appliances. Queensland has enacted similar legislation, and this was due to be enforced by the end of 1992 (National Greenhouse Steering Committee 1992, pp. 52-53).

close to the system's maximum capacity. Rather than increasing capacity to accommodate peaks, this can be achieved by altering demand patterns so as to smooth out the variations in energy use. Policies that address the goal of smoothing out demand may promote peak load reduction, off-peak load growth or load shifting from peak to off-peak time (SEQEB 1992:a, p. 1).

Most energy services can be provided in a variety of ways and the quantity of energy used by each may differ substantially. Recycling for instance is often less energy intensive than production from raw materials. For example, the energy required to recover and recycle aluminium, glass, paper, polyethylene and polystyrene is considerably less than the energy required to produce these materials from primary sources (Environmental Protection Authority: Western Australia (EPAWA) 1989, p. 8). Many recreational activities require less fuel than others. Bushwalking uses less fuel than water-skiing but may satisfy comparable recreational needs. Similarly, cycling is less fuel intensive than driving a private car but can satisfy comparable travel needs in many cases. Policies that seek to reduce energy demand by encouraging low energy activities may aim to educate energy users about alternatives, provide the infrastructure and support for low energy pursuits or enforce reductions in energy use by restricting the availability of activities that require high levels of fuel use.

The Compatibility of Supply and Demand

The key feature of policies dealing with the compatibility of energy demand and supply is that they address qualitative, not quantitative aspects of energy supply systems. These policies question the modes by which energy is transferred from sources to services and seek to reduce energy use by optimising the links between these. Issues investigated as part of compatibility policies include conversion efficiencies, ways of improving these and non-fuel based service provision. Compatibility policies are likely to require more significant changes to existing energy systems than either supply or demand polices, since achieving optimal compatibility may involve infrastructural changes beyond those usually associated with energy provision, as well as cognitive changes in the way energy services are perceived.

The services of water and space heating account for more than two thirds of residential and over one quarter of commercial, non-transport energy use in Australia (EUWG 1991, pp. 162-163). A significant proportion of this energy is derived from electricity produced in coal-fired power stations. Four energy conversions occur during this process. First from chemical to heat energy when coal is burnt. Second

from heat to kinetic energy when turbines are driven. Third from kinetic to electrical energy during generation. And fourth from electrical to heat for service provision.

Every time energy is converted from one form to another, a portion of free energy is lost to waste heat, noise or light. In the chain of conversions described above, less than one per cent of the original chemical energy is utilised in final service provision (Goldemberg et. al. 1988, p. 104). An effective way to increase energy efficiency is to minimise the number of conversions required for each energy service. Cogeneration, or combined heat and power is one method by which this can be achieved. This is a method of energy harness in which fuel is burned to produce both electricity and useful heat. Less than 20 per cent of original fuel energy is wasted in an effective cogeneration plant (Patterson 1990, p. 122). Cogeneration power plants are usually small scale and must be located in close proximity to areas in which heat will be used. Experience in Sweden, federal Germany and elsewhere suggests that they operate effectively when owned and operated by local authorities. They are linked to energy users not just by electricity lines but by insulated pipes that carry hot water. In some cogeneration plants, operators can continually re-adjust the proportions of energy delivered as electricity or heat to ensure that energy harness is qualitatively compatible to energy services. In each of these areas, cogeneration plants differ from traditional electricity generation plants. Traditional plants are usually very large scale, distant from users, operated on a regional level, and impervious to the final uses of the power generated. The success of policies encouraging cogeneration would be dependent on their effective recognition of these differences between this and other forms of energy supply. Other strategies that increase conversion efficiencies include using heat-producing energy sources (such as oil, coal or natural gas) directly for heat production (for example for water and space heating). Increasing public transport patronage also improves the compatibility of energy demand and supply, since it provides the energy service of 'movement' with a minimum of fuel use (Diesendorf & Kinrade 1992 p. 2)

Compatibility policies can also encourage energy use that involves no fuels. Passive solar lighting and heating of buildings achieves this goal. Buildings designed to utilise ambient solar energy are "well insulated, and are designed and oriented to catch and store winter sunshine, but to exclude summer heat" (Diesendorf 1991, p. 19). Policies encouraging passive solar heating and cooling in buildings extend into areas not usually considered relevant to energy planning. For example, in urban areas, streets must be oriented in certain ways if sunlight is to be effectively used, but energy use is rarely considered by urban road planners (Diesendorf 1991, p. 19).

Approaches to Energy Policy

The dimensions of energy policy were discussed as separate items above. In practice, energy policies are interdependent. For example the development of an energy system involves decisions regarding acceptable levels and types of environmental impact, depletion rates for non-renewable resources, the nature of the energy demand and the form in which energy is to be transferred to the end user. According to many energy analysts, such as Amory Lovins (1977), Hugh Saddler (1981) and Walter Patterson (1990) there are two distinct approaches to energy policy. Each of these provides an overall framework within which individual policy issues are interpreted and addressed. The two approaches have received various labels, but within this dissertation they are referred to as 'conventional' and 'soft'. A third approach is also suggested. It forms the middle ground between conventional and soft energy analysis and is termed 'alternative' in this dissertation. The following sections describe important elements of each approach.

The Conventional Approach

The conventional approach to energy planning was developed gradually in response to the development of various energy technologies. Although it has been severely criticised by alternative analysts it remains the most widely accepted approach to energy planning. Conventional analysis interprets the energy problem as that of accommodating increasing energy demands, and proposes continuous growth in energy supply as the solution (Lovins 1977, p. 26).

Conventional energy analysis proceeds via interpretation of certain energy aggregates. The prices and quantities of different fuels obtained and used in an economy over the course of a year are recorded. Changes are analysed to indicate shifting patterns of energy demand. The patterns are extrapolated to forecast future energy demand so that new energy supply systems can be developed to accommodate changes (Goldemberg et. al. 1988, p. 16).

The orientation of the conventional approach to issues of energy supply gives rise to certain characteristics of conventional energy systems. Supply orientation means that energy services are rarely explicitly studied. Since little is known about the end uses of the energy supplied under conventional approaches, a logical strategy is to provide power in highly flexible forms so that almost any service can be accommodated. Electricity offers the greatest flexibility for non-transport services and therefore is conventionally favoured. Large scale supply of electricity can only be accomplished via networks of power stations, electric transmission lines and

substations. These operate effectively when linked in large grids since this reduces the likelihood that failure of any part of the system will cause widespread power cuts of extended duration. Centralised control of large electricity systems is logical since good co-ordination between elements is essential. Large initial costs and relatively low marginal costs are involved in such systems and once they are in place it can seem illogical to promote investment into alternative energy systems that would double up on an already substantial investment. The upshot of this is that the conventional approach to energy encourages large, centralised power supply that may become increasingly inflexible and insensitive to energy demands. (see Rosenthal & Russ 1988, Ch. 3).

In conventional analysis, energy systems and decisions are analysed from within an essentially neo-classical economic framework (for example see Brain & Schuyers 1981, Ch. 2). Conventional analysis endorses the view that in an optimal energy future, currently dominant energy resources such as oil and natural gas will be largely depleted in a matter of decades, thus they are considered transitional. Coal and nuclear fuels will replace these during a long and gradual transition to renewable energy. In neo-classical economics, most environmental and social factors are external to the standard analysis. This means that many problems associated with the use of transitional fuels are not emphasised in the conventional approach. For this reason the costs of short term unreliability and inflexibility of energy supply from renewable resources are considered in most cases to outweigh any benefits that might accrue from an earlier transition to these. Thus renewable energy sources such as solar and wind energy are considered to be unnecessary, problematic, and to have few practical applications (see Pearce, Markandya & Barbier 1989, Ch. 3).

Soft Energy Paths

The term 'soft energy paths' was coined by Amory Lovins in 1977 with his publication *Soft Energy Paths: Toward a Durable Peace*. This presented a fundamentally different analysis of energy systems from conventional approaches. The implicit goal of the soft approach is to establish energy systems that engender a sustainable world. Soft energy analysts argue that this goal can be achieved without significant reductions in the energy services currently enjoyed in developed countries, and with improved service provision in underdeveloped countries (Goldemberg et. al. 1988, pp. 61-65).

Soft energy analysts stress the difference between the 'hard' approach of developing a sustainable energy system, and the soft approach of seeking a sustainable world. A

sustainable energy system can technically operate over an extended time period but in doing so may erode long-term sustainability of the world (Goldemberg et. al. 1988, p. 63). A sustainable world may be achieved only if its energy systems satisfy the broad social goals of equity, economic efficiency, environmental soundness, long-term viability, self-reliance and peace (Goldemberg et. al. 1988, p. 61).

As was stated above, conventional approaches solve energy problems by increasing supply. Recent cost-benefit analysis has shown that, even without incorporating environmental costs, it is usually less costly to reduce energy demand by one unit than to increase supply by the same quantity (Goldemberg et. al. 1988, Chs. 2, 3). Energy systems that explicitly address the social goals for a sustainable world would rely on renewable energy sources, be diverse and flexible, use relatively simple technologies, matched in scale, quality and geographic distribution to energy services (Lovins 1977, pp. 38-39).

At this point it is worth stating that no nation that this author is aware of operates exclusively, or even largely along soft energy guidelines. The energy alternative is thus utopian, and its endorsement by any government would constitute a courageous experiment that could bring about profound and unpredictable social consequences. While it looks good on paper, the energy alternative should perhaps be approached with caution.

The Middle Way, A New Alternative

Proponents of soft energy paths argue that conventional and soft approaches to energy are mutually exclusive since a commitment to one may foreclose the other (Lovins 1977, p. 26; Patterson 1990, pp. 168-169). In practice, while energy systems approximate the conventional or alternative models described here it is difficult to identify a modern energy system that exhibits only the characteristics of either.

Many large energy users for instance now recognise the high costs associated with wasting energy and are developing and applying demand management strategies. Similarly, many energy producers recognise that conventional energy systems are inefficient and produce energy at excessively high costs (see SEQEB 1992:a and b). As a result, many energy producers have introduced innovative strategies to reduce demand and these have been enthusiastically received by certain energy users. For example SEQEB now offer optional pricing structures that substantially reduce electricity costs for energy users who shift their demand from peak to off-peak periods (see SEQEB 1991).

These developments suggest strongly that an alternative energy strategy offering a middle way between conventional and soft energy paths is both possible, and has already begun to emerge. This energy alternative utilises existing energy systems and conventional energy data gathering and analysis techniques. In addition, it considers energy demand, aiming to minimise this to reduce production costs. It differs from soft energy paths in that it endorses continued use of non-renewable energy resources while such use remains economically viable and could still involve large scale power production and low compatibility of demand and supply.

Conclusion

Energy is fundamental to all activities in modern societies. Conventional and soft and alternative approaches to energy analysis involve very different treatments of energy supply, demand, and compatibility issues. While both approaches provide a long term, or sustainable vision for energy systems the economic, social and ecological implications of the two approaches differ greatly.

The information and analysis in this and the previous chapter form the basis of the discussions in the following three chapters. The following chapters discuss areas of conflict and compatibility between policies awarding lexical priority to social, ecological and economic concerns within the context of ESD in energy.

CHAPTER 3: AUSTRALIAN ENERGY SYSTEMS

Introduction

This chapter extends the discussion in the previous two chapters by describing specific aspects of Australian energy systems that are central to policy formulation for ESD[1].

Australian Energy Resources

Australia is well endowed with energy resources by world standards. It has used its resource base to develop a large energy export industry, and to engage in energy intensive activities such as aluminium smelting and steel production (ABARE 1991, p. 3). Energy figures highly in the Australian economy. In 1989-90, the Australian energy sector accounted for five per cent of GDP, 18 per cent of total export income and two per cent of employment (EUWG 1991, p. 2).

Fossil fuels predominate among energy sources used in Australia. In the 1989-90 financial year, fossil fuels accounted for over 98 per cent of Australia's total energy consumption (ABARE 1991, p. 96). This is indicated in Figure 3.1, which shows Australian energy consumption by fuel source over the period of financial years ending 1976 to 1990, and projected consumption from 1992 to 2000 under a business as usual scenario (see ABARE 1991, pp. 12-37). The graph shows that black coal and petroleum products are Australia's dominant energy sources. The quantity of each energy source used in Australia has increased over the time period indicated. Australia uses no uranium domestically as a fuel source. Renewable energy sources are relatively minor contributors to total energy supply, and show little growth over the time period. It is worth noting that the category 'renewables' in Figure 3.1 does not include passive uses of solar energy such as solar salt or laundry drying, passive building heating or wind energy such as windmill water pumping. Energy sources indicated as renewables include those from biomass, hydro-electricity and solar energy used for residential water heating (ABARE 1991, p. 3).

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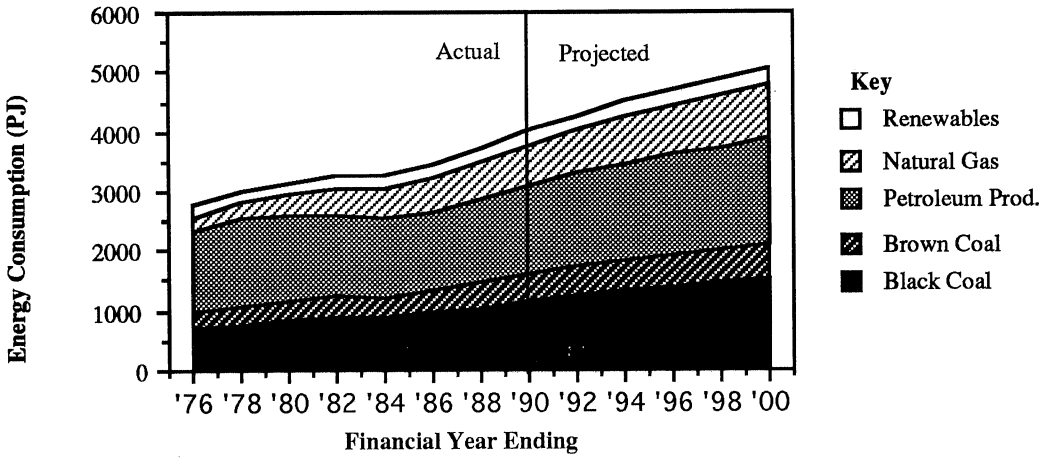
[1] A wide range of data are presented in this chapter. Consistency between time periods represented and data types has been attempted, but has not always been possible. No data are knowingly presented that suggest inaccurate relationships or trends.

Figure 3.1
Australian Energy Consumption by Fuel, 1975-76 to 1999-2000



Source: ABARE 1991, p. 96.

Since fossil fuels are depletable, no nation can rely on them indefinitely for its energy needs. As was stated in Chapter two, the optimal rate of depletion of fossil fuels depends on their extraction costs and scarcity. Australian coal reserves are large relative to those for uranium, oil and natural gas. Figure 3.2 shows the reserve/production ratios for Australia's five major non-renewable energy resources[2]. The ratio shows the relationship between reserves and production in a particular year and is used as a rough indicator of the relative scarcity of resources. The relationship is extremely dynamic, since discovery of previously unknown mineral reserves increases the former, while additional energy demand raises the latter. The reserve/production ratio should thus not be considered to predict the year of ultimate economic depletion, but rather be used as a general indicator of scarcity relative to demand.

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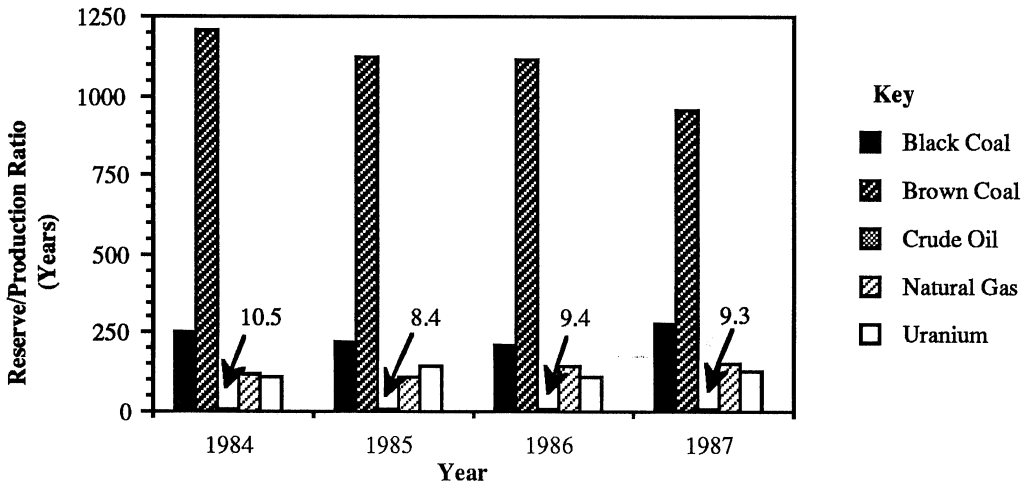
[2] Several categories of reserve data are available for energy minerals. The ratios for black coal, brown coal, crude oil and natural gas were based on estimates in the category of economic recoverable resources (DPIE 1989, pp. 75, 80, 189). Perfectly comparable data for uranium were not available. For this reason, the ratio presented is based on reasonably assured resources (DPIE 1989, p. 259).

Figure 3.2
Reserve/Production Ratios for Dominant Australian Energy Resources, 1984-1987



Source: Department of Primary Industries and Energy, & Bureau of Mineral Resources, Geology and Geophysics, 1989, pp. 57, 75, 80, 81, 189, 257, 258.

International Trade

Australia plays a major role in international energy markets. Figure 3.3 indicates that Australia exports petroleum products, black coal, natural gas and uranium. Of these fuel groups, only petroleum products are both imported into, and exported from Australia[3]. Australia's international trade in petroleum products reflects particular qualities of Australian crude oil, the pattern of demand for various petroleum products in Australia and corporate strategies of petroleum producing companies (Saddler 1981, p. 93; Department of Primary Industries and Energy (DPIE) & Bureau of Mineral Resources, Geology and Geophysics (BMRGG) 1989, pp. 192-194). In the 1990-91 financial year, 72 per cent of black coal, and 20 per cent of natural gas produced in Australia was exported (ABARE 1991, p. 64). Coal is a particularly important export, accounting for nearly 12 per cent of total Australian export earnings in 1991 (Crean and Cook 1992, p. 3). Australia is the world's largest coal exporter. In 1990, Australia supplied over 26% of the coal sold in international trade, primarily to Japan, other Asian countries, and Europe (54, 26 and 17 per cent of total coal exports

[3]Note that crude oil and petroleum products have been combined in the 'petroleum products' graph, and that Australia imports heavy crude oil, and petroleum products and exports light crude oil.

respectively) (Joint Coal Board (JCB) & Queensland Coal Board (QCB) 1990, pp. 1, 31).

Future expansion of Australia's domestic fuel production and international energy trade are anticipated according to 'business as usual' projections. Australian domestic black coal consumption is projected to increase by 26 per cent on 1991 levels by the year 2001, with much of the expansion due to increasing demand for electricity. Black coal exports are projected to increase by 47 per cent on their 1991 levels by the year 2000, and exports are expected to remain concentrated in Asian markets (Barlow Jonker 1992, pp. 2-6, 53; Crean & Cook 1992, p. 4). Domestic production of petroleum products is expected to remain stable, or rise by up to 8 per cent in the period 1988-89 to 2004-05, while imports of petroleum products could rise by 74 per cent over the same time period (Australian Minerals and Energy Council (AMEC) 1991, pp. 1-2). Natural gas production is expected at least to continue to increase roughly in line with the Australian economy under business as usual projections (DPIE 1991, p. 4).

Australian Residential Energy Use

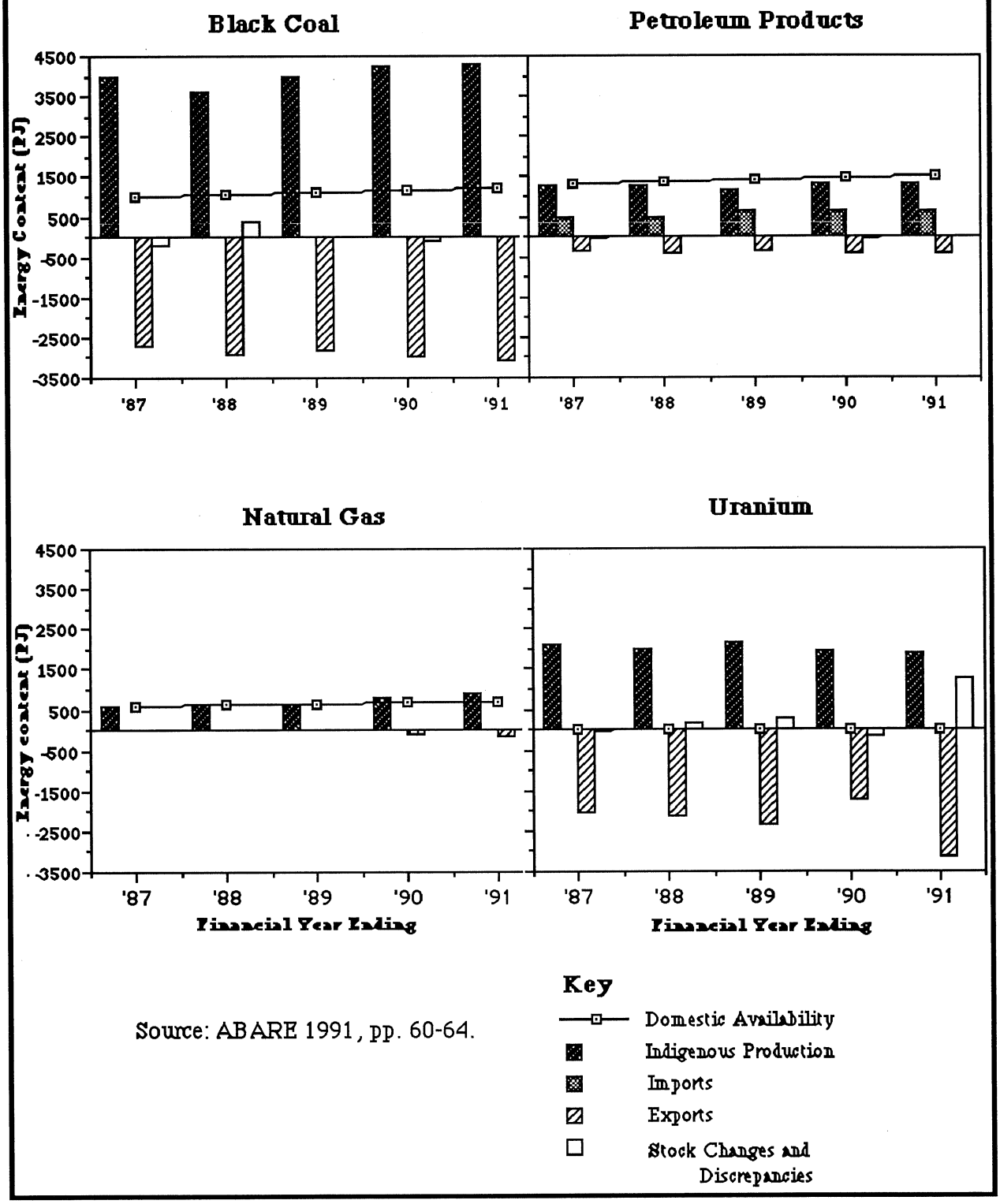
Figure 3.4 shows world total and per capita energy consumption for 1988. It indicates that while Oceanic countries (Australia included) are small energy users compared with other areas of the world, their per capita energy use is among the highest. At 216 giga-joules per person in 1988, Australian per capita energy use was considerably higher than the global average, of 68 (UN 1990, pp. 90, 102).

Residential energy use accounts for about 12 per cent of final energy consumption in Australia (ABARE 1991, p. 20). Figure 3.5 shows that electricity is the dominant power source in the residential sector, accounting for 43 per cent of final energy in the 1990-1991 financial year. In 1989, electricity was supplied to 97 per cent of the Australian population (Industry Commission (IC) 1991:a, Vol. III, p. 32). Coal is the major fuel for Australian electricity production, accounting for over 80 per cent of energy inputs into the industry. Natural gas accounts for nearly nine per cent of inputs and oil for less than one per cent. Hydro-electricity dominates electricity supply in Tasmania, accounting for 98 per cent of energy inputs into electricity in that state and nearly 11 per cent in Australia overall (IC 1991:a, Vol. III, p. 28).

Figure 3.3

Availability, Imports and Exports of Major Australian Fuels

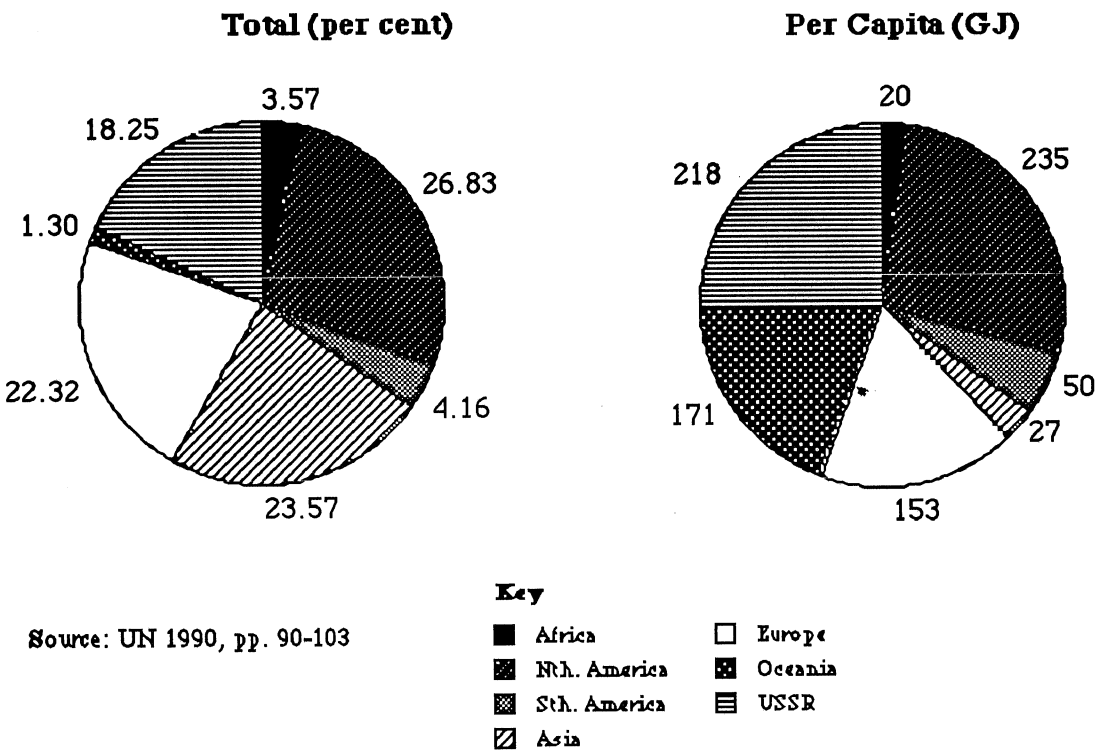
1986-87 to 1990-91



Source: ABARE 1991, pp. 60-64.

Figure 3.4

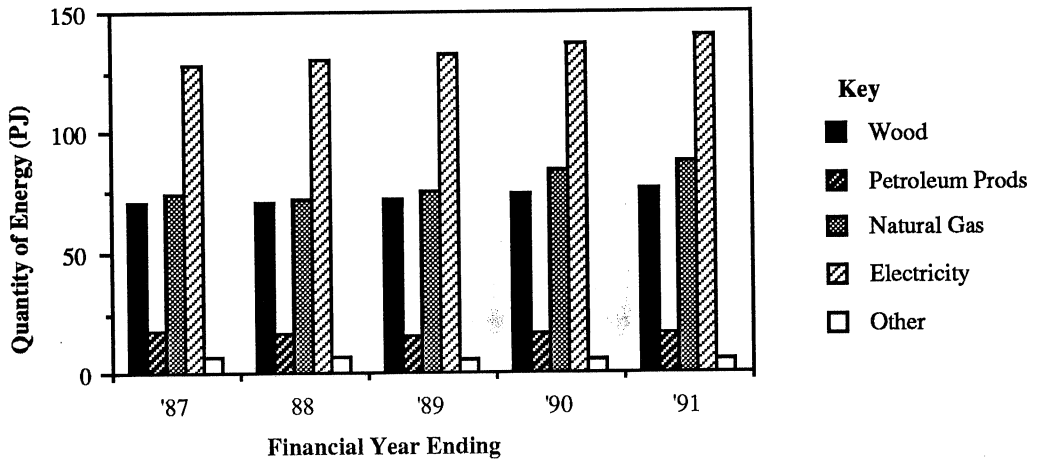
World Energy Consumption, 1988



Source: UN 1990, pp. 90-103

Natural gas and wood are the next highest power sources, accounting for 27 and 23 per cent respectively during the 1990-91 financial year. In 1989 natural gas was supplied to 21 per cent of Australians (IC 1991:a, Vol. III, p. 32, ABS 1991, p. 123). Other energy sources, including petroleum products, solar, town gas, briquettes and black coal together account for less than 7 per cent of final energy use (ABARE 1991, p. 64). While the total quantity of energy used in the domestic sector shows an increase over the time period indicated, the relative proportions of different fuels used has remained fairly consistent.

Figure 3.5
Australian Residential Power sources, 1986-87 to 1990-91



Source: ABARE 1991, pp. 60-64

The figures for wood as a final residential energy source deserve further discussion. The figures are surprisingly high, considering the lack of attention fuelwood receives in Australian energy and ESD literature[4]. The high figure for wood begs the questions of whether the data are correct, and if so, whether Australia's high use of fuelwood has any important implications for ESD in energy. Two separate studies have estimated the quantity of wood used as fuel in the residential sector. The first is the

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[4] No section in the Compendium of Ecologically sustainable Development Recommendations (ESDSC 1992:b) deals with issues relating to fuel wood. In the same publication, five recommendations refer to electricity and three to gas utilities while a further nine refer to public energy utilities in the energy production section alone. Coal boards and electricity utilities throughout Australia are required to publish annual reports, state and local governments regularly publish reports on gas and electricity supply issues, and many national studies and reports have focused on electricity and gas in recent years (see for example Committee of Inquiry into Gas and Electricity Tariffs in Western Australia 1989, Electricity Commission of New South Wales 1989, Industry Commission 1991 (which despite its title deals almost exclusively with electricity and gas supply), Australian Bureau of Statistics 1989, Australian Gas Association 1988, Electricity Supply Association of Australia 1990). In contrast, few studies have dealt with issues pertaining to fuel wood. Those that have, have tended to be locally oriented, minimally funded, and often unpublished (see for example Todd 1986 and Morse 1985) although two recent national studies were apparently not used in the analysis of either the Energy Production or Energy Use Working Groups (Todd 1988; Forestry Technical Services Pty. Ltd & University of Tasmania 1989).

ABARE study from which the data for Figure 3.5 are derived. The second is a study conducted by Forestry Technical Services (FTS) and the University of Tasmania (UT) in 1989. The methodologies of the two studies are explained in Appendix Three. The two studies' estimates of quantities of fuelwood used in the Australian residential sector differ by only 300 mega-joules or less than half a percent of estimated fuelwood used in the residential sector in 1988. This minor variation suggests that the data are probably accurate.

There is significant variation between states in the importance, environmental impact and sustainability of the fuelwood industry. In Tasmania for instance in 1985, 52 per cent of households used firewood for heating (space, water and food) and fuel wood accounted for almost 60 per cent of total residential energy use (Todd 1986, p. 25, 29). Todd's study on fuelwood use in Tasmania reported no serious environmental impacts from wood burning. Todd predicted future shortages in fuelwood supply only in urban forest areas, suggesting that the industry is largely sustainable (Todd 1986, p. 30). In the Australian Capital Territory (ACT) in 1983, 29 per cent of households used firewood for heating, and the quantity of energy obtained from firewood was about 33 per cent of the quantity of electricity used (Morse 1985, p. 10). Environmental problems such as air pollution from wood smoke and habitat destruction from wood harvesting are considered serious in the ACT (Dunn, 1983 and MacArthur 1983 in Morse 1985, p. 1). While the industry is potentially sustainable, wood harvest has typically far exceeded plantation rates, and fuel wood resources are declining noticeably in and around the ACT (Morse 1985, p. 24).

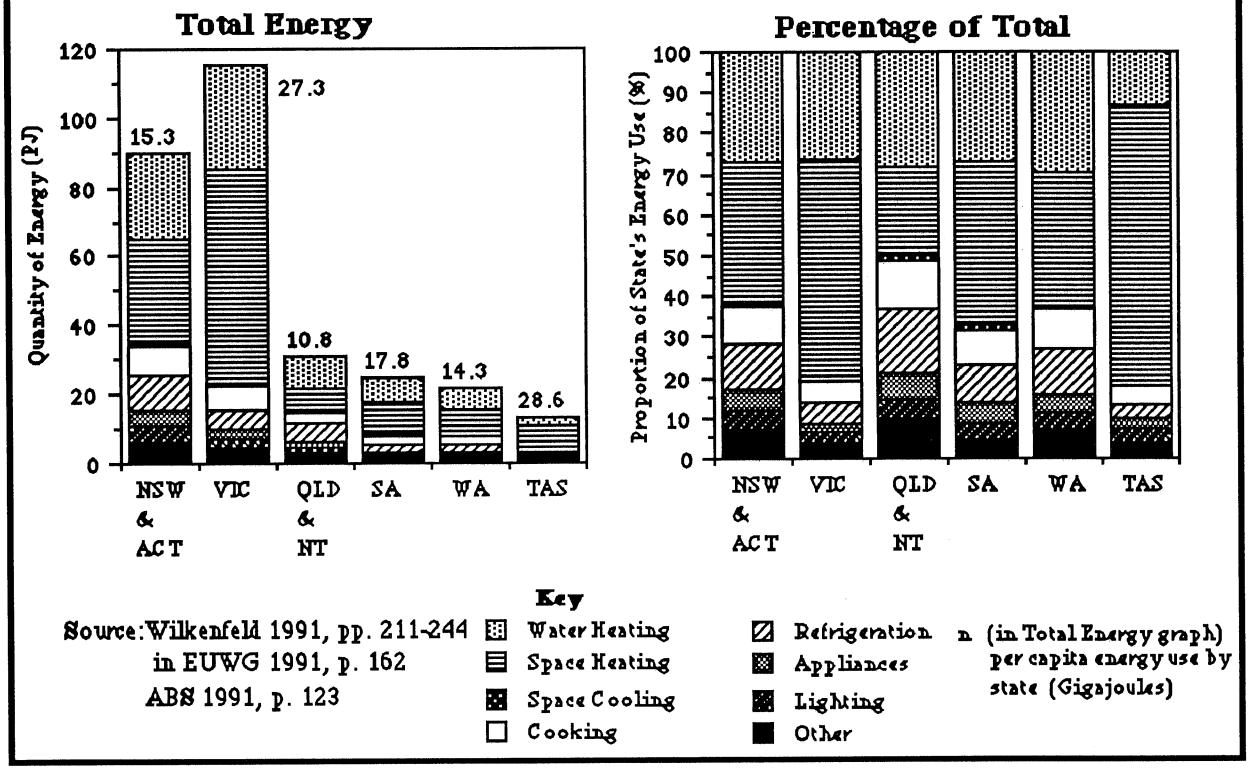
Figure 3.6 gives a breakdown of total energy used in fulfilling various residential energy services in Australia. It indicates that space and water heating (at 42 and 26 per cent of total energy used) are the energy services requiring the greatest energy inputs. Figure 3.6 also indicates marked differences between regions in both the quantity of energy used, and the proportion of each region's energy budget spent in fulfilling various energy services. The most populous states (New South Wales, Queensland and Victoria) exhibit the highest energy usage. Per capita energy usage[5] however varies significantly from state to state and is highest in the coldest states: Victoria and Tasmania, in which the proportion of total energy spent on space heating is also the highest.

---

[5]Note that the per capita figures for energy usage presented in Figure 3.6 are lower that those presented in Figure 3.4 because those in Figure 3.6 include only domestic energy usage whereas those in figure 3.4 covered total Australian energy usage.

Figure 3.6

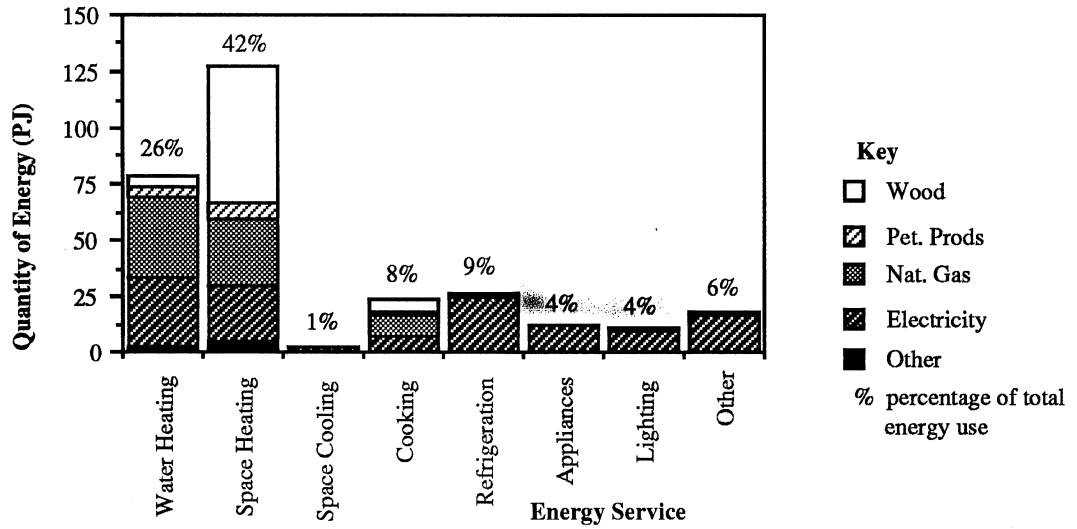
Australian Residential Demand for Energy Services, by Region, 1986-87



Source: Wilkenfeld 1991, pp. 211-244 in EUWG 1991, p. 162
ABS 1991, p. 123

An analysis of the compatibility of demand and supply of energy requires knowledge both of energy services, and energy sources. Data on both energy sources and services used in the Australian residential sector are available, but no study that this author is aware of has integrated this data to allow for a comprehensive analysis of energy demand and supply compatibility. Figure 3.7 presents this authors estimates of quantities and sources of energy used in provision of different energy services in Australia. The methodology used in deriving the data for this graph is explained in Appendix Four. The data are unlikely to be completely accurate, but provide a reasonable approximation of the relative proportions of fuel types used for particular purposes.

Figure 3.7
Australian Residential Energy Service by Fuel Source, 1986-87



Sources: ABARE 1991, p. 60; Todd 1986, p. 6;
Wilkenfeld 1991, pp. 211-244
in EUWG 1991, p. 162

Figure 3.7 suggests that there is considerable scope for increasing the compatibility of energy sources with services in Australia's residential sector. This is particularly the case for the energy services of water and space heating, which between them account for 68 per cent of Australia's final residential energy use. The energy for approximately 38 per cent of residential water heating and 20 per cent of space heating in Australia is provided by electricity. The conversion efficiency of Australian electricity production is around 32 per cent (IC 1991:a, Vol. III, p. 15). Overall, the conversion efficiency for electric heating is much lower than this - probably around one per cent, as discussed in Chapter 2 - due to imperfect appliance efficiencies. Solar water heating is a technically and economically viable alternative to electric water heating in most Australian states during most months of the year and incurs far fewer negative environmental costs than does electric water heating[6] (Taylor 1991, Lowe, Backhouse & Sheumack 1984). Electricity usage in space heating could also be significantly reduced by improved insulation, and use of housing designs that maximise passive solar energy capture (Diesendorf 1991, p. 18).

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[6] Note that this means that solar energy is an economically viable alternative to electricity even under existing electricity pricing regimes that award hidden subsidies for electricity use. These subsidies are explained in the section below on "Major Actors in the Australian Residential Energy Supply". For detailed discussions on these issues see Rosenthal & Russ 1988, and Kellow 1986.

Natural gas fuels approximately 46 per cent of residential water heating and 24 per cent of residential space heating in Australia. This is far less wasteful of raw energy than achieving the same services using electricity, since with natural gas (as with fuel oil, coal and wood), the only conversion occurs at the point of use. More than 47 per cent of space heating is fuelled by wood. As with natural gas, combustion is during final use and conversion efficiencies are high in relation to those for electric heating. The efficiency of fuelwood use in Australia is between 10 and 60 per cent, depending on the type of appliance used (FTS & UT 1989, p. 36). Also, as was discussed above, wood is a renewable energy source in theory, that even at present is sustainably used in some areas of Australia. Once again though, active solar water and passive solar space heating are technically and economically viable alternatives to each of these sources that incur fewer and less severe environmental costs.

Australian Contributions to Global Warming from Energy

Potential global warming from an enhanced greenhouse effect was referred to briefly in Chapter Two as one of the negative environmental effects of fossil fuel burning. There is considerable disagreement within the scientific community about both the likely impacts of, and the appropriate policy responses to global warming. Different analyses of the likely impact of an enhanced greenhouse effect are not discussed in this dissertation[7]. Different approaches to policy development in response to global warming are discussed in this and later chapters.

The term 'global warming' refers to the projected rise in temperature of the Earth's surface that is forecast to result from anthropogenic emissions of certain gases that accumulate in the Earth's atmosphere and trap solar radiation. Some predicted impacts of global warming include changes to:

i) agriculture and forestry, from increased incidence of extreme events such as flooding, drought, forest fires and crop pests;

ii) natural terrestrial ecosystems, from vegetation zone losses and species extinctions;

iii)hydrology and water resources, from increased or decreased precipitation depending on region;

iv)human settlements, from migration due to sea level rise;

[7]For discussion on global warming debates see Moran, Chisholm & Porter 1991, Ch. 10; Lowe 1989; Pearman 1988; National Greenhouse Advisory Committee 1992; IPCC 1990; Jager and Ferguson 1991.

v)energy, transport and industrial sectors, derived from climate-change response strategies and changes to water and biomass resources;

vi)human health, depending on size of populations, the size of the area under national control, and means available for effective response;

vii)the world ocean, from sea-level rise, modification to ocean circulation and associated changes to marine ecosystems;

viii)seasonal snow cover, ice and permafrost. (Izrael 1991, pp. 83-85; Weihe & Mertens 1991, p. 357)

About 61 per cent of the calculated global warming since 1765[8] is the result of anthropogenic CO_2. Atmospheric concentrations of CO_2 have increased by 50 per cent on pre-industrial levels. The sources of anthropogenic CO_2 are fossil fuel burning and deforestation, accounting for approximately 65 and 35 per cent of total CO_2 increases respectively (Marland 1989 in Siegenthaler & Sanhueza 1991, pp. 48-49). The rate of emissions per unit of energy produced differs between common fuel sources. For instance, emissions from coal combustion are higher per unit of energy released than those for any other fuel, while natural gas combustion results in the lowest per unit emissions of any fossil fuel (IC 1991:b, Vol II, p. G11). Burning renewably grown biomass results in no net addition to atmospheric CO_2 since the CO_2 emitted from burning is exactly equal to the carbon reabsorbed from the atmosphere when replacement biomass is grown (Mills, Wilson & Johansson 1991, p. 312). Scientists from the Inter-governmental Panel on Climate Change (IPCC) have calculated that stabilising atmospheric concentrations of the major greenhouse gases at 1990 levels would require immediate reductions of over 60% of anthropogenic emissions of CO_2, in addition to reductions in other greenhouse gas emissions (IPCC 1990, p. xi). Such reductions are unlikely to be achieved in the absence of strong political commitment to them, since 'business as usual' scenarios predict a 69 per cent rise in CO_2 emissions by the year 2020 (World Energy Conference 1989, quoted in Mills, Wilson & Johansson 1991, p. 311).

The contributions to, and predicted severity of effects of global warming are inequitably distributed throughout the world. In general, developed countries have been responsible for more greenhouse gas emissions but are less vulnerable to the

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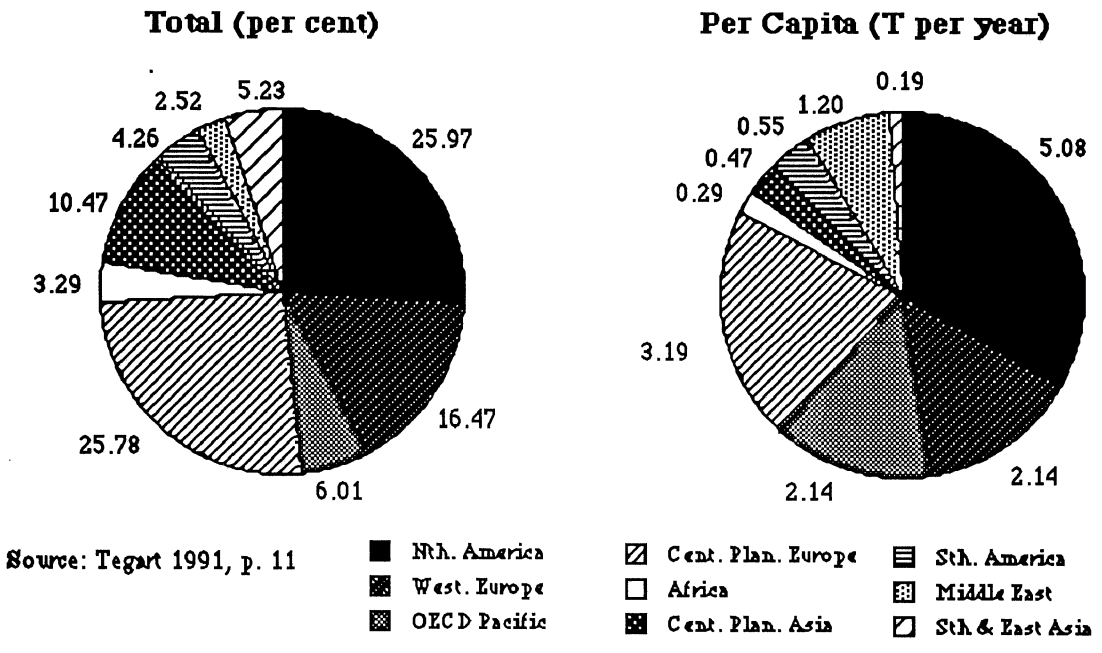
[8]The start of the industrial revolution, and the date identified by researchers contributing to the Inter-governmental panel on Climate Change as the time period at which anthropogenic CO_2 emissions started their exponential climb (see for example Siegenthaler & Sanhueza 1991).

effects of global warming than are developing countries. In illustration, both total, and per capita greenhouse gas emissions are higher for developed than underdeveloped countries. For example, in 1985, mean per capita CO_2 emissions in the USA were 27 times as great as those in South and East Asia. Nearly 26 per cent of total emissions were from North America, compared to just over five per cent from South and East Asia (Tegart 1991, p. 15). Predictions by scientists from the IPCC suggest that the tropical and sub-tropical regions, where most underdeveloped countries are located will experience considerable climate change that will exacerbate environmental and social problems in those areas (Izrael 1991, pp. 82-83). Australian CO_2 emissions are high even among developed countries. In 1988, Australia was responsible for 2.7 per cent of total CO_2 emissions from OECD countires (International Energy Agency (IEA) 1991:a, pp. 198-99). Australian per capita CO_2 emissions are among the world's top ten (National Greenhouse Advisory Committee (NGAC) 1992, pp. 28-30; Tegart 1991, p. 15). This is indicated in Figure 3.8, which shows total and per capita CO_2 emissions from various areas throughout the world.

Figure 3.8

Carbon Emissions from Combustion of Fossil Fuels, 1985.



Major Actors in Australian Residential Energy Supply

The discussion above suggests that major actors in Australian residential energy industries are those supplying coal (as the major input into electricity), natural gas, electricity, wood, and to a lesser extent, alternative energy systems. Other key actors include energy intensive industries whose energy demands influence Australian energy supply decisions. The internal structures and relationships between these actors are described in this section.

Coal, natural gas and electricity supply industries have several key features in common. They each

> i) require large and lumpy capital investments which, once commissioned, have little alternative use;
>
> ii) involve extensive transmission and distribution networks which result in parts of the industries natural monopoly characteristics;
>
> iii) consist of enterprises which produce virtually identical outputs and;
>
> iv) have many major domestic markets in common (IC 1991:a, Vol. II p. 6)[9].

Despite these similarities there are significant differences between the structures of the industries.

The Australian domestic coal industry consists of a large number of sellers and a limited number of buyers. In 1990, the industry consisted of 55 privately owned black coal mining companies located primarily in Queensland (21 companies) and New South Wales (29 companies) (JCB & QCB 1991, pp. 46-50). Brown coal mines operated by the Victorian Government produced 97 per cent of coal mined in that state in 1987, while two privately owned mines produced the remainder (DPIE & ABARE 1989). No coal mines operate in the Northern Territory or the Australian Capital Territory. Approximately 75 per cent of domestic coal sales are to publicly owned electricity utilities (JCB & QCB 1990, p. 54). As relatively unchallenged buyers, these utilities operate as monopsonists and pay only, or close to the supply price for coal. The largest aspect of government involvement in coal mining operations in Queensland and New South Wales is in their provision of transport infrastructure. This usually consists of rail links to sea ports or electricity utilities.

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9 The Industry Commission report cited refers only to electricity and gas industries. However the characteristics are also common to both coal and natural gas industries.

Rail and port use is either charged at fixed rates or negotiated in contracts between state government bodies and mining companies. Government revenue from infrastructure is generally less than replacement but more than operating costs (see Crean & Cook 1992, pp. 13-16).

Natural gas can generally only be economically produced when gas pipelines link reserves to markets. Pipeline developments involve considerable capital investments (DPIE 1991, pp. 1-7). Transmission and distribution of natural gas in Australia are performed separately, by State Government bodies in most states although in some cases gas pipelines and reticulation networks are privately owned and operated (DPIE 1991, p. 6; IC 1991:a, Vol II, p. 7). State and Northern Territory government regulations cover all phases of natural gas transmission and distribution. These regulations give significant power to State Governments. For instance the regulations have enabled them to control and even block interstate movements of natural gas, sometimes at the cost of efficiency (DPIE 1991, p. 12). The Commonwealth Government controls one pipeline through the Pipeline Authority, that links South Australian gas reserves to markets in New South Wales. At the time of writing this was also Australia's only interstate pipeline (DPIE 1991, p. 6). Key actors in the natural gas industry are thus state authorities in charge of transmission and distribution of natural gas, and the Pipeline Authority.

The Australian electricity industry is organised almost entirely on a state basis. In both Queensland and New South Wales there is a two tier structure, where state electricity authorities produce electricity and market it to municipal councils who then sell it to final users. In South Australia, Tasmania, Victoria and Western Australia a single authority both produces and retails electricity to the residential sector (Rosenthal & Russ 1988, pp. 24-25). Electricity is generally produced in large power stations. For instance two recent New South Wales stations took six to seven years to construct, have a capacity of about 660 megawatts of and cost approximately $820 million (1991-92 Australian dollars) (Rosenthal & Russ 1988, p. 53; ABS 1992, p. 71). The major actors in the Australian electricity industry are thus the state government electricity boards and authorities.

Some Australian electricity authorities have recognised that economic benefits may derive from energy efficiency and improved use of energy systems. In response to this some authorities, such as SEQEB have initiated demand management strategies. These include promoting demand tariffs that encourage off-peak electricity use, recommending energy efficient hardware such as compact fluorescent lamps, and explaining 'do it yourself' home energy audit procedures (see SEQEB 1991; SEQEB

1992:a, p. 6). Economic and environmental benefits from these measures are emphasised in publications, and consumers are assured that their quality of life will not be reduced. Thus, the measures are promoted only to the extent that they provide economic benefits either to electricity consumers, producers or both. They therefore represent a move towards economic efficiency as well as a response to global warming (see SEQEB 1992:a, p. i; SEQEB 1992:b, p. 3).

Australian fuelwood is supplied either by fuel merchants, part-time firewood cutters, or is collected by final users. Government intervention in the fuel wood industry is minimal, and is restricted to regulations restricting wood collection on publicly controlled land. Fuelwood suppliers are not required to report quantities sold to any authority. These characteristics of the fuelwood industry result in fuelwood data being less readily available than those for other Australian energy sources (Todd 1986, pp. 1-2).

Important and potentially important alternative energy systems in Australia include those harnessing solar and wind energy, and systems that significantly improve energy efficiency or energy storage[10]. Westwind, in Western Australia is the only Australian manufacturer of wind generators. Westwind has installed a number of wind-powered generators in conjunction with the Western Australian State Electricity Commission operates a wind farm at Esperance. The State Electricity Commission of Western Australia is planning to install "many more wind generators at Esperance and other sites purely for commercial reasons" (Taylor 1991, p. 13). Other alternative energy technologies that are both produced and marketed in Australia, include fuel ethanol, domestic solar water heating units, photovoltaics, and a range of energy efficiency innovations. The failure of energy alternatives to achieve full commercialisation in Australia is due to a range of non-technological factors, especially the structure of energy markets. Even when the cost of alternatives is lower than conventional energy systems, market imperfections caused by both intrinsic characteristics of alternative technologies, and the contexts in which they are purchased provide disincentives for consumers to select alternatives.

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[10] It is worth noting the irony of energy classification that labels these systems 'alternative'. As Patterson so eloquently notes, human use of energy from the sun, either directly, or indirectly as wind and water energy predates written history. In contrast, fossil fuel use has been common only since the industrial revolution, about 225 years ago, and nuclear energy was first harnessed in the 1930's (Patterson 1990, pp. 40-42, 128-129).

Intrinsic characteristics include that: i) the small scale of energy alternatives means that individual purchase decisions involve only small increments of energy in relation to conventional systems; ii) initial costs for alternatives are high compared to conventional systems; iii) potential consumers are unfamiliar with alternatives; and iv) conventional energy suppliers have dominated perceptions of energy and have rarely encouraged alternatives. Constraints derived from the context of decisions include that: i) energy users often pay little attention to different energy costs of items since energy usually represents a small proportion of total costs; ii) consumers tend to face higher interest rates and apply higher discount rates than suppliers; iii) consumers tend to have a preference for known and familiar equipment and suppliers; iv) benefits for efficient energy use often do not accrue to purchasers of energy hardware; and v) there is little peer group and community expectation that conservation measures will be taken (Saddler 1990, pp. 10-11). Producers and proponents of alternative energy systems argue that removal of non-technical barriers to development of wind and solar industries would allow Australia to "make the transition to energy supply systems which are totally renewable" during this and the next century (Taylor 1991, p. 4).

The influence of high energy using industries on energy planning in Australia can best be understood in the context of Australian federalism. The Australian Constitution awards major revenue earning capabilities to the Commonwealth Government, while leaving the States in control of natural resources within their boundaries. One of the few ways in which States can earn discretionary revenue and encourage development is by exploiting their natural resources (Walker 1991, p. 5; Galligan 1982, p. 238). There have been many instances in which State Governments have offered electricity at below-cost prices to companies in energy intensive industries in order to secure their investment in the State, and thereby encourage development. In some cases, the proposed developments have been less successful than anticipated and their demand for energy has been lower than expected. This has meant that State Governments have been left with electricity utilities for which there is no demand and which therefore generate no cash flows. In these cases the costs of excess generating capacity have been passed on to other Australian energy users and tax-payers (Rosenthal & Russ 1988, pp. 179-186; Kellow 1986, pp. 2-9, 13-14). State Government energy supply decisions are thus influenced by energy intensive industries, and this influence can affect residential energy users.

Conclusion

Australian energy systems are based primarily on fossil fuels. Low prices, and hidden subsidies for these fuels encourage overuse of fossil fuels, and under-use of renewable energy sources. This is particularly apparent when environmental concerns, such as global warming are considered. Australia captures little of its abundant ambient wind and solar energy which could replace fossil fuels in fulfilling many energy services. Fossil fuels, and electricity produced by fossil fuel consumption are major energy sources for residential energy services. Space and water heating, which between them account for more than three-quarters of total residential fuel use could easily, and economically be achieved by passive and active solar systems in most parts of Australia during most times of the year. Any strategy aiming to engender sustainability in Australian energy use should take these concerns into consideration.

PART II: DISCUSSION OF STRATEGIES

It is beyond the scope of this dissertation to interpret the relevance to ESD of every energy issue. Such a task would necessarily render the discussion and conclusions of this study superficial. A more useful study is provided by an in-depth discussion of a limited number of energy policy issues that are highly significant in ESD debates. Three such issues are discussed in this dissertation. They are versions of least-cost planning, performance indicators for energy provision and use, and Australian responses to the enhanced greenhouse effect. The discussion on least-cost planning looks at the different energy systems that would result from different versions of this approach to energy system planning. Discussion about performance indicators describes the signals that are recognised by different energy analysts in assessing the effectiveness of an energy system. The enhanced greenhouse effect is a particular environmental impact of energy systems and the discussion on responses to it has important international implications that are largely absent from the other two issues. Part II of this dissertation, consisting of Chapters Four, Five and Six investigates conventional Australian, economic, and ecological approaches to each of these energy issues. It compares these to one another, and to the approach to each issue recommended in the *National Strategy for Ecologically Sustainable Development.*

These particular three issues have been selected for in depth discussion for several reasons. Firstly, each has recognisable economic and ecological aspects. This means that their analysis lends itself well to this dissertation's central theme of the significance of different disciplinary perspectives in defining policies for ESD. Secondly, each issue is well represented in the final recommendations presented in Australia's *National Strategy for Ecologically Sustainable Development* (ESDSC 1992:a) and its supporting document, the *Compendium of Ecologically Sustainable Development Recommendations* (ESDSC 1992:b, Sections 2, 3, 6). This means that there is ample data to draw on in explaining the approach taken to each issue within the framework of the Federal Government's ESD process. Thirdly, each issue relates to a very different aspect of Australian energy systems so a range of different problems are addressed.

CHAPTER 4: VERSIONS OF LEAST-COST PLANNING

Introduction

Energy system planning refers to the goals and strategies adopted or endorsed by different analysts for improving energy systems. The *National Strategy for Ecologically Sustainable Development* recommends a 'least-cost' approach to energy system planning in Australia. Least-cost planning (LCP) represents a significant departure from traditional Australian approaches to energy system planning. This chapter describes these traditional approaches, and compares them to the LCP strategy recommended in the *NSESD*.

Economic and ecological perspectives on ESD could suggest a range of strategies for energy system planning. Proponents of each perspective would also support a distinctive version of LCP. The theme of this dissertation is to explore the strengths and limitations of the *NSESD* by comparing its recommendations to a range of alternatives. For this reason, it is more insightful to compare the different approaches to LCP endorsed by ecologists and economists than to describe a range of approaches to energy system planning. This chapter compares the likely impacts on residential energy systems of different contexts within which LCP could be applied. To facilitate the discussion on LCP that comprises the bulk of this chapter, the general LCP strategy is first described.

The Least-Cost Approach to Energy System Planning

Integrated LCP is a synoptic model of energy system planning that focuses on energy service provision. LCP is an application of the neo-classical economic least-cost rule. According to this rule, maximum efficiency can only be achieved when production costs are minimised (Jackson & McConnell 1985, pp. 421-23). LCP represents a change from conventional energy system planning because it identifies the 'product' as fulfilment of an energy service rather than a quantity of energy supplied. The context in which LCP is applied will significantly affect the resulting energy system. In particular, LCP will lead to quite different energy decisions when undertaken by public, as opposed to commercial utilities, when it is applied in perfect, or imperfect markets, and when social, as opposed to private costs are recognised.

The ideal model of synoptic decision strategies involves consideration of all possible options, selection of the option that best satisfies all requirements, and

implementation of the selected policy. The appeal of synoptic decision strategies derives from their comprehensiveness, and political neutrality (see Braybrooke & Lindblom 1970, pp. 37-41). Figure 4.1 is a diagrammatic representation of the LCP framework which clearly shows the synoptic nature of the strategy. According to the figure, LCP involves identification of energy service requirements followed by identification of all potential policy responses, identification of all potential instruments, and development of a strategy bundle. Implementation occurs outside the framework, and is incorporated only as "possible follow-up work to refine [the] strategy" (OECD & IEA 1989, p. 79).

Unfortunately, despite its appeal, the synoptic ideal is both impossible to achieve in practice, and can be unhelpful to approximate. Difficulties in achieving synoptic decision making stem from:

i) limited problem solving capacities of humans;
ii) inadequacies of available information;
iii) costliness of analysis;
iv) the model's failure to adapt to failures in constructing satisfactory evaluative methods;
v) the impact of values on fact identification;
vi) the openness of real variables;
vii) the analysts need for strategic sequences of analytical moves; and
viii) the diverse forms in which problems arise;

(Braybrooke & Lindblom 1970, pp. 48-57)

Approximation of synoptic models can be unhelpful because approximations involve simplification, and simplification necessarily requires a loss of comprehensiveness and this reduces political neutrality. Yet these are the proclaimed virtues of the synoptic model (Braybrooke & Lindblom 1970, pp. 49-50).

A recognition of the inherent limitations of synoptic decision strategies such as LCP does not render the *NSESD's* recommendations to adopt LCP meaningless. Rather it means that adoption of LCP will not automatically lead to achievement of the goal of providing optimal energy services at the least-cost. Instead, the context in which the strategy is adopted will significantly affect the outcome of any particular decision (see Ham & Hill 1984, pp. 101-110). An understanding of the context within which LCP decisions are made would allow decision makers to pre-empt areas in which comprehensiveness is likely to be low, which in turn would allow them to ensure that those areas were specifically investigated. Contextual factors that are likely to

influence policy formulation and implementation in energy system planning are described in the next section.

Contextual Variables in Least-Cost Planning [1]

The context within which LCP is undertaken will influence the decisions that are made as a result of this planning strategy. Three important contextual variables are: i) industry ownership and control; ii) industry structure; and iii) cost considerations. The discussion below indicates the likely effect of these variables. on decision strategies deriving from different values for each For each variable, the discussion compares the imperatives derived from extreme positions. In practice, the extremes are unlikely to be realised. Instead, the context of decision-making will lie somewhere between the two extremes. Despite this, it is worthwhile sketching the extreme positions since this will shed light on the rationale behind observed policy recommendations. The implications of the context of LCP for energy system planning will be discussed in later sections of this chapter.

At the two extremes for ownership and control are purely commercial, and purely public industries. The goal of any economically rational commercial enterprise is to maximise profit. In general, the profit-maximising strategy for a firm is to produce the quantity of a product that equates its marginal cost to its marginal revenue (Tisdell 1982, pp. 182-84). In contrast, it is not necessary for a public enterprise to make a profit. Many government-owned and operated ventures are primarily concerned with the provision of a range of goods and services for which there is no natural market (see Ham & Hill 1984, pp. 23-25). The goal for a public enterprise would be to *optimise* a range of values (for example social equity, reliability and revenue generation) subject to a cost consideration.

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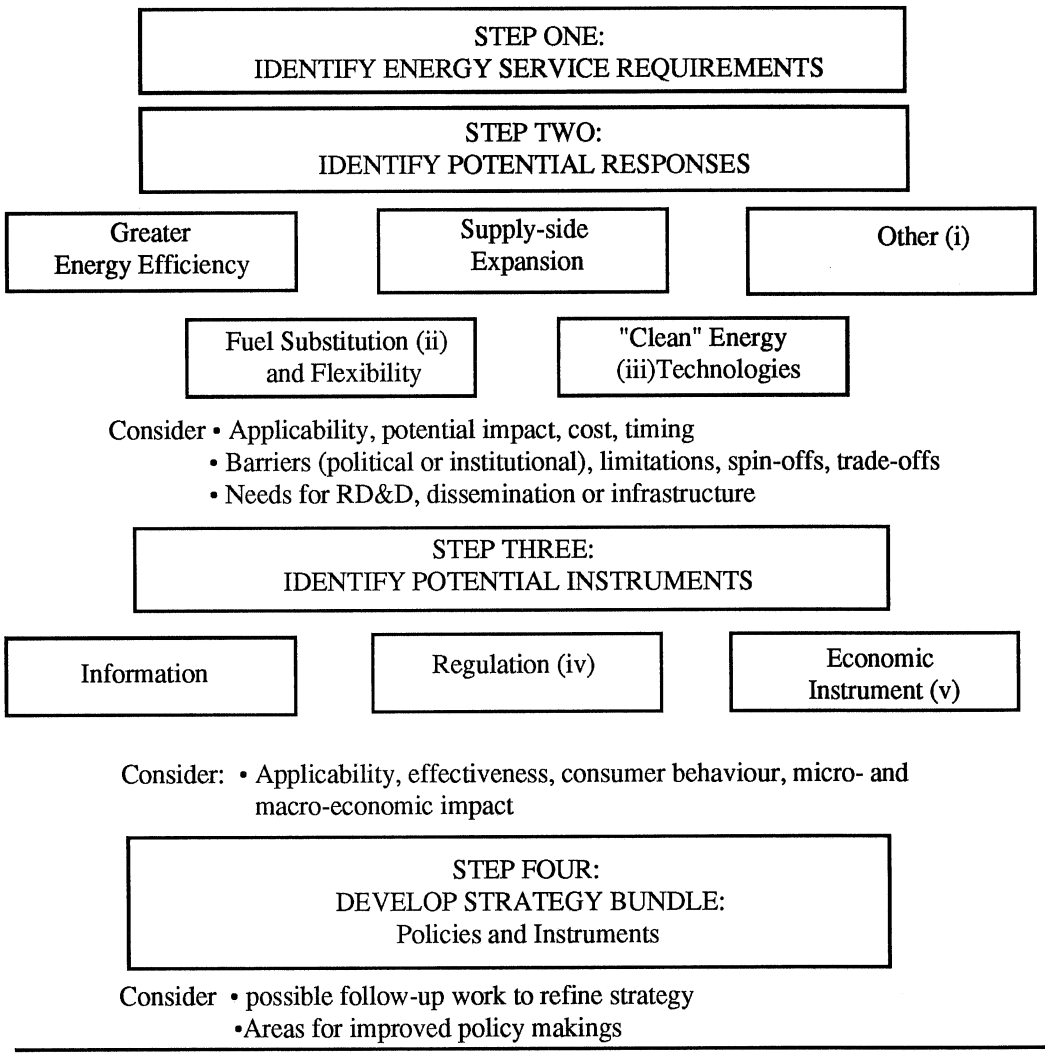
[1] The variables that are described in this section are explained more fully in economic texts. For additional discussion see Tisdell 1982, Jackson & McConnell 1985.

Figure 4.1
Framework for Least-Cost Planning



(i) Other responses would be mostly non-energy-related, such as structural changes in economic systems
(ii) Fuel substitution refers to switches in fuel qualtiy or fuel type (e.g., from fossil fuels to renewable energy sources), or temporarty fuel switching tominimise seasonal or short-term environmental impacts (e.g. from gasoline to natural gas).
(iii) "Clean" energy technologiess are defined here as those which combine more energy efficient processes or operations and reduced pollutant production without necessarily entailing a change in the form of energy used.
(iv) Regulation here is meant to include the so-called "command and control" and related measures, which are used in protection of the environment (from emission standards to the requirements of environmental impact assessment procedures) and all of those applied to energy security (from end-use efficienty standards to requiring the use of fuels in certain sectors).
(v) Economic instruments include the broad areas of taxes, charges, subsidies, and pricing policies, whether used to reinforce regulations and thus increase the overall effectiveneess of their environmental protection actions or to subsidise the support of RD&D of new pollution-control or "cleaner" energy technologies.

Source: Adapted from OECD and IEA 1989, p. 79.

Competitive (or perfect) and monopolistic (or imperfect) industry structures are the extreme cases of the second contextual variable for LCP. In a competitive market, the demand curve facing each firm is perfectly elastic (horizontal), therefore no firm can influence product prices, regardless of the quantity of goods or services produced. Under competitive conditions the demand curve facing a firm is equal to its marginal revenue since the quantity of goods sold by any firm cannot influence the market price (Tisdell 1982, pp. 182-84). Figure 4.2A shows the demand curve facing a firm in a perfectly competitive market and indicates the profit-maximising price (PA) and quantity (QA). The demand curve facing a monopolist is inelastic (downward sloping), and is above the monopolist's marginal revenue curve (see Figure 4.2B). As with competitive firms, monopolists maximise profits by producing a quantity that equates marginal costs to marginal revenue. In contrast to a perfectly competitive market structure, the quantity produced at this point is less than would be demanded under perfectly competitive conditions (where production would occur at the point at which demand equals marginal costs), and the price per unit of the product is higher (see Figure 4.2B). This means that the profit-maximising strategy for a monopolist results in under-supply of their product, and generation of super-normal profits for the monopolist (Tisdell 1982, pp. 208-09).

Government-owned and operated industries are frequently monopolies (for example as the sole producers and distributors of electricity in an area), and, as was stated above, their goals may be other than profit-maximisation. According to the theory of public utility pricing, government owned utilities should produce where price is equal to marginal cost and thus not take super-normal profits. This allows public utilities to optimise a range of non-economic values.

The third contextual variable influencing the outcome of LCP concerns the types of costs considered in decision making. The two extremes for this variable are when only private, or all social costs are considered. Private costs are those are that borne directly by economic agents and that are therefore automatically considered in economic decisions. Social costs are the sum of private costs and externalities. Externalities are the negative impacts of economic activities that are borne by society as a whole, rather than by those who are benefiting from the activities (see Baumol & Oates 1988, Ch. 3). Environmental costs are externalities associated with the negative environmental impacts of economic activity. Environmental costs associated with energy production and use include the environmental damage that occurs at all stages of energy harness (see Table 2.1).