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Prospects for Energy-Economic-Environmental Research in SE Asian Countries

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PROSPECTS FOR ENERGY-ECONOMIC-ENVIRONMENTAL RESEARCH IN SOUTH EAST ASIAN COUNTRIES

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1. INTRODUCTION

1.1 Energy, Economy and Environment (EEE)

Energy-economic-environment (EEE) interactions can be expected to play a crucial role in the development process. Energy is a critical resourced underpinning economic growth. Countries in SE Asia have reached different levels of economic welfare, and this is reflected in their energy use patterns. Some of the countries are well endowed with energy resources - to the extent of being major exporters of energy. Others face serious poverty, accompanied by low levels of energy use. To achieve improved standards of living throughout SE Asia, significant increases will be needed in supplies of available energy.

As noted by Ramani (1992) environmental quality is contingent on economic growth, and at the same time economic growth may be constrained by environmental quality. The developing countries in SE Asia are currently in a state of transition from traditional to modern energy sources, that will require major structural change to the economy and energy system. So far, attempts to safeguard the environment have been mainly of a curative nature.

The current focus on sustainable development has brought new problems in the management of natural resources and the environment, and energy resources in particular (ADB 1990). Possible constraints to sustainable energy development identified by Ramani (1992) include:

- low levels of awareness among decisionmakers
- conservative approaches to planning
- financial investment constraints
- wrong price signals
- institutional shortcomings
- technology diffusion problems

The management of energy systems requires a holistic approach that takes into account the multiple objectives of economic development, adequate resource supplies and management of environmental impacts. These objectives may be pursued at different scales, ranging from individual energy projects, through regional and national development considerations, to transnational and global policies.

While energy scarcity may occur in specific countries or in particular circumstances, it seems unlikely that there will be serious limitations on the overall supply of energy. Historically, predictions of impending scarcities for natural resources, including primary energy, have largely proved to be unfounded. Scarcities have been countered by changing the composition of energy inputs to the economic system, improved technologies for discovering and extracting energy, increased efficiencies in energy production and use, and improved energy demand management including energy conservation programs.

In the future, constraints on energy system management are more likely to derive from environmental considerations than from energy scarcity. The enhanced greenhouse effect has emerged as a serious international policy concern, raising critical questions about the extent to which countries will be able to rely on fossil fuels as a basis for future economic growth. As SE Asian countries endeavour to achieve improvements in their living standards over time, energy development within the region will be of relevance to individual countries, the SE Asian region itself and increasingly, the global community.

1.2 Policy Obstacles to Improved EEE Interactions

Various studies have been conducted into policy obstacles to improved EEE interactions. Sasmojo and Nawangsidi (1992 p201) contend that:

"The obstacles and barriers to better energy-environment interactions are:

- insufficient knowledge, tools and resources to devise strategies and plans for the development of environmentally sound energy systems
- the inability to devise policies and regulatory measures that implementable, achievable and effective
- the lack of accepted criteria regarding an appropriate balance between economic growth and ecological sustainability
- the difficulty of venturing into alternative policy paradigms, the development and formulation of which require a better understanding of technological functions and the capacity for assessing technological options."

Following an extensive policy review, Fesharaki and Wu (1992) concluded that:

- commercialisation of energy and conservation (reliance on market forces) is important for stimulating economic development, but if environmental impacts are not addressed, energy policy may be self-defeating
- each country must adopt policies suited to its own particular circumstances
- pricing is an important part of energy policy - prices are frequently distorted through government policies; low energy prices discourage indigenous energy development and encourage unnecessary consumption, which can create a bottleneck in the development process
- energy problems facing Asian-Pacific developing countries are complex but are not intractable

- there is a strong need to formulate long-term assessments of the energy sector; set up a long-term energy strategy; create a safe, stable and favourable investment environment for foreign investors; evaluate the relationship between energy consumption and the environment; and develop a workable energy policy in which the policy objectives, incentive structure and tax system are transparent and least distorted.

1.3 Role of EEE Research

Research into EEE interactions can facilitate assessments of future prospects for energy system management and assist in the evaluation of the impacts of policy options (Munasinghe and Meier 1993). A large body of EEE research has already been accumulated, initiated by the oil shocks of the mid-1970s and early 1980s. The main focus of that research was how to shift away from petroleum as a primary energy source, at the same time minimising adverse impacts on the global economy and on the environment.

The search for alternative configurations of energy systems led to accelerated R&D into energy technologies and the development and application of a wide range of tools for policy evaluation, including new economic models and tools, environmental impact assessment, risk assessment and integrated models combining economics, technology and management science. These methods can still be used to facilitate energy system planning and management, but where new challenges have arisen, further development may be required for concepts, tools and analytical methods.

1.4 Aims of Paper

The main aim of this paper is to examine EEE issues in SE Asian countries and identify areas of research that could be usefully undertaken in the future.The paper provides a general description of energy production and use in SE Asia, reviews existing literature and research programs, identifies special features and key policy issues and discusses models and methods that can be applied in policy evaluations, especially those drawing on economic concepts and techniques. Examples are cited from SE Asian countries and, where the context is relevant, other parts of Asia and the Pacific region. The scale of analysis covered in the paper ranges from individual projects to national and global policy arenas.

2. ENERGY PRODUCTION AND USE IN SE ASIA

2.1 Primary Energy Resources

Production of energy usually depends on natural resource endowments, although extraction technologies, infrastructure, processing facilities and economic costs are also relevant. The accompanying tables provide some basic information on energy resources for a selection of Asian countries (not all in SE Asia), Asia as a whole (including central Asia) and the world. Details of energy use in SE Asia are covered by ADB (1991a, 1993), Desai (1990a), Drysdale and Huang (1995), ESCAP (1991a), MacRae (1991), UN (1996), WEC (1992) and WRI (1996) as well as many others.

Table 2.1 provides estimates of in situ, recoverable and estimated additional reserves of coal. China has the largest reserves within the Asian region, and a significant proportion of total word reserves. Other important coal reserves occur in India and the Philippines.

Table 2.2 contains estimates of crude oil and natural gas reserves. The largest reserves occur in China, India, Indonesia and Malaysia.

Table 2.3 shows that large reserves of uranium are located in China, India, the Republic of Korea and, to a lesser extent, Japan and Indonesia. The table also indicates hydro power potential. The largest potential supplies occur in China, India, Japan, Indonesia and Malaysia.

2.2 General Pattern of Energy Production, Trade and Consumption

Drysdale and Huang (1995) have documented growth rates for energy use in East Asia. They note a strong correlation between per capita income and per capita energy consumption. The average growth rate in energy consumption during 1965-1989 for East Asian developing economies was 4.4 % per annum, more than double the growth rate for energy consumption for the world as a whole (2.1 %). The share of world energy consumption by these economies increased from 7 in 1965 to 9 % in 1980 and 11 % in 1989. Solid fuels account for a much larger proportion of energy use by these countries, compared with the world, largely due to China's use of coal which accounts for 90 % of its total energy use.

Statistics on primary energy production, trade and consumption by Asian countries in 1994 are shown in Table 2.4. All the entries are measured in a common energy unit (thousand terajoules). Per capita statistics are in gigajoules.

The table reveals the dominance of China as an energy producer in the Asian region, accounting for 28 % of total primary energy production in Asia and 10 % of the world total. India is also important energy producer. Other major producers include Indonesia, Japan, the Democratic People's Republic of Korea, and Malaysia.

China, India, Indonesia, the Democratic People's Republic of Korea, and Malaysia import relatively small amounts of energy (ie are largely self-sufficient). Indonesia and Malaysia export a significant proportion of their total production. Japan has a large energy import requirement.

An important feature of Table 2.4 is the large variation in per capita energy consumption within the region which ranges from less than 5 gigajoules for Bangladesh, Cambodia, Sri Lanka and Vietnam to 284 gigajoules for Singapore. The countries with low per capita consumption are among the poorest in the Asian region. These statistics also give an indication of the potential expansion in the demand for energy (and the associated scale of environmental impacts) if those countries follow a development path similar to that taken by the more highly industrialised countries. The quantities of energy potentially required by China and India are enormous.

2.3 Electricity

As shown in Table 2.4, electricity production is highest in Japan. China is the next most important producer, followed by the Republic of Korea, India and the Philippines. The growth rate for electricity production has averaged around 6 % per annum, implying a doubling every 12 years.

TABLE 2.1 COAL RESOURCES - 1993
(Million metric tonnes)

Country	Bituminous Coal, Anthracite			Sub-bituminous Coal, Lignite		
	In Situ	Recoverab	Additional	In Situ	Recoverab	Additional
Banglades	1054					
Cambodia						
China	177600	62200	363200	108800	52300	304700
Hong Kong						
India	196892	68047	86088	2600	1900	3932
Indonesia		962			31101	
Japan	8296	804		175	17	
Korea (DP	2000	300	2700	300	300	2200
Korea (Re	276	183	237			
Malaysia	15	4	78	126		575
Philippines	64650	29100	113300	14413	13000	30700
Singapore						
Sri Lanka	1000	850	5500	950	600	1600
Thailand						
Viet Nam	300	150				
Sub-Total	452083	162600	571103	127364	99218	343707
World	1092083	519357	4182297	1278281	512263	4414712

Source: United Nations (1996) 1994 Energy Statistics Yearbook, United Nations, New York

TABLE 2.2 OIL AND NATURAL GAS RESERVES - 1993
(Oil: million metric tonnes; N Gas: 10^9 cu m)

Country	Crude Oil, N Gas Liq Reserves	N Gas Proved Reserves
Banglades	1	370
Cambodia		
China	3264	1670
Hong Kong		
India	776	686
Indonesia	759	2000
Japan	8	30
Korea (DPR)		
Korea (Rep)		
Malaysia	585	2150
Philippines	33	98
Singapore		
Sri Lanka		
Thailand	27	175
Viet Nam	68	105
Sub-Total	5521	7284
World	140766	141203

Source: United Nations (1996) 1994 Energy Statistics Yearbook,
United Nations, New York

TABLE 2. 3 NUCLEAR AND HYDRO RESOURCES - 1993

(Uranium: million metric tonnes; Hydro: Gross theoretical capability 10^9 WH/yr)

Country	Uranium		Hydro
	Reasonabl Assured	Estimated Additional	
Bangladesh			
Cambodia			
China	72100		5922180
Hong Kong			
India	66360		2637800
Indonesia	5420	2150	400063
Japan	6600		596098
Korea (DPR)			
Korea (Rep	31000	21700	77201
Malaysia			107000
Philippines			46759
Singapore			
Sri Lanka			10000
Thailand			55500
Viet Nam		200	6490
Sub-Total	181480	24050	9859091
World	3643542	1106875	33989264

Source: United Nations (1996) 1994 Energy Statistics Yearbook, United Nations, New York

TABLE 2.4 PRODUCTION, TRADE AND CONSUMPTION OF COMMERCIAL ENERGY - 1994
(Thousand terajoules and gigajoules per capita)

Country	**Primary Energy Production**					**Imports**	**Exports**	**Consumption**					
	Total	Solids	Liquids	Gas	Electricity			Per Capita	Total	Solids	Liquids	Gas	Electricity
Bangladesh	241		5	233	3	91	0	3	305	0	68	233	3
Cambodia	0				0	7		1	7	0	7		0
China	33488	25930	6115	684	758	1208	1564	27	32020	25648	4937	684	751
Hong Kong						821	229	69	403	189	191		23
India	8690	6370	1339	664	317	1997	3	11	10073	6662	2424	664	322
Indonesia	7483	837	4238	2323	84	538	4415	14	2651	103	1558	905	84
Japan	3569	169	30	93	3277	16378	349	146	18209	3490	9061	2381	3277
Korea (DPR)	2646	2561			85	236	13	123	2896	2625	187		85
Korea (Rep)	793	140			653	5321	497	111	4926	1176	2784	313	653
Malaysia	2309	5	1331	953	20	513	1381	67	1322	58	731	514	20
Philippines	279	34	13		232	652	22	12	827	62	533		232
Singapore						3069	1754	284	800	1	799		0
Sri Lanka	15				15	97	4	5	85		70		15
Thailand	716	187	159	354	16	1183	47	31	1830	225	1231	354	19
Viet Nam	518	164	297	0	56	164	351	5	339	118	164	0	56
Sub-Total	60747	36397	13527	5304	5516	32275	10629	61	76693	40357	24745	6048	5540
Asia	117720	39789	56474	15063	6394	39837	48766	30	101224	44150	35496	15147	6431
World	348568	97619	136759	79688	34503	123732	124055	58	329945	98340	118813	78293	34499

Source: United Nations (1996) 1994 Energy Statistics Yearbook, United Nations, New York

TABLE 2.5 NET INSTALLED CAPACITY OF ELECTRIC GENERATING PLANTS - 1994
(Thousand kilowatts)

Country	Total	Thermal	Hydro	Nuclear	Geothermal
Bangladesh	2970	2740	230		
Cambodia	35	25	10		
China	190100	142000	46000	2100	
Hong Kong	10323	10323			
India	91555	68600	20904	2005	46
Indonesia	16265	12650	3365		250
Japan	220743	137891	41931	40531	390
Korea (DPR)	9500	4500	5000		
Korea (Rep)	31665	21556	2493	7616	
Malaysia	7830	6200	1630		
Philippines	7640	4275	2315		1050
Singapore	4513	4513			
Sri Lanka	1557	418	1139		
Thailand	15838	13228	2610		
Viet Nam	5320	1550	3700		70
Sub-Total	615854	430469	131327	52252	
Asia	812794	584140	169230	57603	1821
World	2991212	1937464	698315	345626	9807

Source: United Nations (1996) 1994 Energy Statistics Yearbook, United Nations, New York

TABLE 2.6 PRODUCTION, TRADE AND CONSUMPTION OF HARD COAL - 1994
(Thousand metric tonnes and kg per capita)

Country	Production	Imports	Exports	Consumption	
				Total	Per Capita
Bangladesh		198		198	
Cambodia					
China	1239902	1209	24194	1231928	1037
Hong Kong		8450		8450	1447
India	254658	7933	102	264899	288
Indonesia	28549	275	25364	3460	18
Japan	6933	116171		123062	986
Korea (DPR)	71500	2350	425	73425	3127
Korea (Rep)	7438	39406		43892	985
Malaysia	174	1736	64	1846	94
Philippines	1730	800		2500	38
Singapore					
Sri Lanka				1	
Thailand	12	1418	0	1425	24
Viet Nam	5600		1900	4000	55
Sub-Total	1616496	179946	52049	1759086	
Asia	1729792	222975	82182	1883160	550
World	3580153	448995	439727	3591303	636

Source: United Nations (1996) 1994 Energy Statistics Yearbook, United Nations, New York

TABLE 2.7 PRODUCTION, TRADE AND CONSUMPTION OF MOTOR GASOLINE - 1994
(Thousand metric tonnes and kg per capita)

Country	Production	Imports	Exports	Consumption	
				Total	Per Capita
Bangladesh	105	19		125	1
Cambodia	0	35		35	4
China	28541	1053	2181	26857	23
Hong Kong		620	266	353	60
India	4097	10	0	4107	4
Indonesia	5529	0	868	5818	30
Japan	36671	977	632	36849	295
Korea (DPR)	970	850		1820	78
Korea (Rep)	5966	0	67	6010	135
Malaysia	1868	1800		3593	182
Philippines	1725		75	1610	24
Singapore	4300	96	5938	1200	425
Sri Lanka	181			169	9
Thailand	3488	616	177	4137	71
Viet Nam	7	900		907	12
Sub-Total	93448	6976	10204	93590	
Asia	137631	12633	15335	138411	40
World	775463	75632	94571	769360	136

Source: United Nations (1996) 1994 Energy Statistics Yearbook, United Nations, New York

TABLE 2.8 PRODUCTION, TRADE AND CONSUMPTION OF GAS-DIESEL OILS - 1994
(Thousand metric tonnes and kg per capita)

Country	Production	Imports	Exports	Consumption	
				Total	Per Capita
Bangladesh	255	650	3	907	8
Cambodia	0	39		39	4
China	34795	6561	1216	38491	32
Hong Kong		7230	3068	3813	653
India	19676	8577		28253	31
Indonesia	13200	3000		15150	78
Japan	60841	2220	2385	60174	482
Korea (DPR)	1045	285		1330	57
Korea (Rep)	23380	2414	4716	20369	457
Malaysia	5160	1950	800	6115	310
Philippines	4050	1000		4910	74
Singapore	18200	5164	17537	4727	1676
Sri Lanka	657	201		812	45
Thailand	7327	4161	62	11574	199
Viet Nam	17	1700		1717	24
Sub-Total	188603	45152	29787	198381	
Asia	285683	57655	51268	282453	83
World	884262	152266	171439	838171	148

Source: United Nations (1996) 1994 Energy Statistics Yearbook, United Nations, New York

TABLE 2.9 PRODUCTION, TRADE AND CONSUMPTION OF KEROSENE - 1994
(Thousand metric tonnes and kg per capita)

Country	Production	Imports	Exports	Consumption	
				Total	Per Capita
Bangladesh	420	45		465	4
Cambodia		40		40	4
China	4072	653	314	4437	4
Hong Kong			6	2	0
India	5206	4514		9720	11
Indonesia	6605			8295	43
Japan	22138	1822	391	23408	188
Korea (DPR)	210	49		259	11
Korea (Rep)	4158	2199	60	6156	138
Malaysia	720	15	500	210	11
Philippines	635			485	7
Singapore	2900	260	452	1708	605
Sri Lanka	190	11		195	11
Thailand	105			94	2
Viet Nam	3	280		283	4
Sub-Total	47362	9888	1723	55757	
Asia	63466	10597	9108	64928	19
World	86016	15146	11863	88878	16

Source: United Nations (1996) 1994 Energy Statistics Yearbook, United Nations, New York

TABLE 2.10 PRODUCTION OF WOOD AND BAGASSE - 1994

Country	Fuelwood	Bagasse
	'000 cu m	'000 tonnes
Bangladesh	5900	3300
Cambodia	6512	
China	204059	16544
Hong Kong	193	
India	269187	38794
Indonesia	148916	7987
Japan	141	412
Korea (DPR)	4276	
Korea (Rep)	4491	
Malaysia	9602	359
Philippines	35790	6100
Singapore		
Sri Lanka	9580	207
Thailand	68573	14956
Viet Nam	29810	1330
Sub-Total	797030	89989
Asia	884121	102699
World	1820695	281325

Source: United Nations (1996) 1994 Energy Statistics Yearbook,
United Nations, New York

TABLE 2.11 FOREST AREA AND FUELWOOD PRODUCTION - 1990 (INCL. CHARCOAL)

Country	Total Forest Are million ha	Productive Forest Area million ha	Fuelwood Production '000 tonnes
Bangladesh	1.2	0.6	3570
Cambodia	12.7	6.7	3886
China	128	119	134357
Hong Kong			140
India	59.3	44.9	181189
Indonesia	119	75.6	102179
Japan	25	22.5	1500
Korea (DPR)	4.8	3	2965
Korea (Rep)	6.5	4	1400
Malaysia	21	15.6	6318
Philippines	15.9	1	24322
Singapore			
Sri Lanka	2.4	1.2	10000
Thailand	23.2		25064
Viet Nam	10.3	5.4	17499
Sub-Total	429.3	299.5	514389
Asia	511	340	585200
World	3878	2542	1415168

Source: World Energy Council (1992) 1992 Survey of Energy Resources
World Energy Council, London

Electricity generating capacities as at 1994 are shown in Table 2.5. Capacity is largest for thermal power, but hydro is also significant. Fesharaki and Wu (1992) note that hydropower is widely used , with large-scale schemes in China, North Korea and Indonesia; the share in total electricity production ranges from 61 % for North Korea, 22 % for Indonesia, 20 % for China, 9 % for Taiwan and 5 % for South Korea.

Japan has a large capacity in nuclear power generation. According to Fesharaki and Wu (1992) five nations in Asia, in addition to Japan, have nuclear power facilities: South Korea, Taiwan, China, India and Pakistan. China has a 300 MW plant at Qinshan in Zhejiang Province; a 180 MW plant is being built at Daya Bay in Guangdong Province near Hong Kong; and there are plans to import two 1,000 MW reactors to build a 2,000 MW plant in the province of Liaoning. It is estimated that Indonesia will have a requirement of 1,000 to 4,000 MW of nuclear power capacity. Geothermal power is important in the Philippines and to a lesser extent in Japan, Indonesia, Viet Nam and India.

2.4 Coal

Table 2.6 shows the strong reliance of China, India and the Democratic People's Republic of Korea on coal as a primary energy source. These countries consume most of their production domestically. Japan and the Republic of Korea are large-scale coal importers. The main applications are in industry in industry and electric power generation. As major consumers of coal, all these countries are placed in a special position as regards the management of environmental impacts of the coal fuel chain, including greenhouse gas emissions.

2.5 Petroleum and Natural Gas

Table 2.4 shows that Indonesia's energy system and economy rely heavily on petroleum and natural gas. These energy sources account for the bulk of domestic energy consumption. Exports of petroleum and natural gas are an important source of foreign exchange and government revenue.

Tables 2.7 and 2.8 contain statistics on production, trade and consumption of motor gasoline and diesel distillate and thus give an indication of potential environmental problems associated with transport systems, especially motor vehicle emissions and consequent impacts on air quality and human health. The largest consumers are China and Japan. The highest per capita consumption levels for motor gasoline occur in Singapore and Japan. Singapore has the highest per capita consumption of diesel, but consumption rates are also high in Hong Kong, Japan and Malaysia.

Statistics for kerosene are given in Table 2.9. Kerosene is used in large quantities in Japan, Indonesia, India, the Republic of Korea, China and Singapore.

2.6 Fuelwood and Bagasse

Table 2.10 reveals the dependence of many Asian countries on fuelwood as a primary energy source, and to a more limited extent, bagasse. Asia as a whole produces 48 % of the world supply of fuelwood. In some of the poorer countries fuelwood accounts for almost half of total energy use, often being collected and used as a non-commercial product.

The capacities of different countries to produce fuelwood are shown in Table 2.11. Indonesia and China have the largest forest areas, but there are also large areas in India, Thailand, Cambodia and the Philippines. The statistics in Table 2.10 differ from those in Table 2.6 underlining the fact that reliable information on fuelwood production is difficult to obtain.

3. POLICY ISSUES AND RESEARCH NEEDS

3.1 Policy Background

Policymakers with responsibilities for EEE systems management in SE Asia face a wide range of problems. Providing an expanding and environmentally acceptable energy supply is one of the key requirements for economic growth and improving living standards. Problems of poverty and environmental degradation in some countries compound the difficulties of making progress. International concerns over increasing fossil fuel use in developing countries, and emerging pressures for developing countries to share the burden of containing transboundary and global environmental impacts have added a further dimension to the difficulties facing policymakers in the SE Asian region.

There is an extensive literature dealing with policy issues surrounding EEE interactions in SE Asia (ADB 1987, Chatterji 1981, Dutt and Ravindraneth 1992, ESCAP 1988a, ESCAP 1991b, Fesheraki and Wu 1992, Goldemberg 1990, Gosh 1984, Lucas et al 1987, Munasinghe and Saunders 1988, Panayatou 1993, Ramani et al 1992, Sasmojo and Nawangsidi 1992, Siddiqi 1991).

3.2 Enhancing Supply Capability

As indicated in the previous section of this paper, many countries in SE Asia at present face shortages of energy relative to their aspirations to achieve further economic development. A serious concern is the reliance on traditional fuels, which include fuelwood, bagasse, charcoal, vegetable and animal residues, and municipal wastes. ESCAP (1990) has estimated that 80 % of households in Asia and the Pacific depend on wood or charcoal for domestic heating and cooking. According to Siddiqi (1991) the total amount of wood used as firewood and charcoal in the Asian region in 1988 was estimated at 775 million cubic metres, of which more than 70 % came from India, China and Indonesia and 22 % from Bangladesh, Myanmar, Nepal, Pakistan, the Philippines, Thailand and Viet Nam.

Further details on the use of traditional fuels are presented in Table 3.1. Traditional fuels, primarily firewood, provide 100 % of total energy requirements in Bhutan, 75% in Lao, 65 % in Myanmar and about half of total primary energy in Indonesia, Sri Lanka and Vietnam.

There are two important features of this situation, both negatively reinforcing each other. The first is that the vast bulk of traditional fuels are obtained and used outside the market economy, many being collected from open access common property resources such as natural forests.

The second feature is that the absence of an orderly and effective pricing and/or rationing system means that the resource base is being seriously overused, depleted and degraded. Where access to forests is not well controlled, unsustainable production and deforestation are common outcomes. This occurs predominantly in the low-income countries and represents a double obstacle to sustainable energy use: not only is the resource depleted but the low levels of income make it impossible for people to purchase substitute fuels. Poverty and environmental degradation thus enter a negative feedback cycle. The process is explained by Dixon et al (1989) as well as by many others.

Table 3.1 Energy from Traditional Fuels in Asia, 1987

Country	**% of Total Energy**	**Country**	**% of Total Energy**
Afghanistan	44.2	Mongolia	10.8
Bangladesh	55.7	Myanmar	65.2
Bhutan	100.0	Nepal	
Cambodia	89.1	Pakistan	19.9
China	7.1	Philippines	37.8
India	26.2	Sri Lanka	50.0
Indonesia	48.2	Thailand	41.5
Lao, PDR	75.0	Viet Nam	49.2
Malaysia	11.1		

Source: Siddiqi (1991)

Tuan (1992 p219) comments that "the underlying causes of deforestation and degradation are poverty, inequitable land distribution, low agricultural productivity, poor land use policies, inappropriate development (including projects outside the forestry sector), weak institutions and rapid population growth."

Table 2.11 displays the results of some simple calculations based on the available statistics, which indicate the average yield of fuelwood (tonnes per ha per year) for productive forest areas. If the statistics are correct, the implied harvesting rate is 24 t/ha/y for the Philippines, 8 for Sri Lanka, 6 for Bangladesh, 4 for India and 3 for Vietnam. Whether these yields are sustainable depends on the forest type, age class of the standing stock, natural growth rates and regeneration rates. The results suggest that the Philippines and possibly some of the other countries may be harvesting beyond sustainable rates.

This conclusion is confirmed in a study by Watanabe (1992) who analysed the role of forestry and biomass in relation to greenhouse gas emissions. His analysis includes a table of estimates of fuelwood availability compared with requirements in year 2,000 indicating that nearly every country in the Asian region will harvest beyond sustainable yields. The energy balance for fuelwood is hugely negative for India and to a lesser extent Pakistan, Nepal, Bangladesh. In SE Asia the balance is negative for Thailand, Vietnam and Indonesia. The only countries with a positive balance are Malaysia and New Guinea.

According to ESCAP (1990) during the past decade, the rate of deforestation in Asia and the Pacific increased by 70% from 1.8 million ha/y to 3 million ha/y. While in principle trees can be grown to provide a sustainable yield, in practice the harvest rate has exceeded the regeneration rate. Panayatou (1993) notes that in Malaysia, closed forests have declined from 240,000 km^2 in 1900 to 154,000 km^2 in 1980 and in Thailand forest cover has been reduced to 29 % of total land area. Panayatou predicts that at current rates of harvesting, timber reserves in Asia will last for less than 40 years.

Other adverse environmental impacts associated with the use of traditional fuels are localised air pollution (including particulate matter and carcinogens), exposure to carbon monoxide poisoning in households and net additions to greenhouse gas emissions resulting from biomass depletion.

Policymakers face a major challenge to reverse these trends. It will involve implementing policies to encourage restoration of the natural resource base, including improved management of natural forests and encouragement of "social forestry". A case study of social forestry is presented in James (1994) and other examples can be found in Dixon et al (1990). Tuan (1992) discusses strategic options for forestry development, and Barnard and Krisoferson (1985) discuss the role of agricultural residues as a fuel in the Third World, with detailed assessments of impacts on soils and fertility.

The developing countries of SE Asia are thus in a state of transition from traditional to commercial energy supply. Part of the challenge will be to bring the non-commercial energy sector into a more commercial mode of operation, to generate monetary incomes, provide appropriate pricing signals and achieve a more efficient balance between the use of traditional fuels with other energy products supplied from commercial sources.

The other major policy objective to achieve in relation to energy supply is to provide a range of energy commodities that are better suited to a growing, technologically advanced economy. This requires supplying appropriate fuels for industrial and commercial use. Cleaner energy sources will also have to be provided for household use.

An important requirement is greatly expanded production of electricity. Electricity is a clean form of energy at the point of end-use and will increasingly be required by industry and households. It is an essential input to information technology and telecommunications, which are predicted to be a mainspring of global economic growth in the next century. The dilemma facing developing countries is that electric power is most commonly generated using fossil fuels, which will exacerbate the greenhouse problem. One of the most important issues to be faced by SE Asian countries is whether it is prudent to rely on fossil fuels for power generation or whether other forms of power generation may, especially in the longer term, be a wiser policy option. Some of the technological options are identified in Section 6 of this paper.

3.3 Energy Use and Sustainable Development

Achieving sustainable energy systems is an important requirement for SE Asian countries (Dutt and Ravindraneth 1992, Munasinghe 1995b, Pearce et al 1990). The main ingredients of a sustainable energy policy may be summarised as:

- ensuring continuing and reliable energy supplies, including a switch to renewables in the longer term
- achieving improved efficiency in energy production and use
- energy demand management
- containment of adverse environmental impacts

Ensuring expanding and reliable energy supplies will involve significant investments in energy facilities and the introduction of appropriate technology. In the short term, distribution of energy products, especially electricity, may be hampered by the high costs of infrastructure.

Solutions should be sought at the local scale. Sustainable energy supplies may be achieved through sustainably managed forests and other forms of biomass (which may be used in direct combustion, the production of liquid fuels, biogas and electric power generation). Geothermal, wind and hydro power may also be feasible, depending on specific local conditions.

Where large-scale conventional thermal power stations are used - for example to supply electricity to industry and housesholds in urban regions - they should be fitted with improved emission controls. Consideration should also be given to new and emerging thermal power technologies such as combined cycle gasification, fluidised bed combustion, co-generation and the use of clean and super-clean coals. These technologies offer the prospect of greatly improved efficiency as well as more effective environmental controls.

Technologies are available for a shift to large-scale electric power generation from renewable sources but they are often too expensive in comparison with conventional forms of generation. Fesharaki and Wu (1992) note that electricity generated by geothermal, solar, biomass, wind and other renewables in SE Asia and Oceania accounts for less than 1 % of the total generated. Given the constraints surrounding traditional and conventional sources of energy, nuclear power could become a realistic option for SE Asian countries, if they can muster the necessary capital and engineering skills.

Improving the efficiency of the energy system is an important requirement for sustainability. Ramani (1992) takes a broad view and considers that energy efficiency refers to:

- energy conservation meaning the use of lesser energy to produce similar or greater output and, in more general terms, minimising losses of in existing processes of energy production and use
- resource and/or technology substitution ie altering the mix of a given energy system by replacing less efficient fuels with more efficient fuels or by introducing new technologies that are more efficient eg substitution of woodfuels by decentralised electric power
- structural change by shifting away from high energy-intensive industries to high capital- or labour-intensive industries or by changing lifestyles that result in excessive energy consumption

Fesharaki and Wu (1992) cite studies of energy efficiency by Levine and Meyers (1992) and Levine et al (1991) which indicate that savings in energy use of 20-25 % are possible in the near future, with payback periods of 2 years. With new installations of capital equipment, energy savings of 30-60 % are achievable. Munasinghe and Schramm (1983) have explored demand management and energy conservation, while Bleviss and Lide report on energy efficiency strategies for Thailand.

3.4 Technological Development and Technology Transfer

The literature on technology and innovation is extensive (Dosi et al 1988). SE Asian developing countries depend critically on the adoption of appropriate technology as a basis for expanding and improving their energy systems. Impediments to technology transfer include a lack of engineering skills, shortages of investment funds, inadequate evolution of commercial energy markets and retention of intellectual property rights or patents by energy companies in the industrialised world.

Many of the technologies that could be usefully applied by developing countries are cost-prohibitive, despite the fact that they might also bring significant environmental gains. The wider adoption of some of the biofuels and solar technologies is currently hampered by bottlenecks in R&D. Adoption rates for energy technologies will thus depend on further advances in innovation, economies of scale in production and economies of "learning by doing".

One possibility for achieving technology transfer is for developing countries to undertake joint ventures with companies from advanced countries to establish and operate energy facilities. This helps to overcome the problems of capital shortage, limited technical skills and patent protection. Such ventures may also be undertaken for environmental reasons. It is well known, for example, that it may be more cost effective for advanced countries to invest in environmental controls in less developed countries rather than attempt to move to a higher point on their own abatement cost curves. Japan, for example, has expressed strong interest in assisting China with its coal mining operations and installation of modern electricity and industrial plants to combat potential problems of transfrontier acid precipitation.

3.5 Urban Air Quality

One of the most significant trends occurring at the present time, and predicted to continue in the next century, is the expansion of urban areas, especially in SE Asia. A full review of urbanisation and its environmental implications has recently been conducted by the World Resources Institute (WRI 1994, 1996).

According to the World Resources Institute it is estimated that by 1995 more than 45 % of the world's population will be living in urban areas (see Table 3.2). Over the last three decades the growth rate of the urban world population has averaged 3 % annually, compared with a rural population growth rate of 1 % annually (WRI 1994). By 2,006 half the world's population will be urban. Within the following decade half the population of Asia will be urban also.

In Asia the urban population has increased from 22 % of its total population to 34 % since 1965. By 1991 there were 149 cities in Asia with a population of more than 750,000 inhabitants, accounting for 13.3 % of its total population. Of the world's 21 megacities (cities with a projected population exceeding 10 million by the year 2000) 13 are located in Asia (see Table 3.3). Projected populations are 28 million for Tokyo, 18 million for Bombay, 17 million for Shanghai and between 11 and 14 million for Dacca, Beijing, Tianjin, Calcutta, Delhi, Jakarta, Seoul, Karachi and Manila. These cities will have unprecedented demands for goods, services and technologies to deal with the severe environmental pressures they are expected to face.

The environmental impacts from energy use in urban areas are extensive and have serious implications for community welfare, especially human health. Emissions from transport systems are already creating air pollution and health problems in Bangkok, Manila and numerous cities in China. Other impacts from transport include traffic congestion, lost time and reduced productivity of the workforce. Power stations and heavy industry may be located within or adjacent to urban areas, contributing to pollution problems.

Table 3.2 Relative Importance of Urban Populations in Asian Countries (1995)

Country	Urban as % of Total	Av Annual Growth %	No Cities > 750,000
World	45.2	2.7	376
Asia	34.0	3.5	149
- Bangladesh	19.5	6.7	3
- China	30.3	3.5	51
- India	26.8	3.3	34
- Indonesia	32.5	4.6	9
- Japan	77.9	1.3	7
- S Korea	77.6	4.6	7
- Malaysia	47.2	4.6	1
- Pakistan	34.7	4.2	8
- Philippines	45.7	3.9	2
- Singapore	100.0	1.4	1
- Thailand	25.4	4.5	1
- Vietnam	20.8	3.0	1

Source: *World Resources 1994-95* WRI/UNEP/UNDP

Table 3.3 Asian Megacities (Projected Population > 10m)

Country	City Area'000 Ha	Pop Yr. 1990 ('000)	Pop Yr. 2000 ('000)
Bangladesh - Dacca	x	6,578	11,511
China - Beijing	1,680	10,867	14,366
- Shanghai	630	13,447	17,407
- Tianjin	x	9,249	12,508
India - Bombay	60	12,223	18,142
- Calcutta	130	10,741	12,675
- Delhi	60	8,171	11,692
Indonesia - Jakarta	59	9,206	13,380
Japan - Osaka	x	10,482	10,601
- Tokyo	216	25,013	27,956
S Korea - Seoul	165	10,979	12,949
Pakistan - Karachi	353	7,943	11,895
Philippines - Manila	64	8,882	12,582

Source: *World Resources 1994-95* WRI/UNEP/UNDP

Energy use may create additional problems of solid waste disposal, especially from coal and biomass. Where waste ash is not properly handled, the quality of surface water runoff may be adversely affected. Controlling energy-related environmental problems in urban areas can be expected to emerge as one of the most difficult tasks facing policymakers in the SE Asian region.

3.6 Transfrontier and Global Environmental Problems

The scale of energy production and use in SE Asia is reaching proportions that now have transfrontier and global environmental implications. International cooperation may be needed to overcome problems of this kind.

A serious concern is acid precipitation associated with coal combustion. Efforts to reduce localised air pollution problems may result in more serious transfrontier effects. For example, one of the approaches used by China to reduce local SO_2 concentrations has been to construct higher stacks for its coal-fired power stations. The emissions are thus discharged higher into the atmosphere, where SO_2 is oxidised to sulphate ions and transported over large distances to other countries including Korea and Japan.

Another potential transfrontier problem is the risk of airborne radiation from a nuclear accident. Several SE Asian countries have already have constructed nuclear plants, and further expansion is likely, especially if there are growing international demands to restrict CO_2 emissions.

The problem causing greatest concern to SE Asian countries is the prospect of having to contain greenhouse gas emissions. The policy implications have been discussed by many analysts (Munasinghe 1995a, Drysdale and Huang 1995, ESCAP 1991b, Ramani et al 1992, Siddiqi 1991, Watanabe 1992).

According to Drysdale and Huang (1995) the growth rate for carbon emissions by East Asian countries is 8.5 % per annum. By 2010 world carbon emissions will reach 10,336 million tons, or 60 % more than current emissions. China is predicted to produce 2,737 million tons and other East Asian developing countries 935 million tons.

Siddiqi (1991) notes that a major study has been undertaken by ESCAP to estimate the present and future emissions of CO_2 from the use of fossil fuels in each of the developing countries of the ESCAP region, with two scenarios for the year 2000 and three scenarios for the year 2010. The energy projections were based on :

- business as usual - implying minimal changes from current policies and practices
- emphasis on energy conservation
- emphasis on energy conservation plus switching from coal and oil wherever feasible, to energy sources that emit less or no carbon dioxide.

Policies and incentives to limit greenhouse gas emissions can be expected to have wide-ranging economic and environmental effects including:

- rates of extraction of fossil fuels such as coal and petroleum
- design, construction and operation of fossil-fuel power plants
- evaluation of energy sources other than fossil fuels
- consideration of biomass as a source of fuel and as a carbon sink
- trade in energy products
- structure of the energy system and the economy as a whole

3.7 Policy Instruments

Economic instruments to support the implementation of EEE policies have been explored but not widely adopted in SE Asian countries. Such instruments include pollution charges, tradeable permits, resource taxes, differential excise on energy products and appropriate pricing of natural resources.

In SE Asian countries, one of the main obstacles to more efficient energy systems management is subsidisation of energy prices. This may occur in the form of special concessions to energy producers, resource taxes that do not reflect the potential for resource depletion, and below-cost pricing where energy facilities are owned and operated by governments. These practices result in over-consumption of energy products (thereby also contributing indirectly to environmental degradation) and provide little incentive for investments in energy resource development. The prevalence of a large non-commercial energy sector is the extreme example of distortions in energy prices.

A common potential application of economic instruments is in the control of pollution. The main rationale for considering them is that environmental targets may, at least in principle, be achieved at least cost to the community. The two most commonly considered instruments for emission controls are pollution charges or tradeable permits. In SE Asian countries, there are immense opportunities for using economic instruments to control urban air pollution, water pollution and a range of other pollution problems.

If agreements are reached to limit greenhouse gas emissions, economic instruments may be an effective and efficient means of policy implementation, either in terms of a tax on CO_2 emissions or a system of tradeable quotas for total CO_2 emissions. This issue is the subject of intense international debate and is of major significance to developing countries. Quotas for greenhouse gas emissions may be applied at the global scale but could also be applied at a national scale to meet nationally agreed targets.

Determining an equitable distribution of responsibility between developed and developoing countries is a large part of the problem. The advanced industrialised countries have already made a cumulative contribution to the global atmosphere, dating back to the Industrial Revolution, yet the developing countries have barely started on their energy development paths. One possibility under consideration is a system of credits or initial allocations of permits to the developing countries, as well as offsets for developed countries from investments in emission reductions in developing countries.

3.8 Integration of Energy and Environmental Concerns

Lack of integration of energy and environmental concerns in SE Asian countries has many causes, some of which have already been discussed in this paper. A narrow or short-run approach to environmental protection and an inadequate awareness of technological and economic options are major obstacles to better planning and management. Segmentation of agency responsibilities (especially the division between energy development agencies and environmental protection agencies) is another institutional constraint. Last but not least are insufficient development and application of planning tools and analytical methods (Munasighe 1988). The remainder of the paper is dedicated to a description of useful models and analytical techniques.

4. APPROACHES TO EEE SYSTEMS PLANNING AND MANAGEMENT

4.1 Aims of EEE Modelling

The primary aim of EEE modelling is to provide energy system planners, environmental regulators and economic policymakers with information that helps to identify a more effective, efficient and environmentally acceptable energy system. The volume of literature dealing with this matter is already large and is growing rapidly. Useful references dealing specifically with economic modelling include Codoni et al (1985), Desai (1991b), Meier (1984, 1986), Munasinghe (1988), Munasinghe and Meier (1993) and Pachauri and Srivastava (1988).

The core elements of EEE systems planning are energy supply and demand. Improved planning and/or management of these elements involves identifying:

- the optimal pattern of end-use demands, ensuring that it matches the requirements of a growing economy, including sectoral needs, incorporates demand conservation measures and achieves improved efficiency in utilising devices
- the optimal energy supply system, including technically efficient extraction, conversion and distribution of energy, and application of the most appropriate and cost-effective production technologies

Meeting environmental objectives introduces a third overlay of analysis. Fesharaki and Wu (1992) emphasise the importance of addressing environmental management as an integral part of energy systems planning, pointing out that failure to address environmental concerns may lead to constraints on future energy system expansion. This observation reflects the common perception that the environmental impacts of energy systems are essentially adverse.

In principle, all aspects of the energy system (supply, demand and environmental management) should be optimised simultaneously. However, the planning and management of EEE systems invariably involves a wide range of technical and economic options, and in most modelling work, the analysis tends to be undertaken as a sequence of connected stages or in terms of sub-components of the overall energy system.

4.2 Boundaries of Analysis

EEE models may be applied at different scales of analysis, ranging from individual energy projects, through regional systems, to national and global energy systems. Models may be developed also for specific sub-sectors of the energy system, such as coal, petroleum, electricity and renewable energy.

Proper analysis, either in economic appraisals or in environmental impact statements (EIAs), should be undertaken for individual energy projects. However King, in his Introduction to the ADB report on *Environmental Considerations in Energy Development* (ADB1991b) cautions against undertaking EEE assessments only at the project level.

King notes that EIAs are usually conducted on a project basis and points out that:

"a case-by-case approach is merely reactive and misses opportunities to achieve overall optimization through trade-offs involving entire projects, even supply strategies, which can only be achieved when environmental considerations are integrated fully into energy planning proactively." (ADB 1991b, p3)

Meier and Munasinghe (1994) in a World Bank study on power sector planning in Sri Lanka also emphasise that environmental impact assessment is inadequate if carried out only at the project level and that system-wide models are usually required.

It is apparent that, in addition to the economic and technological scale of assessments, the geographic boundaries for analysis should be carefully considered. Many of the environmental impacts of energy systems correspond to regional airshed or watershed boundaries; others such as acid precipitation may be transfrontier; while some, such as greenhouse gas emissions, are global in scale.

Time frames are also important. Energy system infrastructure is among the longest-lived of all infrastructure. Dams, for example, may remain operative for hundreds of years, and coal-fired power plants often have a life of fifty years, including a major refurbishment around thirty years. The long-term problems associated with the decommissioning of nuclear plants, including storage of radioactive waste and other materials, are well-known. The long life of energy infrastructure emphasises the need to avoid locking into options that will remain inflexible or extremely costly in the future, and the importance of undertaking a "whole of life" approach in both economic and environmental assessments.

4.3 Least-Cost EEE Modelling

A great deal of analytical work on EEE systems pre-determines energy demand requirements and seeks to optimise the energy supply system while simultaneously minimising adverse environmental impacts. The relevant methods can be described as "least-cost" models. This approach has been promulgated by the Asian Development Bank (ADB 1991b) and can also be found in energy sector studies undertaken by the World Bank (Meier and Munasinghe 1994). Techniques for projecting demands, including allowance for policy changes, are discussed in Section 5 of this paper.

The conceptual approach to least-cost EEE modelling is described by King (ADB 1991b) as follows:

"The approach taken for integrating environmental considerations into energy development makes use of the conceptual framework for least economic cost investment planning, which is routinely used in evaluating power system capacity expansion plans and, less frequently, overall energy sector plans over periods of ten or fifteen years. By incorporating generic data on environmental impacts and valuing those impacts in economic terms, least-cost planning tools could be used, at least in principle, as the basis of energy-environment planning." (ADB 1991b, p5)

Several analysts have enunciated the general principles of least-cost energy system planning. The following listing has been provided by Ramani (1992):

- "energy supplies should adopt a mix of resources and technologies that yield the greatest economic benefit at the lowest possible cost
- likewise, energy demand should should be rationalised and matched to the best-suited supply sources and technologies by end-use at the lowest possible user cost
- benefits and costs should include not merely those elements that are measured in a conventional financial sense and of an immediate nature, but others such as social and environmental benefits and disbenefits with longer gestations
- the means of ensuring the above should be to reflect the true cost of energy supplies in the prices that are set, so that energy users are induced to choose options that maximise the net benefits to themselves and to the economy as a whole
- where the true cost of an energy service falls beyond the means of certain categories of users to meet their basic needs, they should be provided appropriate development assistance without, however, compromising the principle of competitive pricing among their energy options
- the ultimate objective of energy development should be to provide the energy services that most closely match the needs of users and carry the least economic, social and environmental cost to the society at large." (Ramani 1992, p12)

4.4 Operational Analytical Frameworks

The concept of least-cost EEE planning may in principle be applied through the use of extended benefit-cost analysis (BCA) in which the aim is to identify the optimal energy supply system, including specific measures to mitigate environmental impacts, that minimises the total direct costs and remaining environmental damage costs of the system. Such analyses require full specification of environmental damage cost functions. A good example is the study of sulphur oxide control conducted by the OECD (1981) which applies full benefit-cost analysis to control costs and environmental benefits.

In practice, however, it is not always possible to value all environmental effects, thus other evaluation methods must be applied. One commonly used technique is cost-effectiveness analysis (CEA). CEA makes no attempt to derive environmental damage cost functions. In CEA environmental benefits are encapsulated in environmental quality targets or standards established by technical experts. Environmental management agencies and international organisations have compiled a wide range of standards relating to air quality, water quality, soil conservation and, in particular, human health. CEA thus aims to identify the minimum-cost energy supply system, including specific measures to mitigate environmental impacts, that simultaneously meets environmental standards or other enviromental performance requirements. The analytical or modelling frameworks that are adopted in CEA vary from spreadsheet models and manual search procedures to mathematical programming models, especially linear programming (LP). A relevant example is the study of an electric power plant by Mendelsohn (1981) which identifies tradeoffs between pollution control costs and environmental protection benefits for an electric power plant.

A third kind of operational framework makes use of multi-attribute analysis, using a mixture of economic values and environmental indicators as a proxy for environmental damage cost functions. Multi-attribute models can take many different forms and indeed are often described as multi-objective models or multi-criteria analysis (MCA). An excellent review of such models, with an emphasis on environmental applications, can be found in Janssen (1994).

Multi-attribute analysis has been applied in energy systems analysis since the 1970s. Foell (19??) for example, used multi-attribute utility analysis (pioneered by Keeney and Raiffa 1976) to evaluate energy development scenarios in a number of studies of energy-environment systems. Janssen (1994) describes a case study for the location of nuclear power plants in the Netherlands. The technique has also been applied at the sectoral level, in a study of the power sector in Sri Lanka by Meier and Munasinghe (1994).

4.5 Analytical Procedures in Multi-Attribute Models

In the approach recommended by King (ADB 1991b) environmental impacts are valued where possible in economic terms and other kinds of impacts are incoporated by means of multi-attribute analysis. King explains the rationale as follows:

"The approach..stops well short of complex modelling because of the still unresolved conceptual issues in integrating energy and environment planning....The approach has retained the conceptual framework of the least-cost investment plan, economic valuation techniques where applicable, and the discounting of economic cost and benefit streams as typically used in BCA. However, multi-attribute asessment rather than optimization is advocated for overall evaluation since not all the costs and benefits can be valued precisely...Alternative plans are compared in terms of the net present value of quantified and economically valued cost and benefit streams as well as the other factors, appropriately weighted but open for inspection." (ADB 1991b, p5).

The stages of analysis that are required in practical application of the method have been specified by MacDonald (ADB 1991b) as follows:

- Identification of overall goals and development targets
  -economic development goals
  -environmental protection goals
  -social goals
  -energy development goals
- Assessment and development of regional energy resources
  -assesssment of energy and environmental resources
  -demand projections by sector and by source type
  -identification and assessment of potential demand and supply side measures
  -development of a shortlist of alternative strategies
- Economic analysis of energy strategies
  -estimation of costs of implementing each strategy (capital, operating etc
  -estimation of opportunity cost of energy shortages
- Economic analysis of environmental costs and benefits
  -identification of impacts for which monetary benefits can be developed
  -monetary valuation of impacts

Figure 4.1 The General Methodology

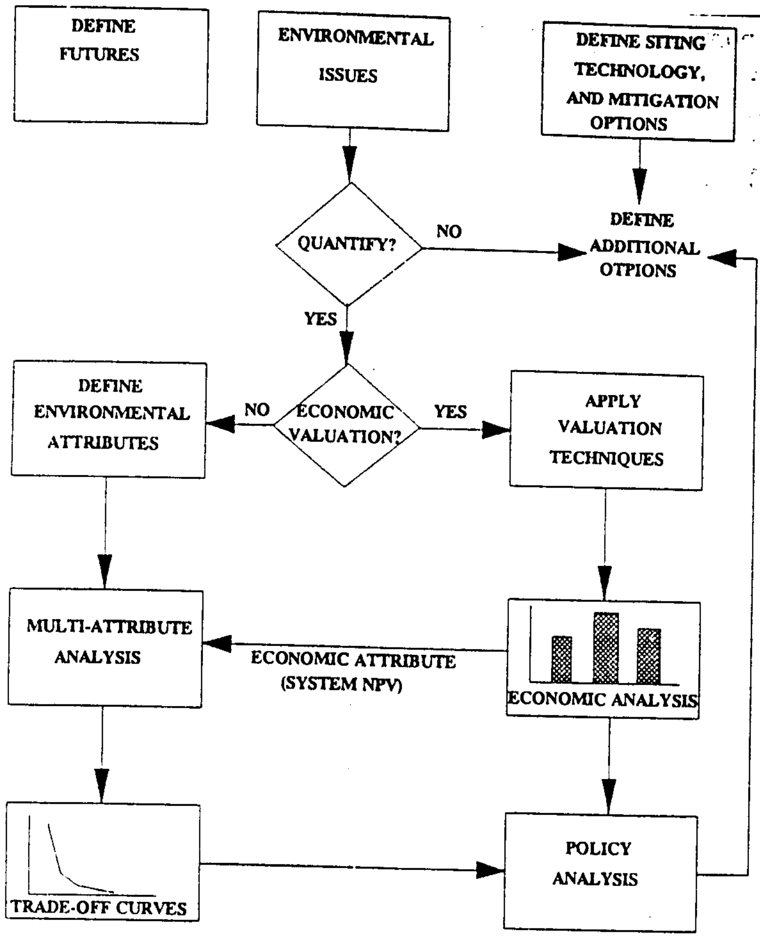
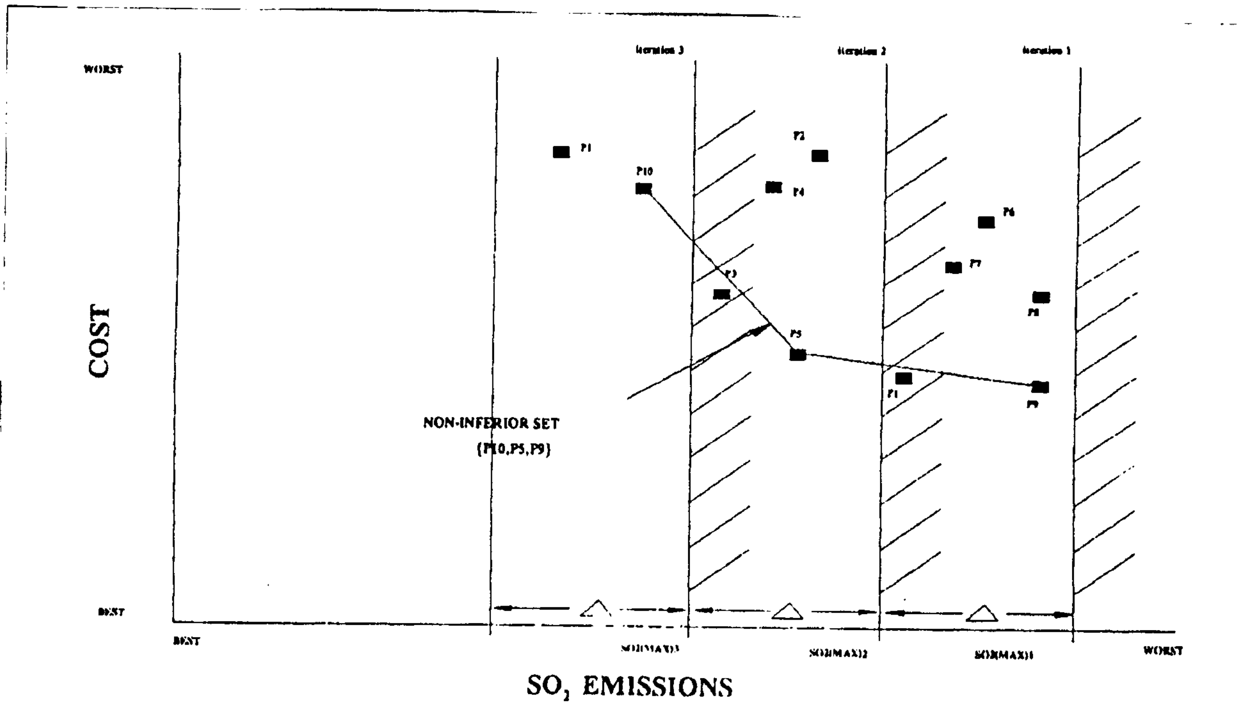


Figure 4.2 The Constraint Method



Meier, P. and M. Munasinghe (1994) *Incorporating Environmental Concerns into Power Sector Decisionmaking: A Case Study of Sri Lanka*, World Bank Environment Paper No 6, World Bank, Washington, D.C.

- Multi-attribute assessment of environmental impacts
  -development of hierarchical structure
  -development of scoring systems
  -estimation of impacts
  -amalgamation to provide overall measure of impact
- Evaluation
  -impact summary and sensitivity analysis
  -evaluation of strategies with regard to overall goals and ranking of strategies in terms of costs and benefits
  -selection of preferred strategy.

The analytical framework adopted by Meier and Munasinghe (1994) in their study of the power sector in Sri Lank is shown in Figure 4.1. The stages of analysis undertaken are similar to those in the recommended ADB modelling approach:

- identify development options for the power sector, including technology, fuel supply, siting options as well as systemwide mitigation options
- identify and assess relevant environmental issues
- conduct economic valuation of environmental impacts, including estimation of monetary damage costs where possible
- apply multi-attribute techniques, including narrowing the set of candidate options to a subset for further examination
- define environmental attributes to be used and assess impacts
- carry out multi-attribute analysis, including derivation of cost tradeoff curves
- derive and present policy implications and conclusions

4.6 Evaluation of Policy Options

The criteria for policy evaluation in BCA are well known and accepted: the most preferred option is that which maximises the present value of net benefits. The benefit-cost ratio and internal rate of return can be used to judge whether an option is desirable on the grounds of economic efficiency but should not be used for ranking options. In the presence of capital constraints, however, options may be ranked according to the marginal benefit-cost ratio.

Multi-attribute or multi-criteria analysis (MCA) offers a complementary means to evaluate policy options. As already noted, it is especially useful when full monetary valuation of impacts is not possible and mixed units must be used for the measurement of impacts.

There are many different forms of MCA. A commonly used technique is the weighted summation method.The required steps of analysis using this method are as follows:

- specify options
- specify the criteria or attributes through which the options are to be evaluated
- quantify and score the effects or performance of each option in terms of each criterion
- standardise the scores
- introduce relative weights for each criterion
- calculate the weighted score for each option
- compare the final scores and rank the options

- conduct sensitivity analysis
- identify the preferred option

In their discussion of multi-attribute analysis Meier and Munasinghe (1994) note that four issues must be addressed in the selection of attributes:

- double counting - an attribute should not be used if it is already represented by other attributes or impacts
- value independence - preference independence is required to allow additivity of values, especially in weighted summation models
- specificity - it is important to consider why a particular attribute has been selected; attributes should not be used simply because of ease of information
- proliferation of attributes - this increases risk of double counting and also makes it difficult to assign weights; the analyst needs to ensure that attributes are appropriate to the scale of the problem and also are important enough to affect the choice decision

Other factors that should be taken into account, according to Meier and Munasinghe, are:

- the need for quantification
- appropriate scaling (including normalisation if a weighted summation model is used)
- appropriate weighting

Meier and Munasinghe use multi-attribute analysis to derive tradeoff curves showing the relationship between the direct monetary cost of environmental protection measures and various indicators of environmental quality. In addressing the fact that the same level of environmental protection may usually be achieved with a number of different measures, and hence may result in a scatter of points on a graph of cost-and-effect options, Meier and Munasinghe apply a technique known as "exclusionary screening" to identify the non-inferior set of cost-tradeoffs - ie the envelope of most efficient points from the set of feasible points. An example is shown in Figure 4.2. The trade-off curves can be inspected to facilitate selection of the preferred option.

4.7 Other Conceptual Frameworks

While the above conceptual approaches and operational frameworks offer a practical means of integrating environmental considerations into energy system design and management, it is also important to be aware of other approaches that rely more on the concepts of ecological economics and sustainable development. Some of these ideas have been explored by Peet (1992) who cites the relevance of work by Daly (1991) on steady-state economics and work by Repetto et al (1989) on natural resource and environmental accounting in energy systems planning. Indeed, extensive literature emerged in the 1970s on the ecological role of energy in economic processes , including the pioneering work of Gorgescu Roegen (1971) applying entropy theory to economics and work on energy analysis by Slesser (1978) among others.

A recent innovation of relevance to energy planning is the concept of industrial ecology. Industrial ecology draws an analogy between natural ecosystems, where nothing is wasted, and the industrial system, including the energy sectors. Under this conceptual model, energy and material residuals become valuable resources for the economy rather than wastes discharged to

Sounds great but what does it mean?

STEEL RIVER

So what is "a world leading eco-industrial park", what sort of industries might want to locate in one, and why would anyone think one might work on a piece of contaminated land just down the road from one of Newcastle's oldest and dirtiest industries?

Good questions. In truth, no one really knows the answers. Not for sure. But the University of Newcastle's environmental ethicist Dr Glen Albrecht believes the process of finding the answers will write an important chapter to Newcastle's history.

"It has the potential to change the city's image forever. I really believe that."

The goal of the Steel River Project is to create an industrial precinct that is "aesthetically pleasing, functionally efficient and environmentally and ecologically sustainable for residents, workers and business operators."

Nice aim. But as Albrecht points out, it is a commercial venture and that is how it will succeed or fail.

"It could end up as a fairly conventional industrial development, but I think that is a last resort," he says. "My gut feeling is that both BHP and the community want to create something that is innovative and outstanding. The idea is good. If investors can be found, it might work."

The term industrial ecology, according to the project's official literature, describes the symbiotic interrelationships that can occur within industrial complexes.

"In theory, industrial ecology models the flows of resources, materials and energy in industry as though they were natural systems. Waste can be eliminated as a by-product of industry through one industry's waste becoming another's raw material."

A real world example of such a conceptual scheme is Kalundborg in Denmark where a number of diverse enterprises work as one integrated system spread out over an area of some 20 kilometres.

A coal based power station supplies steam, a by-product of electricity generation, to a pharmaceutical company and an oil refinery. Its waste heat is diverted into local greenhouses, a fish farm and some 3,500 homes. The oil refinery produces surplus gas which is high in sulphur. It removes the excess sulphur and sells it to a sulphuric acid producer. The cleaner gas is then sold to other users including a gyproc manufacturer and the power company, which also takes the refinery's wastewater. The gyproc plant uses waste gypsum and calcium sulphate created by the desulphurisation system at the powerplant. Fly ash from burning coal is used in road construction and a cement works. Sludge from the fish farm and yeast byproducts of the pharmaceutical company used as fertiliser and pig food by surrounding farms.

This is a closed eco-industrial system, very organised, very Scandinavian.

Albrecht says this closed system is not an essential part of the Steel River concept. It could, for example, be developed as a "virtual" eco park - networked to complementary industries elsewhere in the region or the state.

The most recently-published Project Update, written by Newcastle University academic Dr Phillip O'Neill for development consultants APT Pedle Thorpe and Hassell Ltd identifies three options for the Steel River site that might incorporate the principles of industrial ecology.

◆ An investment by a single large user whose outputs might potentially include simply transformed manufactures and simply transformed commodities. This would be a capital intensive operation employing between 400 and 600 employees on site. It would have low range local and regional multiplier effects, but significant national multiplier effects due to the "positive trade outcomes deriving from export-oriented processing investments." It would, moreover, have great "stickiness" - that is, the temptation to shift to a new site - perhaps to another region - would be dampened by the venture's high sunk costs.

◆ A multi-user (single sector) application. This would involve one or two lead firms as hub investments, around which satellite firms and others would locate. Outputs from a concentration of users from a single sector would probably include elaborately transformed manufactures of moderate to low export intensity, but with opportunities for niche marketing. This option has high eco-industrial and networking potential.

◆ The multi user (multi sector) application. Investments would range over many industrial and service sub-sectors including business and office services, producer services, R&D activities, information technologies and networks, light engineering fabrication, leisure products, packaging, printing and publishing, warehousing and storage.

The danger identified with this application is its lack of inherent "stickiness" because SMEs are relatively more mobile businesses. There is also a risk of fragmentation of land use on the site, disrupting eco-industrial principles.

On the other hand, multiplier effects have the potential to be moderate to high locally if firms can be embedded in strong local and regional networks. It is, the report says, a view of Steel River based on the concept of regional enhancement rather than that of a fortress.

The third option appears to be the favoured one by key proponents of the Steel River scheme at the moment. But the fact is that no one can be sure what the ultimate occupant mix on the site will be. That will depend on what companies respond to BHP's marketing pitch, scheduled to kick off in the second half of this calender year.

◆ **Alan Norton**

Certainly the site has attractions for potential investors: excellent transport infrastructure close to the Port of Newcastle and a well trained workforce with world-quality research facilities at the University of Newcastle as a bonus. New industries will need new skills, and both the Hunter Institute of Technology and the University are already closely involved.

But is the site the right place for such a project, given the widely held belief that it has been badly contaminated by historic waste disposal practices?

The site today bears no resemblance to the site you would have seen 50 years ago. Then a large river channel ran through the centre and roughly a quarter of the area was a low lying island used for dairy cattle grazing. BHP infilled over about 25 years, using any materials available. Fortunately, the amount of "clean" fill outweighed the amount of "dirty" fill - and as time passed and the understanding of the environmental impacts of certain wastes grew, the group developed various alternate methods for dealing with its dirty waste streams. But what was already in the ground was left in the ground.

As part of the site assessment, about 120 boreholes and test pits have been sunk and over 360 soil samples collected and analysed for the presence of over 20 chemicals, together with more than 100 ground water samples.

The consultants concluded that while contamination "hot spots" certainly do exist, there is no reason why the site can not be developed for industrial purposes. BHP says the studies confirmed what the company itself had suspected for some time - "that the biggest contamination problem with the site is its stigma as opposed to any practical problem."

Two alternate strategies have been considered for remediating those portions of the site identified as having an unacceptable potential for contamination - removing and replacing all the contaminated soil (or as BHP Group Manager Property Mr Alan Norton puts it, "shifting the problem somewhere else") or containment on site so that the problem is isolated and can not interfere with whatever activities might occur there.

This "capping" solution - basically, burying the hotspots under at least 2m of clean fill, or under concrete hard stands - also happens to be the most cost effective solution.

But it leaves the potential for contaminates to leach into the river. The EPA is especially concerned about this, and has put BHP on notice that effective controls to prevent leachate leaving the site will be a requirement of any new Pollution Control Licence.

Norton, however, argues that development itself will cut the leachate to about 20 per cent of existing levels. This is because about 75 per cent of the site will ultimately be covered by buildings and drained hard stand areas, substantially reducing runoff and underground water pressure.

"We don't think the EPA's requirements are an insurmountable problem," he says.

Source: Thinking Business: Enterprise in the Hunter and Central Coast Regions, Issue No 6, University of Newcastle, Callaghan, NSW 2308.

the environment. Detailed empirical information on the potential for applying the concepts of industrial ecology is provided by Ayres and Ayres (1996). One of the most notable examples, established around a thermal electric power plant, is the Kalundborg complex in Norway.

Realisation of the need to combat the enhanced greenhouse effect has resulted in greater emphasis on improving the efficiency of the energy system, introducing demand management programs and encouraging a shift away from fossil fuels to renewable energy sources. The main thrust of analysis has been to seek "win-win" strategies that result in better energy use and reduced environmental impact (Greene 1990, Lovins et al 1981). Practical experience has demonstrated that producers and consumers are not always aware of the technological possibilities for achieving energy savings, nor do they always operate at minimum economic cost. The Greenhouse Challenge (BIE 1996, Greenhouse Challenge 1996) recently introduced by the Australian Government relies on voluntary agreements between industry and government to improve energy efficiency and simultaneously reduce greenhouse gas emissions. Some significant gains in energy efficiency have been achieved in certain firms and industry sectors.

None of the above implies that existing modelling frameworks are necessarily deficient, although at the very least, it may imply that much more creative thinking will be required in considering the shadow prices for primary resources and environmental impacts. However, there is no reason why existing models cannot be used and/or adapted to accommodate the principles of sustainability and ecological limits to growth. The way that models function, and the results they yield, depend largely on the planning objectives and exogenous information that is fed into them rather than on their own inherent structures. As a policy analyst once remarked: models are useful not so much for the answers they give as for the questions they prompt to be asked.

4.8 Policy Implementation

The primary purpose of formal analysis is to identify the optimal configuration of the energy system, including appropriate and cost-effective measures for environmental management. The final task of the analyst is to make recommendations on ways of implementing preferred options. This involves, among other things, specifying the appropriate legislation, institutional arrangements and incentive systems. In this respect, economic instruments such as resource pricing, pollution charges, tradeable permits and other incentives may play a valuable role.

Tietenberg (1985) among others has indicated the potential for cost savings from economic instruments, compared with the more traditional command-and-control systems. Hufschmidt et al (1983) point out, however, that if systems of economic instruments are poorly designed they may perform no better than arbitrary regulations.

The general theory of economic instruments is explained by Bohm and Russell (1985) and practical experience in developed countries has been documented by the OECD (1989b). The theory demonstrates that, from an economic efficiency viewpoint, the marginal costs of environmental protection should be equated with the marginal environmental benefits. This specification of an optimal economic incentive scheme requires fully defined environmental damage cost functions. The optimal conditions may be achieved by applying environmental charges, equating the charge to marginal environmental damage or protection cost, or a system of tradeable quotas which also should result in equalised marginal damage or protection costs.

In reality, it is difficult to derive damage cost functions, and the management goal usually then involves in meeting prescribed environmental constraints (such as a total discharge load, ambient concentrations of pollutants or limits to natural resource exploitation) at minimum cost to the community. Operational models for determining the optimal conditions are discussed by James (1985). While the theory of economic instruments is quite straightforward, many factors need to be taken into account in actual situations, including legislative and institutional constraints, the attitudes of potential participants and complexities of the environmental systems to be managed.

5. ENERGY DEMAND ANALYSIS

5.1 Aggregate Energy Demand

Predicting or specifying total energy demand by an economy may provide a starting point for EEE systems planning. The simplest means of undertaking this task is to construct macro-econometric models at the national scale, in which energy demand is studied as a function of variables such as income and the price of energy. These measures can typically be obtained from regression models of the national economy, identifying the changing relationship between real GDP and energy use over time.

Drysdale and Huang (1995), among others, have compiled estimates for the income elasticities of energy demand for SE Asian countries. The results reveal that the income elasticity of demand for developing East Asia was 0.6 during 1965-89 compared with 0.5 for the world as a whole. These authors note, however, that the income elasticities have been declining for a number of SE Asian countries: from the early 1970s to mid-1980s it has declined from 1.0 to 0.4 to 0.4 for China; 1.0 to 0.9 for Korea; 1.0 to 0.8 for Hong Kong; 2.6 to 0.9 for Singapore; and 2.5 to 1.5 for Indonesia. As noted by Fesharaki and Wu (1992) studies undertaken by MacRae (1991) and Lucas et al (1987) demonstrate wide variation in the income elasticities of demand between different countries.

A second indicator of energy demand is the energy-output ratio, or the energy intensity of production, measured as the number of units of energy use per unit of output. Improvements in the efficiency of energy use will be indicated by a decline in energy intensity. Data complied by Drysdale and Huang, reproduced in Table 5.1, indicate that East Asian developing countries have higher energy intensities than the world as a whole and significantly higher than for OECD countries. Estimates for China, even when corrections are made for GDP, are higher than other East Asian countries and the world as a whole.

The price elasticity of aggregate demand for energy is usually estimated by means of econometric or regression models. By constructing aggregate production functions it is possible to analyse energy demand as a derived demand thus allowing for substitution between different kinds of fuels and between energy and other inputs to the economy. Aggregate productions constructed for this purpose are usually KLEM functions (capital, labour, energy and materials). They may be represented as Cobb-Douglas, CES (constant elasticity of substitution) or translog functions. References on energy demand modelling include Bohi (1981) and Donnelly (1987).

Table 5.1 Energy Intensity in Selected Countries and Region (Tons of Oil Equivalent/$1000)

	1971	1990
World	0.46	0.41
United States and Canada	0.54	0.40
W Europe OECD members	0.35	0.28
Australia, NZ and Japan	0.23	0.17
Other SE Asian developing economies (excl China)	0.62	0.52
South Asia countries	0.44	0.55
E Europe and former USSR	0.64	0.73
China (a)	2.44	1.75
China (b)	0.98	0.70

Source: IEA World Energy Outlook 1993; Drysdale and Huang 1995.
(a) Using official GDP data (b) Using adjusted GDP data

Codoni et al (1985) express reservations about the use of econometric models and elasticity measures, particularly price elasticities, in making predictions about energy demand. Price elasticities may be important in developed countries, and are especially important for studying inter-fuel substitution, but may be less relevant in developing countries, especially in the non-commercial energy sectors. The reliability of econometric estimates may also be questioned if they have been derived from time series data - simple estimates applicable to a given time period imply the same speed of adjustment throughout the period. This can, perhaps, be overcome by incorporating time lages such as polynomial or Almon lags. Some analysts (Brain and Schuyers 1982) have used Koyck lags in their energy demand models. Codoni concede that price elasticities may be useful for partial projection work, for individual sectors or segments of the energy market. For long-term, large-scale demand projections, however, Codoni et al favour the use of models based on energy balances and the general structure of the economy.

5.2 Energy Demand in Multi-Sectoral Models

Multi-sector models, based on detailed data bases on flows of energy commodities to the different sectors of the economy (including households and export markets), provide a feasible means of making comprehensive assessments of energy use in the economy.

Input-output models are a popular means of documenting energy flows through the sectors of the economic system. The main purpose of constructing energy-based input-output models is to assess the relationship between energy production and use and the structure of the economy. The base-year flow table identifies inputs of primary and secondary energy products into the economic sectors. The economy can be partitioned into energy and non-energy sectors (Meier 1984, Codoni et al 1985) and all energy flows can be quantified in a common unit of measurement such as petajoules, tonnes of oil equivalent or tonnes of coal equivalent.

An empirical example of a partitioned system can be found in James (1980). In this study the inter-sectoral flows and coefficients for the energy sectors were derived from "energy make" and "energy absorption" matrices. The concept was later applied in extensive EEE modelling work for the Australian economy (James et al 1985b).

The direct requirements of energy by each sector can be estimated by means of "direct requirements coefficients" indicating the input of each energy type per unit of output by each economic sector. Total energy requirements (direct and indirect) for each sector are found by multiplying the direct energy input coefficients by the Leontief inverse coefficients for the input-output system (James et al 1978, Hufschmidt et al 1983). Coefficients have been derived for Asia by Ang (1987) among others.

Once derived, energy input coefficients can be used to analyse the "energy intensity" of different kinds of production, the energy intensity of different categories of final demand (consumption, government purchases, investment and exports) as well as to simulate energy use patterns associated with different growth scenarios for the economy.

Dynamic input-output models can also be constructed, incorporating capital formation coefficients. An example of such a model can be found in Miernyk and Sears (1974)..

5.3 Environmental Impacts in Input-Output Models

Environmental impacts of economic sectors can be studied in terms of "environmental coefficients" indicating a prescribed kind of environnmental impact per unit of output by each sector. A common form of analysis is the estimation of discharge loads associated with energy production and/or use by individual sectors. For example, combustion emissions by each sector can be calculated by means of "discharge coefficients". An important application is the derivation of discharge coefficients for greenhouse gas emissions from specific sectors of the economy. An emissions inventory is the usual starting point for these calculations (see for example ANZEC 1990). Total loads of each type of emission for the economy as a whole are found by aggregating loads across all sectors, including discharges from the household sector.

Input-output models can thus be used to calculate the "pollution intensity" of different kinds of production as well as their "energy intensity" (Leontief 1970, 1972). There are many examples of empirical applications, including James (1982), James and Chambers (1986) and James et al (1985a).

5.4 Integrated EEE Models

The main limitation of input-output models is that they are based on the assumption of fixed coefficients - that is, they do not allow for input substitution in response to price changes or technological change.

Ways of incorporating technological change in input-output models have been suggested by Ayres and Gutmanis (1972). More comprehensive approaches involve coupling the input-output model to a detailed technological model of the energy system (James et al 1985b). This procedure will at least ensure that price and cost changes in the energy sectors are translated into changes in the coefficients of the input-output model.

Another limitation is that an input-output model must be "driven" by a set of exogenous final demands (consumption, investment, government expenditure and trade). While this may be satisfactory if future trends in final demands can be established, a more flexible modelling framework for policy simulation purposes can be built by linking the input-output sectors to a full-fledged dynamic macroeconometric model of the economy. This approach was adopted by the Brookhaven National Laboratory in collaboration with DRI.

SEAS (Strategic Environmental Assessment System) is a different kind of large-scale macroeconometric model capable of simulating a wide range of resource use and environmental effects, including those related to energy. SEAS originated in the US EPA and Department of Energy and was further developed at Resources for the Future by Ridker and Watson (1980). Other examples of large-scale EEE macro models are described by James (1983). Extensions of more conventional large-scale economic models to accommodate energy and environmental considerations are discussed in Section 8 of this paper.

6. ENERGY TECHNOLOGIES AND ENVIRONMENTAL IMPACTS

6.1 Energy Technologies

The range of energy technologies already in wide use and potentially available is immense. A brief list is provided below. It includes conventional technologies and new and emerging technologies. Many of the technologies are not currently being used on a commercial scale, but with an increased emphasis on internalising environmental costs, they may become more economic in the future.

Direct combustion
- domestic and industrial boilers
- internal combustion engines
- domestic cooking and heating

Heatpumps

Steam turbine power generation
- black coal
- lignite
- oil
- gas
- integrated gasification and combined cycle (IGCC)
- fuel cells
- pressurised fluidised bed combustion

Nuclear power generation
- fission reactor
- breeder reactor

Geothermal power
- aquifers
- hot dry rock

Hydro power
- large scale
- small scale

Biomass

- fuelwood and crop residues
- energy forestry
- biogas
- producer gas
- fuel ethanol
- electricity from biomass
- anaerobic biomass digestion

Solar

- passive solar space heating
- water heating systems
- solar ponds
- air conditioning
- solar drying
- solar cooking
- solar thermal energy generation
- solar photovoltaic
- solar-thermal technologies for power generation
- photovoltaics
- solar hydrogen

Ocean

- Ocean thermal energy conversion (OTEC)
- tidal power
- wave power

Wind power

Environmental impacts associated with these technologies are documented by Ahmed (1994), ESCAP (1988), Pearse (1991), Siddiqi (1991) and others. Some of the impacts resulting from the different conventional energy sources are listed below:

Coal mining

- changes in land and water use
- possible loss of topsoil
- disposal of solid waste
- land subsidence
- drainage of acids from mines
- drainage of chemicals and suspended solids into water
- erosion of land

Coal transportation

- high level of dust in the air
- noise from loading, unloading and trains/trucks carrying coal
- water runoff carrying potentially hazardous trace elements from storage piles

Table 6.1 Summary of Major Impacts of Case Study Projects

	HYDROELECTRICITY Thailand	HYDROELECTRICITY India	THERMAL POWER Hong Kong	THERMAL POWER China	GEOTHERMAL POWER Philippines	OIL (OFFSHORE) Malaysia	GAS (OFFSHORE) Malaysia	COAL (UNDERGROUND) India	COAL (UNDERGROUND) China	COAL (SURFACE) India	FOREST RESOURCES Nepal	BIOMASS RESOURCES Bangladesh
1. PHYSICO-CHEMICAL												
Air quality	○	N	◓	◓	○	◓	○	○	◓	◓	◓	◓
Water quality	◓	N	◓	◓	◓	N	N	N	◓	◓	N	N
Soil quality	◓	N	○	◓	○	N	N	N	N	N	●	◓
Noise level	○	N	◓	○	●	○	○	●	◓	○	N	N
2. BIOLOGICAL												
Flora	○	○	○	N	○	◓	○	N	N	○	●	N
Fauna	○	N	○	N	○	◓	○	N	N	○	●	N
Micro-organisms	N	○	○	N	N	○	○	N	N	○	N	N
Deforestation	○	◓	○	N	N	N	N	N	N	◓	●	◓
3. GEOLOGICAL/ PHYSIOGRAPHICAL												
Seismicity	N	●	N	N	○	N	N	N	N	N	N	N
Landslides, erosion, subsidence	◓	●	○	N	◓	N	N	●	N	N	◓	N
Siltation, water body transformation	◓	●	○	◓		N	N	◓	N	N	◓	◓
4. HUMAN HEALTH												
Major diseases/ impairment	○	○	N	◓	N	N	N	N	N	N	◓	◓
Minor diseases/ impairment	◓	○	N	◓	N	N	N	N	N	N	◓	◓
Safety hazards	N	●	N	○	○	○	◓	●	N	N	N	N
5. SOCIO-ECONOMIC												
Population dislocation	●	●	○	○	◓	N	○	◓	N	◓	N	N
Cultural stress	◓	◓	○	N	◓	◓	◓	N	N	N	N	N
Urbanization, infrastructure development	○	◓	○	◓	◓	◓	◓	◓	◓	◓	N	N
Income level	N	◓	N	N	◓	◓	○	N	N	N	N	N
Cost of living	N	◓	N	N	○	◓	●	N	N	N	N	N
Employment generation	◓	○	◓	◓	◓	◓	◓	◓	N	◓	N	N

● Serious
◓ Significant
○ Not significant
N Not assessed/not applicable

Source: Hills, P. and K.V. Ramani (1990) Environmental Dimensions of Energy Planning in Asian Developing Countries, in P. Hills and K.V. Ramani (eds) (1990) *Energy Systems and the Environment: Approaches to Impact Assessment in Asian Developing Countries*, Asian and Pacific Development Centre, Kuala Lumpur.

Coal combustion
- emissions of particulates, sulphur oxides, nitrogen oxides
- solid waste generation, fly ash and bottom ash
- emissions of greenhouse gases, especially carbon dioxide
- creation of secondary air pollution impacts - acid precipitation, greenhouse effect
- adverse impacts on health, materials, ecosystems

Oil
- production blowouts, especially adverse for offshore wells
- transportation - spills
- refining - gaseous emissions
- combustion - SOx, NOx, HC, CO, CO_2

Hydropower
- inundation of catchments
- algal blooms
- change in flood regimes
- change in sedimentation patterns
- need for relocation of people, structures, activities

Firewood and biomass
- particulate pollution
- carbon monoxide poisoning (especially for household use)
- solid waste generation
- deforestation and land degradation (including adverse impacts on water quality)

A summary of the major environmental impacts associated with a range of case study projects compiled by Hills and Ramani (1991) is shown in Table 6.1. It is important to note that all the projects, even those described as "alternative" energy technologies, have some kind of environmental impact.

In identifying environmental impacts of energy facilities it is essential to take a whole-of-life approach and also recognise the possible need, especially with some of the renewable energy technologies, for system reliability, storage and backup capacity. All these features of the energy system have implications for the environment.

6.2 Mitigation Measures

The range of options for environmental mitigation (and restoration) of environmental impacts is also large. It is technically feasible to control virtually any impact resulting from the energy system, but the critical consideration, from an analytical viewpoint, is the effectiveness of control options relative to their cost.

Some important mitigation technologies for coal-fired power stations - one of the major sources of air pollution and greenhouse gas emissions in SE Asia - are listed below:

- coal beneficiation
    - washing and ash reduction
    - clean coal
    - super clean coal
- flue gas desulphurisation
    - wet scrubbers
    - spray dry scrubbers
    - in-furnace sorbent injection
    - Wellman-Lord and magnesium oxide processes
- denitrification technologies
    - low NOx combustion modifications
    - selective catalytic reduction
    - selective non-catalytic reduction
- combined desulphurization with denitrification
    - activated carbon process
- particulate control technologies
    - cyclones
    - electrostatic precipitators
    - bag filters
    - wet scrubbers
- CO_2 removal technologies
    - MEA absorption process
    - coal gasification shift process
- advanced technologies
    - gas-fired combined cycle
    - co-generation of heat and power
    - fluidised bed combustion

Similar controls are available for other energy sources.

6.3 Environmental Impact Assessment

Environmental impact assessment (EIA) is both an administrative process, guided by legislation and regulatory provisions, and a set of procedures for technical predition of impacts. EIA is mostly project-based, but increasingly is being used for strategic, regional and sectoral assessments. Discussion of EIA legislation and practices in a number of countries, including Thailand, Nepal and the Philippines, can be found in James (1994).

Barron (1992) has advocated the use of rapid EIA to facilitate the assessment of energy systems. Rapid EIA uses available information to make assessments, identify major information gaps and determine what the data indicate about potential environmental problems, relative scale and priorities for further action.

Important factors to be taken into account in an EIA include:

- initial audit of development site and potentially affected environments
- general objective of the proposed development

- statement of alternative projects to achieve the same objective
- identification of project attributes, including phases of construction, operation and decommissioning
- specification of initial impacts
- geographic scale and time scale of impacts
- prediction of impacts on environment, including secondary physical, biological, chemical and ecological effects
- identification of relevant receptors and their exposure to environmental change
- prediction of impacts on receptors, using dose-response functions
- specification of feasible mitigative measures, provisions for monitoring and ongoing environmental management

Numerous guidebooks are available to assist EIAs for EEE systems. Their content ranges from checklists of environmental effects typically associated with different kinds of development projects to detailed explanations of how to conduct the relevant scientific and technical assessments, including the use of natural systems modelling where applicable. References of note are ADB (1988), ADB (1996), Basta and Bower (1982), Carpenter (1983), Hills and Ramani (1990) and UN (1991).

6.4 Economic Valuation of Impacts

The range of literature, explaining how to place monetary values on environmental impacts, is now so extensive that it is beyond the scope of this paper to provide a full review of methods. Useful references include ADB (1996), Dixon et al (1994), Hufschmidt et al (1983), James (1994) and OECD (1989a, 1994).

Economic valuation techniques for the environment can be classified as follows:

Market-based techniques
- productivity method
- replacement/repair cost
- shadow project
- defensive/avertive expenditures
- opportunity cost (including the threshold model)

Surrogate markets
- property value or hedonic price model
- travel cost model
- wage differential

Simulated markets and survey methods
- contingent valuation
- contingent ranking
- priority evaluator technique
- choice modelling

Impacts to be valued usually can be placed in the following categories:
- human health
- premature loss of life
- labour productivity
- productive systems including agriculture, forestry and fisheries
- materials and structures
- ecosystems and biodiversity
- landscape and aesthetic values
- cultural and heritage values

7. ENERGY SUPPLY MODELLING

7.1 Reference Energy Systems

Reference Energy Systems (RES) were invented by Brookhaven National Laboratory in the 1970s. An RES shows energy flows in the economy for a base year. Energy sources are identified in terms of primary energy inputs as well as imports. The flows of energy are documented for different stages of production, conversion, transmission/transportation and end use (including exports). All flows are measured in a common energy unit. It is thus possible to analyse the overall efficiency of different chains of energy technology capable of meeting end-use demands from the different sources. An example is shown in Figure 7.1.

7.2 BESOM

Large-scale mathematical programming models of the energy system were pioneered by Brookhaven National Laboratory in USA in conjunction with work on Reference Energy Systems.

The first model constructed at Brookhaven was the Brookhaven Energy System Optimisation Model (BESOM) (Cherniavsky 1974). BESOM is a single-period linear programming model. It seeks to identify the optimal configuration of energy production that minimises the total cost of the whole energy system while meeting supply constraints for primary energy, energy conversion efficiency and minimum end-use demand requirements.

Each activity level in the model represents a possible path involving transformation of primary energy into secondary energy products that are used to meet end-use demands for energy services. Each chain of energy conversion and transmission has an efficiency level defined in terms of energineering parameters and there is an overall cost associated with each energy path. End-use demands for energy services can be met through a variety of different energy utilising devices, each of which has an end-use efficiency. End uses are exogenously determined.

7.3 DESOM and MARKAL

BESOM was replaced by a Dynamic Energy System Model (DESOM) (Cherniavsky et al 1979) which was subsequently adopted by the International Energy Agency and developed into the MARKAL (Market Allocation) model for use by its member countries (IEA 1980).

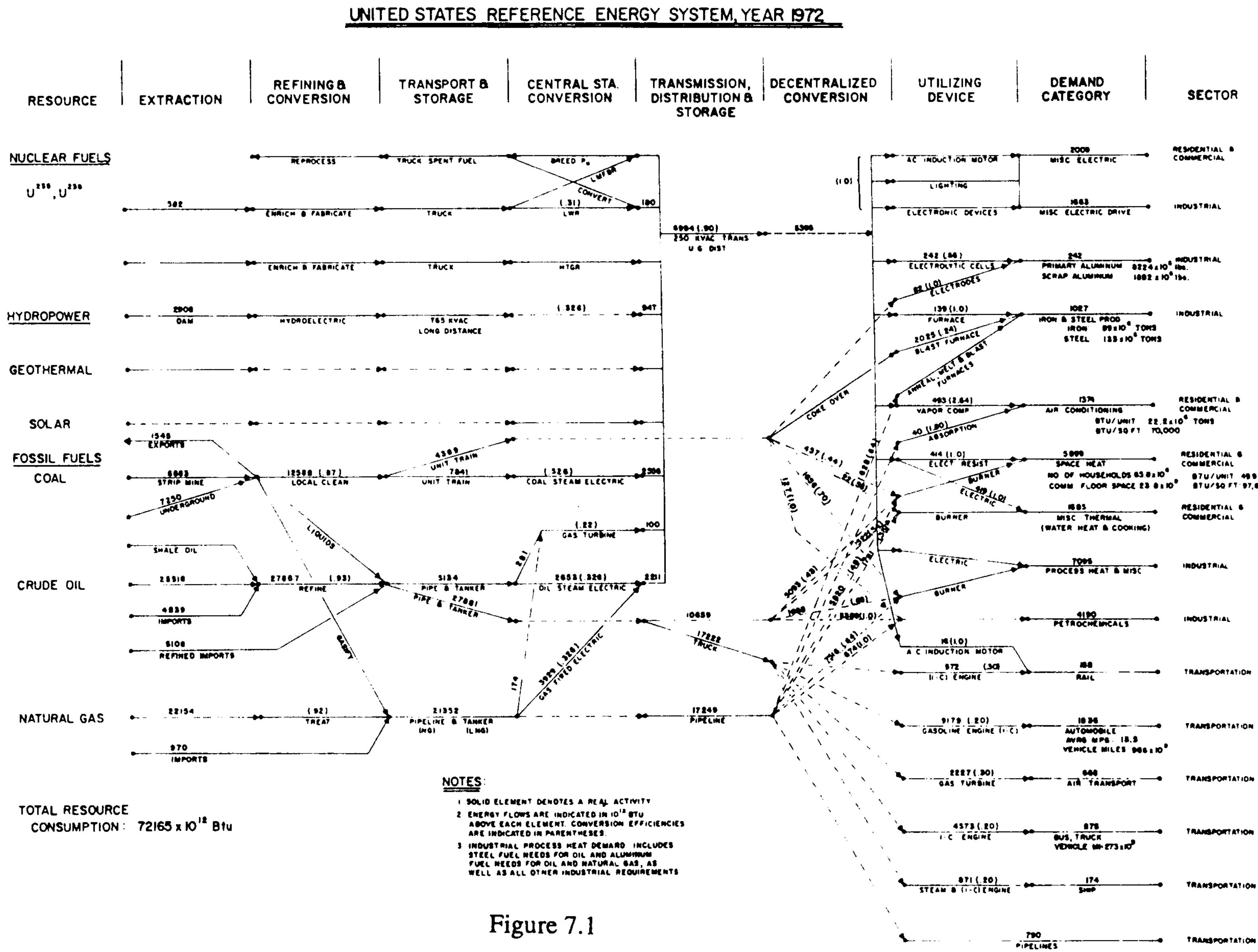


Figure 7.1

Source: BNL (1977) *Regional Reference Energy Systems*, Report prepared for Electric Power Research Institute by Brookhaven National Laboratory, New York.

MARKAL is a multi-period linear programming model that optimises energy technologies over time. Different objective functions can be used, such as minimising the present value of costs for the whole energy system or minimising oil imports. Constraints are similar to those for BESOM, except they are dynamic, and additional constraints are incorporaed for capacity limits of energy facilities. Developmental work on MARKAL was conducted by Brookhaven National Laboratory and Kernforschunsanlage (KFA) (Atomic Energy Agency) of Germany.

7.4 Environmental Extensions of LP Models

All three models (BESOM, DESOM and MARKAL) have the capacity to identify environmental impacts associated with each energy path, such as energy-related emission loads. Environmental objectives can thus be handled by introducing additional constraints - for example, maximum total emission loads for different types of emissions. Shadow prices can be determined for environmental constraints.

7.5 Applications in Asia

Munasinghe and Meier (1993) note that linear programming models of the energy system have been constructed for a number of Asian countries, including applications of MARKAL by Brookhaven National Laboratory and Kernforschunsanlage in Indonesia, the TEESE model in India (Pachauri and Srivastava 1988) and Reference Energy Systems and LP models by Tsinghua University in China.

8. POLICY SIMULATION MODELLING

8.1 National/Global Policy Modelling

As energy is a pervasive input to the economic system, it follows that a wide range of energy-environment policy options should be modelled on a national or even global basis. Modelling policy options for greenhouse gas abatement is a relevant example. The most appropriate models are computable general-equilibrium (CGE) or dynamic macro-econometric models that feature a multi-sectoral core with a focus on the energy sectors and energy flows throughout the economy. In such models, production functions allow for substitution between different energy forms, as well as between energy and other inputs to production. Consumption, trade and investment functions are included. Balance equations are specified for supplies and demands of primary factors of production and final commodities to ensure that equilibrium is achieved. An important feature of these models is that they are capable of simulating the economy-wide effects of policies that involve price changes. In some cases, it is possible also to model quantity restrictions, such as quotas on energy use and/or restrictions on greenhouse gas emissions.

An experiment using four such models was recently supported by the Australian Department of the Environment, Sport and Territories (DEST) to assess their usefulness in environmental policy simulation (James 1996). A carbon tax, set at two different levels ($1.25 and $5.00 per tonne of CO_2) and simulated under a variety of other policy constraints, was selected as the basis for undertaking the model simulations, evaluating the results, and making model comparisons. The models compared were ORANI-E, MEGABARE, G-Cubed and NIEIR. The general features of the models are summarised in Table 8.1.

Table 8.1 Summary of Model Features

FEATURE	ORANI - E	MEGABARE	G-CUBED	NIEIR/IMP
Model Type	Comparative Statics	Dynamic CGE	Dynamic CGE/ Macro	Dynamic Macro
Scale	National	Multi-country	Multi-country	National
Time	Short and Long Run (Non-explicit)	Short and Long Run (Explicit)	Short and Long Run (Explicit)	Short and Long Run (Explicit)
Production Functions	Leontief for Commodity Inputs; CRESH for Primary Inputs Land, Labour and Capital	Leontief for Commodity Inputs; CES for Primary Inputs Land, Labour and Capital	Multi-tiered CES; Capital, Labour, Energy, Materials and Natural Resource Input	Generalised Leontief
Energy Use	Nested Functions CES for Fixed Capital/Energy Bundles	Explicit Technology Bundles for Key Energy Using Sectors	Nested Functions CES for Different Energy Types	Explicit Technologies for Key Energy Transformation Sectors
Investment	Endogenous, Funds Allocated According to Rates of Return	Depends on Level of Savings in Each Country, but International Flows are Possible	Function of Cash Flow and Expected Future Profit	Endogenous
Final Demands	Klein-Rubin Utility Functions; Government Expenditure Linked to Household Expenditure	Constant Difference Elasticity for Households, Consumption Linked to Demographics; Cobb-Douglas for Government	Nested CES Functions; Government Spending Cobb-Douglas Expenditure in Each Sector in Fixed Proportions to Total Govt Spending	Generalised Leontief
Imports	CES for Domestic Substitution (Armington Assumption)	CES for Inter-Country Substitution; CES for Domestic Substitution	Bilateral Demands Based on CES Nesting of Domestic and Foreign Goods	
Special Features		Endogenous Population Model	Monetary Model; Emission Permits Modelled Explicitly	

Source: James (1996)

It is worth noting that two of the models are global in context. G-Cubed has been used extensively in the USA and MEGABARE has been associated with work by GATT to assess the implications of energy-environment policy options for international trade and the performance of national economies. The other two models are national in scale, although they do allow for different external trade scenarios. Some features and findings of the study are presented below.

8.2 ORANI

ORANI is a CGE model developed at Melbourne University in the early 1980s. It has been used extensively for policy evaluation in Australia, particularly by the Industry Commission. The original model has been documented by Dixon et al (1982). The particular version used to simulate the carbon tax is ORANI-E, which features detailed development of the energy sectors and energy products (McDougall 1993). The model has been used before to simulate energy policy options (McDougall and Dixon 1994).

ORANI is a comparative static model that can simulate adjustments of the economy to prescribed "shocks" which include changes in policy variables. The results represent alternative states of the economy at a given point in time, rather than changes through time. Short-run and long-run adjustments are simulated by making different assumptions about capital and investment in the simulations.

ORANI has been extended and modified since its inception and is available in many different versions. ORANI has been re-named the MONASH model. It is now based in the Centre of Policy Studies at Monash University, where it is being developed as a dynamic model.

8.3 MEGABARE

MEGABARE is a multi-region, multi-country inter-temporal CGE model, developed by the Australian Bureau of Agricultural and Resource Economics (ABARE). A description of the model, including its structure and workings, can be found in a recent report (ABARE 1996).

MEGABARE has been used for, among other things, an analysis of international policy responses to global climate change (ABARE/DFAT 1995). Parts of MEGABARE have been reproduced from the GTAP (General Trade Analysis Project) model, which is used by GATT to analyse the impact of policies on international trade. Full documentation is available for the GTAP: the main source of information consists of a training programme by Purdue University (Hertel and Tsigas 1993) shortly to be published in book form. GTAP evolved from the SALTER model of the Industry Commission (Jomini et al 1991).

MEGABARE contains many more features than GTAP, including dynamic functions for savings and investment, an endogenous population model and detailed specification of the technologies for the electricity and steel production sectors.

The MEGABARE model simulations of a carbon tax originally conducted for DEST are subject to revision, following improvements made to the model over the last year. Only one MEGABARE simulation was made available for the model comparisons exercise: a tax of $1.25 per tonne of carbon, excluding petroleum products, with no revenue recycling.

8.4 G-Cubed

G-Cubed is a multi-country, multi-sector dynamic model developed by McKibbin and Wilcoxen (1992) for the US Environmental Protection Agency. It has been adapted to the Australian economy (McKibbin and Wilcoxen 1995).

G-Cubed combines the features of CGE and macroeconomic models, including real and financial markets for each economy, producer and consumer behaviour, international trade and international capital movements.

The model simulates impacts at an annual frequency. The short-run impacts are based on a weighted average of neoclassical optimising behaviour and ad-hoc "liquidity constrained behaviour" while the long-run equilibrium is based on a long-run Solow/Swan neoclassical growth model.

8.5 NIEIR Models

The National Institute of Economic and Industry Research (NIEIR) uses a model known as the Institute Multi-Purpose (IMP) model, which has been constructed on a quarterly and annual basis. The IMP model is not a computable general equilibrium model - it is a dynamic macroeconomic simulation model. Simulations are conducted using baseline and "shocked" scenarios, with short-run solutions leading into long-term equilibrium solutions. The general structure of the model is described by Brain (1986).

The annual IMP model links with a Regional Energy Supply and Demand (RESD) model that simulates changes in energy supply and demand, as well as simulating energy-related environmental impacts. Early work on the energy sectors has been documented by Brain and Schuyers (1981).

The NIEIR models can be operated in four basic modes:

- The direct (or Keynesian) mode.
- The neoclassical mode.
- The balance of payments constrained mode.
- The (physical) resource constrained - investment crowding out mode.

The mode preferred by NIEIR, best representing economic conditions in Australia over the last two decades, is the investment crowding out mode, but the simulations carried out for DEST adopted the neoclassical and balance of payments constrained modes to make them compatible with ORANI and the other models.

How to cut use of fossil fuel

Rescuing Australia from its greenhouse dilemma, **Warwick McKibbin** and **Peter Wilcoxen** propose a low-cost way of reducing carbon emissions.

Australia's greenhouse negotiating strategy is not succeeding. The world is moving closer to an international agreement on curbing the emissions of carbon dioxide primarily through reducing reliance on fossil fuels. Current proposals could be very expensive for Australia and will not solve the problem globally.

But rather than pleading that Australia is a special case that deserves to be treated differently, the Australian Government should offer feasible solutions to the rising emissions of carbon dioxide that address the greenhouse problem at least cost for the world.

The only way to significantly reduce carbon-dioxide emissions is to reduce the burning of fossil fuels. A range of studies suggest that stabilisation of carbon emissions at 1990 levels by 2010 would require Australia to cut its fossil fuel by about 40 per cent relative to what emissions otherwise would occur.

A reduction in carbon emissions of this magnitude would have a similar impact on Australia as the oil price shocks of the 1970s which we know led to significant declines in economic activity. For example, the GCUBED econometric model (a model we developed which is currently used by the US Government for greenhouse gas policy evaluation) suggests that the short- to medium-run costs to Australia of reducing emissions to 1990 levels by 2005 would be between 1 per cent and 1.6 per cent of GDP every year.

Alternatives to the current negotiating position are available and should be considered. One alternative global strategy suggested by McKibbin and Kym Anderson of the University of Adelaide would be to tackle distortions in world coal markets as a way of beginning to address greenhouse emissions as well as raising global economic efficiency.

Europe and Japan now subsidise coal production more than they do agriculture. The price of energy facing consumers in the developing world is half that of the world market prices because of subsidies to the consumption of coal. GCUBED results suggest that removing these distortions in the developed and developing world between now and 2005 would reduce carbon emissions by up to 8 per cent relative to what they otherwise would be by 2005. This reduction in global emissions is the same order of magnitude as that which we estimate would be achieved if all industrialised economies moved towards stabilising carbon-dioxide emissions by 2005 at 1990 levels and developing countries did not stabilise.

Some suggest that a system of internationally tradable emission permits would be a better system for Australia. But, while tradable permits work well for small environmental problems within countries, they would pose serious problems of monitoring and enforcement at the global level.

More importantly, a tradable permit system would involve a massive transfer of wealth between countries. To encourage developing countries to participate, advocates suggest that they would have to be given permits that they could sell to developed countries. Estimates of the value of permits are hundreds of billions of dollars every year.

‘ Our alternative proposal is a system of national permits and user fees. ’

But developing countries receiving permits could experience massive real exchange-rate appreciations, crowding out exports of goods and services and thus retarding the conventional development process. This problem is a direct illustration of the classic "Gregory thesis" or "Dutch Disease" facing countries that have a booming resources sector (in this case, in emission permits!). Such a system would soon collapse.

Our alternative proposal is a system of permits and user fees at a national level. Each country would be allowed to issue permits to industry within its borders to emit carbon at no charge up to 1990 levels. Additional user-fee permits could be issued at, say, $US5 to $US10 a ton.

Such a system would be efficient because the marginal costs of cutting greenhouse emissions would be equal across countries. Because, in effect, it grandfathers existing emissions and projects, it would encourage business not to oppose an international greenhouse agreement.

Because the user fee would only apply to new emissions, it is not a traditional carbon tax. But because the sale of the extra permits would provide budget revenue, governments would have an incentive to also reach an international agreement and to monitor and enforce emissions within their national boundaries.

That is, this permit/user-fee system offers a feasible way to reach an international consensus on how to begin to respond to the greenhouse threat. It would set in place a global mechanism to adapt to new information about the severity of the greenhouse problem.

The industry response to the sale of the extra emission permits would provide a measure of the costs of abatement over the next few years. Currently, estimates about how high the price of extra emission permits would have to rise to actually stabilise emissions by 2010 range from $US35 a ton to $US300. The user-fee system would pinpoint this price more accurately.

International negotiations could then focus entirely on the single price of the national permits rather than about the cap on emissions or the international allocation of permits each year.

This proposal offers a viable alternative that would be far more beneficial to Australia than alternatives such as tradable permits and more politically feasible than "differentiation".

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Source: Australian Financial Review, March 20. 1997.

8.6 Results and Model Comparisons

Results of the model simulations are reported in James (1996). Several conclusions were drawn on comparing the models.

The results initially appear to diverge , but there are certain patterns of similarity and consistency in the results. The models generally tend to predict the correct algebraic sign of change, at least for some of the broad macroeconomic indicators, with uniformly larger impacts for a levy of $5.00 compared with a levy of $1.25. The same economic sectors most affected by a carbon tax are identified by each of the models.

The results obtained from ORANI and G-Cubed are remarkably similar. This is rather remarkable, since the two models have very very different structures and scope of application. For the one common scenario where comparison of all four models was possible, MEGABARE appears to have under-estimated the general economic impacts of the carbon tax, as well as CO_2 emissions. The reasons are still not fully understood. The results from the NIEIR model seem reasonably credible when considered against the underlying broad assumptions and policy parameters, although they are not completely consistent with those of ORANI and G-Cubed.

8.7 Applications in SE Asia

Applications of EEE CGE models specifically to SE Asian countries have yet to be undertaken. It should be emphasised that the development of CGE models is an intricate, expensive and time-consuming process, with large data requirements, detailed econometric analysis, large-scale computing requirements and the need for specialist skills. Such work is feasible only for well-resourced research groups, such as research departments of major government or international agencies or university research centres.

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