ASIA PACIFIC ENERGY RESEARCH CENTRE

SUSTAINABLE ELECTRICITY SUPPLY OPTIONS FOR THE APEC REGION

THE EMERGING IMPORTANCE OF NEW AND RENEWABLE ELECTRICITY SUPPLY OPTIONS

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FOREWORD

I am pleased to present the report of the study "Sustainable Electricity Supply Options for the APEC Region: and the Emerging Importance of New & Renewable Energy." The study is one of five new research projects commenced in the year 2000.

The objective of the study was to investigate ways in which rapidly growing APEC economies can sustainably meet their burgeoning electricity supply infrastructure requirements. The report considers the trend towards more distributed power systems as one industry model that could provide a cost effective alternative to the traditional electricity supply industry development pathway. The report also considers the growing importance of renewable resources and new technologies as important ingredients in any future energy development path, and suggests that the continued development of natural gas infrastructure will be a key to long-term energy sustainability, as natural gas has great potential as the "bridging fuel" to the future.

The principal findings of the study are highlighted in the executive summary of this report.

This report is published by APERC as an independent study and does not necessarily reflect the views or policies of the APEC Energy Working Group or of individual member economies.

Finally, I would like to thank all those who have been involved in this major and I believe successful exercise including the staff at the Centre, both professional and administrative, the experts who have helped us through our conferences and workshops, and many others who have provided interesting and useful comments. I hope this report will be useful to a wide audience.

Keiichi Yokobori
President
Asia Pacific Energy Research Centre

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We would like to thank all of those who worked so hard on the project. The development of this report could not have been accomplished without the contributions of many individuals.

We wish to express our appreciation to the APERC Conference and Workshop participants who met with us and provided invaluable insights into the issues raised in the draft report.

We also thank all members of the APEC Energy Working Group (EWG), APEC Expert Group on Energy Data and Analysis (EGEDA), APERC Advisory Board and other government officials for their stimulating comments and assistance with the study. Our thanks go also to the APERC administrative staff for their help in administration and publication of this report.

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List of Abbreviations

AIT	Asian Institute of Technology
APEC	Asia-Pacific Economic Co-operation
APERC	Asia Pacific Energy Research Centre
ASEAN	Association of Southeast Asian Nations
BCM	Billion Cubic Meters
CCGT	Combined Cycle Gas Turbine
CDM	Clean Development Mechanism
CO_2	Carbon dioxide
DG	Distributed Generation
EDMC	Energy Data and Modelling Centre (Japan)
EIA	Energy Information Administration (USA)
GDP	Gross domestic product
GHG	Greenhouse gas
GW	Gigawatt (10^9 Watts)
GWh	Gigawatt hour (one million kilowatt hours)
IEA	International Energy Agency
IPPs	Independent Power Producers
kW	Kilowatt (= 1,000 watts)
kWh	Kilowatt hour (= 1,000 watts hour)
ktoe	Kilo tonnes of oil equivalent
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
METI	Ministry of Economy, Trade and Industry
Mtoe	Million tonnes of oil equivalent
MW	Megawatts (= 1,000 kilowatts)
NASA	National Aeronautical Space Administration
NREL	US DOE National Renewable Energy Laboratory
NO_X	Nitrogen oxides
OECD	Organisation for Economic Cooperation and Development
PV	Photovoltaic
SO_X	Sulphur oxide
TWh	Terawatt hour (one billion kilowatt hours)
US or USA	United States (of America)
US DOE	United States Department of Energy

PREFACE

RATIONALE FOR THE STUDY

At the very first meeting of APEC Energy Ministers in 1996 in Sydney, Australia, ministers agreed "*to cooperate extensively in research and development, technology adaptation and uptake, and programs related to energy efficiency, cleaner fuels and renewable and alternative sources of energy. Significant improvement in regional environmental performance will result from such cooperation*."

And at the Third Meeting of APEC Energy Ministers, in Okinawa, in October 1998, ministers declared that "*Considering, the strong forecast growth in demand and increasing dependence on oil from outside the region Ministers recognised the need to promote diversification of energy supply, including where appropriate natural gas, renewables and nuclear energy, to promote market-driven energy infrastructure development*."

The project is also in support of Policy No. 1, 2 and 8 of the APEC 14 Non Binding Energy Policy Principles, which are set out respectively below:

- Emphasise the need to ensure energy issues are addressed in a manner which gives full consideration to harmonisation of economic development, security and environmental factors;
- Pursue policies for enhancing the efficient production, distribution and consumption of energy; and
- Promote the adoption of policies to facilitate the transfer of efficient and environmentally sound energy technologies in a commercial and non-discriminatory basis.

OBJECTIVES OF THE STUDY

The main objective of this study is to consider current and future electricity supply requirements in the Asia Pacific region within a framework of energy sustainability. To achieve this primary objective, the term "sustainability" must be clearly defined and understood within the context of the electricity supply requirements needed to ensure the attainment of the social, economic and environmental goals of the member economies in APEC.

The idea of energy sustainability frequently focuses on renewable energy resources (which by definition are considered sustainable), and consideration of the importance of these resources in meeting the energy requirements of APEC economies are given high priority in this study. However, this report embraces a broader definition of the term "sustainable," and looks at the electricity supply resources, technologies and energy policies which will prove instrumental in both guiding economies towards true energy sustainability over the long term, and will provide for immediate energy needs.

The focus of the study is quite narrow - electricity supply, with particular focus on the rapidly industrialising economies in the APEC region. The subject of energy sustainability is by contrast, very broad. It encompasses transport energy options (the largest single energy consuming sector), energy efficient building design (including both active and passive energy design features), energy efficiency policies and programmes to limit or influence demand for energy, and strategic research on clean and renewable energy technologies that may have long-term commercial potential.

Within the context of sustainable development, all these issues are important, and it is difficult to address this subject without attempting to encompass the whole gamut of sustainability issues. However, to do so would cloud the one or two important messages this initial report would wish to convey.

Over the next decade or two, rapidly growing APEC economies must, at current annual growth rates of 6-8 percent, duplicate their entire electricity supply infrastructures. This means twice the number of power generation plants, a transmission system with twice the capacity of the existing system, as well as all other equipment, infrastructure and ancillary services needed to double the size of an entire electricity supply system. To achieve this enormous challenge, economies are planning this future power system now, and finance and investment partners are being sought to bring these plans into effect.

Generally, these electricity supply plans envisage a continuation of well-proven power generation and distribution technologies. This equates to single cycle steam coal plants, large-scale nuclear power plants, large-scale hydropower developments, and more recently combined cycle gas-turbine (CCGT) plants. Of these technologies, CCGT is relatively new. If one goes back a decade or so, this technology was still in the early adopter stage of its product life cycle. Today, 95 percent of new power plants being planned in the US are of this type, and turbine manufacturers are struggling to keep up with demand.

The goal of this report is to alert energy planners in the Asia Pacific region to the possibility that a continuation of past electricity supply practices may not make the most commercial sense in a world where a number of paradigm shifts over the next one or two decades could fundamentally change the way in which power is delivered and consumed. Firstly, the much talked about concept of "distributed power" is now on the verge of reshaping energy supply in the developed economies in APEC.

This trend is leading to a surge in demand for small-scale power technologies - often utilising renewables or clean sources of energy - which not only supply electricity close to the load, but also reduce transmission and distribution capacity constraints, or obviate the need for constructing new networks.

Along with this technological revolution, there is the further refinement and development of mini-grid and stand-alone village power systems. New technologies and innovative ideas for delivering electricity services are poised to undermine the historical solution to remote power demand - extending the transmission and distribution network to remote locations.

Lastly, the environmental impacts of burgeoning electricity supply growth in rapidly industrialising economies in Asia and elsewhere are beginning to have severe local, regional and even global ramifications. In fact, alleviation of air and water pollution impacts may over the next two decades be the single biggest driver of sustainable electricity supply systems.

It is generally true that new renewable energy technologies have high up-front capital costs and are currently unable to compete with traditional fossil fuels in most mainstream power generation applications. However, this does not take into account the external costs of fossil fuel consumption (something that will have to be factored into investment decision-making in the near future), and does not allow for the niche areas where these technologies can compete now. Full costs of fossil fuels and a greater number of successful niche applications will launch renewables into more main-stream markets as confidence in them grows, as the service infrastructure needed to support them develops, and their competitiveness increases with further technological development. One has only to consider the exponential growth in wind-power installations in a number of regions of the world to see that once new renewable technologies reach a certain threshold of acceptability and commercial viability, they are assured of an important place in modern-day electricity supply systems.

EXECUTIVE SUMMARY

THE ELECTRICITY SUPPLY CHALLENGE

Rapid economic expansion in the Asia Pacific region over recent decades has led to a large growth in demand for electricity. In much of the APEC region, demand growth has put a severe strain on the ability of individual economies to expand their electricity infrastructure capacity rapidly enough to meet the surge in demand.

Over the next decade or two, rapidly growing APEC economies will, at current annual growth rates of 6-8 percent, duplicate their entire electricity supply infrastructures. To achieve this enormous challenge, economies are planning this future power system now, and finance and investment partners are being sought to bring these plans into effect.

DEFINING SUSTAINABILITY

In order to consider the energy supply systems that may contribute to the long-term sustainability of economies in the APEC region, it is first necessary to define what one means by the term “sustainable.” Although this term is used often in public debate, it unfortunately means very different things to different people.

This report suggests that from an energy supply and demand perspective, a broad definition of “sustainability” must be accepted, broader than would be commonly accepted by staunch environmental advocates, but less broad than might be accepted by many traditional energy economists. Energy supply is critical to social and economic development, and there are both direct and indirect impacts on the environment from this activity.

Some environmental advocates call for an immediate halt to further oil and gas exploration, and for radical policy measures to reduce and eventually halt consumption of all fossil fuels. However, is such radical action the wisest route to long-term economic as well as environmental sustainability? Common sense would suggest that in the short-term, continued promotion and use of cleaner fossil fuels (for example natural gas), the widespread dissemination of clean and efficient fossil fuel combustion technologies, and energy efficiency improvements might prove to be the more prudent pathway to the future. In the longer-term, one would hope that investors turn increasingly to renewable energy resources to supply a substantial amount of the energy needed to maintain economic development.

This report suggests that poor and rapidly industrialising economies are as critically dependent on energy supply as are the world's richest nations. Renewable energy will have an important role in providing for the energy requirements of the emerging economies, and its importance in developed economies will grow. The immediate pathway to the future may be primarily through transitional fuels such as natural gas, accompanied by large-scale investment in new and emerging technologies including renewables where they are cost effective to allow for a smooth transition to a truly sustainable future.

EMERGING TECHNOLOGIES

This chapter reviews the major emerging energy technologies, including small and micro-scale power sources, cogeneration technologies, and advanced integrated techniques. Many emerging energy technologies are renewable, including solar, wind, biomass, and small-scale hydropower. Some, such as micro turbines and fuel cells, can operate on renewable and fossil fuels. The well-established traditional renewable technologies such as geothermal and large-scale hydro are not covered in this chapter, but nonetheless still remain an important ingredient in electricity supply infrastructure development.

A key feature of almost all the technologies discussed is the fact that they are either small-scale by nature, or suited to small-scale applications. Rather than being a disadvantage in modern energy systems, such technologies are at the forefront of an emerging trend - distributed power - that may change the face of the energy supply industry over the next few decades.

The development of mini- and micro-scale energy technologies, as well as liberating energy consumers in economies where energy market reforms are allowing much greater choice with respect to power supply options, may also provide much needed solutions to the needs of isolated and poorer rural communities.

PROVIDING ELECTRICITY TO REMOTE & POOR COMMUNITIES

All APEC member economies have the social goal of providing basic energy services to all citizens. Electricity is widely viewed as a service essential to economic development, and the extension of electrical grids, as well as provision of remote area power supplies, are actively pursued policy goals.

Remote area power systems have had a mixed history in terms of success, and both lending institutions and governments tend to promote investment in grid extension over investment in remote power systems. This is an area of policy that could benefit from further investigation. With the ongoing development of energy technologies suited to small-scale, micro-grid applications, it may prove more cost effective, at least in the short-term, to focus on investment in micro-grid system development in many situations, and intensify efforts to ensure the success of such ventures.

Large-scale grids increase security of supply, and ensure higher quality of power for demanding applications, but may be much less cost-effective, and a poorer policy option for poor rural communities in immediate need of economic stimulation. It is clear that newly emerging small-scale energy technologies could play a very important role in meeting the energy needs of rural and poor communities in the Asia Pacific.

ENERGY SYSTEMS IN SELECTED APEC ECONOMIES

This chapter looks at some specific energy system issues in a number of Asia Pacific economies. Included are descriptions of the emerging energy systems and issues in some selected developed and developing APEC economies.

Developed economies have very different energy growth patterns, and energy policy issues are different to those in the rapidly industrialising part of the APEC region. The developed case studies include consideration of specific emerging electricity supply situations in New Zealand and Japan. The developing economy case studies focus on China, the Philippines, Malaysia and Thailand.

APEC RENEWABLES INVENTORY

This chapter looks at the available data on renewable energy resources in the APEC region. Unfortunately, data on renewable resources is difficult to collate for many economies, either because it is not collected or the potentially available resources are as yet poorly defined and understood.

This is not the fault of energy policy analysts, as investigation of the potential of renewable energy resources to supplement traditional energy fuels is still at a very early stage of development, even in the more developed economies. For example, measurements of wind resources potentially available for power generation exist only at a very macro-scale even for developed economies. Actual investment in a wind power project requires detailed wind resource measurements on the actual proposed site for some time before bulldozers break ground. An even more difficult problem exists with respect to the measurement of the potentially available biomass resources in many APEC economies. Biomass data issues are covered specifically in an appendix to the main report.

ACHIEVING SUSTAINABILITY

How do fast developing APEC economies meet the challenge of exponential growth in electricity supply requirements, while at the same time minimising the impacts this growth will have on the environment?

In this report, this challenge has been addressed within the context of long-term sustainability. Decisions made now will have a great impact on the ability of individual economies to put in place electricity supply systems that can be maintained over the long-term. The continued construction of traditional coal-fired steam turbine plants can be considered an unsustainable practice, not because of resource scarcity (there are sufficient coal reserves world-wide to last for hundreds of years even with expanded consumption), but because the environmental and health impacts are too great.

This chapter looks at new and renewable energy technologies in turn and considers the important role these could play in encouraging a sustainable electricity supply growth pattern in fast developing APEC economies.

THE NEXT PHASE

This is an initial report, and only touches on some of the important issues related to energy sustainability. The next phase of the study will attempt to investigate more comprehensively the key issues. These include: capital requirements for specific energy development options; the impact of energy sector reform on energy system development; the role new and emerging technologies are likely to play over the next two decades; the short-term role of transitional fuels such as natural gas; and the relative importance of network energy infrastructure and micro-grid development.

A possible next phase of the study could also attempt to develop a number of forecast scenarios that could assist in development of the forthcoming APERC Energy Demand and Supply Outlook. These scenarios would focus on the likely importance of environmental policy initiatives in shaping future energy investments, the role renewables could play in regional energy systems in 2020, and some discussion of sustainability pathways for specific economies.

CHAPTER 1

INTRODUCTION

THE ELECTRICITY SUPPLY CHALLENGE

Rapid economic expansion in the Asia Pacific region over recent decades has led to large growth in demand for electricity. In much of the APEC region, demand growth has put a severe strain on the ability of individual economies to expand their electricity infrastructure capacity rapidly enough to meet the surge in demand.

Growth in demand for electricity is outstripping demand for primary energy in the Asia Pacific region, as the region becomes increasingly electrified and per capita consumption rises. This trend is particularly marked in the developing economies. How this rapid growth in electricity demand will be satisfied is possibly one of the most critical issues facing the region over the medium term.

APERC has projected that electricity consumption in Asia Pacific Economic Cooperation (APEC) economies will grow by 65 percent between 1995 and 2010 (an annual growth rate of 3.4 percent) [APERC, 1998]. This compares to a 74 percent (3.8 percent annual) increase for the five-year period 1990 - 1995.

Southeast Asia is expected to have the fastest growth in electricity demand over the forecast period with 7.8 percent per annum, contributing 11 percent of the total APEC increase. Northeast Asia will have the next fastest growth in electricity demand (5.2 percent per annum).

There are a number of important characteristics of this growth pattern. As shown in Table 1, the economies with high net electricity supply growth per annum are developing economies - those that have achieved sustained economic growth over the last two decades. All the developed economies in the APEC region have achieved only low to medium growth in electricity supply - reflecting the mature state of their economic development.

Not only have some developing economies in the Asia Pacific and in Central and South America been able to maintain sustained economic growth, forecasts suggest this growth will continue for another two decades or more - at least until the disparity between the developed and emerging economies has closed considerably.

As demonstrated in Table 1, the US consumes - by far - the most electricity in the APEC region (and is the largest consumer in the world). In APEC, China comes next, closely followed by Japan. Other rapidly emerging economies have relatively modest electricity supply requirements. It is clear that China is a key economy from an electricity supply growth perspective. If the annual average growth rate shown in the table were projected ahead for the next two decades, by 2020 China will be the largest consumer of electricity in the APEC region (and in the world).

Apart from the enormous capital requirements to develop such an infrastructure, the environmental implications could be very great, especially if much of this additional generation capacity is coal-fired, as currently projected [APERC, 1998]. This study is not just focused on China however. If one adds up the current net power requirements of all fast developing economies in APEC, excluding China, the result is a number very close to current Chinese power consumption.

This is a regional issue. Achieving sustainable electricity supply growth in the APEC region will be a major challenge for the region over the next two decades and more. If decisions are being made now to put this infrastructure in place, these decisions need to be well informed, in particular with respect to the possible policy and technology options which may help assure sustainable growth at a reasonable cost.

Table 1 Net electricity generation and growth rates in the APEC region

	GDP - Ave annual growth rate (1988-1998)	Electricity consumption Ave annual growth rate (1988-1998)	Net power generation in 1998 (TWh)
Oceania	3.05	3.20	232
Australia	3.17	3.51	195
New Zealand	1.92	1.56	36
Americas	2.83	2.35	4,414
Canada	1.80	1.07	577
Chile	7.59	8.39	35
Mexico	3.34	5.82	171
Peru	2.23	3.38	19
USA	2.86	2.31	3,611
Southeast Asia	5.74	11.19	322
Brunei	1.84	12.10	3
Indonesia	5.44	12.84	77
Malaysia	6.96	13.12	61
PNG	3.43	0.25	2
Philippines	3.04	5.94	42
Singapore	8.10	9.36	28
Thailand	5.90	11.00	90
Viet Nam	7.67	13.44	22
Northeast Asia	3.16	5.40	2,605
China	9.41	7.07	1,167
Hong Kong, China	3.68	5.20	31
Korea	5.83	10.88	215
Japan	2.05	3.37	1,028
Chinese Taipei	6.40	7.75	163
Russia	-6.24	-2.08	827

High: > 5.00 Medium: 3.00-5.00 Low: <3.00

Source: EDMC, 2000 and APERC, 2001

CHAPTER 2

DEFINING SUSTAINABILITY

INTRODUCTION

The concepts of economic and environmental sustainability revolve around the allocation of resources. However, economists and ecologists tend to have different definitions of "sustainability," and this has led to much argument about the degree to which our natural environment should be exploited and degraded in the interests and pursuit of economic development.

In the Brundtland report *Our Common Future* sustainability was promoted as the idea that society should not impoverish future generations by our economic and resource exploitation activities today. One of the implications of this definition of sustainability is that it is possible to use resources (even depletable resources) as long as the interests of future generations are protected [Brundtland, 1987].

The problem environmental advocates have with the above concept is that it is possible to show theoretically, using traditional economics, that dynamically efficient economic allocations (even for an economy relying heavily on depletable resources) can be perfectly consistent with the above definition of sustainability if the scarcity rent earned through exploitation of the non-renewable resources is invested in capital [Tietenberg, 2000].

The difficulty this raises for environmental advocates, and for societies putting heavy pressure on their local environments in terms of resource extraction and pollutant loading, is that over time, the natural environment is degraded, and in the worst cases eventually destroyed.

At one end of the spectrum, many traditional economists would argue the case for economic sustainability, and allow resource depletion as long as the value of the capital stock (natural plus physical capital) does not decline over time. If this approach is combined with a healthy dose of technological optimism, it can be argued that the natural environment - over time - will not be adversely affected by economic development because increasing wealth and technological development have traditionally tended to work together to mitigate environmental impacts and bring about environmental restoration. This assumes that although people wish to achieve economic development, they also value the environment highly, and will ultimately work to ensure its protection.

Environmental advocates have countered this argument by saying that natural and physical capital cannot be substituted in this way, and that the physical flows of individual resources should be maintained, because if they are not, the inadequacy of economic systems in accounting for environmental values will lead ultimately to their degradation and demise.

The discussion about sustainability is particularly pertinent to the subject of energy transformation and use in modern rapidly industrialising economies, as well as the wealthy post-industrial nations, because high levels of demand for energy are a core fundamental requirement for the continued existence of the modern way of life in developed societies.

In fact, the myth that the energy requirements of post-industrial economies should stabilise (or even decline) as they export their energy-intensive industries to economies with cheaper labour (and perhaps lower environmental standards), was dealt a heavy blow in a recent press article [Japan Times, 2000]. According to this article, the Electric Power Research Institute in Palo Alto, California, estimated that power demand in Silicon Valley grew by 12 percent in the year that ended August 2000. Amongst energy experts, arguments rage about the amount of energy required to provide the services the average US citizen now takes for granted, such as telephone and Internet access, as well as the computer with its myriad of peripheral devices such as scanners, printers and fax machines.

Because energy is vital to maintaining economic activity, and has serious environmental impacts, the price at which it is provided is a very important issue in this discussion. There is widespread agreement between economists and environmental activists that the full environmental impacts of energy consumption are not adequately reflected in the price paid in most markets in the world - especially for fossil fuels. This has the effect of encouraging greater consumption than is optimal, and acts as a barrier to improved energy efficiency and the introduction of less environmentally damaging energy generation technologies.

ACHIEVING THE GOAL

One approach to future energy sustainability, advocated by the Rainforest Action Network and other activist groups such as Friends of the Earth and Greenpeace, is an immediate halt to further construction of electricity generation plants that burn fossil fuels - with a phase-out of existing facilities - and a halt to all further oil and gas exploration.

This raises an interesting question, if in the longer-term (perhaps beyond 2050), economies will be forced to turn in earnest to renewable energy resources derived from the sun, would it be economically and socially feasible to force that shift through drastic policy actions today? Would this be the wisest route to a truly sustainable future (in the environmental sense of the term), or would the continued promotion and use of cleaner fossil fuels (for example natural gas), the widespread dissemination of clean fossil fuel combustion technologies, and energy efficiency improvements prove to be the more prudent pathway to the future?

There is another important dimension to this question. The “First World” has undergone rapid social and technological development over the last hundred years or so, aided greatly by intensive exploitation of indigenous and imported natural resources. Many developing economies are going through a stage of rapid industrialisation, and energy resource requirements in these economies are burgeoning. Some of the poorer economies in the world are in the pre-industrial stage, and have very low overall energy consumption per capita, much of it non-commercial energy such as biomass. The key point is that, as the world enters the 21st century, global energy consumption has never been greater, and yet is far below future requirements to meet the needs of economies with rapid industrial growth, as well as underdeveloped nations.

Should these nations be denied the opportunity to access the natural resource requirements they need to develop socially and economically because of First World concerns about the effects of resource exploitation on the global environment? Or should ways be found to allow this development in a way that is economically and environmentally sustainable - or at least minimises the damage such development might be likely to cause? A conundrum is the fact that many of the world's poorest and least economically developed nations are actually resource-rich, and many resource-poor nations - especially in Asia - have done well economically in recent years.

A study carried out in the mid 1990s by researchers at Harvard University assessed 97 developing economies for their possession of natural resources and their economic growth from 1971 to 1989 [Sachs and Warner, 1995]. They argue that their results show a negative relationship between an economy's reliance on natural resource extraction and overall economic growth, even when the results are adjusted for initial per capita income, trade policy, government efficiency, and other variables.

According to the Rainforest Action Network [RAN, 2000], "the exploitation of natural resources requires considerable investment, diverting capital away from productive investments in traded goods, including manufacturing." This is considered especially important if, as some economists believe, manufacturing plays a critical role in generating economic growth. It is further argued that states wedded to digging or drilling their way to wealth fail to develop their non-resource sectors such as manufacturing and services. This focus on natural resource exploitation is then said to lead to a cycle of indebtedness and economic failure.

However, such a far-reaching conclusion is simplistic at best, and in many respects, wrong. The Harvard study measured resource dependence as the ratio of primary product exports to GDP, including agricultural commodities as well as other natural resource outputs. The authors argue that their negative correlation between economic growth and natural resource base is "highly statistically significant" but if one looks at the scatter of data points, it is obvious the correlation - if it indeed exists - is not a strong one. The authors admit that the apparent negative association between resource wealth and growth could be spurious, and could actually reflect an association between resource wealth and something else that affects growth.

The authors also acknowledge that - assuming this correlation is accepted for the period 1970 to 1990 - it goes against some important historical precedents. For example, the resource rich nations of Great Britain, Germany and the USA, experienced particularly rapid industrial development at the end of the 19th century largely because they were able to exploit indigenous coal and iron ore deposits, and were not forced to pay high transportation costs for these vital ingredients of industrial growth.

It is true on the other hand that Japan; Korea; Chinese Taipei; Singapore; and Hong Kong, China have all experienced very rapid economic growth and industrialisation over the last twenty or so years, despite their lack of natural resource endowments, and that many resource-rich economies such as the oil-rich economies of Mexico, Nigeria and Venezuela have faced serious financial difficulties. However, it seems unlikely that resource endowments are the primary reason behind these phenomena.

One could consider the case of Japan for example. Japan imports almost all its energy resources. However, what would have been the situation if Japan had substantial oil resources, and had been able to exploit these to fuel its rapidly expanding economy over the last 40 years? The overall social and economic outcome would almost certainly have been very similar, but perhaps at a considerably reduced cost, if one takes into account the large sums of money Japan has spent over the last four decades trying to secure stable supplies of crude oil from the Middle East and other supply regions of the world.

The reasons why one nation does well economically, and another founders, may be influenced by natural resource endowments, as some researchers have suggested. But such a conclusion would not, however, be a valid reason to argue against resource development on a global, regional or local scale. One is also on weak moral ground in using this as an argument that poorer nations should not exploit their natural resources, but rather import what they need in order to support economic development. The alternative fate might instead be one of long-term economic stagnation and political turmoil, grinding poverty, and eventual social breakdown - with the accompanied environmental devastation seen in some regions of the world today where a cycle of poverty has led to disaster.

Of course we face the problem that the energy requirements needed to bring much of the developing world up to the standard of living enjoyed by the average citizen in the rich nations are very large indeed, and if this development follows traditional patterns, the environmental and social consequences will likely be grave. Developing economies today have much higher population densities than the rich nations of today had when they were rapidly industrialising, so the implications of unchecked economic activity can be much greater. It is believed by many that developed economies have a responsibility to assist those that are developing to attain prosperity in a sustainable manner.

ENERGY RESOURCES ARE CRITICAL TO ECONOMIC GROWTH

For economies to grow their manufacturing sectors, to increase national wealth and the well-being of their citizens, they require energy and other resources. Energy resources alone, whether imported or indigenous, require huge amounts of capital for resource exploration, development, transportation and transformation. For example, in it's 1997 report "Financing the Global Energy Sector: The Task Ahead," [WEC, 1997] the World Energy Council estimated that about US$30 trillion will be needed between 1990 and 2020 to finance the world's burgeoning energy supply requirements. In the Asia Pacific region over the same period, the capital requirements will be more modest, but still very large - probably in the vicinity of US$3 trillion.

The 1987 Brundtland report concluded that: "energy is necessary for daily survival. Future development crucially depends on its long-term availability in increasing quantities from sources that are dependable, safe and environmentally sound. At present, no single source or mix of sources is at hand to meet this future need."

The two billion poorest people, many located in rural areas, use only 0.2 toe of energy per capita annually, whereas the billion richest people use 25 times as much. The WEC at its 17th World Congress in Houston in September 1998 concluded that the number one priority in terms of sustainable energy development today is the extension of commercial energy services from the rich nations to those living and being born into poverty who do not have access to these services.

As noted in the 2000 WEC report *Energy for Tomorrow 's World: Acting Now* , the opportunity of the world's poorest people for education, good health and individual dignity is in doubt, "progress in meeting the energy requirements of these roughly two billion people should be regarded as the first test of the sustainability of our energy development path" [WEC, 2000].

However, according to WEC, financial cooperation between developed and developing economies has not improved since the publication of its 1993 report *Energy For Tomorrow's World*. "According to recent World Bank data, OECD economies have failed not only to fulfil their international commitments of Official Development Aid (slightly more than 0.2% of their GDP in 1998, compared to the 0.7% they promised), but also have failed to create the appropriate institutional tools to promote a larger amount of Foreign Direct Investment which today is about $100 billion per year (if one excludes portfolio investments)" [WEC, 1993].

Apparently, the problem is not a shortage of money [WEC, 1997]. WEC concludes that global capital resources in principle are more than adequate to meet any potential demands coming from the energy sector. While the estimated energy investment requirements of the 1997 study and *Energy for Tomorrow's World* were reduced in the subsequent work with IIASA entitled *Global Energy Perspectives* published in 1998, the key for many economies is still to establish the legal, financial, and market reforms which will attract the necessary domestic and foreign capital for new energy projects. It is still generally more expensive to invest in a developing than a developed economy today because the risks and transaction costs are higher [Nakicenovic *et al,* 1998].

The challenge is relatively clear, developing economies have the right to improve the lives of their citizens, and providing them with modern energy services is a fundamental starting point. At the same time, their citizens will desire clean air along with improved economic conditions. Providing sustainable energy systems at an early stage of development can achieve both objectives. Developed economies have the technologies that could allow this to happen in a way that does not imperil the global ecosystem in the process. Modern clean energy technologies must increasingly become the options of choice for developing economies (replacing old inefficient and polluting fossil-fuelled plants).

THE RENEWABLE RESOURCE POTENTIAL

The earth receives annually around 130,000 Gtoe of solar energy. This can be compared with total global energy consumption in 1997 of 9.5 Gtoe. In terms of human requirements - today and into the foreseeable future - renewable energy resources are essentially limitless. However, there is a catch, the annual flows of solar energy may be enormous, but renewable resources offer energy densities orders of magnitude lower than those provided by deposits of fossil fuels. In addition, solar energy potential varies seasonally and regionally.

Apart from the promise of sustainability, renewable resources offer the promise of relatively low environmental impacts, being either carbon free or carbon neutral, and generally having relatively low emissions of other pollutants. The general exception to this is the burning of fuel wood in confined spaces for cooking in third world regions. This practice is inefficient and leads to substantial health impacts including poor indoor air quality, and contributes to local air pollution in urban areas. According to the World Health Organisation (WHO), more than one billion people in developing world cities are exposed to unacceptably high ambient concentrations of suspended particulate matter and sulphur dioxide [World Bank, 1992].

Despite a current global focus on greenhouse gas emissions, the most pressing environmental problems in very poor economies are local pollution and ecosystem destruction, much of it caused by combustion of fossil fuels and unsustainable use of fuel wood. Although environmental advocates promote a rapid decline in fossil fuel combustion, and an equally rapid uptake of renewable energy technologies, it must be remembered that the poorest two billion people in the world already rely almost totally on renewable resources for their energy requirements, and this practice is both unsustainable and leading to localised pollution and widespread destruction of natural bio-systems.

The fact that local environmental problems, and their attendant health effects, are the major concern in the developing world would suggest this is the first priority for socio-economic policy action in these regions. The urgency of the problem requires a mix of efficiency improvements, cleaner fuels, as well as end-of-pipe control technologies [Nakicenovic *et al*, 1998]. One of the solutions is the replacement of non-commercial biomass and fossil fuel consumption on a local scale with commercially supplied electrical energy. Even if the electricity is generated using fossil fuels, if it is done so using relatively clean modern technology, overall urban pollutant levels (particulates, SOx and NOx) will decline. Even net carbon emissions may decline where unsustainable fuel wood burning is occurring, as in some parts of Southeast Asia, some areas in South America, and Africa.

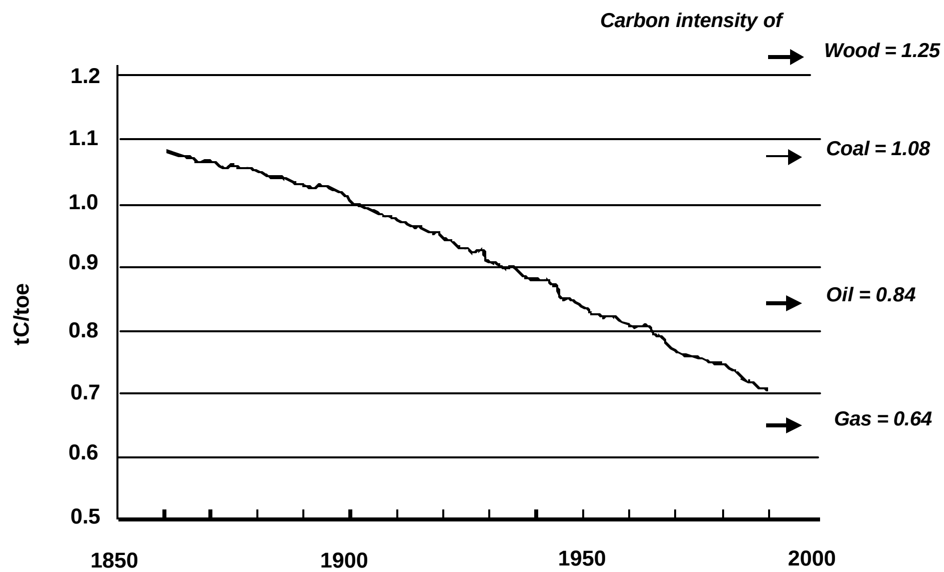
Efficiency improvements and a shift to cleaner fuels tends to result in lower resource use, lower overall energy system costs, and lower emissions. Figure 1 shows the carbon intensity of primary energy over time. A downward trending line can be taken as an indicator of other pollutant emissions from energy consumption. NOx, SOx and particulate emissions tend to be lower in less carbon intensive fuels.

Measured in terms of final energy, the declining carbon intensity over time has resulted from the increasing use of clean, grid-dependent energy carriers such as electricity, district heat, and gas [Nakicenovic *et al*, 1998].

CARBON REDUCTION FROM BIOMASS

Though biomass burning results in emissions of CO2, biomass absorbs about the same amount of CO2 during its growing cycle as is emitted from a boiler when burning. Biomass production is considered to be a sustainable or “closed-loop” process. Net CO2 emissions on a complete fuel cycle are considered to be nearly zero. Therefore, if other forms of energy emitting carbon can be replaced with biomass, then the overall effect will be a reduction in carbon emissions. A key consideration is that the biomass has to be managed in a sustainable manner.

Figure 1 Carbon intensity of world primary energy mix



Source: Nakicenovic *et al*, 1998.

Unlike coal, most forms of biomass contain very small amounts of sulphur. Therefore, replacing coal with biomass can significantly reduce sulphur dioxide (SO2) emissions. Lastly, firing biomass in boilers with pollution control can reduce burning of wood residue in uncontrolled furnaces or in open fields, and hence provides another means of reducing CO2 or other emissions. Biomass will be analysed in greater detail later in the report.

THE ROLE OF RENEWABLES IN POWER GENERATION

Exploitation of renewable energy resources is not a new idea. In fact the use of hydropower to generate electricity is as old as the power industry itself. Amongst APEC economies, New Zealand and Canada use hydropower to generate more than 50 percent of their total electricity requirements. Even in the USA, which has a heavy reliance on fossil fuels to generate power, renewables - mostly large-scale hydro - provided 11 percent of net power generation in 1998.

The focus on renewables in this study is less on large-scale hydropower than on smaller mini and micro-scale hydro developments, and newly emerging renewable technologies such as wind, thermal and PV solar, and improved methods of biomass utilisation.

Large-scale hydropower facilities grew as a natural extension of smaller scale technology, as the ability to transmit power over long distances developed and economies of scale took hold on the electricity supply industry. The largest hydropower development to date in the world, the Three Gorges hydropower scheme in China, will have an expected capacity of 18,200 MW. Large-scale hydro is a mature technology with generally favourable economics, but future development options are limited in developed economies in the Asia Pacific region, and also tend to be limited in emerging Asian economies.

In addition, large-scale hydro developments have fallen out of favour with environmental advocates and lending institutions because of their substantial environmental and social impacts, and have become very controversial. The main impacts include disruption of fish breeding cycles, dislocation of large numbers of people, loss of considerable amounts of productive land, and downstream impacts (upstream diversion of water and trapping of silt). One can find many examples in the literature where such developments have been actively opposed in the planning phase, or vigorously questioned after commissioning.

If one looks beyond large-scale hydro, renewable energy resources currently represent a small component of the total primary energy supply situation, and are mostly dominated by biomass consumption. Despite very rapid growth rates for wind-power, solar thermal and solar photovoltaic (PV) in some situations, this is growth from a very small base. Even if the long-term prospects for these technologies are good, more widespread adoption of these technologies is constrained currently by the relatively low price of fossil fuels. This situation is not expected to change greatly over the next decade or two if the true environmental costs of burning fossil fuels are not factored into the prices paid for those fuels.

Currently, a debate continues regarding climate change and global warming. If burning of fossils fuels are the main cause for carbon emissions and subsequent environmental damage, then one can easily assume that a “carbon” or “environmental” cost should be associated with the use and burning of fossil fuels. If the cost of fossil fuel were to significantly increase because of a change in the political climate, then the barrier of low priced fossil fuels would not exist.

Consequently, the conservative supply/demand forecasts provided by energy modelling experts tend to project a very limited role for new renewable energy resources out to 2020. APERC's 1998 Demand and Supply Outlook to the year 2010 projects that renewable energy other than large scale hydro will represent only two percent of final regional energy consumption in 2010 [APERC, 1998].

The US Energy Information Agency (EIA) expects the worldwide renewable energy share including large scale hydro to match growth in total primary energy consumption, and remain at around eight percent of global energy consumption in 2020, despite a projected 54 percent increase in consumption of hydroelectricity and other renewable resources [DOE EIA, 2000].

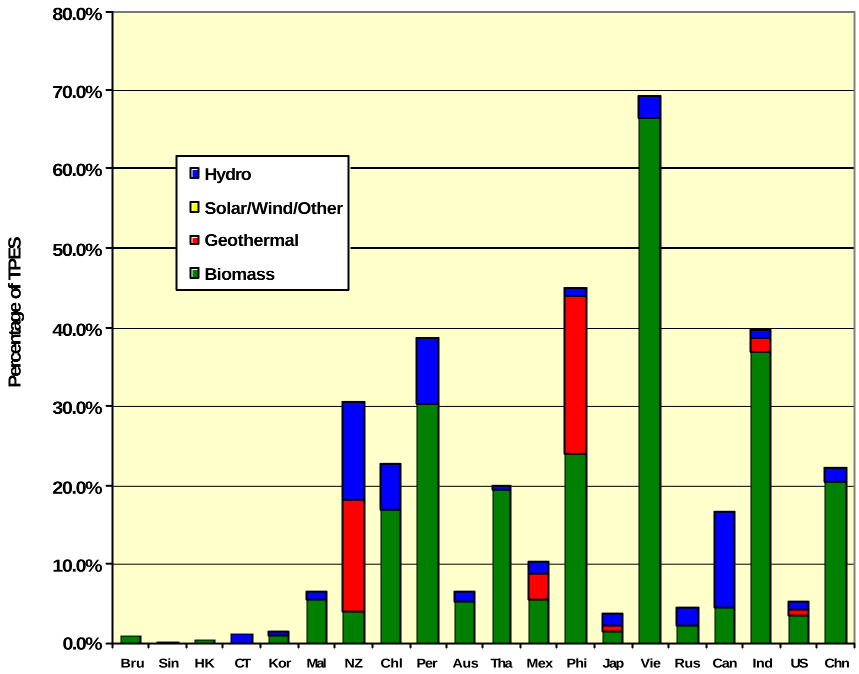
Some energy experts are more optimistic about the future of renewable energy. Shell, for example, has published information suggesting that by 2050 half of the world's electricity supply will be generated by new and renewable resources [Shell, 2000].

Nakicenovic *et al* in *Global Energy Perspectives*, predict in some scenarios, that a significant expansion in the use of renewables will occur by 2050. This trend will be reinforced by 2100 with the gradual phase out of traditional renewables, and replacement by new renewable technologies. According to the authors, the renewables portfolio is particularly diversified, and varies geographically in response to available resources and technologies, and the level and structure of energy demand. It proceeds at different rates, depending on policy incentives and specific market niche opportunities. Importantly, from a policy perspective, the authors believe “even massive policy interventions would appear limited in their ability to shortcut the learning and experimentation required for the spread of new renewable technologies” [Nakicenovic *et al*, 1998].

This implies slow growth in the market share of renewables, even if driven by strong environmental policy pressure. The widespread rejection of polluting and hazardous technologies in favour of clean technologies that - for the time being at least - come at a higher cost, will be tempered by the realities of the marketplace. The capital requirements for adoption of new technologies, even in wealthy nations, is limited, and will favour energy resources that can compete favourably in an increasingly deregulated energy sector marketplace. This favours oil and gas as important sources of energy.

Most industry analysts agree that the peak of the fossil fuel era is close to passing, and that fossil

Figure 2 Contribution of renewable energy to TPES for the APEC region



Source: IEA, 2000 and EDMC, 2000

energy consumption will soon grow more slowly than primary energy needs. However, Nakicenovic *et al* suggest that by 2050 oil production could still be a factor of two greater than today, and gas production larger by a factor of five in a high energy growth scenario.

The 1993 WEC study, *Energy for Tomorrow's World* predicted a more rapid penetration of new renewables in meeting energy demand than has actually happened in the subsequent seven years. Since the study was published, WEC produced a study on new renewables that highlights their progress, their special cost and financing challenges, and some of the steps that must be taken to link new renewables to base and mid-load energy systems.

General obstacles to the current lack of further development and utilisation of renewable energy are many. In developing economies these obstacles include high initial investment costs, lack of access to financing, low levels of technology awareness, lack of information dissemination, lack of technical expertise, the limited number of renewable energy technology suppliers, ineffective distribution and marketing, inefficient designs, few or no financial and fiscal incentives, inadequate facilities for technology adaptation and development studies, and a lack of institutional and project management capabilities. These difficulties vary from one economy to another.

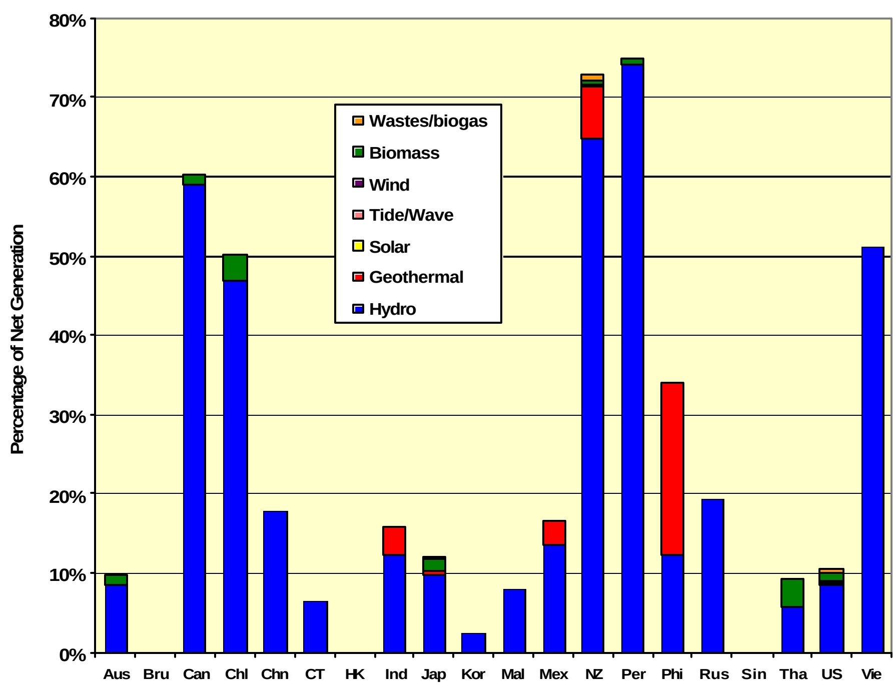
Figure 2 shows the contribution renewable energy resources currently make to total primary energy supply for each of the 21 APEC member economies. Biomass, mostly combustion of fuel wood, makes by far the greatest contribution to total energy supply overall, and particularly to the energy requirements of the lesser developed economies. The data includes estimates of non-traded biomass. In the developed economies, biomass consumption is largely commercial, comprising combined electricity and heat generation plants running on forestry and agricultural wastes, as well as biogas generated in landfills and combustion of urban wastes.

The contribution of renewable energy resources to net electricity generation gives a better idea of the role renewables could potentially play in supporting sustainable development. This is shown in Figure 3 for each APEC economy. For individual economies the contribution of renewable resources to total net power generation is impressive. However, one must bear in mind that almost all of it is large-scale hydro that is limited in the future, as discussed above. Power demands are growing exponentially in rapidly industrialising Asian economies, and the gap between the current situation and one where renewable resources provide the bulk of our power requirements is vast.

INVOLVEMENT OF OIL COMPANIES IN RENEWABLES

For a number of years international oil companies have been investing in technologies that could be commercialised in a future, carbon-constrained world. The world leader, for example in solar PV manufacturing and marketing is BP Solar. BP Solar is a recent amalgam of the former BP Solar with Solarex,

Figure 3 Contribution of renewable energy to net power generation in APEC region



Source: IEA, 2000 and EDMC, 2000

and has 20 percent of the world PV market. As noted in the company's promotion material: "major recent projects include multi-million dollar contracts for rural electrification in Indonesia and the Philippines." Obviously, the majority of sales are in the developed world, and quoted PV electric rates are usually well above those for electricity generated by other means (except for remote power systems and possibly peak demand mitigation). However, the fact that the technology is being promoted by such an international heavyweight would tend to suggest that technology costs will be driven down over time.

Shell Renewables' (Shell) involvement in renewable energy covers an even broader range: biomass (especially forestry and wood wastes), wind energy, solar energy, and energy conversion systems utilising fuels such as hydrogen. Shell is in the third year of a US$ 500 million five-year investment plan to make a profitable business from renewable resources. Shell first concentrated on forestry, the use of wood wastes to produce energy, and the manufacturing and marketing of PV panels, before starting to invest in wind energy in 1999.

DEVELOPMENT OF RENEWABLE PORTFOLIO STANDARD IN SOME ECONOMIES

A Renewable Portfolio Standard (RPS) has been implemented in some economies, including Australia, the USA and part of Europe. A RPS usually specifies that a certain portion or percentage of electricity generation must be from a renewable source other than hydropower, such as solar, wind, or biomass. The implementation of RPS has various approaches and preferences of policy makers.

In the USA, the RPS along with system benefit charges (SBC) have been implemented in 12 states as part of electricity industry restructuring policies, and has been under consideration in other states. There are no national RPS regulations, but a number of federal bills have proposed a mandatory national RPS requirement. The National Association of Utility Regulatory Commissioners supports such a policy. The target of the national RPS proposal has varied, but is currently specified that 7.5 percent of net electricity generation be supplied from renewable energy sources (other than hydropower) by 2010.

Analysis by the US DOE Lawrence Berkeley National Laboratory of the existing RPS and SBC legislation in 12 US states, estimates that by 2012 the installed capacity of renewable energy technologies will more than double from today's level, accounting for 8.4 GW of new generation, see Figure 4.

Australia has announced a RPS programme that will be implemented beginning in 2001 through a renewable certificate trading scheme. The target is to increase the renewable electricity market share by two percent by 2010. Electricity providers in all states and territories with over 100 MW of installed capacity will have to contribute proportionately to the achievement of the programme. The Australian RPS programme standard will be aimed at wholesale purchases of electricity either from the power pool, or directly from a generator. This standard excludes self-generators, as long as they do not make wholesale purchases [Berry and Jaccard, 2000].

China already has a number of renewable supporting measures, such as funding allocation, and certain incentives for renewable resources. However, these current mechanisms do not ensure the same level of achievement that a RPS can deliver. China is considering a RPS programme suited to its economy. One important consideration is the distinction between large hydro and other renewable sources.

Although China does not have a single grid covering the whole economy to trade renewable electricity production between regions such as in Australia and the USA, trading is still possible. If some regions fail to meet the RPS standard, then they could subsidise renewable developers in other regions by buying their excess credits [Union of Concerned Scientists, 2001].

If the proposals of the RPS work well in economies that are more advanced, then other economies could follow in the future, taking into account their specific characteristics for designing their own policies.

ENERGY EFFICIENCY PROGRAMMES

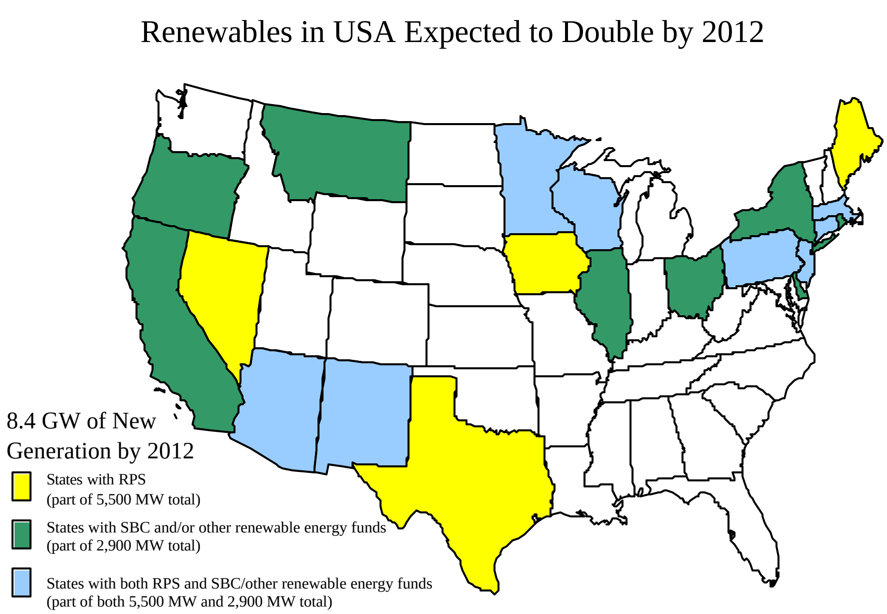
This study is primarily focused on electricity supply sustainability, however as demand management is closely interlinked with the supply issue, it needs to be considered. APERC recently completed its second report on energy efficiency indicators for the APEC region, and this document provides a very good overview of energy efficiency trends and policies [APERC, 2001].

Every economy can moderate electricity demand growth through the adoption of more efficient practices, products and services. High efficiency products exist on the global market for a wide range of end-use applications, such as space conditioning equipment, industrial motors and chillers, residential appliances, lighting, office equipment and many more. Also, building components such as improved windows, high reflectance roofing, energy management systems, and services such as improved construction techniques, can result in significant electricity load reductions.

Please refer to the referenced APERC report for a wide range of policy mechanisms to implement these highly efficient products and services. Many installations are very cost effective and can be achieved at costs lower than the cost of new electricity generation. Plans for energy efficiency policies and measures need to be an integral part of any electricity supply plan.

Demand-side savings will not avoid the eventual requirement for new generation, but the reduced supply growth rates will result in substantial economic advantages. In addition, the delay allows for technological advances in power generation technologies, and cost reductions as cleaner technologies become more competitive.

Figure 4 RPS and SBC policies adopted in US States



Source: Adapted from US DOE Lawrence Berkeley National Laboratory, Van Rest, 2001

CHAPTER 3

EMERGING TECHNOLOGIES

INTRODUCTION

This chapter reviews the major emerging energy technologies, including small and micro-scale power sources, cogeneration technologies, and advanced integrated techniques. Many emerging energy technologies are renewable, including solar, wind, biomass, small-scale hydropower, and some, such as micro turbines, and fuel cells, can operate on renewable and fossil fuels. The well-established traditional renewable technologies such as geothermal and large-scale hydro are not covered.

The concept of distributed power systems will also be considered in this chapter, as well as in the next, as such emerging power systems have applications on and off the power-grid.

The term "emerging" is used here to characterise technologies that are just becoming, or are on the verge of becoming, commercially competitive in the general marketplace. Most are not new- photovoltaic panels and wind turbines have been around for many years, as have fuel cells and micro-scale hydro power plants. These technologies have all been used in specific niche applications - fuel cells power satellites and spacecraft equipment, small-scale hydro power plants were some of the first power plants ever built. However, in combination with the growing need for innovative ways to provide electricity services to remote communities, the ability of modern power handling equipment to manage the characteristics of some of these power sources, and the opportunities opening up with deregulation of power markets, it is likely that the technologies discussed below will become increasingly common in the marketplace.

RENEWABLE TECHNOLOGIES

In 1997, it was estimated that the world used 9,521 Mtoe of primary energy. Around 80 percent of this energy was provided by fossil fuels, hydrocarbon deposits that consist of the remains of animal or vegetable life from past geologic ages such as oil, coal, or natural gas. Not only do fossil fuels provide a large share of total global energy consumption, the demand for energy has grown greatly in recent decades, for example increasing around 57 percent from 1973 to 1997 [IEA, 1999]. If the world continues with the two trends of rapidly growing demand for energy, and rapidly growing consumption of fossil fuels, eventually there will be two inevitable outcomes, serious environmental impacts on a global scale, and depletion of fuel resources. While the possibility of the latter has occupied the minds of energy planners and politicians alike for decades, it is the former which posses the greatest danger and represents the more difficult challenge.

To meet these dual challenges, significant attention has been focused on research, development, and application of renewable sources of energy, resources that can be exploited in a sustainable fashion for an indefinite period of time, and which leave a much lighter imprint on the face of the earth.

SOLAR TECHNOLOGY

The sun is an enormous sustainable energy source, and this has important implications for energy consumption on earth. For example, people can dry their cloths or industrial products using the sun's heat, thus avoiding the use of secondary forms of energy. Similarly, solar gain contributes significantly to air conditioning loads in all types of buildings. There are many kinds of technologies and design practices to avoid this unwanted energy from the sun.

At the same time, there are several sophisticated ways to use solar energy instead of burning fossil fuels and using electricity provided from the grid. The most straight forward technology is to use passive solar radiation to heat residences and buildings in colder climates, or to use thermal solar systems to heat or preheat water for domestic use.

A technology that has received significant attention recently is the use of photovoltaic (PV) cells to convert the sun's energy directly into electricity. There are also several other solar technologies that involve highly concentrating solar heat to produce electricity on a larger scale, but these are still developmental and high cost. Of more concern here are smaller scale applications using PV to power facilities, buildings, homes, or to provide power back to an electricity distribution grid.

PV cells are solid-state semiconductor devices with no moving parts that convert sunlight into direct current electricity. PV cells or panels have been around for quite some time and have high profile applications such as space exploration. Recently, the international space station installed its PV power system while the world watched. Because of these sophisticated applications they have found their way into almost everyone's life. PV cells are commonly used in a large array of products such as pocket calculators, watches, chargers, and outdoor decorative lights. PV is also very cost effective for remote applications. Market potential has encouraged global private and public research and development of this technology. The price of PV cells has fallen from around US$13,000 in the early 1980s to around US$5,000 in the late 1990s for each kW of installed capacity [UNDP, UNDESA, & WEC, 2000].

Furthermore, since PV cells generate power without producing pollution, many governments continue to support research and development activity along with outreach or market deployment programmes. For example, in 2000 the Japanese government invested approximately US$ 224 million [NEF, 2000], and the US government invested approximately US$ 65 million [US DOE, 2000].

Often, the cost or price of energy from a particular technology such as PV is referred to in US$ per kWh. Several technologies including grid power are compared using this rate. However, the rate for a technology such as PV is basically amortised over the life of the system. PV has a very high capital cost, but has a very low operating cost consisting only of limited maintenance and possibly battery replacement. Though a technology such as a diesel generator would still have a significant capital cost, the operating costs are much higher due to significant maintenance and high fuel costs. The entire life cycle cost for the capital, operating costs, and disposal costs (if significant or different) are amortised over time to produce the amortised rate of electricity, usually expressed in US$ per kWh. Current amortised rates of electricity generated from PV range from US$ 0.12 to US$ 0.20 per kWh that makes it competitive for providing remote power or where extension of the utility grid would prove expensive in relation to the expected load. Predicted amortised rates in the next 10 to 30 years are expected to be less than US$ 0.06 per kWh [US DOE, 2001].

Technological advances are expected to improve conversion efficiencies. Improved manufacturing techniques are also expected to reduce costs. Current efficiencies of conversion range from around 10 to 20 percent. The entire manufacturing process involves trade offs of material costs, manufacturing costs, efficiencies, and product durability. An interesting area is the development of thin film PV modules. There are several types of cell materials and most have been in the research and development phase for quite some time, however a few products are starting to be introduced to market. Usually, thin-film modules have offered a greater potential to reduce cost but the efficiencies have been lower than traditional PV panels. Recent accomplishments of thin-film prototype modules have seen the efficiencies match those of the traditional PV panels [US DOE, 2001]. One example of a thin-film PV application is the cell being configured into roofing shingles. These PV shingles resemble typical asphalt shingles but are cheaper to install, and offer greater acceptance and aesthetics by potential owners compared to conventional solar panels. Thin-film PV has had problems with durability but recent developments appear to be overcoming these issues.

A major concern with the use of solar technology is that the sun does not always shine. Days are shorter in the winter and some times it is cloudy or rainy. Furthermore, electricity generated during the day needs to be stored in batteries for use at night. The use of batteries and other storage devices have been problematic, such as high cost, poor reliability, and high maintenance; but these and other issues are some of the challenges facing the greater acceptance of renewable energy systems. Research and development continues to progress on storage technologies, and the capability and efficiency of storage technology does not appear to be a major hurdle to greater acceptance of PV.

If the world economies and populations are going to continue to grow and prosper in a sustainable manner, the answer has to include the use of PV as a significant contributor to our energy supply needs. Although private sector investment in PV has been rather limited to date, this is changing, and the number of firms involved in the PV market is growing, with strong competition between the EU, Japan and the US. In 1998, the installed capacity was around 500 MW and is expected to grow rather quickly [UNDP, UNDESA, & WEC, 2000]. Global production of PV is expected to reach one GW per year by 2010 [Siemens, 2001].

WIND TECHNOLOGY

Wind energy is actually derived from the sun through the heating and cooling of the earth and from the earth's rotation. Electricity that is generated using wind turbines, or wind power, can be harnessed and used to power homes and businesses. Wind power technology however, faces the same technical hurdle as solar power, the wind does not always blow. Furthermore, the wind resource varies greatly in strength and consistency from place to place. Because the potential power from wind is equal to the cube of the velocity, locations with a pattern of frequent strong winds have a much greater potential for power generation than do places with low velocity steady winds.

Wind has been used for thousands of years to drive windmills and sailboats, but the modern wind power turbine is a very recent technological advance. Years of optimisation of engineering design, including sophisticated aerodynamic modelling, have resulted in systems that are able to maximise efficiency. Turbines are mounted on tall poles to intercept the less turbulent air, and the large blades used are able to rotate at relatively slow speeds while driving the generator enclosed in the “hub,” at the higher speeds needed to produce electricity.

Wind turbine technology continues to improve. For example, ABB has a 500 kW prototype called the Windformer that is expected to reduce the cost of generation to US$0.04 per kWh. The Windformer's design eliminates the gearbox and transformer, reducing costs and possibly improving reliability. A 3 MW prototype demonstration is being erected on the island of Gotland in the Baltic Sea and is expected to be operational for the summer of 2001 that will have conditions similar to off shore applications.

Off shore applications are away to avoid negative impacts associated with wind turbines, such as noise and aesthetics. Also, wind over the water is less turbulent compared to land applications.

The Windformer also avoids the problem of varying frequencies caused by changes in wind speed by converting the output to high voltage direct current for transmission. ABB also has a technology to transmit power using high voltage direct current light that uses semiconductor and control technology to do away with frequency. ABB has several contracts for installation of its new transmission system that is expected to reduce energy losses by 50 percent [Mechanical Engineering, 2000].

Despite concerns regarding the aesthetics of large turbine wind farms, potential noise problems, and avian impacts (bird fatalities), the installed capacity of wind power has increased significantly in recent years. In 1999, installed capacity increased by 36 percent from 1998 to a total of 13.4 GW [Mechanical Engineering, 2000]. Wind power capacity is expected to increase significantly in economies with suitable wind resources situated close to major centres of demand. In many applications with large wind resources, cost of generation using wind turbines is lower than generation using any other resource, renewable or traditional.

Wind power does have a number of technical constraints - historically wind velocity varies constantly causing power fluctuations. High wind speeds do not necessarily coincide with peak demand and there is no easy way to store the power generated at one time for use at a later time. Technological advances may reduce these constraints. A certain percentage of wind power in a grid is viable and should be exploited in the future supply mix to the extent that it is cost effective. Although wind speed does not necessarily match electricity demand, in many coastal applications the strongest wind speeds often occur while buildings are experiencing their greatest air conditioning loads. Therefore, wind can play an important role in peak demand mitigation in certain circumstances, and can also contribute to rural and village power needs. Later in the chapter, the ways in which wind power can be combined with other technologies to meet the needs of future demand will be discussed.

SMALL-SCALE HYDROPOWER

Water has been used to power equipment, such as water wheels, for a very long time. The Greeks, 2000 years ago, made use of mechanical power from falling water to grind wheat into flour [USDI, 2000]. The first hydropower facilities were small and were installed close to the demand centre - usually a small town or industrial facility of some kind.

Small-scale hydropower resources generally include either run-of-the-river or low head power generation, and generally encompasses resources that are less than one MW in size [WEC, 1994]. Because these systems are small, many opportunities exist for the application of this type of technology. Small-scale hydropower schemes avoid most of the undesirable impacts of large-scale developments, and can produce electricity where it is needed (avoiding transmission losses). For example, small-scale hydro schemes could provide power to remote and poorer communities in developing economies where the resource is available (for example China, Indonesia and the Philippines).

One drawback of small hydropower, similar to wind and PV, is matching supply with demand. With wind and PV, peak supply and demand periods often do not coincide and power storage is required on a daily basis. With small hydropower, there are seasonal concerns that need to be assessed in the design phase. Thus, total reliance on small hydropower for electricity could lead to supply interruptions. Small hydropower, with water storage, could be used to meet peak daily demand.

BIOMASS TECHNOLOGY

Biomass is growing matter (plants and trees) that can be used for energy purposes. Plant material contains stored energy that originally came from the sun through photosynthesis. Thus, biomass is another form of solar energy. In addition, animal waste is also considered biomass since its origin is the food (plant matter) consumed by the animal. This energy can be converted and used in several ways such as, biogas (methane) in a digester and used for cooking, or ethanol and used (usually mixed with gasoline) as a transportation fuel.

The use of firewood for cooking and the use of rice husks for industrial boiler water preheating are examples of biomass use, but may have very different impacts. Generally, the use of agricultural wastes and fuel wood from forests can be considered sustainable, although there are arguments about the sustainability of much modern agriculture. This is true for developed and developing economies, the latter is often heavily dependent on large-scale applications of fertiliser to maintain the fertility of soils used for crops such as rice. If the soil is depleted of its nutrients, or artificial fertilizers cause other environmental impacts, then the practice cannot be considered sustainable. With proper agricultural management, crop rotation, and partial use of crops as natural fertilizer, a more sustainable future can be followed.

The consumption of fuel wood is, in many places in the developing world, unsustainable. In many places, including in the Asia Pacific, indigenous tropical forests are being irreplaceably destroyed to provide agricultural land for burgeoning populations, or for the valuable hardwood timber they contain. Forest management is a key to the sustainable use of wood for energy purposes.

More efficient biomass energy technologies are rapidly advancing. These include direct combustion (co-firing steam boilers is one application), fermentation, and anaerobic digestion. These technologies increase the attractiveness of biomass as a sustainable energy source. One of the most beneficial aspects of these and other technologies that can generate clean electricity or provide gas for cooking, is the mitigation of some of the harmful impacts of current biomass usage.

Cooking practices are an area of major concern in developing economies. Women and children spend a significant amount of time gathering firewood and tending the cook stove. Smoke emissions from improperly vented stoves are considered a health hazard, and there have been many attempts to improve the efficiency and reduce the emissions of cook stoves. China and India have most aggressively pursued this problem, and have installed over 200 million improved stoves since 1982. However, even these improved stoves may lead to health problems and may be using fuel sources such as firewood or animal wastes in an unsustainable manner.

Although there may not be a single solution to this problem, an attractive option would be to leapfrog to more efficient and cleaner sources of energy for cooking, optimally biogas or electricity. Biogas (bacterial action) from animal wastes or producer gas (chemical action) from crop residues are an obvious answer for cooking requirements, and are being used increasingly in some developing economies (India is a leader in the development of these technologies). Also, the use of high-grade fuels such as LPG are a possible option (although perhaps too expensive for poorer communities), and may be a more sustainable option when one considers the overall environment impact of fuel wood consumption [UNDP, UNDESA, & WEC, 2000].

Often forgotten are the economic consequences of the large amount of time and energy spent gathering and transporting fuel wood in poorer economies where unsustainable practices have led to increasing scarcity of supply. The reduction in labour associated with the use of more advanced forms of energy can allow women and children to spend more time concentrating on educational, social and economic activities which lead to greater overall economic prosperity. Over time, and with developmental assistance, small isolated communities have the potential to leapfrog to the most modern technologies (hot plates, rice cookers or community microwave ovens) through the application of small-scale electricity generation technologies.

LOW POLLUTING/COGENERATION TECHNOLOGIES

Natural gas is significantly less polluting and often more cost effective than other fossil fuels used for power generation, such as coal and petroleum. Due to the increasing availability of this resource (through extensions of pipeline networks), investment in modern electricity generation plants has increasingly favoured combined cycle natural gas turbines. This technology has generation thermal efficiencies approaching 60 percent [Anex *et al*, 2001]. In addition, several technologies exist that have the ability to significantly increase this efficiency (discussed below).

For many years, consumption of natural gas for power generation has not been highly favoured due to the low efficiency of earlier steam turbines, but also because of concern about the long-term availability of the resource. A recent report concludes that this is not a near-term issue.

> "The perception of natural gas availability has changed dramatically during the last decades. The traditional view is that conventional reserves of natural gas in the world are limited, say to some six decades at current consumption levels. This is strictly speaking still correct. However, this is a static view that is challenged by many recent assessments. It is now quite widely accepted that natural gas resources are quite abundant and more widely distributed than those of oil" [Nakicenovic, 2000].

Currently, gas supplies in the USA have been constrained by high demand (resulting from high crude oil prices) which has pushed up gas prices substantially. This is a short-term problem. The history of the natural gas industry in the USA is not great, and not a good example of the way in which this valuable resource could be developed to assist in mitigating the environmental impacts of consumption of less clean fossil fuels. The historical problems are rooted in the way in which the industry was regulated in the past, and misunderstandings about the potential of this resource. It is now clear, however, that in the longer term, continental America has large natural gas resources. Once these are fully explored and developed, and the required transmission pipelines put in place, this resource has the potential to facilitate a revolution in the way in which the electricity supply industry is structured (see below).

In a British study analysing the full fuel cycle from "cradle to grave" for the main fuels used in the power sector, concluded that compared with other fossil fuel cycles, the gas fuel cycle had the lowest impact. Lower atmospheric emissions and higher efficiency of the modern gas powered station, explained this finding. It was also stated that detailed assessment of green house gas (GHG) emissions from upstream activities undertaken as part of the study did not support claims in the literature that upstream methane losses may give rise to higher global warming impacts than for the coal fuel cycle [AEAT, 2000].

MICRO TURBINES

Gas micro turbines are small-scale versions of their larger cousins, but often with important design differences (for example, frictionless air bearings). Integrated power producing gas micro turbines are connected to a generator on the same shaft. These are small packaged units that can be placed on a skid. They can be installed at the site where electricity is needed in a very short period of time. Capacity ratings range from around 25 kW to 300 kW, with larger but still small turbines producing about 1 MW. An important component of a micro turbine is its recuperator (basically a heat exchanger) that preheats the combustion air from the exhaust gas to increase efficiency. Electric generation efficiencies range between 25 to over 30 percent, but waste heat can be used for space heating, water heating, or even cooling with the appropriate equipment such as indirect absorption chillers. System efficiencies can approach 70 to 80 percent. They are reliable and have very low emissions [Valenti, 2001].

Some micro turbines are not integrated and can be connected to a generator with a second shaft or to typical vapour cycle chillers for cooling. This allows a site owner to avoid peak electric conditions through either direct cooling using natural gas, or through on-site electric generation. Summer gas prices usually are less expensive which also improves the economics. All of the different micro turbines offer low emissions, flexibility to meet local loads, increased reliability and improve the quality of site power, and can be very cost effective. Typical installations include oil field sites where wellhead gas can be used in lieu of flaring. This is less expensive compared to stringing long lengths of power cables, or using other generation technologies. Micro turbines are starting to be used for more mainstream applications by utilities to meet local demand and by progressive facility owners.

FUEL CELLS

A fuel cell uses a chemical reaction to convert fuel (hydrogen) directly into electricity with very low, or almost no emissions. Fuel cells were first developed by NASA, for use in space vehicles, and although they use hydrogen as their primary fuel, and work like a battery with an anode (fuel electrode) and cathode (oxidant electrode), they can be operated on hydrocarbon fuels.

Modern fuel cells intended for the transportation or building/industrial industries use a variety of fuels such as gasoline or natural gas respectively, but also can use methane and biogas. This requires the use of an initial reformer process to convert the hydrocarbon fuel into hydrogen, which then is passed through the fuel cell to produce electricity. The by-products of the process are water, heat, and electricity if pure hydrogen is used. Even when typical fuels are used the emissions are low, and they operate very quietly. When the waste heat is recovered such as for space heating or other applications, efficiencies can reach 80 to 90 percent. There are a variety of fuel cell types such as phosphoric acid, alkaline, molten carbonate, solid oxide and PEM (proton exchange membrane).

Fuel cells are in the very early stages of commercialisation and are still fairly expensive. Installations have been limited to high profile demonstrations and field studies. There are a variety of approaches and applications being pursued by many companies with and without government support. One area is the transportation industry with a goal of commercialising fuel cell automobiles and buses by 2003 or 2004. Building applications range from individual residential units producing 2 kW of power to large systems intended for commercial building or industrial applications producing hundreds of kW of power. Market introduction is expected very soon for the building/industrial sectors [NFCRC, 2001].

One interesting concept is a hybrid system that combines a micro turbine with a fuel cell. Compressed air from the micro turbine is diverted through the fuel cell and increases the voltage produced by the fuel cell. Electricity is produced from both the fuel cell and micro turbine. Total system efficiency, using waste heat, approaches 80 percent. However, 60 to 70 percent of the utilised energy is electricity, making it much more practical for applications that cannot use the large quantity of waste heat that is produced by independent fuel cells and micro turbines [Valenti, 2001].

CLEAN COAL TECHNOLOGY

To many environmental advocates, the term “clean coal” is an oxymoron. However, extensive research has resulted in new coal burner technology that is much more environmentally friendly, especially with respect to reduction of NOx emissions, than burners used a generation ago. For example, in the USA over three quarters of the coal fired power plants use improved burner design [Chun, 2001].

Obviously, currently deployed coal technology is not environmentally sustainable. But advanced research continues in many economies including Australia, Japan, the USA, and China. If one looks at the large coal resources of APEC economies like China, Australia, and the USA, then it is easy to understand why each of these economies would want to utilise the resource to the greatest extent possible - taking into consideration local and global environmental impacts.

Currently, there are research projects, and even demonstration plants, that convert coal to less polluting gases (hydrogen and carbon monoxide), which are then burned in a combined cycle gas turbine. These processes are fairly expensive, but with future advances, costs are expected to decline, and clean coal technologies may become cost effective. The release of CO2 emissions from such a plant can be prevented by separation and sequestration in a suitable reservoir (either deep ocean or deep underground).

Other long-term technologies include the conversion of coal to hydrogen and methane, with carbon dioxide recovery. Japan has a research project - started in 2000 and running until 2007 - to investigate hydrogen production from coal. A pilot plant is expected to be operational by 2004. The hydrogen could be used in many applications, but fuel cells would be an ideal application [Tanabe, 2001].

The sequestration of carbon dioxide in deep reservoirs is still an idea very much in the research phase. Researchers believe that coal, with carbon dioxide recovery, may be used in a very environmentally friendly manner in around 30 years.

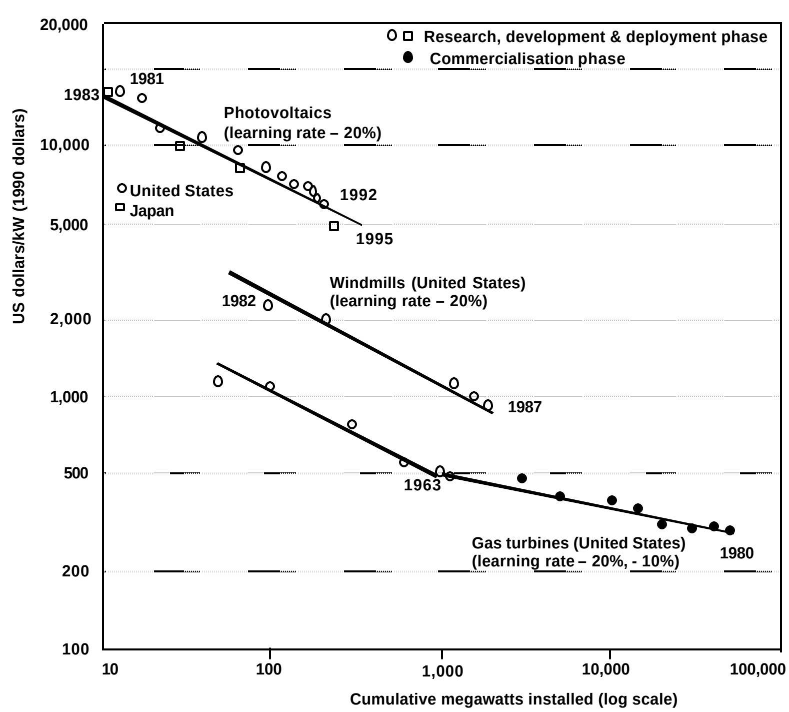
Considering the vast coal resource-base and expected growth in energy demand, coal will remain an important fuel well into the future. In the short-term, increasing the efficiency with which it is burned, and installing technologies to capture pollutants such as SOx and particulates will assist greatly in reducing the health and environmental impacts of coal consumption. In the longer-term, clean coal technologies may allow coal to continue as an important fuel for uses such as power generation, but in a way which has few negative environmental impacts.

COMMERCIALISATION OF NEW TECHNOLOGIES

The performance and costs of particular technologies improve over time as a result of experience gained in manufacturing and utilisation. The specific shape of a technology experience curve depends on the specific technology, but a persistent characteristic of diminishing costs has been noted, and termed the "learning" curve. The curve is likely to fall sharply as technologies first seek a market niche, then full commercialisation, because lower costs become increasingly important for wider success [Nakicenovic *et al*, 1998].

Technology learning curves for installed capacity of photovoltaics, wind and gas turbines are shown in Figure 5.

Figure 5 Experience curves for some new energy technologies in Japan and the US



Source: UNDP, UNDESA, & WEC, 2000

DISTRIBUTED POWER SYSTEMS

The idea of distributed power systems has received a significant amount of attention lately, and it is now possible to see the emergence of such systems in a number of APEC economies. The underlying concept may not be particularly new - early power systems were of this type - involving the generation of electricity close to centres of demand, usually in small-scale generation plants. This avoids transmission and distribution losses, and facilitates recovery of waste heat for space and water heating, or even cooling through advanced systems. The economics of this trend are enabled by a significant reduction in economies of scale in the power generation sector, especially in developed economies with relatively low incremental load growth.

A distributed power system would ideally include a variety of energy resources, all of which are likely to be significantly more environmentally friendly than large-scale generation technologies. The primary technologies suitable for distributed systems include PV, biomass, wind, small-scale hydropower, gas micro-turbines, and fuel cells.

Newly emerging distributed power technologies should also find applications in poorer, developing economies that still require large-scale base-load capacity growth, primarily in more remote areas, or in growing industrial zones where both electricity and process heat are required. The use of these systems in lieu of, or to supplement, grid power offers a variety of benefits. For the purposes of discussion, it is convenient to divide the subject into micro-grids where distributed resources are independent of grid power, and on-site resources working in tandem with grid power to handle peak demand loads and/or provide ancillary services.

An obvious role for small-scale distributed power systems is to supplement grid power, and manage the load for individual consumers. For example, although commercial and industrial electricity consumers can negotiate term supply contracts in some deregulated power markets, this is not universally possible, and many consumers face high electric rates at times of peak power demand. Also many industries and vital service providers (for example hospitals) require un-interruptible supply. As seen in California in the winter of 2000/2001, this cannot be guaranteed even in wealthy, highly developed societies, and costs of power disruption can be so high that the cost of investment in distributed power systems is easily outweighed by the risk of loss of supply.

The use of PV in climates with afternoon air conditioning peaking conditions is an excellent example of the use of a sustainable technology to curtail demand impacts. The overall community use of PV in this fashion, with a variety of PV panels oriented for optimal performance and others oriented for peak demand concerns, the entire system can avoid or significantly reduce the construction of additional electricity generation capacity. The net effect to the PV industry will be greater product demand, and thus greater research and development, economies of scales, and eventual reduction of PV prices, further spurring sustainability.

New Zealand's deregulated electricity market is more advanced than that in the USA, and has real time pricing in the wholesale market and full retail choice for residential customers. Market data shows rather dramatic swings in on- and off-peak pricing. These swings can range up to 60-1, with typical averages around 6-1 to 12-1. These large variations in pricing are spot price swings, and are both a characteristic of fluctuations in power demand with time, and the nature of the supply technologies (New Zealand has a high reliance on hydropower, a resource than can vary greatly between wet and dry years) [M-Co, 2001].

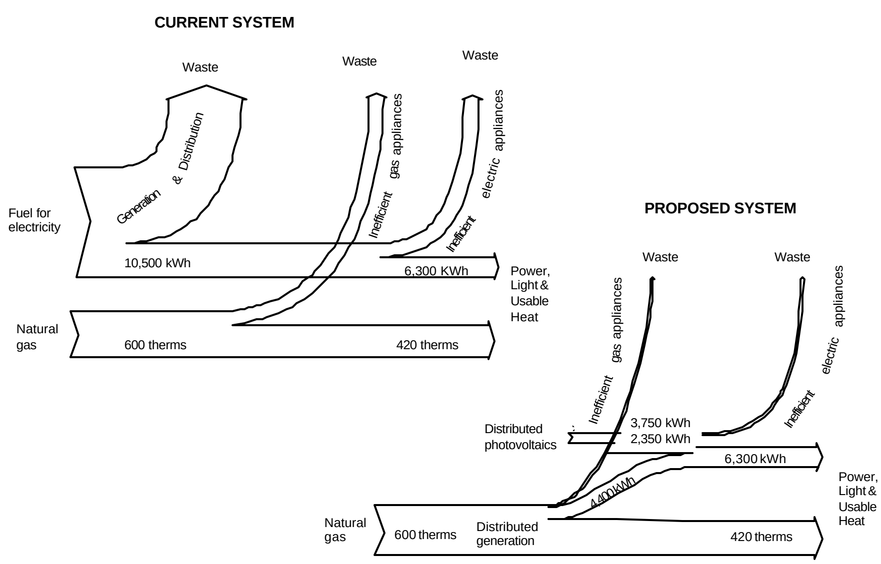
Although early in the product lifecycle, one should expect to see rapidly increasing use of natural gas-fired micro turbines and fuel cells to provide distributed power to specific customers or blocks of customers in the near future. These systems could be used in applications where they will be utilised almost 100 percent of the time to provide base-load power. The waste heat can be used for a variety of purposes, including preheating of process water for industrial applications. Since the overall efficiency can reach approximately 80 percent, the system can be very cost effective compared to grid power.

Distributed power offers such an opportunity for growth in new power systems that major shifts in corporate structure and operations are occurring to address this new market. For example, in 2000 ABB abandoned its large-scale traditional power operations to focus attention on the distributed power market with its micro turbines, wind turbines, gas technologies, and transmission systems in pursuit of higher profit margins [Mechanical Engineering, 2000].

The net reduction in environmental impacts once distributed power systems become widely adopted could be substantial. Furthermore, micro-turbines or fuel cells can be combined with PV systems to optimise power delivery while further reducing environmental impacts.

Figure 6 compares a “traditional” grid system to a distributed power system for a typical USA residence. The overall effects are rather significant. By using a distributed generation (DG) system, total purchased energy can be reduced by approximately 65 percent. On site electricity is obtained from the fuel cell and the PV panel. If it is assumed that the displaced grid electricity comes from fossil fuel generation, then the resulting emissions will be reduced by almost 75 percent. The following box below shows an example of a commercial building that uses DG in New York City.

Figure 6 Comparison of grid power verses distributed power for a typical US residence



Source: Hoff *et al*, 1998

According to the American Gas Association (AGA), natural gas is used in 69 percent of combined heat and power (CHP) projects in the USA, the great majority of the 2,167 CHP projects surveyed - representing 53,300 MW of electricity - being in the industrial sector. Of 34,145 MW of CHP generation capacity fired by natural gas, 25,080 (73.4 percent) is provided by combined cycle turbines. Natural gas is also used as fuel in boiler/steam and combustion turbines, and reciprocating engines (although the latter are mostly small <1 MW facilities).

The important consideration is that once natural gas distribution infrastructure exists, the fuel becomes a powerful driver of the DG option. In the US, coal and oil are relatively minor CHP energy

Conde Nast building at Four Times Square, New York

The building generates electricity using fuel cells and photovoltaics. The building has two fuel cells located on the fourth floor. The fuel cells are expected to generate enough electricity to cover the building's base load during the night. Photovoltaic panels are located in the spaces between rows of windows on the southern and eastern facades on the top 19 floors of the building. The PV installation is expected to generate 15 kW of power. The building also incorporated the latest in energy efficiency technologies.

Source: US DOE, 2001a

Note: Photo Credit: Copyright Andrew Gordon Photography - Fox & Fowle Architects, P.C.

sources, while waste, wood and other fuel sources are used where they are economically available.

There is widespread agreement in the energy industry that gas will be the primary fuel for DG.

According to the AGA, DG has a number of consumer and public benefits in the US:

- The units are more economical to build and operate than large, base-load power plants;
- Efficiency savings of 7-10 percent are automatically achievable because DG technologies eliminate transmission losses;
- Natural gas is used to power DG technologies, reducing greenhouse gas emissions;
- In areas where power transmission capacity is limited (or unavailable), DG can reduce or eliminate the need for upgrading of transmission infrastructure [AGA, 2000].

GRID CONNECTION AND BARRIERS

Until this point, the discussion about DG has been limited to where renewable and low polluting resources are installed on-site to provide base power or to reduce peak power. However, there is often the situation where a renewable or low polluting resource may be producing power in excess of demand. Thus, the distributed resources can fully satisfy the local requirements and the power producer would like to feed power back to the grid. This is called a grid interconnection. Thus, the power avoided on the grid will most likely be more polluting than the renewable or low polluting resource, so the renewable resource provider should get an economic, and possible environmental benefit. In addition, during peak demand conditions there may be times when an on-site generator is satisfying the additional power demand above a predetermined base load demand that has been contracted at a predetermined price. In this case, the on-site generator wants to sell power back to the grid for economic reasons since doing so would be more economically advantageous than to reduce the use of base load power that was contracted at a relatively low price. Although in such a scenario, the on-site generator may choose to increase its power system reliability by reducing grid usage rather than to sell the excess on an open competitive electric market.

In the US, legislation promulgated over 20 years ago encouraged this concept and required that "utilities" purchase excess power from customers. In the past, this had not been done that often. However, with the recent insurgence of DG technologies, this has become a much more frequent occurrence. Unfortunately, there have been many problems reported by installers and owners of buildings and facilities trying to interconnect to the grid. The basic interconnection provides improved reliability for both the customer and the utility. A study by the US DOE's National Renewable Energy Laboratory (NREL) found that significant barriers exist. [Alderfer, *et al*, 2000] The three main categories of barriers are technical, institutional practices, and regulatory.

Technical barriers involve interconnection requirements to ensure the safety and well being of grid workers and equipment. The requirements will also ensure that the quality of the power from the grid is maintained. Owners of DG have reported that often the utility cost for interconnection analysis, equipment, and annual maintenance are duplicative and excessive. Often, the independent power source (or equipment) provides the same function as may be required by the utility.

In the US, utility deregulation is changing the role of the "utility." Traditionally, the utility generated the electricity, transmitted it to the locality, and provided customer service. Now, with the electric industry restructuring these roles are being performed by different entities each with their own perspectives, objectives, and market conditions. Therefore, it is more difficult to promote DG.

Regardless of these challenges, many states and DG equipment manufacturers want to promote the use of DG technologies. Several states are pursing the promulgation of interconnection regulations. For example, the state of New York has requirements for distributed generators with capacities of 300 kW or less. The requirements are complex including a detailed application process, and leave many requirements to the discretion of the utilities. However, they do offer reduced burdens for generators with less than 15 kW, and it has provisions for pre-certifying equipment and streamlined approval for similar equipment installations with like conditions [NYSPSC, 2000].

In March 1999, the Institute of Electrical and Electronics Engineers (IEEE) Standards Association Board voted to develop uniform standards for connecting distributed resources to the electric grid. Currently, work is going on to complete standard, IEEE P1547, that will include technical requirements related to performance, operation, testing, safety, and maintenance involving grid interconnections and associated equipment. Accelerated completion is expected in late 2001 or in 2002. In March of 2000, the Board approved a standard, "Recommended Practice for Utility Interface of Photovoltaic Systems" IEEE std 929-2000, that is applicable to the grid interconnection of PV systems under 10 kW [US DOE, 2001a].

Institutional barriers analysed in the NREL report were mostly related to the administration aspects of installing an interconnection to the grid. This is not surprising because something new will always have transactional barriers, however it does highlight an important area to address if one wants to encourage such systems. The administrative barriers reported ranged from straight forward concerns about the utility not having anyone assigned to handle interconnection issues, to assertions that the utility was deliberately stalling because it did not want the interconnection. Furthermore, there were reports of utilities trying to offer the owners of DG better deals for grid power to discourage their interconnection.

The last type of barrier analysed by NREL was regulatory. Often, application processes were totally not conducive to DG systems. Furthermore, extended delays resulted in some entities not pursuing interconnection to the grid. This area appears to be significantly improved with the regulations in New York. The New York regulations encourage such activity and establish time frames for utility response. However, it will be interesting to see how the process works, especially the streamlining provisions. For example, it is conceivable that a small business or residential customer may choose to install their own PV, wind, and possibly fuel cell or micro turbine, however, unless the process of connecting the system to the grid is extremely easy, then it is unlikely that the complicated process would be pursued. In such cases, the excess power could be stored in batteries, but this would not directly help improve the grid reliability or mitigate the construction of new generation capacity.

In New Zealand, an enquiry into electric sector restructuring was conducted by the Minister of Energy. In regards to distributed power, it presented limited data regarding the current situation but asserted that an important goal was to increase the use of DG technologies. Specifically, it suggested more liberal guidelines for distribution companies to offer limited generation. In addition, it strongly supported regulatory reform so that more entities can become involved in DG and can interconnect with the grid. The study also suggested that an improved economic environment will lead to increased grid reliability and price trade-offs [MED, 2000].

From these assessments, one can conclude that the "utility" industry and most of the regulatory bodies are not ready, or have not embraced DG as the preferred direction to meet demand growth. Although with reliability issues surfacing from electric industry restructuring in the US, this is a time when DG could provide the greatest benefit to the grid. It appears that New Zealand recognises this and has successfully implemented competitive electricity markets and plans to pursue DG. However, in the US, it appears that several states are struggling with these issues, and find it challenging to implement both competitive electricity markets and DG at the same time.

These barriers are real and need to be addressed before DG and all it has to offer becomes a mainstream resource to combat carbon emissions and peak energy demand requirements. Further study and planning needs to be conducted for the APEC economies so that developing economies can gain from the lessons learned in some of the developed economies.

The provision of electricity to remote communities is another challenge. Although temporary remote area power systems can be installed prior to grid extension, this whole philosophy could be rethought. A major effort should be put into the development and operation of micro-grid power systems that can either remain indefinitely independent of a grid network, or operate in a way which complements and strengthens such infrastructure. The provision of power to remote and poor communities does more than turn on light bulbs, the whole economic and social fabric of a community can be transformed. This is discussed further in the next chapter.

MICRO GRIDS

A micro-grid is a self-sufficient electric system. Using a combination of resources and technologies, an independent system can be developed that will meet the required demand while being reliable and significantly less polluting. Using resources such as PV, wind, biomass, small hydropower, micro-turbines and fuel cells in a manner that is best suited for the local conditions, the system can be self sufficient. For example, PV and fuel cells are complementary in many applications with PV performing best during the hot summer and the waste heat from fuel cells or micro-turbines being used to the greatest extent during the winter for space heating. In order to meet demand in a cost effective way, high efficiency energy conservation measures will need to be utilised. Thus, to fully meet demand, a combination of resources such as PV and wind can be combined with high efficiency end-use equipment (for example, dedicated compact fluorescent light bulbs, state of the art refrigeration systems, and other products). Another important conservation area is to reduce the thermal load of a building by improving the thermal envelope of the structure, such as increased insulation or improved windows.

The concept of a micro grid using renewable and low polluting technologies is applicable to many applications. Highly developed areas such as islands or communities that are isolated with long transmission lines are ideal candidates for this concept. The US Department of Energy's National Center for Photovoltaics partner Clean Power Research has several papers on its web site that show various potential case studies for this concept. More information can be obtained at URL (http://www.cleanpower.com/research.htm). An offshoot of this concept is when an existing transmission line reaches its capacity. Renewable and low polluting technologies can be used to supplement the grid power without increasing the capacity of transmission lines that can be very costly. Through new distributed resources and energy conservation measures, the community is able to grow to accommodate increased demand, although the individual demand per home or building will be reduced. The box shows an example of this approach.

DISTRIBUTED GENERATION TO MEET INCREASED DEMAND ON "MAZAMA FEEDER" LINE

Mazama Valley in Washington State, USA has an existing electrical cooperative that provides power to residences and a few businesses via a 22.5 km transmission line. Residential development of new homes will soon require that the transmission system be upgraded. It is estimated that a total of 1,500 new homes will eventually be built in Mazama Valley. The estimated cost of increasing the capacity of the transmission line, including the addition of a new substation is US$ 2.3 million. NREL conducted a preliminary study using various scenarios with alternatives of distributed resources and end-use efficiency measures. The following measures were considered to be optimal considering peak demand concerns.

- 500 of the 1500 homes install 1 KW of PV
- 1000 of the 1500 homes use district heating from cogeneration (fuel cell or generators owned by the cooperative)
- 500 of the 1500 homes use propane space and hot water heating
- All 1500 homes use reasonable end-use efficiency measures, such as high efficient lighting, refrigerators, propane dryers, and high efficient thermal envelopes

The preliminary study concluded that net present value savings of US$ 1.4 million could be achieved if the measures were implemented, however a key assumption is that the investment in the transmission line upgrade is incurred immediately whereas the new homes, distributed resources, and end-use efficiency measures are implemented incrementally over a 10 year period. The study suggested this concept be seriously considered and a full engineering study be conducted.

Source: Hoff, 1998.

CHAPTER 4

REMOTE POWER SYSTEMS

INTRODUCTION

In the world today, nearly two billion people or almost one third of the world's population, in developing economies do not have access to reliable sources of energy, especially electricity. While the number of people being provided with electricity has dramatically increased, the number without electricity is still very high because of population growth. For example, from 1970 to 1990 rural population grew by around 23 percent and the percent of rural homes with access to electricity grew from 23 percent in 1970 to 44 percent in 1990. However, the reduction of rural homes without electricity was reduced by only about 10 percent, from 2 billion in 1970 to 1.8 billion in 1990 [UNDP, UNDESA, & WEC, 2000]. Currently in the APEC region there are approximately 232 million people living without electricity. Table 2 shows the APEC economies without access to electricity.

Table 2 Number of people without electricity in APEC economies.

APEC economy	People without electricity (millions)	Percent of population without electricity
Chile	0.8	5%
China	63.5	5%
Indonesia	97.2	45%
Malaysia	1.2	6%
Mexico	5	5%
Papua New Guinea	4.3	92%
Peru	4.8	18%
Philippines	19.8	25%
Russia	1.5	1%
Thailand	10.9	18%
Viet Nam	22.9	29%
APEC Total	232	10%

Source: APERC, 2000

In any economy, the major impediment to expanding existing electricity transmission and distribution grids to reach remote locations is the high capital cost of the additional network infrastructure. The cost of extending electricity distribution lines to rural areas is high relative to urban areas due to the predominantly domestic load profile, low population density and lower per capita consumption. Also, average system losses tend to be high. For example, in the Philippines it was estimated that in 1997 system losses were 18 percent for rural distribution networks, compared with 12 percent for urban networks [Philippine DOE, 1999].

SOCIAL POLICY ISSUES

Governments face a difficult dilemma in developing economies with large numbers of poor rural dwellers, and relatively more affluent urban populations. The lack of resources, including energy resources, in the rural areas acts as a very strong driver encouraging people to migrate to the cities. To some extent, this may be unstoppable and necessary due to the inability of the land to support large populations. However, the provision of energy services to rural areas is an important factor in controlling this trend, because it improves economic potential and raises quality of life.

Governments need to be transparent with respect to their rural-to-urban transmigration policy - while probably unable to prevent such trans-migration, access to modern energy, the creation of job opportunities and other services in remote areas would help to limit this trend.

World population growth is an important issue when discussing a sustainable future. Although it may not be known exactly why access to electricity usually leads to lower birth rates, but there appears to be a strong correlation [UNDP, UNDESA, & WEC, 2000]. Providing access to electricity is primarily a social issue, providing better quality of life and improved access to information. Fundamental problems such as the required investment and revenue streams are major obstacles to electrification. These are serious issues that need to be fully addressed. Subsidies from urban rate-payers and potential increased incomes of rural residents as a result of modern energy are important aspects to be analysed and considered.

Local cooperatives provide a sense of ownership of a rural energy system, and are a good way of getting rural people involved in projects from design to operations. For certain economies, where the responsibility of implementing rural electrification lies with the state utility company, the training and use of local labour relieves the utility from the burden of recruiting new staff to operate projects located in remote places. For example, Pertamina in Indonesia has used this approach successfully in rural electrification projects.

Governments can take the initiative for the establishment of rural energy cooperatives and coordinate with the state utility companies to provide initial education and training to locally recruited staff to operate energy systems, and conduct periodic training to sharpen the skill of these local workers over time. Job opportunities provided by completed projects include meter reading, bill collection services, general operations and maintenance.

Involving local co-operatives will generate amongst local people a sense of ownership of the project and discourage the pilfering of electricity and equipment.

To ensure maximum performance, the utility company responsible for implementing the plant must be responsible for maintenance of the more critical components of the system. In the case of battery storage in a renewable energy system, for example, it is important that replacement batteries are optimised for the system. If maintenance of such critical components is left to less skilled technicians it is possible that the overall performance of the system will be compromised by the use of less suitable replacement parts, such as car batteries which are cheaper.

THE ROLE OF GOVERNMENTS

Governments in developing economies have a major role to play in providing electricity services to poor rural communities in remote locations. For example, even though the Philippine government is tendering the provision of power services to remote barangays (smallest political subdivision) to private companies, and expecting them to provide services at commercial rates of return, this can only practically be achieved through some form of cross-subsidisation of tariffs. In cases where distribution networks are extended to rural areas, the current customers within the area of utility franchise are usually forced to cross-subsidise the "missionary" extension of electricity services.

Even in developed economies, rural electricity consumers largely enjoy distribution services at subsidised rates. This is because historically the extension of electricity to the most remote locations has been widely viewed as a social obligation of government. It is only in recent times, and in line with changes in public policy and economic reasoning, that rural consumers in deregulated power markets are beginning to face the real costs of supply. For example, in New Zealand, the government obligation to supply electricity to all taxpayers was repealed in 1996, and the obligation on distribution companies to maintain existing rural networks will expire in 2013. Cross-subsidies have been by and large eliminated, and there is a reluctance to offer direct energy subsidies to rural communities. The high electric rates needed to recover electricity infrastructure costs make a remote area power supply (RAPS) an attractive alternative

In developing economies, governments still tend to own and operate the power system, or are actively engaged in the granting of permits for construction of generation or network assets. Public policies also still widely support the "obligation to supply" philosophy. Electricity markets are not well suited to commercial solutions in this situation, especially where the cost structure in the supply industry is not transparent, and financial institutions and laws are poorly developed.

With respect to recent efforts to encourage the dissemination of commercial renewable energy solutions in rural areas, experience has shown that government policy support is the key to implementing initiatives in the initial stages. Government-supported financial incentives play an important role in helping to develop commercial markets and reduce the capital and life-cycle costs of renewable energy technologies. Other necessary policy support elements include effective long-term planning, careful establishment of priorities, and coordinated programmes involving a variety of government and commercial institutions, such as long-term research and development, and technology transfer programmes [World Bank, 1997].

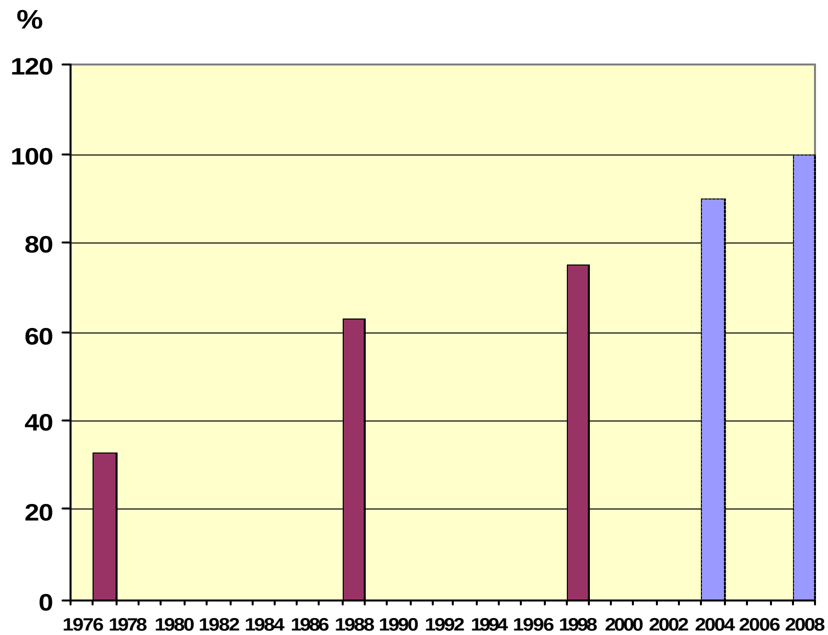
However, despite the necessity that governments support rural energy development schemes, history has demonstrated that this support - and the financial assistance of international lending agencies - can be largely squandered in situations where poor policy design and implementation has led to unexpected and/or sub-optimal outcomes.

These problems have not been limited to developing economies. For example, California currently has a large amount of installed wind power capacity (1,689 MW in 1998). Most of it was built in the early 1980s through to the early 1990s with federal and state government support in the form of generous tax credits and accelerated depreciation allowances. Unfortunately, although government support encouraged rapid capacity additions, they did not encourage efficiency with respect to operation. Projects tended to be developed by individuals and corporations with little wind power experience, but strong appetites for short-term return on investment. California is now revising its policies toward performance-based incentives.

However, despite the drawbacks of extending transmission and distribution grids to remote locations, some governments in the Asia Pacific region are still committed to this objective. The reasons are usually related to social policy objectives, principally a desire to lift the living standards of all citizens, and promote economic sustainability in poorer communities.

For example, the Philippine Energy Plan 1999-2008 seeks to achieve 90 percent electrification of all barangays by 2004 and then full electrification by 2008. This will be achieved largely through extension of transmission and distribution grids, and will be accompanied by substantial cross-subsidisation of electric rates because of the inability of the poorer rural consumers to pay the full costs of electricity. Only for areas where it is "not technically and economically feasible" to connect to a grid system will other alternatives be considered, such as a "new and renewable energy-based system." Figure 7 shows

Figure 7 Philippines electrification plan (1977- 2008)



Source: Philippine DOE, 1999

the Philippine's electrification plan that include historical rates and future goals. As can be seen from this graph, achievement of these targets is very ambitious given that the urban electrification rate is now 100 percent, and achievement of the target involves getting electricity to the most inaccessible (and hence expensive) areas of the economy where remainder of the population live.

Currently, rural electrification continues among the APEC economies, although the rate at which electricity is provided to people in rural locations is quite different. This is a sensitive, economic and political issue that cannot be easily solved. However, since it does continue, it can be assumed that there is a budget for such activity with anticipated revenue streams that may include subsidies.

ELECTRICITY SERVICES IN REMOTE LOCATIONS

Indonesia, the world's fifth most populated nation, has an electrification rate of 55 percent. As of February 1999, over 10,000 villages still remain unconnected to electric power supply [ACE, 1999]. Even in Thailand, which is 82 percent electrified, the Provincial Electricity Authority (PEA), the organisation responsible for electrifying all non-metropolitan areas of the economy, has about a thousand villages to supply with electricity [Sookkaew, 1997].

For insight into current thinking in the region on the issue of provision of electricity services to

Table 3 Planned grid capacity build-up on small islands in Philippine archipelago

Small Island Grids Capacity Build-up				
Plant Type	Installed Capacity (MW)	Capacity Addition (MW)		Installed Capacity (MW)
	As of 1998	1999-2004	2005-2008	As of 2008
Diesel	108.8	9	27.6	145.4
Fuel Oil (Bunker C)	36	95.2	77.5	208.7
Geothermal	-	16	-	16
Hydro	1.8	35	18	54.8
Geothermal	-	-	16	16
Total	173.6	155.2	123.1	451.9

Source: Philippine DOE, 1999

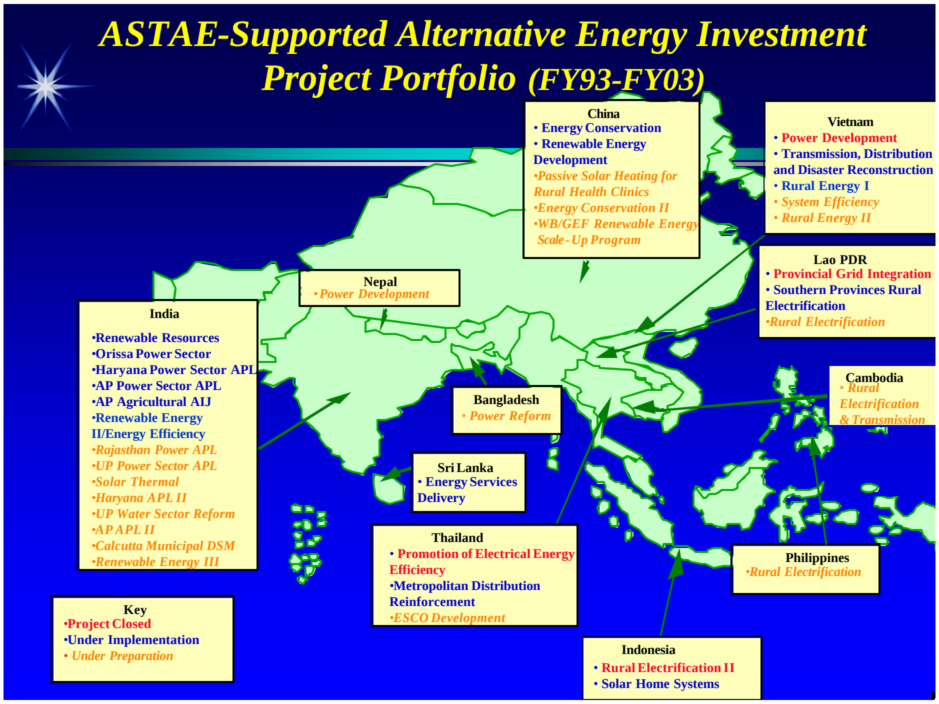
remote locations, it is useful to consider the plans for capacity additions in the Philippines. Table 3 shows the planned capacity build-up for small islands in the Philippine archipelago with independent grids, and Table 4 shows planned capacity additions in off-grid areas. The small islands included in Table 3 are those islands too remote from the main transmission grids to make connection economically feasible, but large enough to already have or to support small-scale distribution systems. As can be seen from the tables, it is envisaged that diesel and fuel oil powered generators will provide the most economic means of building up these systems. However, for remote areas with no existing network infrastructure and low load requirements, it is envisaged that renewables will be able to economically compete with traditional carbon-based fuels.

Table 4 Planned capacity additions in off-grid areas in the Philippines

NRE Capacity Additions in Off Grid Areas (MW)			
	1999-2004	2005-2008	Total
Biomass	10.1	11	21
Coconut Residue	5.1	6	11
Rice Residue	-	5	5
Bagasse Power Plant	5	-	5
Micro-hydro	3	5.5	8.5
Solar PV	8.6	10.3	18.8
Wind	3.8	33	36.9
Total	25.5	59.8	85.3

Source: Philippine DOE, 1999

Figure 8 World Bank ASTAE supported project portfolio



Source: World Bank, 2000

The World Bank (WB) in 1992 developed the Asia Alternative Energy Program (ASTAE) to encourage renewable energy and energy efficiency investments into the Bank's mainstream lending programmes in the East Asia and Pacific and the South Asia regions [World Bank, 2000]. Although initially launched as a three-year pilot effort, the Bank and donors agreed that it should become a full-scale programme with continued support from both groups.

According to the WB, “ASTAE provides a useful model of a bank/donor partnership to integrate alternative energy options into delivery services. In FY1999, the energy policies and environmental action plans of Asian client economies and the Bank Country Directors demonstrated increased commitment to developing alternative energy resources.” [World Bank, 2000].

In 1992, 10 percent of WB financial assistance to the power sector in Asia was allocated to alternative energy as a target and indicator of ASTAE programme effectiveness. By 1999, alternative energy accounted for 46.3 percent of total power sector lending, with 38 renewable energy and energy efficiency projects in 11 borrowing economies in Asia, with a total alternative energy cost of US$3.5 billion and total WB/Global Environment Facility (GEF) commitments of US$1.0-US$1.3 billion. Figure 8 shows the ASTAE projects and locations in Asia.

In most developing economies, the number of remote locations to be electrified is in the tens of thousands with total areas covering hundreds of thousands of square kilometres for example Indonesia, Philippines, Thailand, and Viet Nam. To achieve this, governments and lending agencies need longer-term assessments of energy requirements in remote locations, so that the most cost effective solutions can be provided to suit the needs and geographic characteristics of individual sites.

The most common method of rural electrification is the extension of the existing grid system. This can be extremely expensive, especially if the transmission lines travel over difficult terrain or the sea. Alternatively, there are many micro grids powered by diesel generators. In some cases, micro-hydro or geothermal plants have been hooked to small-scale distribution systems to provide power for one or more villages in remote locations.

Recently, people have started to consider using alternative sources such as PV, wind, biomass or gas micro turbines as sources of power in a micro grid. It appears however that planners consider the renewable resource a “stop gap” or “bandage” until the electric grid can be extended in the future. To truly become sustainable, this perspective needs to be changed.

One concern is that often, the people making the decision to extend the grid or to install a micro grid are the owners and operators of the grid power system who are used to traditional practices. Furthermore, cross subsidisation from urban rate-payers can be hidden if the same entity is managing the rural electrification projects. Thus, open public policy controversy is avoided.

Initial results of PV, wind and other system performance's for village power have probably been the reason why micro grids have not been seen as direct replacements for extension of grid power. A NREL report showed how numerous issues impacted the viability of long-lasting sustainable projects. Many of the systems installed lacked basic infrastructure including sound maintainability and repair methodology to think of them as being “long-term” alternatives to grid power.

> Although, the report stated “Renewable energy solutions for village power applications can be economical, functional, and sustainable. Pilot projects are an appropriate step in the development of a commercially viable market for renewable rural solutions. Moreover, there are a significant number of rural electrification projects underway which employ various technologies, delivery mechanics, and financing arrangements. These projects, if properly evaluated, communicated, and their lessons incorporated in future projects and programs, can lead the way to a future that includes a robust opportunity for cost-effective, renewable-based village power systems” [Flowers, 1998].

To design a micro grid there are several important considerations. First, does it make sense to design a system so that the residences can use electricity like people have since the invention of the light bulb! When the grid is extended, it is generally assumed that similar amounts of energy per household will eventually be consumed, thus requiring a large transmission line. Usually, the marginal cost (or added cost) of a larger capacity line will not be as high as the initial cost to put in any line. Furthermore, transmission lines are not considered to be modular systems for easy upgrade. Thus, major savings cannot be obtained by putting in smaller lines once one decides to extend the grid.

However, if you are looking at installing a micro grid that is powered by an independent source, then any demand reduction will directly result in less capital expense in building the renewable or less polluting capacity. So why are people providing electricity to villages with inefficient end-use devices. For example, high efficient, dedicated compact fluorescent light fixtures (lamps with pin bases) offer a reduction of energy consumption by 75 percent compared to traditional incandescent bulbs. Recent developments have made the products more appealing to consumers, less costly, and more reliable. The products are still much more expensive than incandescent light bulb fixtures, but compared to the investment for the new electricity generation, these products are clearly the best investment.

Similarly, if refrigeration in addition to lighting are fundamental needs of communities without electricity, then high efficiency refrigerators should also be installed. Based on the economic ability of the APEC economy, the village, and potential for increased incomes of village residents, micro grids can be developed to meet the local needs in the way that is most cost effective. For example, the least economically capable communities may only be provided with a limited amount of lighting in each home with village community areas for refrigeration at least for medicine and possible access to a community television. Other, more economically advantaged communities could have more services in each home.

The primary approach of many governments has been to provide electrification and possibly provide subsidies for electricity use and charges. However, when it comes to energy consuming devices, the general perspective is that the items are the personal property and responsibility of the people in the community. Rather, from a sustainable and cost effective perspective, it would be best to provide the high efficiency equipment with a much lower capital investment for the generation capacity. Any payments for the use of the electricity from the community should be placed in a fund for the micro grid repair, maintenance, and replacement of high efficiency equipment (for example batteries, compact fluorescent lamp replacement every 8,000 hours, and the like). This fund could also support local employment as part of the maintenance/inspection of the system.

The entire system should be designed with a long-term repair and maintenance fund, and a component to include external support and internal village education for addressing the needs of the power system. A sustainable micro grid can be designed to be modular to increase power capacity as the village's demand and economic ability to afford more amenities grows. Alternatively, if villages are connected to grids, eventual demand growth will lead to greater pollution and will most likely not be the least cost option. Thus, the overall economic well being of the particular APEC economy will be lower than if the least cost option were pursued.

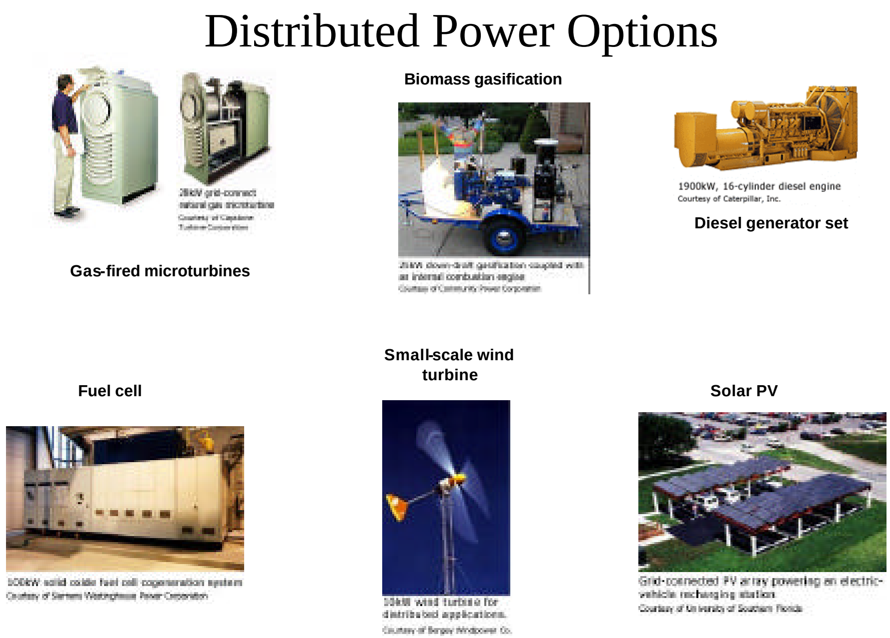
Increasingly, advocates of renewable energy sources have been arguing that this approach should be promoted on its merits as a means of bringing energy to poor communities and at the same time limiting further environmental degradation (in particular CO2 emissions). Although it is acknowledged that installing a solar home system (SHS) in a developing economy may not be the cheapest way to reduce carbon today, or to provide energy services, it is argued that these systems achieve the dual goal of limiting GHG emissions and providing energy services, so this should be a factor in consideration of which technology to promote. Especially if concerns with climate changed are addressed through activity such as Clean Development Mechanisms (CDM) of the Kyoto Protocol [see APERC, 2001a] for more information.

Further, it is argued that this approach is likely to be less expensive than extending networks to remote locations, and provides local employment opportunities for people with different skills and educational levels [Kaufman, 1999]. However, it is suggested that because SHS systems are typically small and located close to the consumer, they are considered a “disruptive technology' because they disrupt the traditional electricity utility business, which typically relies on large-scale power plants connected to consumers via extensive transmission and distribution networks.

It has been suggested [Kaufman, 1999] that vested interests wish to keep the electricity business operating much as it has been traditionally, and that “solutions” to GHG emissions often stress investment in large-scale solutions such as nuclear power, clean coal power stations, or even sequestration of carbon on the sea floor.

This may be so, but there are emerging trends which will tend to mitigate the tendency of some vested interests to maintain “business as usual” in the electricity supply industry. Firstly, electricity sector reform is now becoming an increasingly common trend in the Asia Pacific region, driven by burgeoning demand for electricity in rapidly industrialising economies, and the realisation that the capital requirements will be well beyond the capabilities of individual states. Electricity sector reforms that encourage the separation of the natural monopoly (networks) from the competitive elements (generation, wholesaling and retailing of power) of the power supply industry will tend to disrupt established industry structures and mind sets, and promote innovative solutions with respect to supply [APERC, 2000]. Secondly, the major international oil companies have, over a number of years, been investing very large sums of money into renewable energy, in particular the manufacture and sale of PV systems.

Figure 9 Modern distributed power options



In addition, after much discussion in industry circles, the concept of “distributed electricity systems” is now becoming a reality in developed economies with the appropriate infrastructure and incentives to promote this trend. As noted by industry participants, distributed generation (DG) systems in the developed world are being driven by the availability of cost-effective natural gas supplies and the widespread availability of combined cycle gas turbines in a suitable range of sizes for small-scale power systems. In addition, the increasing availability of fuel cells, micro-turbines and other technologies which can provide heat and power in a range of sizes suitable for households up to large industrial plants, means that over the next decade or two, the conventional notion of remote large-scale base-load power stations feeding extensive power networks will need to be substantially modified to allow for a reality that may include much more widely distributed services operating at higher levels of efficiency. Figure 9 shows examples of some of the technologies discussed, see Chapter 3 for additional information.

Just as distributed power systems will radically alter the way the electricity supply industry is structured in the developed world, this will have a flow on effect in the developing world. The problem for the developing world is the lack of any developed infrastructure in many areas. In the developed economies with affordable supplies, it is becoming clear that many industry people see natural gas as the linking fuel to a sustainable future. In developing economies, this is not always an option, as the costs of development are enormous, and only large-scale reserves are economically viable - which means they are geographically constrained.

This leaves renewables as the most suitable option for developing economies, if the environmental impacts of energy systems are considered. Such systems require higher capital investment than diesel sets, generally need subsidies from governments, and probably support from international lending agencies. Other subsidies in the form of tax-free importation of equipment and soft loans can make such projects economically viable and attractive for private sector participation.

FINANCING & INVESTMENT ISSUES

Renewable energy systems for rural electrification can be expensive, though possibly less capital intensive than the expansion of existing grid systems. While governments may have some budget for electrification of remote areas, this will be far from sufficient, and therefore a decentralised approach to raising capital can greatly ease the financial burden of central governments and expedite implementation of projects.

Encouraged by central government policies, local authorities, in joint activities with utility companies, local cooperatives and local financial institutions can form a good team in establishing distributed power or renewable energy systems.

Banks and financial institutions should be encouraged to provide low-interest short-term and long-term loans to finance such projects, depending on the size and cost of the project. Subsidies from international organisations, and central or local authorities could help cut down capital raised by the private sector or cooperatives, hence making projects more financially manageable.

The financing scheme provided by the supplier directly to the consumers must be innovative enough to make the system affordable to poorer people in these remote locations. The plan may not fulfil its immediate objectives if only the few richer people in rural villages can afford to benefit from such systems, but a “trickle down” effect could occur once the technology is introduced at some level. One of the barriers to implementation of solar systems for example is the lack of understanding of the benefits of such a system, and a lack of technical expertise to install and maintain such systems.

Government is responsible for creating an environment conducive to foreign and private investment. Even when the government is unable to provide direct financing, subsidies in the form of tax exemptions on imported equipment and materials help to trim project costs and keep electricity prices down.

The main barriers in the development of remote systems, in particular renewable energy, lie in their financing:

- Renewable energy systems have high up front end capital costs per kW installed and negligible variable costs (operation and maintenance). This calls for loans with much longer maturity than is usually available in commercial markets.
- Unlike the case for conventional energy systems, renewable energy systems have high project development costs compared to the actual project cost itself.
- The actual project cost itself is so small that it leads to a very high level of transaction costs (such as due diligence reviews) for financing.
- It is difficult to guarantee cash flows for renewable energy projects due to their low capacity factors and intermittency of project operations. Also power purchase guarantees cannot be enforced on the numerous buyers making non-resource financing difficult.
- Renewable energy project asset values are perceived to be “suspect” by financing agencies since they have limited marketability compared to the assets of conventional power projects.

In the 1990s some new financial frameworks have been implemented to overcome these barriers. They can be roughly split into two categories - debt and equity financing.

DEBT FINANCING

- Non-recourse loans from commercial banks are often backed up by government guarantees and are usually applicable only to large renewable energy projects.
- Multilateral and regional development banks, like International Finance Corporation and Asian Development Bank, usually provide co-financing for renewable energy projects performing catalytic and global brand supportive roles.
- Micro-credits, such as rural credit cooperatives, represent a special niche in non-traditional financing for small-scale investments and flexible lending conditions, and they match perfectly for renewable energy end-user financing needs.
- Leasing renewable energy equipment could become an emerging role of energy service companies (ESCO's).
- Self-sustaining revolving loan funds are used as seed capital and can be established by some development institution. They have been successful in financing the purchase of small photovoltaic systems in developing economies [APEC EWG, 1998].

EQUITY FINANCING

The profit margins for renewable energy installations are still low, so loans at below commercial rates from international agencies and national funds are the main instruments to leverage capital from the private sector. Multilateral agencies are trying to promote private capital investments in renewable energy through a variety of programmes. For instance, the World Bank evaluation of rural electrification projects in Asia noted that although overall the projects were considered a success, only four of the ten projects had rates of return greater than 10 percent and none of the projects were financially self-sustaining [World Bank, 1996]. The main reason for this poor performance was that pricing policies include cross-subsidies for rural power, which undermine the economic viability of renewable energy options.

Important policy implications in the area of renewable energy financing are:

- Creating a business enabling environment.
- Reduction and reforming of energy subsidies.
- Promotion of joint ventures, establishment of preferential legal and fiscal status for renewable energy.
- Implementation of Kyoto Protocol mechanisms - CDM, emissions trading - for renewable energy projects.

Finally, end-user access to credit and financing is the key aspect of developing renewable energy systems that will lead to the affordable services for customers in rural areas.

CHAPTER 5

ENERGY SYSTEMS IN SELECTED APEC ECONOMIES

INTRODUCTION

This chapter addresses important challenges that face APEC economies in becoming sustainable. Through examples of selected economies, New Zealand and Japan that are developed, and Malaysia, China, the Philippines, and Thailand that are developing, issues that must be addressed to achieve a more prosperous, less polluting future are presented. Although, in many instances the discussion may highlight an important issue, proposed solutions may not be presented since such recommendations may be the focus of future study. Since each economy has quite different renewable resources and data availability varies significantly, each case study is independent and does not follow a specified format.

DEVELOPED ECONOMIES

Of the twenty-one member economies in APEC, five can be characterised as developed - Australia, Canada, Japan, New Zealand and the United States of America, and the rest as developing. The developed economies share a number of things in common: all are members of the OECD and the International Energy Agency (IEA), have highly developed industrial and commercial structures, are stable democracies, and have high per capita incomes.

They also have relatively modest energy infrastructure growth requirements because almost all citizens have access to grid-based electricity (or can afford remote systems), the energy infrastructure is well established and adequate to meet national requirements.

NEW ZEALAND

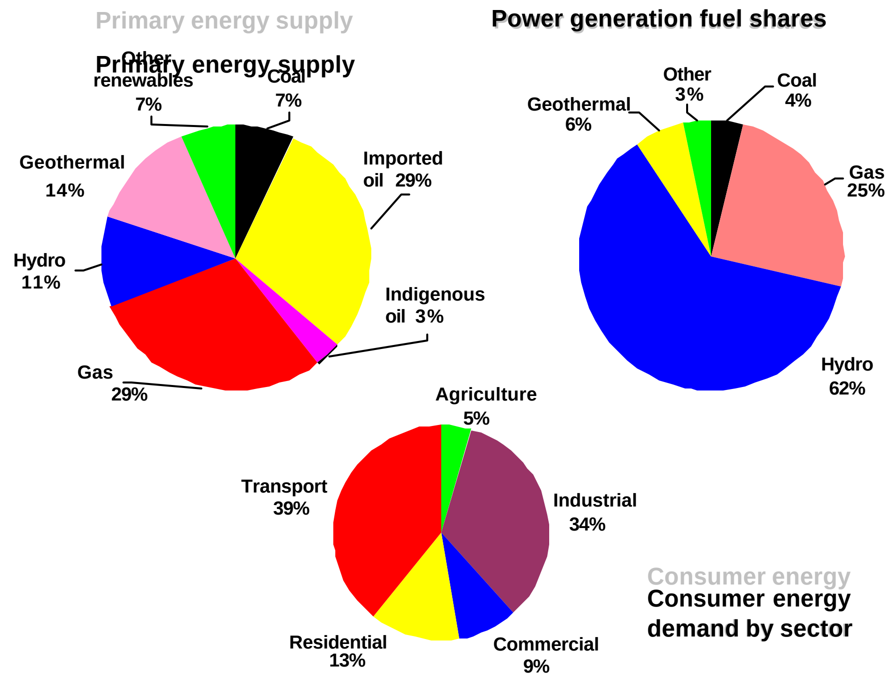
New Zealand has a long history of utilising renewable energy resources to power economic growth, as water has always been a key source of power. The relatively high rainfall, well spread throughout the year, the topography and the scattered nature of settlement all lent themselves to the use of water for power generation. The first use of electricity in New Zealand was in 1861, for a private telegraph line between the southern city of Dunedin and the nearby Port Chalmers. The first significant hydroelectric power station was built in Central Otago in the mid-1880s to operate a gold stamping battery.

In the first few decades of the twentieth century, it became feasible to build transmission lines connecting major centres of population. From the 1940s to the end of the 1980s, New Zealand engaged in the construction of many large-scale hydro plants the largest being 700 MW of installed capacity for the Manapouri development, which takes water from two South Island lakes and feeds it directly down into a powerhouse situated in an underground cavern 213 metres below the surface.

However, despite this long history of renewable energy resource development, and the fact that renewable energy resources (hydro, geothermal, biomass) make a major contribution to New Zealand's energy requirements, fossil fuel sources still accounted for nearly 70 percent of total primary energy supply in 1999 (Figure 10). Much of the fossil fuel consumption is transport fuels, but natural gas is becoming increasingly popular as a power generation fuel, increasing demand for that resource. In 1998, renewable energy contributed around 75 percent of electricity generation, of which hydro comprised 67 percent, geothermal 7 percent and windpower the other 1 percent.

Aside from large-scale hydro, New Zealand is very well endowed with natural renewable energy resources. These include high mean annual wind speeds in many locations; large and increasing volumes of forest residues; numerous streams and rivers with potential for small hydro schemes; available land with fertile soils; a high crustal thermal gradient in many locations (providing good prospects for conventional and deep geothermal); and a good all year round climate suitable for growing crops.

Figure 10 Primary energy supply and consumer energy demand in New Zealand in 1999



Source: EDMC, 2000

Notes: For power generation, other includes biogas, industrial waste, wood and wind, and included cogeneration.

New Zealand's first commercial wind farm of 3.5 MW has been operating successfully for four years. More recently (1998), the 31.7 MW Tararua wind farm was commissioned in the vicinity of Palmerston North. This site experiences average wind speeds of over 10 m/s and indications are that this plant will be able to maintain one of the highest capacity factors of any wind farm so far built anywhere on the globe.

One issue relates to the breakdown between fixed and variable transmission charges. The New Zealand Wind Energy Association has argued that fixed charges disadvantage wind energy projects because they tend to be embedded in the distribution network.

It is also argued that smaller-scale, more DG options are constrained in New Zealand because electricity distribution companies can own a maximum of only 5 MW of generation capacity (and even then, only if this capacity was owned prior to the enactment of the Electricity Reform Act in 1998). Generation companies on the other hand, cannot own distribution lines. The current Government is looking at relaxing this provision, to allow more flexibility at the retail end of the business, and encourage DG technologies.

Below are listed some of considerations pertinent to the further development of renewable energy in New Zealand.

- Although further development of large-scale hydro is likely to be constrained by negative public reaction, environmental impacts and limited suitable sites, there is considerable interest in development of micro-hydro power schemes. These are often close to local demand centres.

- Fifteen high-temperature geothermal fields in the North Island of New Zealand have the potential to supply substantially more geothermal energy than is currently exploited.

- The utilisation of biomass (mainly bark and wood residues from timber, pulp and paper industries) is primarily through cogeneration and wood-burning stoves. The available potential resource far exceeds what is currently exploited (although transport and drying costs are significant impediments to greater use of this resource).

- Landfill gas is utilised in three larger cities, and biogas from sewerage treatment plants, farm wastes and the food processing industry has been used on site for decades to produce power and heat for local consumption or for vehicle fuel.

- Solar energy is mainly used for hot water systems and passive solar heating in buildings by means of architectural features to collect, store and distribute space heat.

- New Zealand has recently updated the energy efficiency standards in the Building Code, and intends to introduce Minimum Performance Standards and energy efficiency labelling for a number of selected consumer appliances.

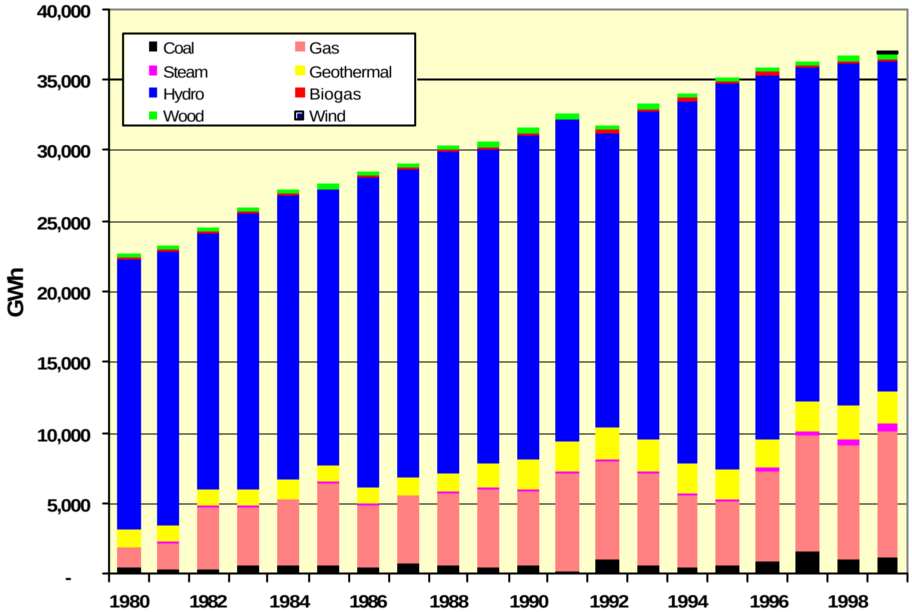
- In 2000 New Zealand enacted Energy Efficiency and Conservation legislation that recognises the value of both energy efficiency initiatives and renewable energy.

In Figure 11, growth in net electricity generation is shown for the last twenty years, along with fuel composition. This graph begins in 1980 - a date by which the frenetic pace of government-funded, large-scale hydro development of the preceding 30 year period had slowed appreciably. Apart from the completion of two schemes in the early 1980s, the only large development occurring during the decade of the 1980s was the Clyde dam, which was very politically controversial, enormously expensive to build, and added 432 MW of large-scale capacity in 1990. There have been no large-scale hydro projects since that time, except for the addition of another “tail-race” (additional tap) to the already existing Manapouri scheme, and further large-scale hydro development is doubtful in the near to mid-term future.

In Figure 12, the growth of power generation for new renewable sources is shown for the period from 1980 through 1999. As can be seen, geothermal resources increased significantly around 1989 and 1990. There also has been some growth in the use of woody biomass and biogas to generate electricity in the last twenty years. Research scientists at the Forest Research Institute in Rotorua estimate that woody biomass, using forest by-products alone, could provide 10-15 percent of generation requirements [Gifford *et al*, 2000]. Natural gas combined cycle plants have provided most of the growth in power generation capacity over the last five years.

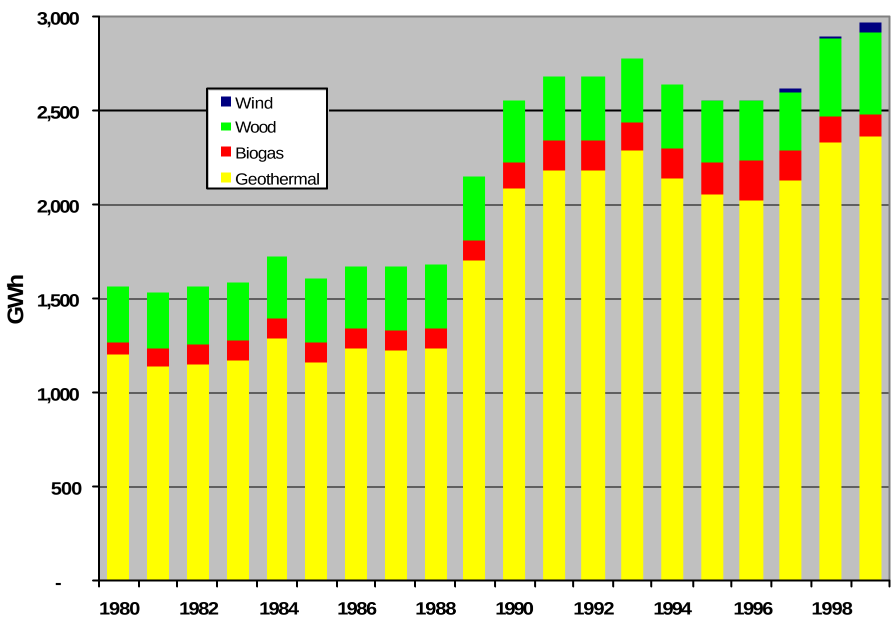
A further idea can be gained of the potential for renewable energy development in New Zealand by looking at recent and proposed power project proposals. Because the New Zealand electricity sector is

Figure 11 Net power generation by fuel in New Zealand



Source: New Zealand Energy Data File, 1999

Figure 12 Power generation by new renewable fuels in New Zealand



Source: New Zealand Energy Data File, 1999 almost completely deregulated, investors in power generation no longer need to advise the government of their intention to build power generation capacity. The only time government has an opportunity to interact with this activity is through environmental legislation, in particular, the Resource Management Act, which may impose restrictions on some developments for environmental reasons.

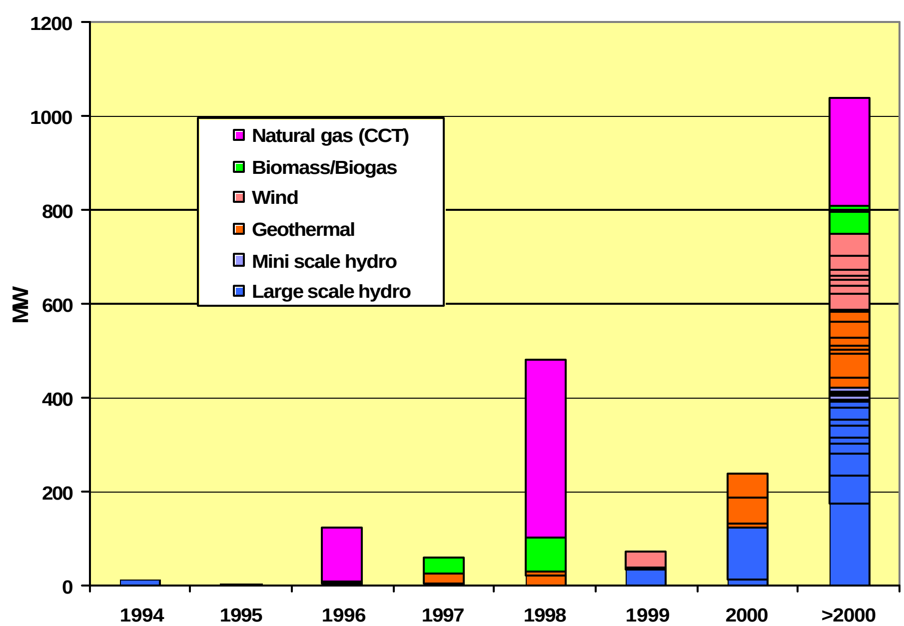
Consequently, the data used to generate the graph in Figure 13 shows recent and proposed power generation projects that are based on a number of sources of varying reliability, including actual developments; conversations between departmental officials and private sector people about their intentions; press clippings; and environmental consent applications.

Natural gas combined cycle has dominated development recently, but future proposals are constrained by the availability of gas. The major New Zealand gas field, Maui, is projected to go into rapid decline in the second half of this decade, and this may impact new investment in gas-fired power generation in the absence of new discoveries - or even with new discoveries, as the gas price rises to align with the high cost of discovery.

The possible and indeed likely power sector investments over the next decade are biomass/biogas, mini-scale hydro, geothermal, and wind. Coal would face stiff pressure from the current government on environmental grounds, and large scale hydro projects may have been mooted, but are not overly likely due to capital cost, location (the best sites have already been developed), and adverse public reaction.

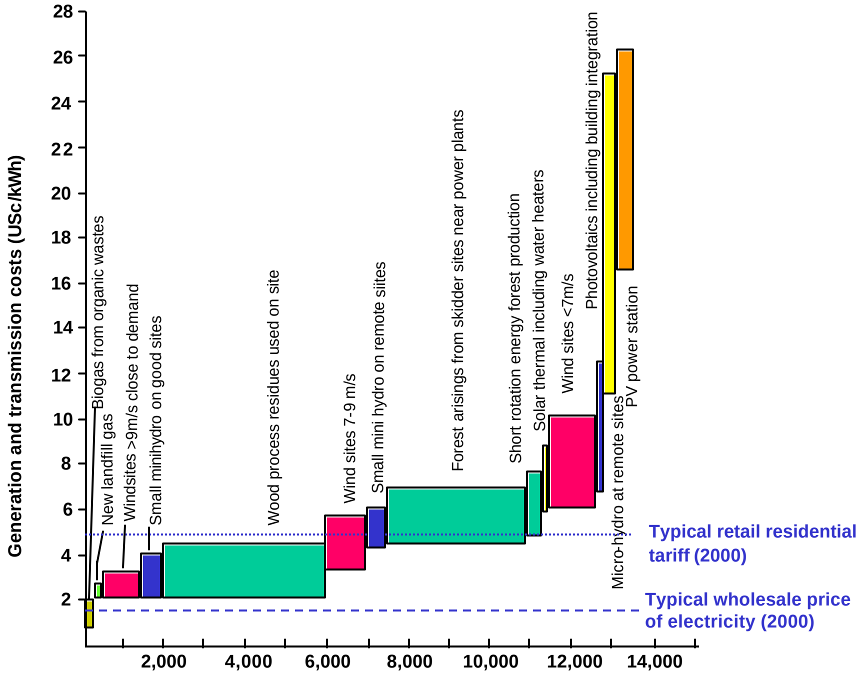
New Zealand is poised to begin the development of a much more distributed power system, with many small projects located close to demand centres - many utilising renewable resources. Although a supply over-capacity has existed recently, further demand growth will eliminate this, and when it occurs, lower capital cost, smaller scale developments will look attractive to investors.

Figure 13 Recent and proposed power projects in New Zealand



Note: Derived from a variety of sources, see text. The lines in the bar for ">2000" represent numerous projects of varying capacity.

Figure 14 Indicative generation costs & potential of renewable energy in New Zealand



Source: Modified from Sims, 2000. (Costs converted to US cents at a rate of 1 NZ$ = 40.42 US cents)

Notes: Technologies shown as cost/supply curve estimates for 2010.

The potential for further development of renewable resources can be investigated further by studying Figure 14. This shows indicative generation costs and market potential for renewable energy technologies shown as cost/supply curve estimates for 2010. The costs are shown in US cents for convenience (at a November 2000 conversion rate of 1 NZ$ = 40.42 US cents).

From this diagram it can be seen that a number of renewable technologies are competitive, or nearly so, in the current market situation, and that 6,000 GWh/year (17 percent of current net generation) of renewable resources could be potentially attractive investments. For example, there is nearly 4,000 GWh/year of power potentially available from wood process residues that could be utilised by large forest industry processing plants on-site. Generation from this source is not competing with the price in the wholesale power market, but rather with the contract retail price negotiated with the electricity retailer if it is to be used on-site. As this price will be below the retail price, on-site generation with available wood residue resources can be an attractive proposition for wood processing industries. During peak conditions, possibly excess power can be sold into the power market. Solar thermal and photovoltaics are not likely to be competing against the wholesale or retail price of electricity, so may be viable options for peak demand issues or for householders with incentives to offset the retail cost of electricity, or consumers in remote locations.

New Zealand is in an enviable, and potentially unique situation in the Asia Pacific region, with a rich endowment of readily exploitable natural renewable resources, the nation has been able to power much of its economic development sustainably. With its climate and highly productive agricultural land, the economy could also potentially derive a significant share of its transport fuels from biomass or other natural resources in the longer term. New Zealand could also be moving into a new phase of power development, the sector now largely deregulated and highly competitive, could trend towards smaller, more highly DG investments closer to demand centres, but still linked through a comprehensive transmission network system which provides security of supply and transports base-load from larger-scale stations.

Although other economies in the region may be less well endowed with renewable resources, there could still be lessons from New Zealand's experience.

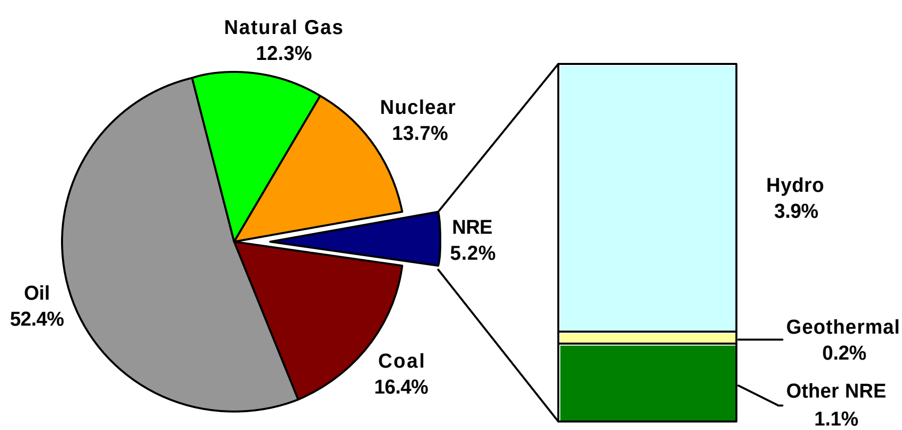
JAPAN

Japan is the world's fourth largest consumer of primary energy (see Figure 15), after the United States, China and Russia. Energy import dependence is also very high - at 80.1 percent in 1998.

Renewable energy makes a small contribution (5.2 percent) to Japan's total energy consumption, although the actual amount of energy involved is significant (28,590 ktoe in 1998) considering the relatively small land area available. In fact, among the 21 APEC economies, Japan is the seventh largest producer of renewable energy.

Considering Japan's heavy reliance on imported energy, and commitments to GHG emission reductions (in accordance with the United Nations Framework Convention on Climate Change), research into new and renewable energy sources is receiving a substantial amount of support in Japan [NEF, 2000].

Figure 15 Primary energy mix of Japan, 1998

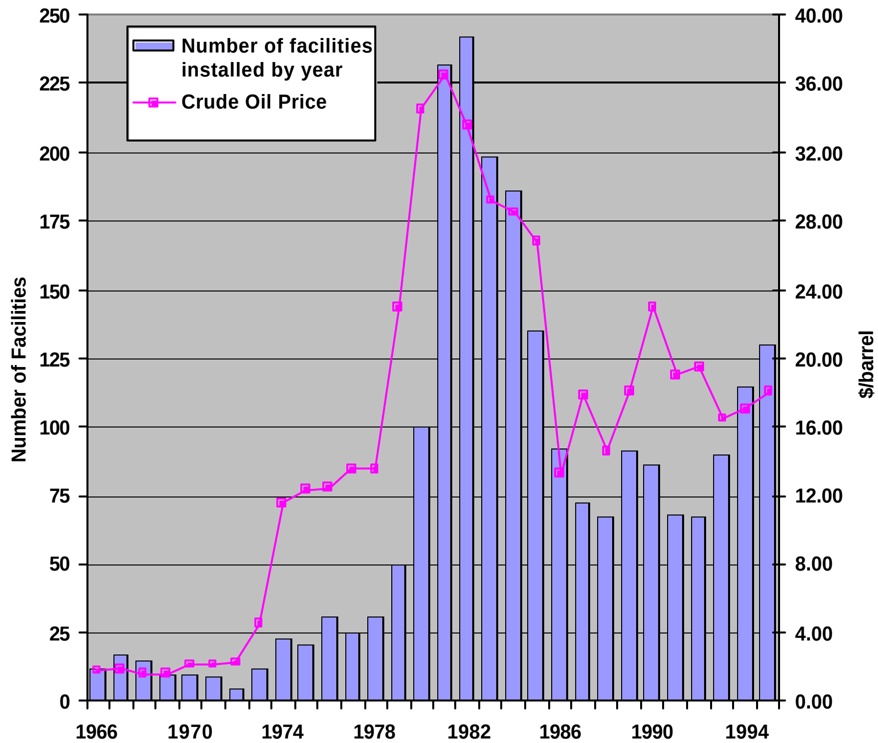


Source: EDMC, 2000

HISTORIC RENEWABLE ENERGY ACTIVITIES

Japan's venture into new energy research started long before the oil shocks of the 1970s, but the resulting high oil prices greatly boosted the installation of new renewable energy facilities. The findings of a survey conducted in 1995 (see Figure 16) revealed a correlation between the number of new energy installations and crude oil prices. The 1973 oil shock produced a small response, but the second oil

Figure 16 Number of new renewable energy installations and crude price, 1966-1995



Source: NEF, 2001

shock had a marked influence on the attempt to diversify energy supply options. However, as in other places around the world, interest in alternative fuels and energy supply options declined markedly in the late 1980s as the price of crude in world markets collapsed. Japan, however, has continued to maintain a significant effort - as suggested in Figure 16 - in researching and installing alternative energy technologies. A subsidy programme for residential PV installation was starting in 1994, and the number of facilities installed - and number of applicants for subsidies - has increased steadily.

RENEWABLE ENERGY TARGETS

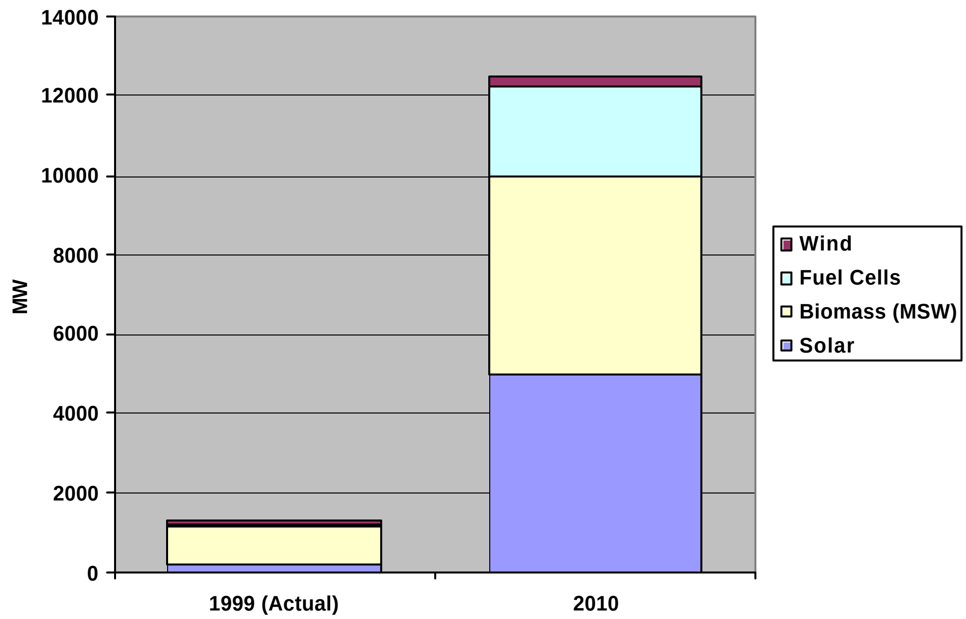
Japan's new Long-Term Energy Supply and Demand Outlook [NEF, 1999] which was revised in 1998, anticipates a significant increase in electricity generation capacity from solar PV, waste power, fuel cells and wind. Figure 17 shows the existing capacity in 1999 and the projected total capacity in 2010. Over the 11-year period, capacity will increase by a factor of ten.

Aside from these targets, the contribution of renewable energy for non-power uses such as solar and waste heat utilisation, thermal energy conversion, and other uses of biomass is also expected to increase substantially.

RESIDENTIAL PHOTOVOLTAIC (PV) SYSTEMS

Recognising the benefits that could be derived from PV power generation, the government of Japan through the Ministry of Economy, Trade and Industry (METI), has promoted wider use through a national subsidy programme. The programme started in 1994 and is administered by the New Energy Foundation (NEF) called the "Monitoring Program for Residential PV System."

Figure 17 Actual and projected renewable energy electricity generation capacity in Japan



Source: NEF, 1999

During the first three years of the programme (1994 to 1996), subsidy levels were set at about 50 percent of the total cost of installation of a residential PV system. From 1997, the subsidy was reduced to about one-third of the total cost [Okazawa & Uto, 2000]. Aside from the subsidy provided by NEF, local governments also provide additional subsidies. It is anticipated that projected reductions in the cost of manufacturing PV systems will lead to a time when subsidies are no longer necessary. The current policy position is that subsidies are needed to maintain demand for PV modules.

A residential PV system is not a particularly sophisticated application. What makes the Japanese programme interesting is the fact that the excess power generated can be sold back to the distribution network operator. The electric utility benefits through improved load management - a reduction in peak generation requirement - an advantage that helps to offset the cost of subsidising the scheme.

The cost of PV systems in Japan has decreased from 978,000 yen/kW in April 1999 to 918,000 yen/kW in May 2000. Costs are projected to decrease to around 880,000 yen/kW by the end of 2000 and further to 370,000 yen/kW by 2004. By 2010, costs are expected to be around 300,000 yen/kW a level at which PV could compete with power generated by the electric companies (around 25 yen/kWh). Projections also anticipate that costs could drop to 200,000 yen/kW in 2020 and 120,000 yen/kW in 2030 with generation costs of 10 - 15 yen/kWh and 5 - 10 yen/kWh, respectively.

A subsidy of one-half the cost of installation of PV power generation systems is also provided for public and industrial uses. A subsidy of two-thirds of the cost is also provided in disaster areas. From 1992 to 2000, 344 PV power generation systems with a total capacity of 9,710 kilowatts have been installed. The government, through the NEF, has provided a total of 1.686 trillion yen in subsidies for these systems since 1992.

A 3.5 kW residential PV system can generate the average electricity requirements for a single Japanese household. The electric company buys the excess power that is not used by the household at the company's selling price. Thus, a household can save as much as 100,000 yen annually in electricity bills.

WIND ENERGY

Installed wind generation capacity in Japan as of June 2000 is 83 MW. The largest wind farm has an installed capacity of 20 MW, using twenty 1,000 kW wind turbines, and is situated in Japan's northern island of Hokkaido.

The development of wind energy capacity in Japan has occurred at a rapid pace - from 3 MW in 1990 to 83 MW in 2000. With wind turbine capacity increasing, generation costs have decreased to around 16-25 yen/kWh - 2 to 3 times the cost of thermal power generation in most economies. The development of wind turbines from small to large sizes has been made possible by the efforts of utility companies.

Japan aims to increase wind power generation capacity to 300 MW by 2010. This will require the positive participation of the national and local governments as well as private enterprises. Non-power applications for wind energy are also being researched [NEDO and NEF, 2000].

WASTE-TO-ENERGY FACILITIES IN JAPAN

Wastes are utilised in Japan for energy purposes in different ways, such as the generation of electricity from solid waste incineration and utilisation of thermal waste for non-power purposes (hot water supply, industrial heating uses and sewerage treatment plants).

WASTE POWER GENERATION PLANTS

The waste-to-energy power generation system is a component of an integrated solid waste management system, combusting waste at temperatures exceeding 980 degrees Celsius, thereby destroying pathogens, bacteria and toxins and reducing the waste volume by 90 percent while harnessing combustion heat to generate energy in the form of electricity or steam [Ogden, 2001].

This type of new energy facility was first installed in Japan in 1965 in an attempt to solve the twin problems of increasing quantities of household and industrial wastes and the growing demand for energy. Many facilities have been installed since 1979, encouraged by government subsidies. As of 1997, the waste power generation capacity was 910 kW from 1,900 units. Due to the small size of these facilities, power generation efficiency is as low as six percent and combustion heat is used for power generation in only 10 percent of the 1,900 units.

Due to the improving cost-competitiveness of waste power generation, large-scale plants have been recently developed and these new installations reach higher efficiency levels of 23 to 35 percent through the combination of steam with gas turbines.

Japan aims to increase waste power generation capacity to 5,000 MW by 2010 [NEF, 1999]. This will be made possible by the development of new technologies combining high temperatures and high efficiency incinerators.

OTHER USES FOR WASTES

Aside from utilisation of combustion heat from waste incineration for power generation, heat is also used for other purposes such as hot water supply, industrial heating and sewerage treatment. Heat from industrial waste, such as black liquor and pulp waste in paper mills contributed 4.9 million kiloliters of oil equivalent (kloe) in 1996, representing 71.5 percent of utilisation of new energy during the year. This is expected to increase to 5.9 million kloe in 2010 with the projected increase in paper production.

Technology for turning combustible refuse into solid pellets or refuse-derived fuel (RDF) has been developed in Japan. RDF can be combusted at high temperatures, suppressing dioxin from gas emissions. Waste plastics can now be turned into RDF with technological development. However, installation of RDF power plants is still constrained by the limited supplies of RDF. In the future, the waste management sector and RDF developers are likely to cooperate to ensure that a continuous supply of RDF is provided to achieve smooth operation of power plants.

DEVELOPING ECONOMIES

The energy supply needs of developing economies in the Asia Pacific region differ significantly from those of the developed economies in the region. Developing Asian economies also stand out on the global scene because of the generally high average economic and energy supply growth rates they have achieved over the last two decades or more. The 1997 economic crisis that hit Asia hard has slowed this overall rate of growth, but by the end of 2000, it would seem the impact has been relatively short-lived - for the more robust economies at least - and the region may begin to grow strongly again.

Among what are officially termed “developing” economies, it is possible to distinguish two distinct groups. Singapore; Hong Kong, China; Korea; and Chinese Taipei all have high levels of overall wealth (and reasonable wealth distribution), stable governments, and provide attractive investment environments for foreign capital. These economies recovered quickly from the 1997 economic crisis, and show signs of being able to return to high rates of economic growth. Strictly speaking, these economies are not developing in the sense that others in the Asia-Pacific region and the rest of the world are - these are wealthy, industrialised economies about to enter the developed world as they are granted membership of the OECD and other “First World” bodies in the years ahead.

As these economies become fully developed, and move into the post-industrial, high technology age, their rates of economic growth will moderate and settle at the modest rates now common in the wealthy nations. Their energy supply requirements will also change from the need for large-scale base-load additions to smaller capacity additions (often peak load oriented), more specialised energy supply services, and the more distributed power supply infrastructure now becoming popular in the developed world.

At the other end of the spectrum, 1997 appears to have been a watershed for Indonesia, Viet Nam, Thailand and the Philippines. These economies have, for one reason or another, suffered substantial economic and/or social set-backs, and their future is somewhat uncertain at this time. In this less developed group, China and Malaysia succeeded in insulating themselves to some extent from the worst effects of the 1997 crisis, and their strongly growing economies look set to continue on that path.

This chapter looks at some specific lesser-developed APEC member economies and considers their options for development of sustainable energy systems. Because these economies are non-Annex I under the Kyoto Protocol, they do not have specific greenhouse gas obligations under UNFCC agreements. Even so, many Asian governments have announced their attention to address this issue. However, the most immediate priority in many cases is stimulation of economic growth and alleviation of poverty.

The implications of this immediate priority are that short-term energy policies may require the promotion of fossil fuel consumption to accommodate the requirement for large base-load power generation additions. For such economies, a short-term commitment to fossil fuels may smooth the transition to a more environmentally and economically sustainable future. The question is whether short-term options can be optimised through the transfer of clean technology from developed nations and the inflow of sufficient capital to encourage cleaner fuel options such as natural gas and renewable energy where cost effective.

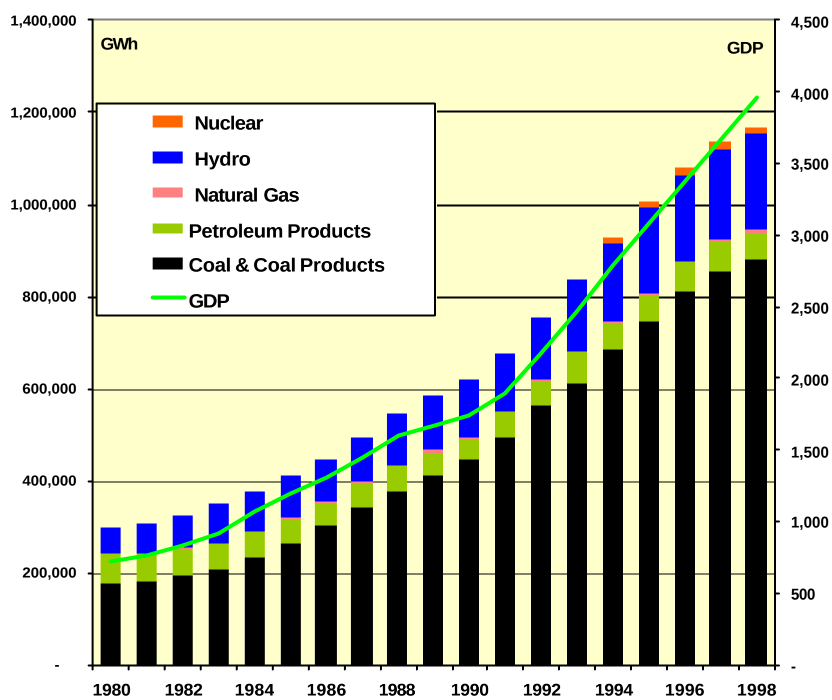
CHINA

China is very important to a discussion of sustainable energy supply development because, next to the US, it has the second highest total primary energy consumption in APEC. Even then, energy consumption is only about half the US total, and consumption per capita about 10 times lower [EDMC, 2000]. If all citizens in China aspired to the average standard of living and average energy consumption of US citizens, the energy supply infrastructure requirements would be truly enormous - and would exceed total current global energy consumption.

Although China's energy intensity has been declining, electricity consumption is likely to continue growing at around nine percent per annum once the economy fully adjusts to the effects of the 1998 financial slowdown and the electricity over-supply situation resulting from recent industrial restructuring [CERA, 2000].

Figure 18 shows total electricity consumption for China from 1980 through 1998, plotted along with GDP. As shown, the economy maintained a high rate of growth through the 1980s and 1990s. This is matched by growth in electricity supply, which will double by 2010 and possibly triple by 2020.

Figure 18 China's electric consumption, fuel mix, and GDP



Source: EDMC, 2000

China is heavily dependent upon coal for direct use and for power generation. Many power plants are small and inefficient, although efforts have been made since the late 1990s to close down the smaller, less efficient plants. Energy policy planners now favour larger-scale modern plants fitted with pollution control equipment to reduce NOx, SOx and particulate emissions - major sources of photochemical smog. Even with these policies in place, some of the most optimistic forecasts show that China's carbon emissions from electricity generation will almost double from 1995 to 2010.

Because China is so heavily dependent upon coal, the economy is now the world's biggest emitter of sulphur, ahead of the USA, Europe, and the former Soviet Union [Higgins, 1999].

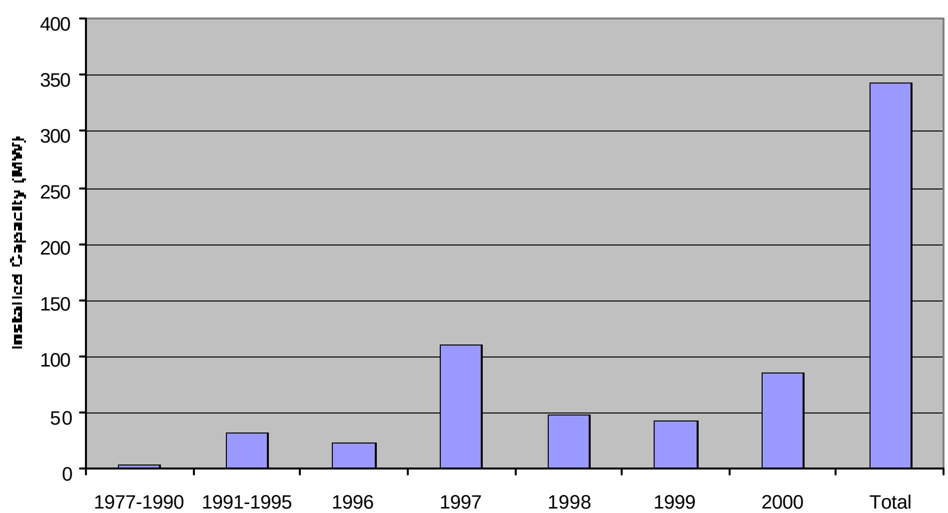
RENEWABLE ENERGY IN CHINA

Exploitation of China's extensive renewable energy resources is an important part of China's policy to mitigate the environmental impacts of energy supply growth. China has a very large total hydropower resource, and is currently generating around 18 percent of total electricity requirements from this source (the installed hydropower capacity in 1998 was 60 GW).

In fact, China has the largest hydropower potential in the world, although the resources are far from city centres. Currently, China is building the Three Gorges Dam, the world's largest hydropower project. There has been significant controversy over the project, similar to that surrounding other large-scale hydropower projects. Even some advocates of hydropower believe the same generation capacity could have been achieved with smaller dams with less overall negative impact. The project will displace approximately 1 million people, while supplying 18.2 GW of electrical power, accounting for around three percent of total installed generation capacity. China plans to continue exploring and utilising large-scale hydropower resources over the next 20 years.

Wind power generation has been growing in China at a high rate, although starting from a very small base. Figure 19 shows the installed wind capacity.

Figure 19 China's installed wind capacity by year and total



Source: Chen, 2001

When the installed wind power capacity is compared to total capacity, it is extremely small, about a tenth of one percent. However, China ranks fourth behind Denmark, Germany, and the USA in terms of installed wind power capacity. Therefore, it is encouraging that China is pursuing its potential wind resource. Currently, in China wind power turbines are being installed with expected amortised electricity rates 25 percent lower than the average grid electric rates [Chen, 2001a].

One expert forecasts that China could have 25 GW of wind power capacity installed by 2010 [Chen, 2001]. If this target were achieved, it would represent an impressive commitment to sustainable development and would account for about five percent of net generation in 2010.

China is also pursuing solar photovoltaic programmes and thermal solar projects. Currently, one of the world's largest central PV sites (100 kW) is operational in Tibet [Chen, 2001]. China's PV programme is still in its infancy, however. Significant infrastructure will need to be developed before PV can become a mainstream alternative to grid power, even for peak demand applications.

China has the world's largest installed base of solar thermal applications. Currently, the industry is constrained by the inability of suppliers to keep up with demand. The long-term prospects for solar thermal may be promising, once fundamental issues such as adequate financing, product testing and certification, and demonstration of commercial applications are pursued [WB, 2000].

Geothermal resources exist in China, but total electric generation capacity is small (30 MW). Total cost effective resources are only expected to provide about 200 to 500 MW. China plans to pursue small geothermal projects, generally around 2 MW applications [World Bank, 1998]. Considering the required demand, geothermal is not expected to provide any real measurable impact.

Another interesting point about China's renewable energy policies is the possibility of adopting a renewable portfolio standard. Such a standard would mandate that a particular percentage of new electricity supply be met from renewable energy resources. In many economies, these standards are established without inclusion of large-scale hydro. One concern in China would be whether such a standard would be specified across a broad range of renewable energy technologies or whether it would specify various generation percentages for each technology [Jaccard, *et al*, 2001].

RURAL ELECTRIFICATION

Over 60 million people, or approximately five percent of its population, do not have access to electricity in China. China has pursued a variety of solutions to provide electricity to remote locations including the extension of existing power grids and the installation of polluting diesel/gasoline generators.

China also has many small-scale renewable energy installations. For example, China is the largest producer of small wind turbines (100 to 300 watts) in the world. There are currently about 40 manufacturers, utilising mostly older designs, producing units for individual homes. Over the past 20 years, approximately 160,000 units have been installed.

A collaborative programme between the Chinese government, the US DOE, and the US DOE National Renewable Energy Laboratory has provided some interesting results. The project involved the collection of data from a variety of applications including stand-alone wind, stand-alone PV, hybrid wind and PV, and traditional diesel and gasoline generators [Weingart & Lee, 2000].

The results showed that the least cost option for remote sites was stand-alone wind, followed by hybrid wind and PV, stand-alone PV, and lastly fossil fuelled generators. Even though stand-alone wind provided the least cost option, programme administrators recommended the hybrid systems because in the Inner Mongolia applications, winter winds provide a significant resource, while summer brings hot sunny calm weather. Thus, the hybrid systems provide more uniform supply and can match demand more effectively.

Two primary systems were recommended for individual households. For poorer households, a 100 watt wind turbine is combined with 50 - 70 watts of PV. This would provide for lighting, colour television, consumer electronics, and some discretionary load. For households that could invest more, a 300 watt wind turbine with 150 - 200 watts of PV was recommended. This would provide the household with refrigeration capability in addition to the other end-uses mentioned above. This part of China has very hot summers, so refrigeration capability is an important amenity.

China has a programme called “Chinese Brightness Program” which is intended to install renewable energy systems to a variety of income level homes and rural villages. The first phase of the programme is expected to provide electricity to eight million people living in 1.8 million homes and in 2000 villages. Subsidies from the Chinese government and local jurisdictions, with foreign investment, will account for about 14 percent of the capital cost, the remainder is to be funded by the users [Weingart & Lee, 2000]. This high requirement makes widespread adoption optimistic, unless financing terms are extremely flexible.

Small hydropower is an abundant resource in China, and well suited for the electrification of rural areas. There are more than 5,000 suitable rivers, with almost half of the counties in China having access to resources of 10 MW or more. Total small hydropower potential is estimated at 70 GW with annual electricity generation potential of 200 - 250 TWh. Currently, only about a quarter of this resource has been utilised.

The costs of such systems are fairly low compared to other generation options. For example, in the mid 1990s small hydro systems in China cost between US$ 700 and US$ 1000 per kW of installed capacity. Considering the low operating costs, these systems are far less expensive than other sources of electricity generation [Jiandong, 2000].

THE FUTURE

Considering the potential, one might expect the Chinese Government to pursue exploitation of renewable resources with great zeal over the next one or two decades. Considering the urgent need to mitigate the adverse impacts of current coal consumption practices, the full exploitation of renewables and enthusiastic development of China's natural gas resources should have a major impact on the future electricity supply path.

Currently, a broad range of renewable applications exist that are cost effective and less expensive than installing coal generation. The greatest uncertainty is whether the world community will provide the necessary financing, since renewable systems tend to be more capital intensive than traditional fossil-fuel options. Without adequate international financing, the likely path for increased electricity capacity even in locations where renewable energy is more cost effective, will probably be coal fired power plants.

MALAYSIA

In the Southeast Asia region, Malaysia stands out for a number of reasons. Malaysia has a stable and investment friendly political environment, well-established and market-oriented monetary and business laws, and a robust economy that weathered the 1997 financial crisis better than many of its near neighbours. Further, Malaysia is rich in energy resources, with large reserves of coal, oil and natural gas, as well as a significant hydropower resource.

Malaysia's natural gas reserves in 1999 were 2,402 BCM, slightly ahead of Indonesia, with 2,156 BCM. To date more than 214 gas fields have been discovered, with only 10 so far developed and producing gas [PETRONAS, 2000]. At the 1998 production capacity level of 41.3 BCM, Malaysia's reserves would have a life of 56 years. With 19.4 BCM of natural gas being exported in 1998, Malaysia was Southeast Asia's second largest exporter of LNG, after Indonesia. Export destinations inclue Japan (68.0 percent), Korea (20.1 percent) and Chinese Taipei (11.9 percent).

The Malaysian government has long seen electricity supply infrastructure growth as indispensable to economic development, and the fruits of this vision can be seen in the relatively high rate of electrification. As of 1997, 99 percent of Peninsula Malaysia was connected to the central power grid, and 75 percent of Sabah/Sarawak was electrified, mostly through grid connections, but with some remote village power systems.

Over the last few years, the electricity sector has undergone substantial reform, with separation of the natural monopoly and competitive elements, privatisation of parts of the infrastructure and encouragement of Independent Power Producers (IPPs). As of September 1999, Malaysia had around 12,000 MW of installed electricity generation capacity, 37 percent of which was owned and operated by five IPPs. In 1999, the fuel mix for power generation was 73.3 percent natural gas, 7.8 percent petroleum products, 7.5 percent coal and 11.4 percent hydropower.

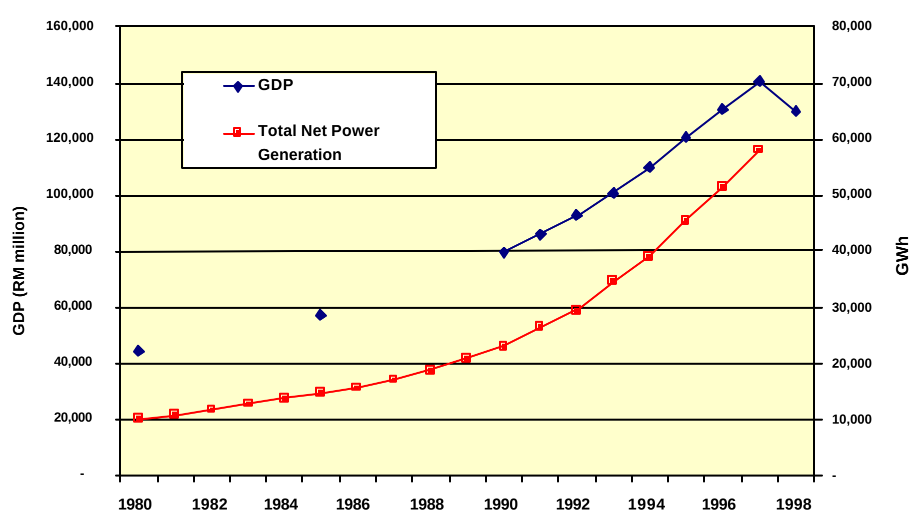
With a very rapidly growing economy in the late 1980s and early 1990s, Malaysia has required large base-load additions to national electricity generation capacity. This has led to acute power shortages, and sectoral reforms have been driven by the requirement to encourage large-scale investment in electricity supply infrastructure. Figure 20 shows GDP growth over the period 1980 to 1998, and primary energy supply growth over the same period.

Between 1987 and 1997 Malaysian electricity demand grew at around 12-15 percent per annum. Peak demand increased from 3,000 MW in 1986 to about 9,200 MW in 1997, and is expected to grow at a modest rate, and then increase again when the economy recovers. Overall electricity consumption increased from 21 TWh in 1990 to 49.1 TWh in 1997, representing a growth of 8-15 percent per annum. Electricity consumption per capita increased from 1,120 kWh to 2,320 kWh during the same period.

As can be seen from Figure 20 and Figure 21, net power generation grew at a faster average annual growth rate than GDP from the mid 1980s until 1997, when the financial crisis hit.

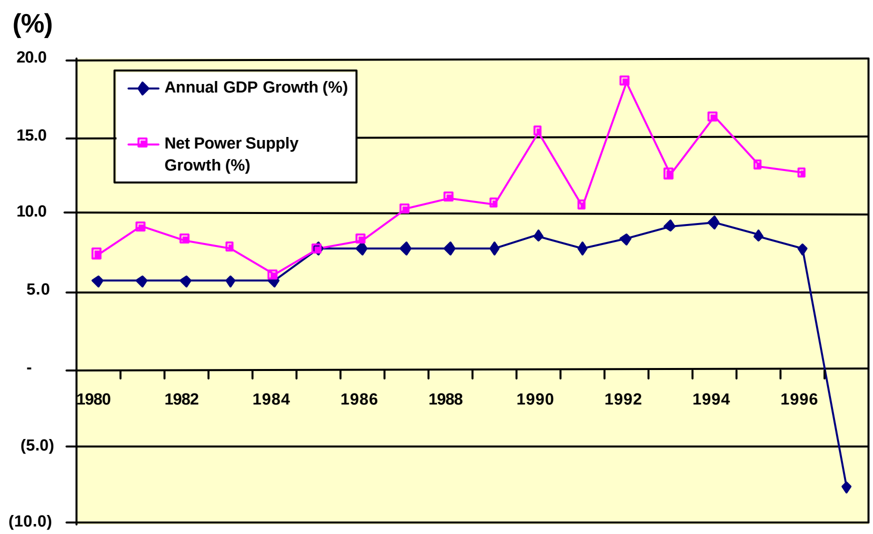
This process of very rapid electricity infrastructure development has forced reform of the sector to encourage the levels of capital needed to make it happen. The outcome is that prices reflect more closely the economic cost or true cost of supply, hence ensuring adequate revenues to allow for the development of the power sector and encouraging international private capital to build generation capacity.

Figure 20 Growth in GDP and net power generation in Malaysia (1980-1998)



Source: GDP data from Thaddeus, 2000 and energy data from EDMC, 2000

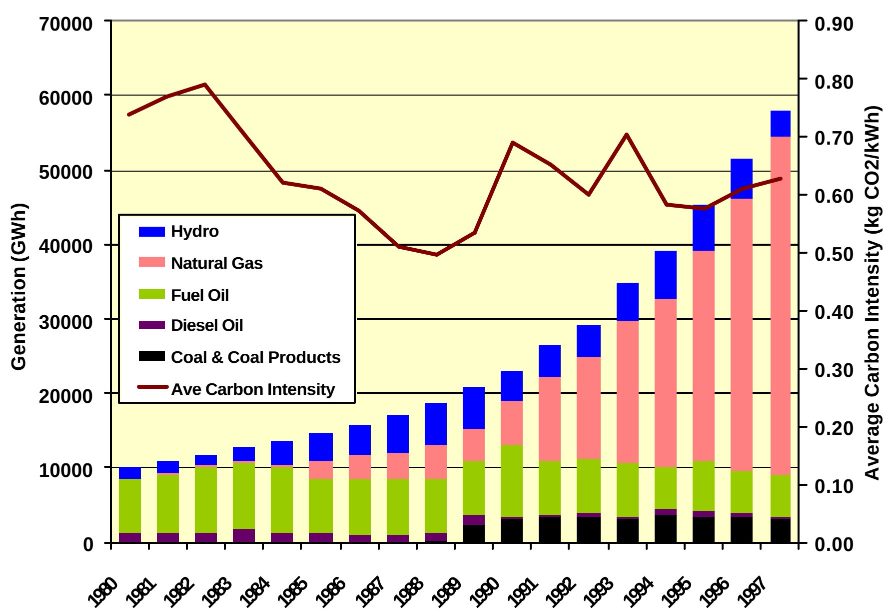
Figure 21 Incremental growth in GDP and net power generation in Malaysia (1980-1998)



Source: GDP data from Thaddeus, 2000 and energy data from EDMC, 2000

In Malaysia, as in other developing Asian economies, economic reforms must be balanced with a strong government social policy precedent and obligation to extend basic services to all citizens, even the most remote and poor communities. In addition, economies that have known strong government control over the energy infrastructure also tend to have a traditional concern over security of fuel supplies.

Figure 22 Power generation fuel mix in Malaysia (1980-1997)



Source: EDMC, 2000

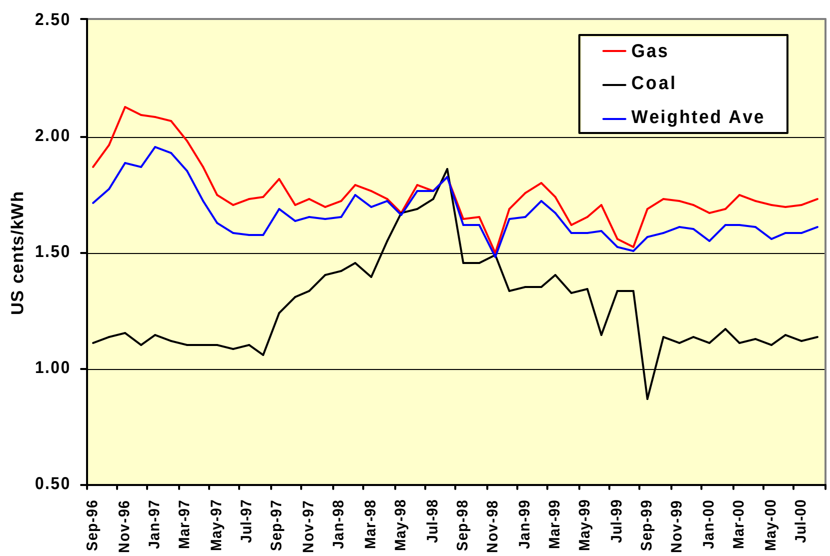
Since 1980, the Malaysian energy supply sector has been guided by the government's "four fuels diversification strategy."[1] This strategy grew out of the oil supply crisis in the 1970s, and the heavy dependence at that time on oil for most energy requirements, including transportation and power generation.

The four fuels are oil, natural gas, coal and hydropower. The government also has a policy (the Renewable Portfolio Standard), to increase the share of (non-hydro) renewable energy to five percent of total net generation by 2005. The additional renewable share is expected to come mainly from biomass co-generation, using wastes from the palm oil industry.

As shown in Figure 22, a high percentage of the growth in electricity demand since 1980 has been met with gas-fired generation, mostly CCGT. This was accompanied by modest growth in hydropower and coal fired generation, and a decline in power generated using fuel oil.

Coal generation to date has been constrained by the lack of competitiveness of indigenous steam coal, 98 percent of which is located in Sarawak and Sabah, mostly in poorly accessible inland areas. However, as shown in Figure 23, coal imported from nearby suppliers such as Australia and Indonesia is very competitive with other power generation fuels, including natural gas.

Figure 23 Power generation fuel costs in Malaysia (in US cents/kWh)

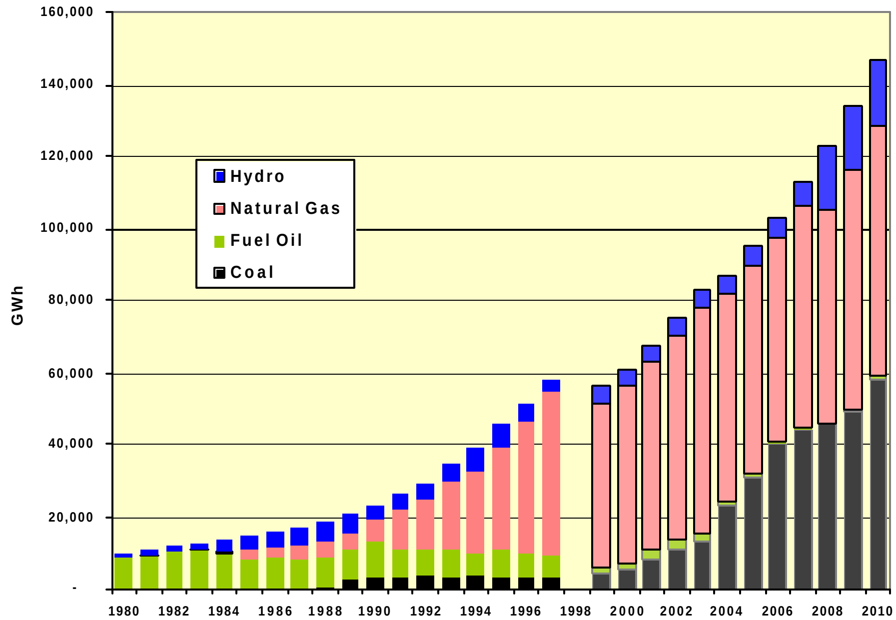


Source: Modified from Thaddeus, 2000

With coal relatively competitive as a power generation fuel, and energy fuel diversification an important government policy objective, coal consumption for power generation is set to grow from 4.2 million tonnes in 2000 to 13 million tonnes in 2005 as new coal-fired plants are commissioned over the next few years [Thaddeus, 2000]. The steam coal will be imported from Australia, Indonesia and China. Figure 24 shows net power generation for Malaysia projected out to 2010. As shown, coal-fired generation could rival natural gas-fired generation by 2010. The provisions of the Environmental Quality Act 1974 will ensure that future coal plants will be fitted with low NO_x burners, electrostatic precipitators, and flue gas desulphurisers, so non-CO_2 pollutant emissions will be reduced.

1 This policy recently has been revised to include renewable energy, this will be discussed later in this section.

Figure 24 Net power generation for Malaysia projected out to 2010



Source: Modified from Thaddeus, 2000

DISCUSSION

Growth in fossil fuelled power generation in Malaysia is being driven by a number of factors working in unison: large growth in demand (driven by rapid industrialisation and an attractive investment environment); ready availability of natural gas and imported steam coal; and the "four fuels" policy designed to encourage diversification of energy supply.

From an energy sustainability perspective, this trajectory has both positive and negative characteristics. Malaysia, like other rapidly industrialising economies in the region, requires large additions to base-load power generation capacity. This type of development raises the general level of wealth in the economy, encourages a transition from primary energy consumption at a local level (often polluting and unsustainable), and brings longer-term environmental benefits as overall levels of prosperity rise and people can afford to demand a higher quality living environment.

Because Malaysia is non-Annex I, it does not have any greenhouse gas emission targets under UNFCC agreements. Hence, from an economic development perspective, it could be strongly argued that the currently projected energy supply scenario represents the most sustainable longer-term option. However, coal power generation plants have a long life expectancy, and are often kept running long after their economic lifetime has expired. From an environmental sustainability perspective, the use of traditional coal-fired technology certainly would not be the wisest choice.

With abundant indigenous natural gas supplies, and the possibility of an ASEAN natural gas grid interconnection with the other major regional gas supplier, Indonesia, one could argue that security of fuel supply concerns are not really justified, and the fuel choice for power generation should be left entirely to the market. In this case, the government would act only to ensure adequate protection for the environment, and to maintain such social policies as are needed to ensure the poor have access to sufficient clean energy sources to meet basic human needs.

POWER GENERATION USING PALM OIL WASTES

Malaysia is the world's biggest exporter of palm oil. In 1999 palm oil exports were worth US$ 5.1 billion, six percent of the economy's total exports [Yearbook of Statistics, Malaysia, 1999].

There were 328 palm oil mills in 1998 with 75 percent of them located in Peninsular Malaysia and the remainder in Sabah and Sarawak. The capacity of these mills ranges from 20 to 90 tonnes per hour of fresh fruit bunches. More than 60 percent of the mills have processing capacity in excess of 30 tonnes per hour. In 1998, the mills received and processed 43.84 million tonnes of fresh fruit bunches and produced 8.3 million tonnes of crude palm oil.

Palm oil mills generated huge quantities of biomass wastes in the form of fibres, shells and empty fruit bunches. Additionally, biogas generated as a by-product of the anaerobic treatment of palm oil mill effluent is a potential supplementary energy source.

The empty fruit bunches, which comprise 21 percent of the weight of fresh fruit bunches, represent the largest waste component, have high potential as a fuel for energy production. It is estimated that 8.5 million tonnes of empty fruit bunches were generated in 1998. This quantity of material could produce around 2.0 Mtoe of energy, representing about six percent of Malaysia's total national energy supply requirements, or 15.2 percent of total fuel input for power generation for that year.

A feasibility study was initiated by the Malaysian Ministry of Energy Communications and Multimedia, and involved four demonstration co-generation plants with an output capacity of five MW per plant [Pusat Tenaga, 2000]. The minimum fuel input requirement is 30 tonnes per hour. The moisture content of the empty fruit bunches fed into the system must be less than 40 percent for efficient operation. With the average moisture content of empty fruit bunches being around 65 percent, a drying system is required, utilising the heat co-generated by the plant. Four sites have been identified, two in Peninsular Malaysia and two in Sabah.

Cost analysis on these demonstration plants revealed a total investment cost of US$ 6.3 million to US$ 7.7 million per plant. The payback period and internal rate of return are expected to range from 5.6 - 6.4 years, and 18.7 - 23.1 percent, respectively. The greenhouse gas emission reduction potential ranges from 23,000 to 27,000 tonnes of CO_2 per annum. Economic analysis of the potential sites has been undertaken using the Standard Techno Economic Model (STEM) developed by the EC-ASEAN Cogen Programme. GHG emissions reductions were estimated using software developed by the Cogen Programme. The EC-ASEAN Cogen Programme, based in AIT, Bangkok, and active for more than 10 years, has been successful in implementing a number of pilot projects in Thailand, Malaysia, the Philippines and Indonesia using cogeneration plants fired by wood wastes.

In June 1999, Malaysia's Prime Minister announced that renewable energy sources would become the fifth fuel, extending the already existing four-fuel energy diversification strategy adopted by the government as complementary measure to its National Depletion Policy. The Malaysian Energy Centre was also formally inaugurated in the same month to pursue a more aggressive renewable energy implementation policy, as well as energy efficiency programmes. In April 2000, the Minister of Energy, Communications and Multimedia went a step further by adopting a Renewable Portfolio Standard for Malaysia, announcing a five percent target for renewable energy power generation by 2005.

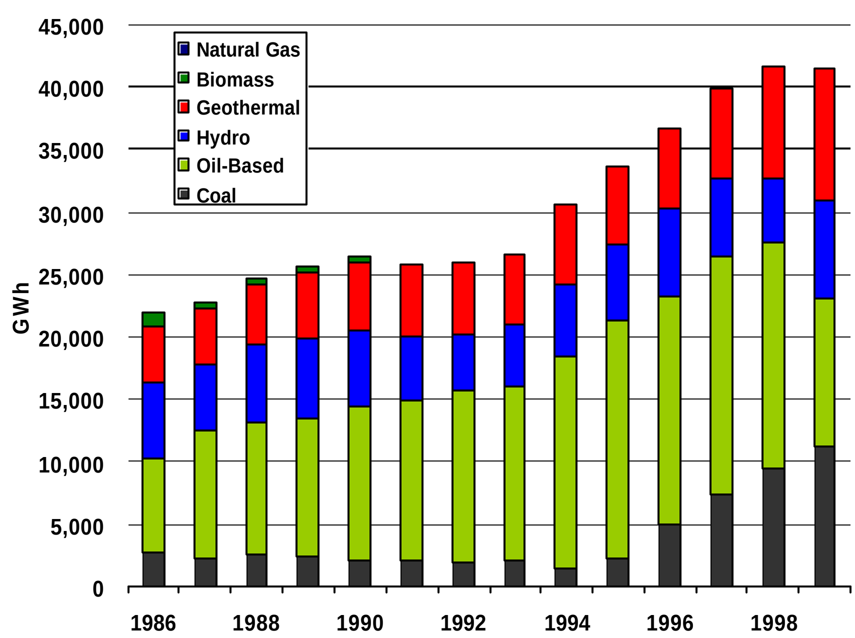
While the 1990s has been a successful decade with respect to encouraging foreign investment in the electricity supply industry, Malaysia is now encouraging the establishment of grid-connected small power producers (SPPs). The four demonstration plants, when implemented, could be the first SPPs, using grid-connected biomass powered technology. Oil-palm wastes (and also wood-wastes), have been identified as a cost effective indigenous approach to solving the problems of energy security, environmental protection, and waste management, as well as utilising locals skill and resources.

PHILIPPINES

The Republic of the Philippines imported 64.5 percent of total energy requirements of 28.8 Mtoe in 1998 [EDMC, 2000]. Of the total imported energy, 92.0 percent comprised crude oil and petroleum products. The electricity industry is also highly dependent on imported oil and coal with 62.0 percent import-dependence.

The power sector has been heavily dependent on imported oil and petroleum products for many years. From 1971 to 1979, oil-based power generation comprised around 80 percent of total generation. As shown in Figure 25, fuel oil still accounts for nearly 45 percent of total net generation in 1998 but has significantly decreased to 29 percent in 1999, primarily due to the stagnation of the electricity demand growth and the increased generation from coal, geothermal and hydro power plants. The Philippines remains one of the few Asian economies still relying on fuel oil and other petroleum products for a significant percentage of power generation output. The Philippines stands alone as the only Asian economy where the use of petroleum-based products for this purpose has actually increased over the last decade.

Figure 25 Net power generation in the Philippines (1986-1999)



Source: Philippine DOE, 2001

Despite the high dependence on imported oil, the Philippines have one of the highest shares of renewables in its total primary energy mix in the APEC region. Renewables represented 45 percent of TPES in 1998, second only to Viet Nam with 70 percent (see Chapter 6).

The renewable resources consumed in the Philippines aside from hydro and geothermal are mostly non-commercial energy resources like firewood, wood wastes and other agricultural wastes that are used by the residential and agricultural sectors for cooking and crop drying purposes, respectively. In the electricity supply industry, geothermal and hydropower accounted for 21.4 percent and 12.2 percent, respectively, of total electricity production in 1998 [EDMC, 2000].

The share of solar and wind in the total energy mix is still insignificant. However, with a government target of extending electricity to all communities by 2008, and a goal of using renewable energy as a form of distributed power generation for communities far from the grid, the contribution of these energy sources is expected to increase significantly.

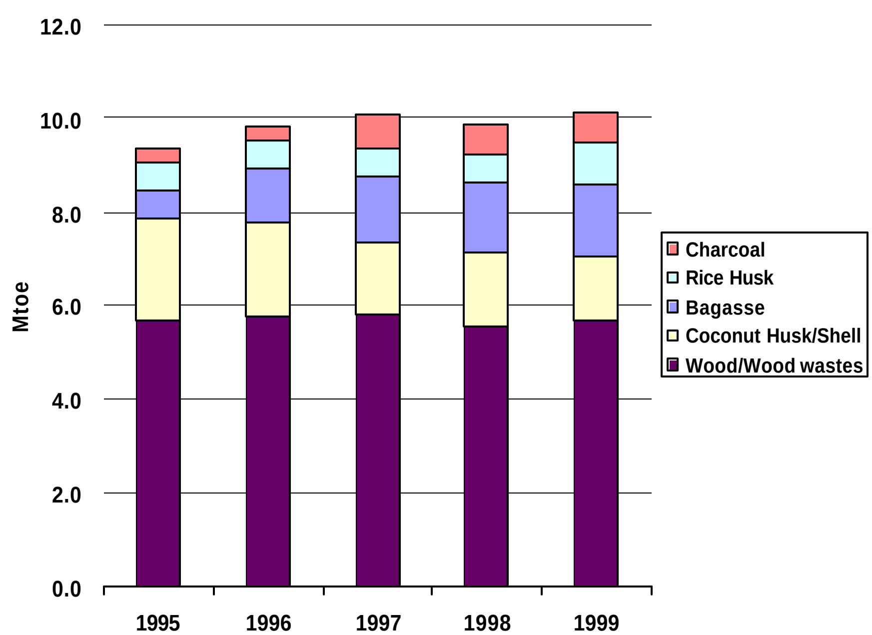
BIOMASS

Biomass in the Philippines includes firewood, wood waste, charcoal, biogas and agricultural wastes. These energy sources are used by the residential, agricultural and industrial sector, particularly, the food processing industry.

Firewood (wood/wood waste) is the most commonly used biomass resource with about 7 Mtoe consumed annually - mostly by the residential and commercial sectors for cooking and water heating purposes. Baggase, which is used as a fuel for in-plant electricity generation in the sugar industry, is next in importance with 1.5 Mtoe consumed. Coconut husks and shells - used for residential cooking and agricultural crop drying - accounted for 1.4 Mtoe. Rice husks and charcoal also contribute 0.9 Mtoe and 0.6 Mtoe, respectively. These are also used for commercial and residential cooking.

Biomass accounted for 28.7 percent of the primary energy mix in 1999. The biomass share is expected to increase in the future if a planned 40 MW biomass-fired electricity generation facility is constructed [Philippine DOE, 1999]. Utilisation of municipal waste for electricity generation is also in the planning stage and is expected to further increase the contribution of renewables in the primary energy mix.

Figure 26 Biomass consumption in the Philippines



Source: Philippine DOE, 2001

SOLAR ENERGY

Solar energy has been exploited in the Philippines since the 1970s, but largely in the form of demonstration projects. In 1998, the Pangan-an solar project was inaugurated. The project was financed through a grant from the government of Belgium amounting to US$ 2 million. It is the first PV solar system powering a mini-grid where the electricity service is not provided free to consumers.

The project was conceptualised with the objectives of providing electricity to an island community to improve living conditions and to ultimately trigger economic activity in the area, as well as to showcase PV power generation in a developing economy [Philippine DOE, 1999a].

The project consists of 504 PV modules of 90 watts each, with a total output of 45.36 kW. The system includes lead-acid storage batteries to ensure a 24-hour supply of electricity, an inverter to convert direct current (DC) stored in batteries to alternating current (AC), as well as power and battery protection units. The system is designed to serve 300 houses.

The project was made possible by funding from Belgium, and the collaboration of the national and local government, the local electric utility, the local Affiliated Non-Conventional Energy Centre (ANEC) and a cooperative established by the consumers who will become the ultimate owners of the system.

The power is six to seven times more expensive than the grid price in Metro Manila but is more comparable to other options such as electricity from diesel generators operated by private individuals and kerosene lamps. Although these two options are somewhat cheaper (by about 29 percent), their service is only for four hours during the night compared to the 24-hour power availability offered by the solar PV system. The 24-hour electricity service provides the opportunity for more economic productivity.

In 1999, another solar energy milestone was put in place. The Shell Renewables Philippines Incorporation (SRPI) and the US Community Power Corporation (CPC) in collaboration with the local government in Aklan province, has established the first of ten planned Rural Energy Service Companies (RESCOs) in the Philippines. It is perhaps the first private commercial venture of a non-conventional energy system. The system is a small-scale hybrid solar PV/propane project that integrates 3.6 kW of PV (48 units of 75-watt modules) and a nine kW LPG-fired generating set. It also includes a four kW bi-directional inverter, a micro-processor-based system controller and a battery bank with a capacity of 50 kWh. The project departed from the usual practice of just providing equipment to beneficiaries and thus addressed the longer-term issue of maintenance and repair [Weingart & Lee, 2000].

This project could become sustainable, as aside from bringing technical innovation it brought about institutional innovation as well. This could become a basis for new policy initiatives and business opportunities that would permit and encourage economy-wide operation of RESCOs.

Aside from the aforementioned developments, more solar energy activities are underway. These include the development work being undertaken by the US DOE's National Renewable Energy Laboratory under their “Philippine Renewable Energy Project” and a project being conducted by the Cagayan de Oro Power and Light Company (CEPALCO), an investor-owned electricity distribution utility [Van Rest, 2001a]. The CEPALCO project involves a one MW on-grid field of PV panels to be installed to maximise the efficiency of an existing seven MW hydro facility. As an on-grid project, the proposed installation will meet peak load requirements in the afternoon and allow the dam to store capacity for the evening load. The project will benefit CEPALCO in terms of reducing distribution and system level demand, assisting in the postponement of the need for additional substation installation for a period of up to three years, and reducing the need to purchase additional quantities of thermal plant-based power thereby, reducing GHG emissions [Van Rest, 2001a].

WIND ENERGY

The Philippines lies in the "Typhoon Belt" and gets on average about 25 storms per year that pass through. Strong wind gusts often result in damage to rotor blades and could even topple a tall wind-tower. Other problems include an absence of local expertise, lack of spare parts and ironically, strong intermittent winds (rather than a lack of wind).

EXISTING WIND INSTALLATIONS

In 2000, there were nine wind turbine generators and 512 wind pump installations reported, making an estimated contribution of around 0.08 ktoe. Below are the successful wind energy systems in the Philippines:

- A 10 kW stand-alone system in Pagudpud, Ilocos Norte (Northern Philippines) commissioned in March 1996, a pilot project of the NPC (National Power Corporation) for 23 households, with an inverter, a 220 VAC small distribution network and a 700 amp-hour battery bank.

- A 25 kW stand-alone system in the Picnic Grove Tagaytay 50 km South of Manila for six different loads with different priority depending on the amount of power produced, and no battery storage.

- A 25 kW stand-alone system in a private compound in Santos City.

- A 3 kW stand-alone system located in Bantay, Ilocos Sur, in operation since 1994 by the Philippine Telegraph and Telecommunications Corporation (PT & T) as a power supply for the relay station in tandem with a diesel generator.

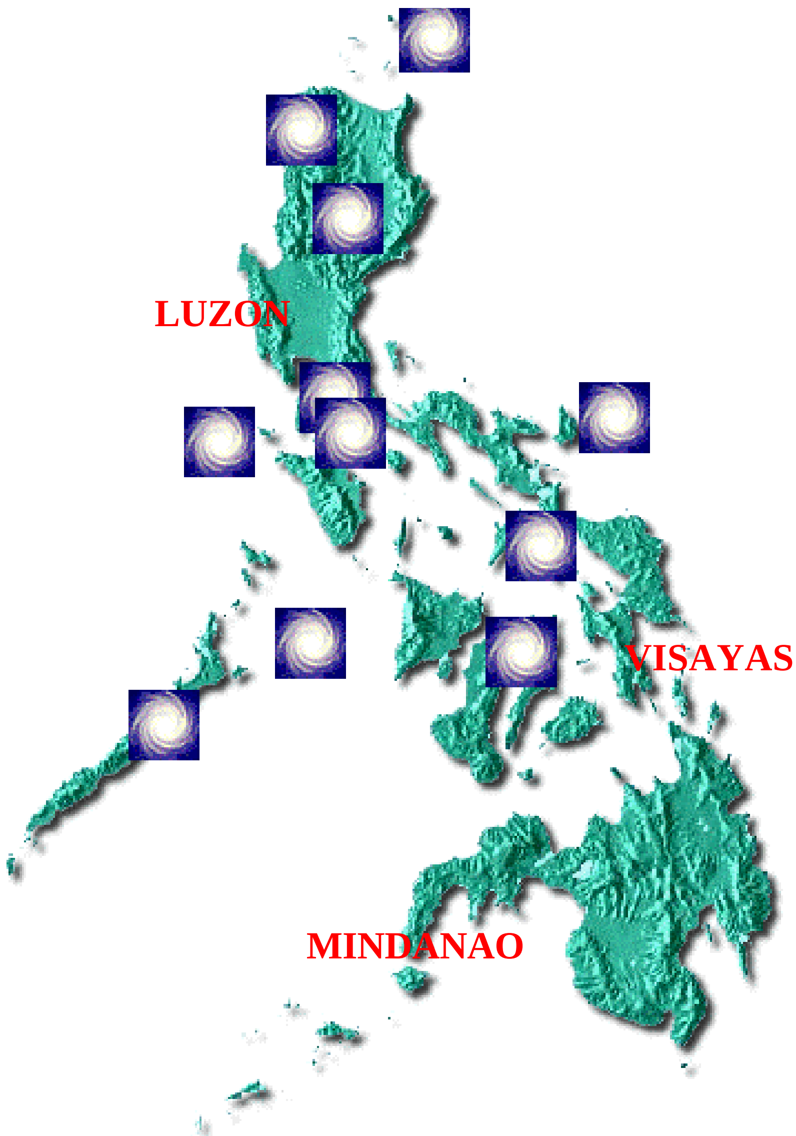
PHILIPPINE WIND RESOURCES

Most of the wind is found in the central and northern parts of the Philippines. There are locations in the Philippines that have sufficient wind for power project development. Areas for consideration should at least have an annual average wind speed of 3.5 m/s but some locations in North Luzon (Region 1) have annual averages of 7.5 m/s. Cut-out speeds vary per system from 15 m/s to 25 m/s.

Identified sites so far are areas mostly in and around northern and central Luzon, while eastern Mindanao in the southern Philippines appears to hold little promise. Figure 27 shows the Philippine wind resource map. A 1994 study "Assessment of Technical, Financial & Economic Implications of Wind Energy Applications for Power Generation" conducted by the United Nations Industrial Development Organisation (UNIDO), indicated a conservative, potential of 250 MW for the entire Philippines. Fortunately, the greatest potential is in Luzon where the demand for electricity is the highest (see Figure 27).

Only small wind energy systems have so far been installed in the Philippines, with "small" being defined as wind turbines with less than 100 kW capacity. Most common are designs based on 3-bladed upwind rotors, with active yawing and 380 VAC induction generators. In addition, private individuals have installed an unknown number of very small systems (100-250 W).

Figure 27 Wind resource map for the Philippines



Source: Modified from Philippine DOE, website: http://www.doe.gov.ph/

GEOTHERMAL

BRIEF HISTORY

Although most of the energy used in the Philippines is imported, it is fortunate to have abundant renewable energy resources in the form of geothermal energy, biomass and hydropower.

The potential of geothermal energy for power generation in the Philippines was demonstrated in the 1960s, when the Commission on Volcanology succeeded in lighting a light bulb with electricity generated from geothermal steam at Albay in the Bicol Region [PNOC-EDC, 1999]. With the first oil shock in 1973, the Philippine government decided to pursue geothermal resource development as part of its energy self-sufficiency programme.

Geothermal electricity came on the power scene in 1977, with the three-MW pilot plant at Tongonan, which supplied power to nearby Ormoc City and neighbouring localities. The first commercial scale plant was the Tiwi plant in Luzon commissioned in 1979. The combined capacity of Tiwi and Makiling-Banahaw of 775 MW supplied 3.8 percent of total net power generation at the end of the 1970s. This percentage gradually increased to 22.4 percent by 1991, but due to rapid growth in electricity demand, the share has remained constant since then. Nevertheless, the contribution of geothermal to the power generation mix has displaced a considerable amount of energy that would have been otherwise imported. At the turn of the century, installed geothermal capacity stands at 1,848 MW and the Philippines remains the world's second largest geothermal producer next to the USA.

The Philippines are an archipelago, comprised of around 7,000 islands in total, a dozen of which are reasonably large and have significant numbers of inhabitants. Population is concentrated in Luzon, Cebu and Mindanao. As a result of the geography of the Philippines, energy resources are often remote from population centres, and separated by ocean. This is certainly true for the geothermal resource. Many of the best geothermal development prospects are on relatively lightly populated islands such as Leyte and Negros, and usually in difficult terrain. So, it is not surprising that substantial technical hurdles had to be overcome to realise the potential of the resource, and a large amount of capital had to be invested.

Geothermal experts believe that the ultimate potential for geothermal power generation in the Philippines is 3,000-4,000 MW. This is lower than some estimates, but accounts for problems encountered in developments to date, such as low permeability in some reservoirs and acidic, highly corrosive conditions associated with active volcanism in many areas.

BENEFITS OF GEOTHERMAL

Geothermal steam is produced through the heating effect of hot crustal rocks, and associated gaseous emissions are at much lower levels than accompany steam produced through combustion of fossil fuels. In normal operating practice in the Philippines, the geothermal steam is condensed after use and re-injected, along with the separated hot water, back into the hydrothermal reservoir, thereby minimising pollutant emissions.

Geothermal power generation in the Philippines has displaced the consumption of 156.7 million barrels of fuel oil equivalent over a 25-year period. This translates to US$3.1 billion in foreign exchange savings. In addition, geothermal development has contributed to the economic development of the localities where the resource has been developed in terms of employment, tax revenues and royalty shares. In doing so, it has also brought electricity services to remote areas.

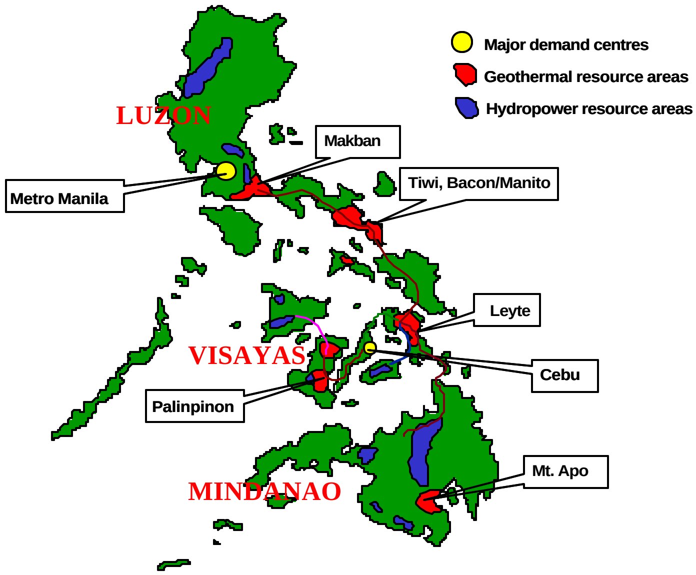
Geothermal power plants attain typical capacity utilisation rates of 85 percent, higher than for oil-fired combined-cycle gas turbines (80 percent) and coal-fired power plants (75 percent) [PNOC-EDC, 1997]. Unlike hydro, geothermal fields are not affected by dry years.

GEOTHERMAL DEVELOPMENT HURDLES

Geothermal development in the Philippines has not been without significant environmental impacts, as well as technical and economic hurdles. Philippine National Oil Company - Energy Development Corporation (PNOC-EDC) in 1997 acknowledged the following environmental effects of geothermal development:

- Surface disturbance due to civil works, including cutting of trees in forested areas, consequent soil erosion and possible impact on biodiversity
- Possible contamination of water resources such as lakes and rivers with geothermal effluent containing natural chemicals;

Figure 28 Geothermal and hydro resource areas in the Philippines



Source: Modified from Philippine DOE, 1999.

Notes: Transmission links shown, as well as major centres of power demand.

- Emission of carbon dioxide, hydrogen sulphide and other non-condensable gases;
- Noise pollution during well discharge.

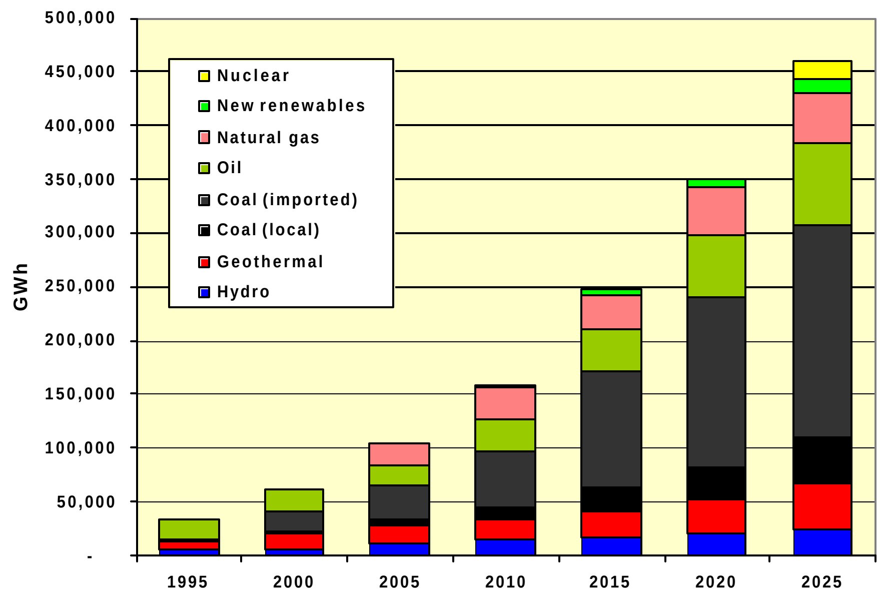
The more serious of these problems are being addressed. Surface disturbance of indigenous forest is being minimised where possible by using previously cleared areas. Utilisation of more advanced technologies such as directional drilling and multi-well pads help to open up new areas with a minimum of site disturbance. Erection of engineering structures coupled with reforestation is also carried out to prevent soil erosion.

Watershed maintenance and management has been enhanced to prevent contamination of water resources. Additional forest guards are deployed to increase coverage. Reforestation is also being undertaken with the assistance and support of local residents. Improved mining practices during drilling are also employed to prevent the contamination of rivers. Mufflers are installed to minimise noise during well testing periods.

Most geothermal areas are located far from major cities. This raises the cost of transmission of electricity to demand centres and decreases the economic competitiveness of geothermal power. The Leyte geothermal field in the Visayas Islands is one such case (see Figure 28). While the island has a very large geothermal resource (estimated at 800 MW), the energy demand of the local population is less than 100 MW. Further, being an island, interconnection with the power systems of the demand centres in Cebu and Luzon required enormous capital investments in submarine and overhead transmission cables.

After commissioning of the 112.5 MW Tongonan Geothermal plant in 1983, and before the island of Leyte was interconnected with Luzon and Cebu, the power plant capacity dwarfed the local demand

Figure 29 Projected growth in net power generation for the Philippines (1995-2025)



Source: Modified from the Philippine Energy Plan 1996-2025 [DOE, 1995].

of around 30-50 MW. Although an interconnection line was supposed to be constructed at the same time as the power plant, political and economic problems at the time resulted in the postponement of the interconnection line project for many years.

THE FUTURE?

The Philippine Energy Plan published in 1996 projected the power generation growth path shown in Figure 29. This plan assumes an average yearly net generation output growth rate of around nine percent a year. This was very optimistic, even in 1996. The historical trend shown in Figure 25 shows an average yearly growth rate of less than five percent from 1980 to 1997, although nine percent per year growth was achieved for a short period in the early 1990s.

With the Philippines hard hit by the 1997 financial crisis, and experiencing some political instability, short-term growth prospects are not good, and this will impact on overall longer-term growth prospects.

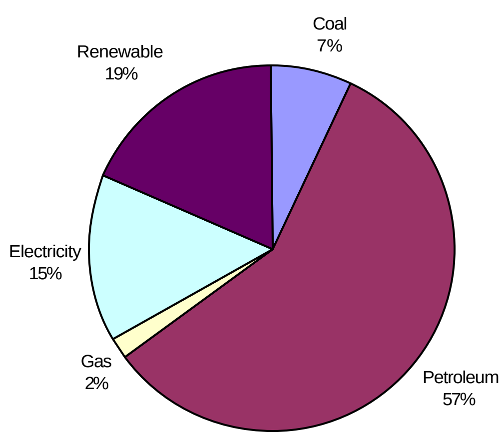
No matter what the economic and energy supply growth prospects, as Figure 29 shows, coal is likely to play a significant role in the future electricity supply industry in the Philippines. The geothermal and hydro resources exist to provide additional capacity, but as the best and most accessible sites are developed, those that are left tend to be much more expensive to develop.

Compounding the economic and technical difficulties of developing and maintaining the availability of geothermal power is the fact that geothermal is not truly renewable. Over time (depending on reservoir permeability, initial temperatures, chemical composition and other factors), the pressure of steam available from a discrete hydrothermal reservoir declines as the temperature of the field degrades with exploitation. Over a period of time, which may not exceed the commercial lifetime of a power generation plant, the resource becomes unusable, and another power generation option must be found.

THAILAND

In 1998, the primary energy consumption in Thailand was 68,971 ktoe, and consisted of the energy mix as shown in Figure 30. Renewable energy consumption is quite high in Thailand, consisting mostly of firewood, charcoal, bagasse, and rice husks that are used mainly for cooking and heating in rural households. Renewable energy is also used in the food processing industry, such as sugar and palm oil milling. Out of 754 food industries surveyed, 71 percent used fuel wood as a source of energy [Panyathanya, *et al*, 1993]. In 1995, an estimated 24 million tonnes of biomass residues [ACE, 1998] were produced, and its consumption had increased by 13 percent from 1993 to 1995 [Ramboll, 1998]. Though biomass is heavily utilised in many industries, it has not been rising as fast as total industrial energy use. Therefore, the share of biomass and renewable energy use has steadily dropped from around 32 percent in 1989 to 19 percent in 1998.

Figure 30 Primary energy mix in Thailand



Source: DEDP, 1998

POWER GENERATION USING RENEWABLE ENERGY

Thailand's renewable energy strategy aims to promote the extensive use of abundantly available renewable energy resources such as solar and biomass. Currently, the government is promoting the use of renewable energy to generate electricity from Small Power Producers (SPPs). The objectives of the programme are to promote the use of domestic and renewable energy sources in electricity generation, promote higher efficiency, and reduce the financial burden of government investment in the supply industry. The benefits of the programme can help the economy to conserve fossil fuel, reduce fuel imports, and other benefits associated with distributed generation such as reduced costs and improved system reliability. Regulations on power purchase allow SPPs to sell power to a state-owned power utility, the Electricity Generating Authority of Thailand (EGAT), with a maximum generation capacity of 60 MW (90 MW in certain locations).

BIOMASS

As of April 2000, only 101 MW of installed generation capacity was fuelled by biomass or non-conventional fuels out of the total SPP capacity connected to the EGAT system (1,491 MW), or 0.6 percent of total electricity generation in Thailand [DEDP, 1998a]. There are currently 40 SPP projects supplying power to the grid, of which 24 use biomass or non-conventional fuel sources. However, only three projects are supplying to the grid on a firm (long-term contract) basis. Though the number of renewable projects is impressive, they represent a very small portion of the total capacity and generation.

Table 5 Biomass based power potential of proven technology in Thailand

Sector	Residue	Theoretical power potential (GWh/year)	Structural power potential (MWe)
Sugar	Bagasses	5797	1900
Rice	Rice husk	2422	66
Oil palm	EFB, shell, fibre	379	69
Wood	(log production)	86	n.a.
	rubber production)	n.a.	950

Source: NEPO, 2000 & Ramboll, 1998a

According to several domestic studies, there is a large potential for power production from biomass in Thailand. Technological developments in the energy sector can allow the residues to be used more efficiently and cleanly. Some proven technologies of heat and power generation in industrial mills are now available for wide spread dissemination. Table 5 shows the theoretical and structural power potential from biomass fuels in Thailand. The potential for proven technologies (structural) has been estimated to be as high as 2,000 to 3,000 MW in the future.

To increase the use of biomass by SPPs, the National Energy Policy Office (NEPO) recruited bids for 300 MW of additional renewable energy electric generation capacity. Winning bids will be provided with incentive payments for a period of five years from the Energy Conservation (ENCON) Fund. The incentive payments will be in the form of a pricing subsidy per unit of electricity (kWh) sold to EGAT (or incremental sale in the case of an expansion of an original project) on top of the SPP purchase prices. The ENCON Fund committee will announce the results of bidding in mid 2001.

Evaluation criteria for non-conventional energy cogeneration SPPs projects include the fuel type, generation technology, capacity requirement, and power purchase rates. Fuels that are eligible for subsidy must be non-conventional energy, waste, or residues from agricultural products, industrial production processes, garbage (municipal waste), and dendrothermal fuels (tree plantations) or technologies that operate in a co-generation mode. Generation capacity must not exceed 90 MW from each SPP to the Power Utility system at the connection point. The power purchase in the eastern area of the Gulf of Thailand including Cha-Choeng-Sao, Prachinburin, Chonburi, Rayong, Chantaburi, and Trad provinces are suspended for SPP power purchase. Power purchase rates depend on the contract with EGAT. Short-term (non-firm) contracts less than five years are indexed to fuel oil price and are only provided for electricity generation rather than installed capacity. Long-term (firm) contracts, greater than five years, include a payment for installed generation capacity in addition to the electric generation payment.

SOLAR AND WIND GENERATION

Thailand started a PV rooftop pilot programme. PV programmes are becoming popular in Thailand because investment subsidies of up to 50 percent make the systems more financially viable. Bangkok residents and businesses have installed grid-connected PV systems on their buildings and the utility buys any excess power. This programme will help create a larger demand for PV and help to spur an indigenous solar industry and planned PV cell manufacturing facilities.

The micro grid solar and wind markets are dominated by government sales. Commercial markets for micro grid wind and solar technologies have not been developed in Thailand. The dissemination of these technologies is fully subsidised. After the 1997 economic crisis, government subsidy programmes were suspended or decreased, which has therefore affected rural electrification programmes. Shrinking government budgets have forced policy makers to turn to market-based approaches. Though rural electrification cost is high, there are some markets where renewable energy can be cost competitive, such as the tourism industry on remote islands. Renewable energy is more attractive than diesel generators that pollute local environments, because it provides higher quality power service, is sustainable, and is environmental-friendly to tourists.

POTENTIAL ELECTRICITY FROM RENEWABLE ENERGY

Table 6 shows the current electricity generation capacity from renewable energy and the technical potential. The current utilisation is about only a fourth of what could be realised.

Table 6 Renewable resources for electricity generation

Application	Current Use (MW)	Technical Potential (MW)
Solar PV for Off-grid uses	2.7	>64
Wind generation	<1	n.a.
Biomass for on-site power	950	3,000
Small Hydropower	128	n.a.
Geothermal Power	<1	100-200

Source: ERI, 1999

RECENT RENEWABLE ENERGY ACTIVITY

For the past five years, the Thai government has progressively funded and supported a number of renewable energy projects through the ENCON - Voluntary Program. The programme funds activities such as financial assistance (subsidies) for project expenditures, and studies such as pricing and policy reform. Approved projects are categorised in one of three types, renewable energy and rural industry, industrial liaison, or research and development.

RENEWABLE ENERGY AND RURAL INDUSTRY PROJECTS

Currently, there are a total of nine projects funded under this programme. For the past five years, 598 million Baht of funds were allocated to assist rural industries, especially agricultural and industrial sectors, in energy conservation. Emphasis is placed on dissemination and transfer of renewable energy technologies, biomass/biogas electrification, and increasing energy efficiency by proven technologies. The total savings from these projects were estimated to be 89 million kWh in electric energy, 109 million kilograms of LPG, and 616 kilotonnes of lignite, a combined value of 2,114 million Baht [NEPO, 1999]. The following list shows examples of participating projects.

- Biogas power generation in livestock farms
- Small-sized biogas systems for cooking and lighting in households instead of LPG
- Solar PV power generation (three kW power generation system for electrical appliances

and lighting, and 225-Watt power system for back-up power generation instead of gasoline-fuelled power generators)

- Power generation from landfill biogas

INDUSTRIAL LIAISON PROJECT

A total of 23 industrial liaison projects are currently being implemented. The objective is to promote renewable and energy conservation technology and to enhance the market for energy-efficient equipment. This will support manufacturers and distributors of high-efficiency equipment, machinery, and materials. After the completion of the programme, it is expected that the following amount of energy use can be avoided: 209 million kWh of electric energy, five million litres of diesel, 203 tons of firewood, and one million kilograms of LPG worth a combined value of 583 million Baht. The following list shows some example of projects.

- Rooftop PV grid connected demonstration project
- Solar water heaters
- PV-pumping for village water supply

RESEARCH AND DEVELOPMENT

This programme supports a wide range of studies. The following activities are being pursued, energy saving potential forecasts for each sector, R&D for energy efficiency and renewable energy technology, transfer of proven technologies studies, joint research with international organisations, renewable promoting programme, demonstration projects, workshops, and seminars. During 1995-1999, a total of 610 million Baht was allocated to the implementation of 50 projects under this programme. The following list provides some examples.

- Utilisation of agricultural residues as fuel
- Solar energy in the vegetable drying industry
- Hybrid power system for national parks and wildlife sanctuaries
- Renewable electrification in remote areas including islands
- Solar-powered electric vehicles
- Development of solar PV cells
- Wind resource assessment on the south coast
- Development of the solar energy park plan

Many R&D projects cannot be evaluated in terms of energy or amount of money saved. However, support given to such projects has brought about various advantages, such as development of researchers' skills and experiences, creation of cooperation and coordination between the public and the private sectors, and establishment of a foundation for further technology development to increase energy efficiency and utilisation of renewable energy. R&D often results in significant long-term results that are difficult to forecast in the initial phases of projects.

SOLAR WATER HEATERS

The current market for solar thermal is still immature. There is a low demand for solar water heaters (SWH) especially in the residential sector because the consumption of hot water is typically limited to showering. However, SWH is potentially cost-competitive in the commercial and industrial sectors, where there is a high need for hot water. NEPO has recently begun a subsidy programme to stimulate the use of SWH outside of Bangkok. A 40 percent rebate, up to 8,000 Baht, will be given for 100 residential systems. Commercial systems are eligible to receive a 40 percent rebate up to 10 million Baht. However, because of current economic conditions, there was a lower response than anticipated from this programme.

One alternative proposed is to replace the investment subsidy with a soft loan. This could be done through a revolving loan fund and would help overcome the high up front cost for participants. The loan terms can be set so that the user can install the SWH and save enough in their energy payments so the user profits from the installation. It has been suggested that investment incentives and soft loans be administered through the Industrial Financial Corporation of Thailand (IFCT).

In addition, other strategy initiatives could also be considered such as building awareness and information dissemination; marketing for hardware, appliance stores, and utilities; coordination among the SWH industry to deliver a coherent message in promoting this technology; and conducting independent evaluation and monitoring of specific installation to demonstrate technical performance and economic benefits.

BIOGAS GENERATION

A significant portion of Thailand's water pollution problem stems from livestock and agricultural sources -- most notably the run-off waste from pig farms and decomposed rice fields. As a result of Thailand's rapid economic expansion, crop cultivation and livestock farming have intensified, thus making biogas technology an excellent alternative for natural resource conservation and environmental protection. In addition, the relatively low cost of installing biogas systems has furthered its popularity among farmers. The construction costs of a large 16-cubic-metre biogas plant are about 26,000 Baht ($600)[2]; and, it is estimated that over a one-year period the energy produced from a plant this size could equal the yearly consumption of five tonnes of firewood, or 1.3 million kilograms of LPG per year. Furthermore, biogas fuel can be used for both domestic and industrial purposes, reduces local air and water pollution, and does not result in greenhouse gas emissions (as sources of biomass are not considered to contribute net carbon emissions) [NEPO, 1999].

THAILAND'S FUTURE

Future environmental policy trends are expected to improve the market for renewable energy in Thailand. The Thai policy of market based environmental protection will allow facility and plant owners to choose alternative approaches to control pollution including the use of renewable energy, instead of only relying on stack controls. In addition, the privatisation of the power sector is expected to facilitate stricter environmental regulation enforcement. The government of Thailand proactively participates in international efforts for climate change that should provide more opportunities for renewable energy projects.

Thailand has already embraced the concept of energy efficiency and has a broad range of programmes compared to other economies with similar financial conditions in its region. Thailand has started to utilise its renewable resources for power generation, although a key consideration will be the availability of international financing. Such financing will be very difficult to obtain considering other important investments that may be considered higher priorities by investors. Thailand's experience with pilot projects should enable it to expand its programmes and policies if the favourable economic conditions exist.

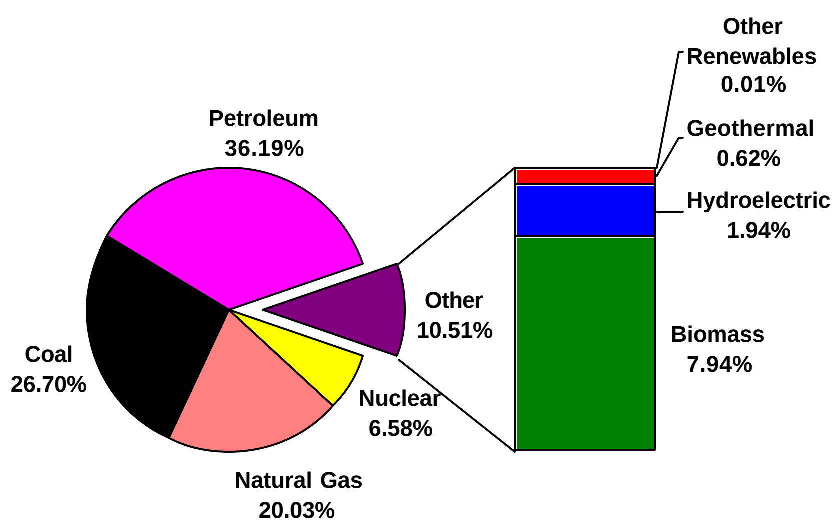
CHAPTER 6

APEC RENEWABLE INVENTORY

INTRODUCTION

Total renewable energy utilisation in many APEC member economies is unlikely to be fully accounted for due to a lack of appropriate monitoring systems and the non-market nature of much biomass usage. Statistical agencies involved in energy data compilation therefore rely on surveys, which understandably only cover a sample of a population. Hence, there is a possibility that the reported renewable energy consumption data is far from accurate. Likewise, many economies do not maintain a renewable energy database, which may be due to the difficulty in gathering such statistics.

Figure 31 APEC primary energy mix (1998)



Source: IEA, 2000

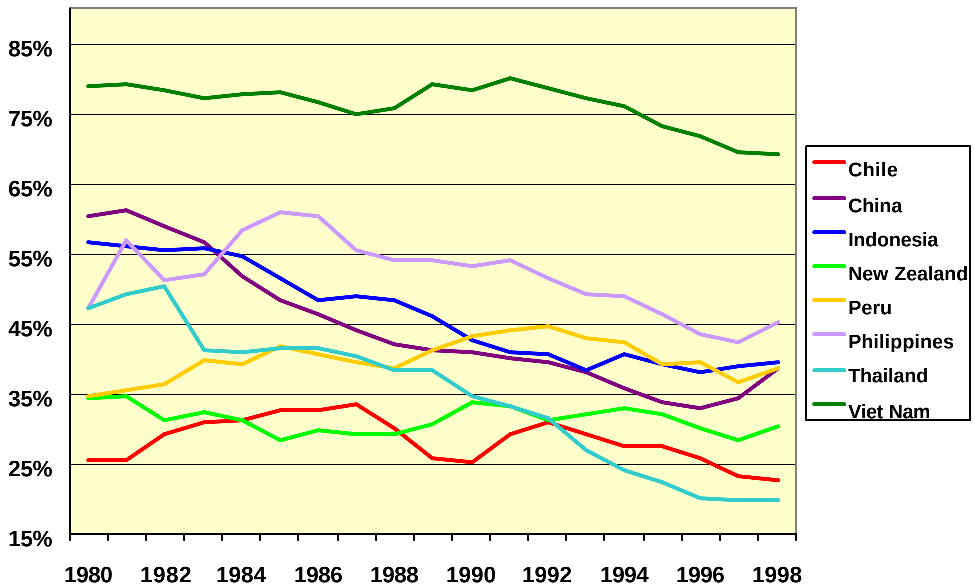
In this study, the data compiled by the International Energy Agency (IEA) was used to achieve consistency of sources. The uniform methodology used in estimation and conversion of raw data makes the IEA database more reliable than relying on individual data sources.

RENEWABLE ENERGY CONSUMPTION/PRODUCTION LEVELS

Renewable energy consumption in the APEC region amounted to 572 million tonnes of oil equivalent (Mtoe) in 1998, accounting for 10.5 percent of the total APEC energy consumption. Biomass dominates the renewable energy scene, with 7.9 percent while hydro and geothermal had shares of 1.9 percent and 0.6 percent respectively (Figure 31). The contribution of wind and solar energy together contribute a negligible share of 0.01 percent or 0.5 Mtoe.

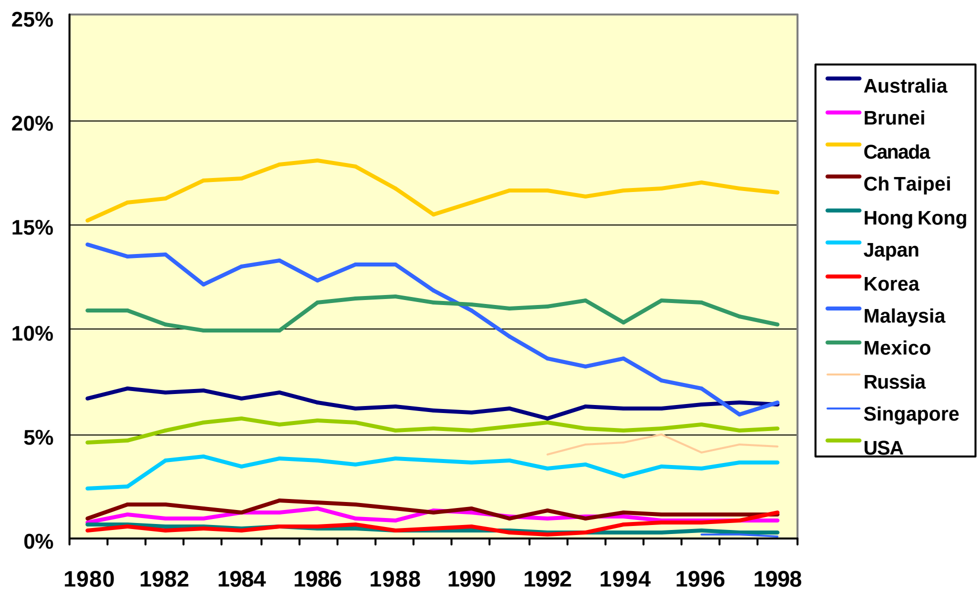
Renewable energy has been a major part of APEC economies' energy mix. Viet Nam's use of RE

Figure 32 Renewable energy share of total primary energy (selected APEC economies)



Source: IEA, 2000

Figure 33 Renewable energy share of total primary energy (selected APEC economies)



Source: IEA, 2000

for one, accounts for 70 percent of its total energy consumption as of 1998, although it went down from about 80 percent in 1980 (Figure 32).

Among the 21 APEC economies, Viet Nam has the highest percentage of renewable energy consumption relative to total energy consumption. This is followed by the Philippines, Indonesia, Peru and China. Incidentally, these five economies also have the lowest per capita GDP and per capita electricity consumption among the APEC economies.

Table 7 Renewable energy production for all APEC economies (in ktoe)

	1975	1980	1985	1990	1995	1998
Australia	4962	4,745	5,165	5,259	5,881	6,765
Brunei Darussalam	18	18	18	18	18	18
Canada	23633	29,246	34,591	33,657	38,644	38,675
Chile	1959	2,470	3,196	3,568	5,201	5,379
China	171913	184,939	196,471	211,305	222,474	227,267
Hong Kong, China	34	39	42	43	47	48
Indonesia	30415	33,802	37,772	42,306	46,600	48,588
Japan	7259	8,367	13,908	15,894	16,950	18,557
Korea	145	171	315	550	1,109	2,011
Malaysia	1531	1,715	2,120	2,443	2,892	2,829
Mexico	10064	10,767	11,032	13,899	15,067	15,139
New Zealand	3004	3,180	3,258	4,803	5,086	5,205
Peru	4023	4,069	4,619	4,821	5,285	5,555
Philippines	7052	10,007	13,967	15,064	16,079	17,289
Russia	n.a.	n.a.	n.a.	n.a.	31,151	25,805
Singapore	0	0	0	0	0	24
Chinese Taipei	510	272	610	717	777	925
Thailand	9985	10,756	11,065	15,073	14,548	13,770
United States	65774	83,067	98,023	99,771	110,734	114,518
Viet Nam	13749	15,452	16,925	19,363	21,877	23,352
Total APEC	356,030	403,082	453,097	488,554	560,420	571,719

Source: IEA, 2000

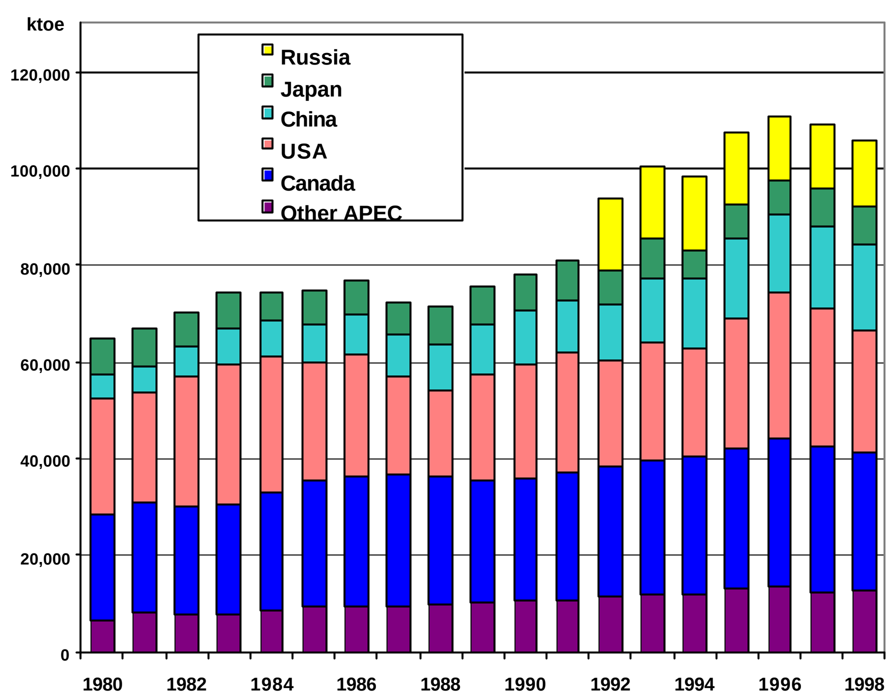
Eight of the 21 APEC economies have at least 20 percent renewable energy in their energy mix. These are Chile, China, Indonesia, New Zealand, Peru, Philippines, Thailand and Viet Nam. Of these eight economies, seven could be considered as lower income economies. New Zealand has a large percentage of renewable energy use, this being due to the large share of hydroelectric energy production relative to total energy consumption (see Chapter 5).

The remaining 13 economies have renewable energy contributions of less than 20 percent in the energy mix. Among them, Canada stood out due primarily to its large hydroelectric energy production, which is the highest among the APEC economies in terms of absolute value. Singapore and Hong Kong, China have the lowest utilisation of renewable energy, which could be explained by their limited resource potential as their land areas are smaller not to mention the higher population density compared to other APEC economies.

In absolute terms, China has the highest renewable energy utilisation in 1998 at 227 Mtoe, followed by the USA at 115 Mtoe (Table 7). It should be noted however that China's renewable energy production is mostly biomass while that of the USA's has major contributions from new energies like solar, wind and geothermal.

Based on the data collected by IEA, utilisation of renewable energy is directly proportional to the population and inversely proportional to each economies land area. Economies with large population tend to consume more renewable energy than those in less populated economies. Those with small land area consume less renewable energy as the resource potential for such energy type is minimal. Further, economies with low per capita income and low electrification coverage consume more renewable energy per capita compared to the more affluent economies.

Figure 34 Hydropower energy production in the APEC region



Source: IEA, 2000

HYDROELECTRIC ENERGY

Hydroelectricity contributes about 18.5 percent or 105.8 Mtoe to the total renewable energy production in the APEC region. Canada has the highest hydroelectric energy production with 28.5 Mtoe in 1998 followed by the United States and China with 25.2 Mtoe and 17.9 Mtoe, respectively.

Figure 34 shows that hydroelectric energy production has not been increasing considerably during the last 20 years, except for China and Russia. However, Russia has not significantly increased it capacity, rather the graph depicts new data that had not been available before 1992. This could be due to the fact that most of the viable hydroelectric sites in industrialised economies have been already developed thus; the remaining potential sites are deemed uneconomic. In addition, as previously mentioned in the report, there is significant controversy regarding development of new large hydropower resources.

GEOTHERMAL ENERGY

Figure 35 shows that geothermal energy production had a relatively high annual growth rate of 3.2 percent from 1980 to 1998. Indonesia led the fast growers at an annual rate of 23.0 percent, followed by Mexico with 10.6 percent increment.

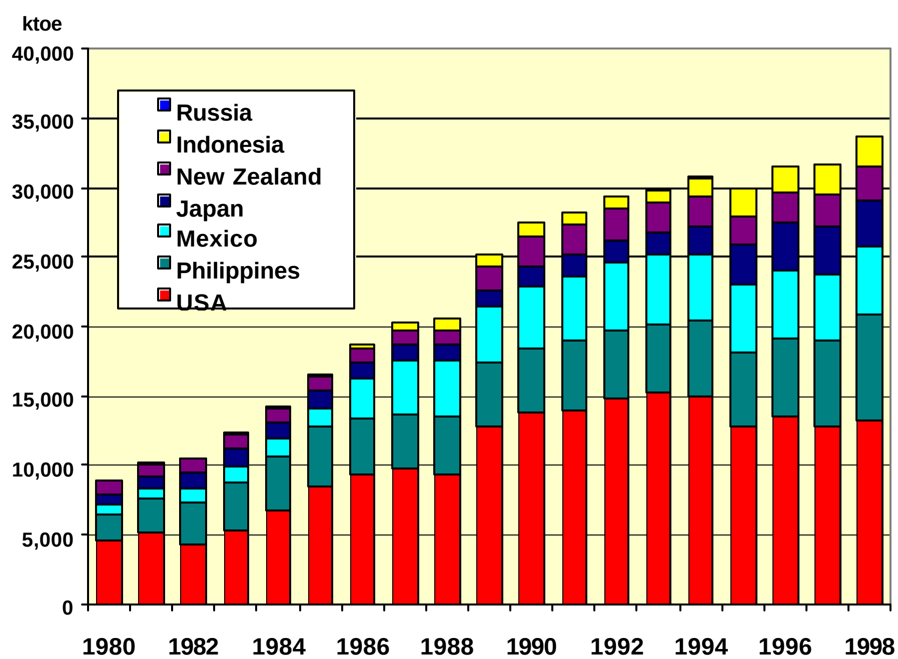
The USA led the geothermal energy producers with 13.2 Mtoe or 39.2 percent of the total geothermal energy in 1998. The Philippines follows with 7.7 Mtoe or 22.7 percent. Mexico comes next at 14.4 percent.

Japan has also increased its geothermal energy production from 0.8 Mtoe in 1980 to 3.3 Mtoe in 1998 at an annual rate of 8.4 percent.

The USA, who is the largest geothermal energy producer in the world, has shown a declining trend in geothermal electricity production. After increasing from 4.3 Mtoe in 1980 to 15.3 Mtoe in 1993, production has declined to 13.4 Mtoe in 1998. This could be due to the declining steam availability at the Yellowstone National Park geothermal field, which was developed in the early part of the century.

New Zealand, which was the leader in geothermal energy production in the APEC region before

Figure 35 Geothermal energy production in the APEC regi



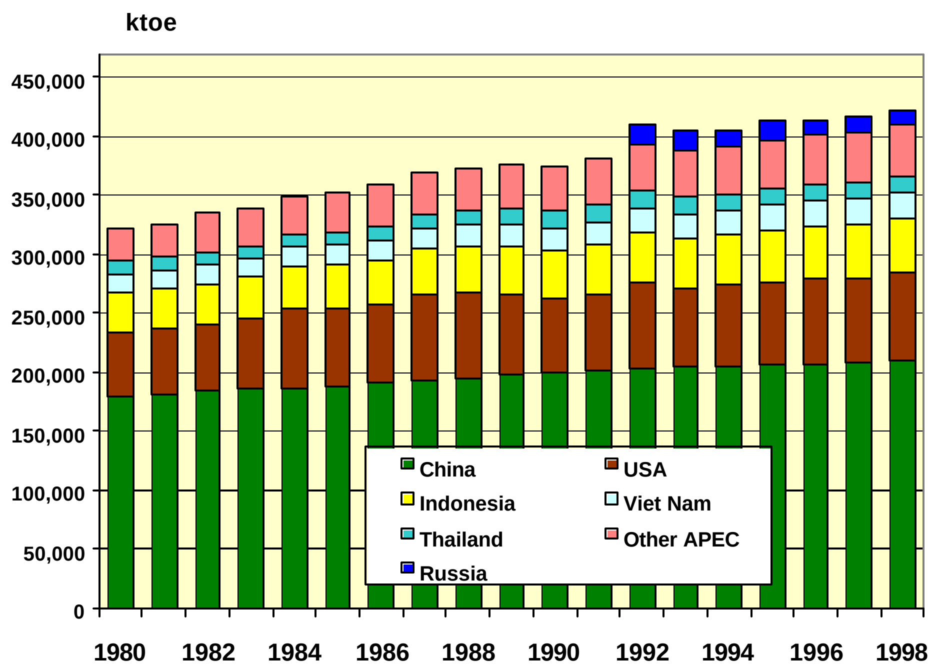
Source: IEA, 2000

being overtaken by the United States, is still increasing its production. From 1.1 Mtoe in 1980 its geothermal electricity generation has increased to 2.4 Mtoe in 1998.

BIOMASS

Biomass remains to be a major fuel for cooking and heating in the developing economies. This is primarily due to insufficient energy infrastructure that will supply alternative fuels like LPG. While electricity production using biomass fuel is gaining support in both agricultural and industrialised economies, the traditional uses for cooking and heating are still the major users of biomass.

Figure 36 Estimated biomass energy utilisation in the APEC region



Source: IEA, 2000

Biomass consists of 75.5 percent of renewable energy production in the APEC region. China, owing to its big population, large land area and relatively underdeveloped energy infrastructure, consumes more than 50 percent of the total APEC biomass production. Biomass forms 92 percent of China's total renewable energy utilisation in 1998.

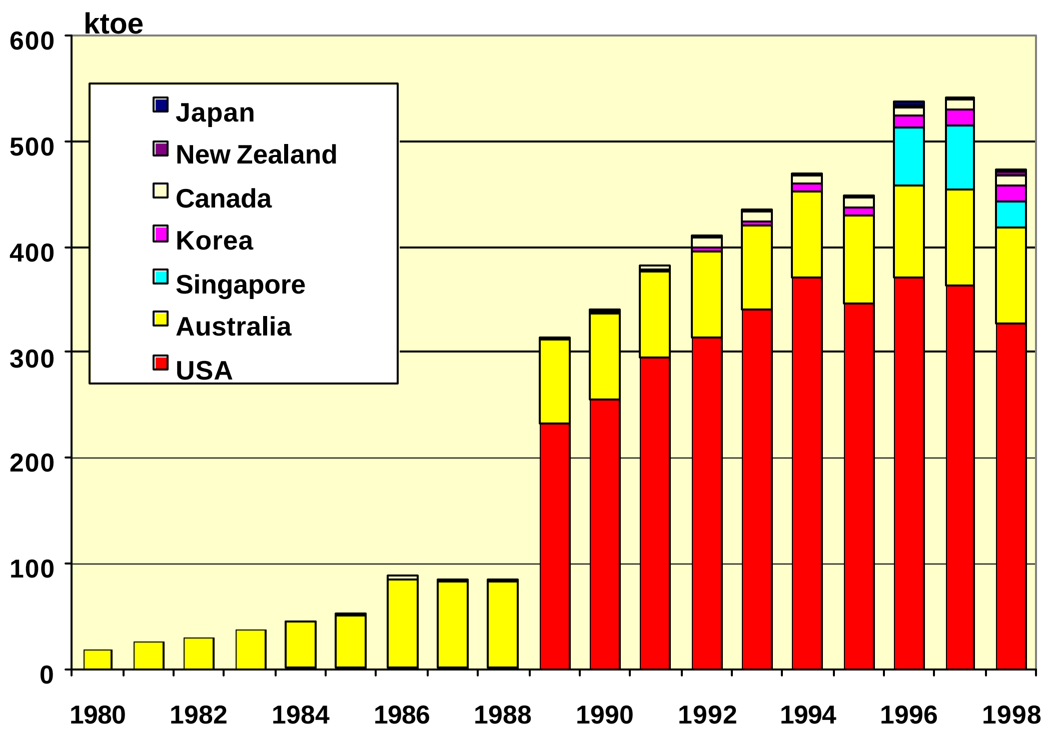
The USA has the second highest consumption of biomass in the APEC region. In 1998, biomass consumption amounted to 75.6 Mtoe or 3.2 percent of the total energy consumption in the USA. The high consumption of biomass in the USA is due to 10,700 MW (2,600 of which waste-to-energy facilities) of installed electricity generating capacity using biomass as fuel [DOE EIA, 1998].

The three Southeast Asian economies of Indonesia, Viet Nam and Thailand consumed a total of 81.2 Mtoe of biomass. Biomass is a major fuel for cooking in these economies. The use of biomass for electricity generation is also gaining popularity in developing economies especially for cogeneration purposes. See Figure 36 for a graph of the biomass use in the APEC region.

SOLAR AND WIND

Statistics compiled by IEA show that contributions from solar, wind and other renewable energy sources amounted to 0.47 Mtoe in 1998, down from 0.54 Mtoe in 1997 (Figure 37). The USA leads the APEC economies with 0.33 Mtoe or 69.3 percent of the APEC total in 1998, mostly from solar and wind energy.

Figure 37 Renewables - net power generation in selected APEC economies



Source: IEA, 2000

Notes: Renwables include hydro, solar, wind and biomass

Only seven of the 21 APEC economies were reflected in the IEA database. This could be due to the minimal contribution of these RE's in the 14 other APEC economies. This however does not mean that the 14 other economies have production of these types of RE's but rather, if they have production then they are very small.

Significant contribution from the United States started in 1989 based on IEA data. Production of these RE's increased from 0.001 Mtoe in 1988 to 0.23 Mtoe the following year. This further increased to 0.37 Mtoe in 1996 and gradually declined to 0.33 Mtoe in 1998.

Other economies with production data for solar, wind and other energy are Australia, Singapore, Republic of Korea, Canada, New Zealand and Japan, in order of descending absolute value. Their respective productions are 91, 24, 16, 8, 4, and 2 ktoe. See the graph in Figure 37.

However, installed capacity has increased significantly for wind and solar since 1998. IEA data is not available for all APEC economies, but looking at a few examples it can be seen that the growth is rather high. For the IEA member economies, which excludes Korea and Singapore in Figure 37, the installed capacity for PV increased by around 25 percent in 1999 from a base of around 400 MW in 1998 to over 500 MW in 1999 [IEA, 2001]. Current data of installed capacity or net global electricity generated from

PV is not available for 2000, but it is expected to be much higher than it was in 1999.

As noted in the wind section in Chapter 3, wind generation capacity grew by 36 percent in 1999 to 13.4 GW [Mechanical Engineering, 2000].

Some economies have aggressive promotional programmes for increasing the utilisation of RE resources. One very interesting scheme being used in Japan is the Residential Photovoltaic (PV) System. It is a conventional PV system wherein the energy generated is used in household appliances. What makes this special is that when the household does not need the electricity, it can be sold to the local electricity company through a grid interconnection. The electricity bill is then adjusted depending on the amount of energy purchased from and sold to the utility [NEF, 2000].

In the US, there are a variety of programmes that are in place to promote wind and solar electricity generation. Activity ranges from traditional research and development, to tax incentives, minimum renewable portfolio standards, demonstrations, educational campaign, competitions, and government purchases [US DOE, 2001] and [US DOE, 2001b]. See Chapter 3 for additional discussion regarding these renewable technologies.

CHAPTER 7

ACHIEVING ELECTRICITY SUPPLY SUSTAINABILITY

SUMMARY

How do fast developing APEC economies meet the challenge of exponential growth in electricity supply requirements, while at the same time minimising the impacts this growth will have on the environment?

Over the next decade or two, rapidly growing APEC economies must, at current annual growth rates of 6-8 percent, duplicate their entire electricity supply infrastructures. This means twice the number of power generation plants, a transmission system with twice the capacity of the existing system, as well as all other equipment, infrastructure and ancillary services needed to double the size of an entire electricity supply system. To achieve this enormous challenge, economies are planning this future power system now, and finance and investment partners are being sought to bring these plans into effect.

In this report, this challenge has been addressed within the context of long-term sustainability. Decisions made now will have a great impact on the ability of individual economies to put in place electricity supply systems that can be maintained over the long-term. The continued construction of traditional coal-fired steam turbine plants can be considered an unsustainable practice, not because of resource scarcity (there are sufficient coal reserves world-wide to last for hundreds of years even with expanded consumption), but because the environmental and health impacts are too great.

The next best option commercially is the gas-fired combined cycle power plant. This option has been promoted in this report as a cost-effective and environmentally clean alternative to oil and coal as fuels, and as a possible "bridging" fuel to a longer-term solution to the problem of power supply. Although natural gas pipelines and LNG terminals are very costly capital investments to make, the installation of a gas distribution system creates opportunities that cannot be ignored. These include the ability to develop on-grid distributed power infrastructure - an idea that could obviate the requirement for upgrading or building transmission lines, more closely match supply to customer needs, increase the overall efficiency of the supply system, and increase supply security. This is becoming a reality in developed economies because they have the gas distribution infrastructure to allow for such development. Why not developing economies? They could benefit greatly by reducing the overall investment required to build a secure, customer responsive, power supply system.

In the longer-term, this distribution system can be used to carry other fuels (such as hydrogen perhaps?), or methane derived from renewable resources.

Two important renewable resources are already being exploited on a large-scale in the APEC region - biomass and small-scale hydro -- both have considerable potential for further exploitation. Hydropower is probably the most important among renewable energy sources. It is a clean, cheap source of energy, requiring only minimal running costs and with a conversion efficiency of almost 100 percent [UNDP, UNDESA & WEC, 2001]. For developing economies, there is great development potential in

small-scale, run-of-river hydro schemes where the resource is close to centres of demand.

The other major renewable resource with considerable immediate potential for exploitation is biomass. Traditional biomass includes fuel wood - the main source of biomass energy - dung, and crop and forest residues. Efficient biomass energy technologies are rapidly advancing. These include direct combustion (co-firing steam boilers is one application), fermentation, and anaerobic digestion, are all increasing the potential of biomass as a sustainable energy source. One of the most beneficial aspects of these and other technologies that can generate clean electricity or provide gas for cooking, is the mitigation of some of the harmful impacts of current biomass usage.

If one considers that nuclear power and large-scale hydropower are too fraught with difficulties to be major future players in the electricity supply scene (although an individual economy such as China will pursue both these options out of necessity), then the next options are the newly commercialised renewable technologies - wind power and solar PV.

These technologies are now reaching commercial viability as mainstream electricity supply options. If one considers wind power, in Europe and the US this technology is now a serious competitor in the power generation market. During the year 2000, up to 3,500 MW of new wind energy generating capacity were installed worldwide, representing annual sales of close to US$ 4 billion and boosting total installed capacity to 17,000 MW. Growth in the European wind energy market has been so strong and steady that the European Wind Energy Association has raised its goal for the region by 50 percent from 40,000 MW to 60,000 MW of installed capacity by 2010 [AWEA, 2001].

Wind power has the potential to grow at similar rates in fast developing APEC economies with good wind resources. For example, one expert forecasts that China could have 25 GW of wind power capacity installed by 2010.

Wind power does suffer two important impediments. It is a capital-intensive technology and financing terms are very important to the commercial viability of a project. So is the mean average wind speed. As the energy that the wind contains is a function of the cube of its speed, small differences in average wind speed from site to site mean large differences in production, and therefore in cost effectiveness.

Solar PV still faces high capital costs for the power output, and it will be some time before this technology is competitive in large-scale mainstream power supply applications. However, solar PV is already proving its suitability for niche applications. For example, PV is used in many industrial situations (telecommunications, cathodic protection, telemetry, navigational systems and other unmanned installations in harsh remote sites), in remote habitations (cabins, homes, villages, clinics, schools, farms, as well as individually powered lights and small appliances), as well as in grid-connected applications (typically multi-kilowatt or megawatt scale systems that are directly connected to an existing power grid network).

Current estimates of worldwide production of solar photovoltaic cells and modules for 1998 are about 120 megawatts (MW), up steadily and dramatically from only 40 MW in 1990. Worldwide sales have been increasing at an average rate of about 15 percent per annum over the last decade, and there is a realistic possibility for the market to reach 1000 MW by 2010. This would make photovoltaics a US $5 Billion industry.

Obviously, the scale of the solar PV industry, even in 2010, will be very small when compared to the electricity supply requirements in fast growing APEC economies. Wind power will probably also be in the early stages of mainstream adoption.

However, these technologies, as well as others such as small-scale hydropower and biomass conversion using modern advanced technologies could play a crucial role in the APEC region over the next two decades by helping to shape the electricity supply system of the future.

This report has looked at a variety of technologies and strategies to implement sustainable energy systems for mainstream applications and for communities that currently do not have access to modern electrical energy. The installation of sustainable technologies will significantly reduce pollution while offering greater flexibility for sophisticated energy users, and will improve the quality of life for people without electricity. If APEC economies aggressively implement these technologies and strategies where it is cost effective and where financing can be obtained, then the economic and environmental impacts could be substantial.

As an example, increasing the demand for PV by combining urban requirements to mitigate peak demand with the potential of rural micro grids to provide power to isolated communities, global manufacturing competition will be stimulated to increase research and development, which in turn should lead to efficiency and cost benefits.

Newly emerging distributed power technologies, combined with greater utilisation of renewable energy resources, and end-use efficiency measures have the potential to substantially alter the energy development trajectories of both developed and developing economies in the APEC region.

Developing economies can rethink the historical philosophy of building a large-scale electrical grid distribution system extending to even remote regions, when regional and local distribution systems using a range of emerging technologies can achieve the same results with reduced costs. Renewable technologies and end-use design practices can meet daily and seasonal peak demand requirements that have been a key driver of large networks. Modern distributed gas systems are achieving efficiencies greater than those previously achieved with large-scale systems fed by centralised power plants.

Because these emerging technologies typically have higher capital costs, established technologies and fuel types enjoy a significant advantage. Achieving market penetration of renewable energy will not be easy - especially for developing economies.

However, the severe environmental and health impacts being faced by rapidly industrialising economies heavily dependent on fossil fuels to meet rapidly growing demand for electricity demands innovative and alternative solutions to the traditional growth paradigm. Just as cellular telecommunications technology offers the opportunity for emerging economies to leapfrog over the traditional telephone technologies, so a similar potential exists in the power sector.

Two separate power development challenges must be met by developing APEC economies. The first is the development of centralised power grid systems in areas where there are concentrated populations and high demand. This type of system will involve large-scale base-load power plants feeding into the market via transmission and distribution networks. Distributed power technologies, on the other hand, hold the potential to radically modify the way in which such a system is developed, by modifying (and reducing) network infrastructure requirements, and improving overall system efficiency. Distributed generation practices along with various micro grid applications offer a variety of benefits especially reduced costs in liberalised markets.

One could envisage a development paradigm, one in which large-scale power generation and transmission systems are not developed at all, but industrial and commercial infrastructure is developed around a distributed power system. Gas infrastructure could provide the fuel to support large-scale industrial plants that use boilers, kilns, and furnaces, with on-site base load electricity generation coming from micro turbines or fuel cells with full utilisation of waste heat. Such applications would be significantly more efficient than traditional generation carried through an electric grid. Peak demand could be met with additional on-site generation capacity or possibly with PV. If resources allow, wind, biomass, or small hydro could be used to support the base load or peak loads. Other sectors of the economy, such as commercial buildings and residences could be supported with localised grid systems.

One would hope that by 2010 to 2020, renewable energy generation systems would begin to make significant contributions to new generation capacity installations. To achieve this, technological advances, as well as political and policy reform will have to occur at an unprecedented rate. Financing and technological assistance from developed economies to developing economies will be key issues in determining whether sustainable systems become the new way of installing electrical generation capacity, or whether traditional practices will prevail.

THE NEXT PHASE

The next phase of the study will attempt to investigate more comprehensively the key issues. These include capital requirements for specific energy development options; the impact of energy sector reform on energy system development; the role new and emerging technologies are likely to play over the next two decades; the short-term role of transitional fuels such as natural gas; and the relative importance of network energy infrastructure and micro-grid development.

Analysis of biomass data for residential, industrial and power generation are problematic due to the way biomass is utilised in most economies. Further study is possible, but expectations should be fairly low due to the fundamental lack of data resources and limited plans for substantial improvement.

A possible next phase of the study could also attempt to develop a number of forecast scenarios that could assist in development of the forthcoming APERC Energy Demand and Supply Outlook. These scenarios would focus on the likely importance of environmental policy initiatives in shaping future energy investments, the role renewables could play in regional energy systems in 2020, and some discussion of sustainability pathways.

BIBLIOGRAPHY

ACE. (1999). *ASEAN Energy Bulletin*. Asean Centre for Energy. 2nd Quarter 1999. Vol. 3. No. 2.

ACE. (1998). "Renewable Energy in Thailand." Asean Centre for Energy. Web page http://www.ace.or.id/preassea

ACE. (2000). Asean Centre for Energy. Webpage http://www.ace.or.id/pressea/index.htm

AEAT. (2000). "Power Generation and the Environment - a UK Perspective. AEA Technology Report.

AGA. (2000). American Gas Association. Web page http:/www.aga.org

Alderfer, R.B., Eldridge, M.M., and Starrs, T.J. (2000). "Making Connections Case Studies of Interconnection Barriers and their Impact on Distributed Power Projects. US DOE's National Renewable Energy Laboratory." May.

Anex, R., Velnati, S., Meo, M., Ellington, R. (2001). *Innovation and the Transformation to Clean Technologies: Life Cycle Management of Gas Turbine Systems*. University of Oklahoma. http://www.ou.edu/spp/turbine/paper.html

APEC EWG. (1998). *Asia-Pacific Economic Cooperation Guidebook for Financing New and Renewable Energy Projects*. APEC, EWG, EG NRET, NEDO, Japan.

APERC. (1998). *Energy Demand and Supply Outlook*. Asia Pacific Energy Research Centre. Tokyo. Japan.

APERC. (2000). *Electricity Sector Deregulation in the APEC Region*. Asia Pacific Energy Research Centre. Tokyo. March. ISBN4-931482-09-0.

APERC. (2001). *Energy Efficiency Indicators - A Study of Energy Efficiency Indicators in APEC Economies*. Asia Pacific Energy Research Centre. March. ISBN4-931482-15-5.

APERC. (2001a). *Making the Clean Development Mechanism Work*. Asia Pacific Energy Research Centre. March. ISBN4-931482-13-9.

AWEA. (2001). "Global Wind Energy Market Report." American Wind Energy Association.

Berry, T. and Jaccard, M. (2000). "The Renewable Portfolio Standard: Relevance to the Chinese Electricity Sector." A paper prepared for Working Group on Energy Strategies and Technologies China Council on International Cooperation on Environment and Development and The State Development Planning Commission of China.

Brundtland, G. (ed) (1987). *Our Common Future*: The World Commission on Environment and Development. Oxford University press.

The Carbon Trader. (2000). The Carbon Trader Pty Ltd. Webpage http://www.thecarbontrader.com

CERA. (2000). "China's Power Sector: Uneven recovery, Uneven Reform." CERA Insight. Cambridge Energy Research Associates. July.

Chen, Z. (2001). "Chinese Wind Power Generation and its Development Potential." Institute of Electrical Engineering. Chinese Academy of Sciences. February.

Chen, Z. (2001a). Institute of Electrical Engineering, Chinese Academy of Sciences. Personal communication. February.

Chun, S.W. (2001). "Possibility and Conditions for Wider Coal Use." Symposium on Pacific Energy Cooperation. Tokyo. February.

DEDP. (1998). "Domestic Production of Primary Energy Sources." Thailand Energy Situation 1998. Department of Energy Development and Promotion, Ministry Of Science, Technology, and Environment. Web page http://www.moste.go.th

DEDP. (1998a). "Electric Power in Thailand 1998." Department of Energy Development and Promotion, Ministry Of Science, Technology, and Environment. Web page http://www.moste.go.th

DOE EIA. (1998). *Renewable Energy Annual 1998*. US Department of Energy, Energy Information Administration. Washington. USA

DOE EIA. (2000). *International Energy Outlook 2000*. US Department of Energy, Energy Information Administration. Washington. USA.

DOE EIA. (2000a). US Department of Energy, Energy Information Administration. Washington. USA. Website: http://www.eia.doe.gov/emeu/cabs/, and http://www.eia.doe.gov/cabs/

EDMC. (2000). APEC Energy Database. Web page http://www.ieej.or.jp/apec/

ERI. (1999). "Thailand Energy Strategy and Policy Report." A Consortium Study. Energy Research Institute, Hagler Bailly Service Inc, Resource Integration System Ltd, Environmental Safely and Energy Service, and Centre of Energy Environmental Research and Development. November.

Flowers, L. (1998). "Lessons Learned - NREL's Village Power Program." US Department of Energy's National Renewable Energy Laboratory. NREL/CP-500-24938. July.

Gifford, J., Hooper, G., Nicholas, I., Hall, P., Li, J., Senelwa, K., Sims, R., and Clemens, T. (2000). "Woody biomass as a sustainable energy source." In *The role of Renewable Energy Technologies in New Zealand's Future*. Proceedings of the Renewable Energy Research Showcase Seminar. March.

Higgins, M. (1999) "China Leads World in Sulfur Emissions." The Environmental News Network. November.

Hoff, T.E. (1998). "Distributed Resources: A Potentially Economically Attractive Option to Satisfy Increased Demand on Okanogan County Electric Cooperative's "Mazama Feeder" Line." Clean Power Research. October.

Hoff, T.E., Wenger, H.J., Herig, C., and Shaw, R.W. Jr. (1998). "A Micro-Grid with PV, Fuel Cells, and Energy Efficiency." Proceedings of the 1998 Annual Conference. American Solar Energy Society. Albuquerque, NM. June.

IEA. (1999). "Key World Energy Statistics." International Energy Agency. Paris.

IEA. (2000). Energy Statistics for OECD and Non-OECD Countries, 1997 - 1998. International Energy Agency. Paris.

IEA. (2001). International Energy Agency Photovoltaic Power Systems Programme web page http://www.iea-pvps.org/

Jaccard, M., Hepin, C., Jingjing, L. (2001). "Renewable Portfolio Standard: A Tool for Environmental Policy in the Chinese Electricity Sector."

Japan Times. (2000). "Hi-tech firms fear aging power grids: Live by the kilowatt, die by the kilowatt." 18 December.

Jiandong, T. (2000). "Rural Electrification in China." (Draft Paper). Hangzhou International Center on Small Hydro Power.

Kaufman, S. (1999). "Rural Electrification with Solar Energy as a Climate Protection Strategy."

M-Co. (2001). The Marketplace Company. Web page http://www.m-co.co.nz/

Mechanical Engineering. (2000). "Small-scale power." October.

MED. (2000). "Inquiry into the Electricity Industry." Ministry of Economic Development. Wellington. June.

Nakicenovic, N. (2000). "Global Natural Gas Perspectives." Paper presented at the Council Meeting of the International Gas Union in Kyoto, Japan. 2-5 October.

Nakicenovic, N., Gruebler, A., and McDonald, A. (1998). Global Energy Perspectives. University of Cambridge. UK.

NFCRC. (2001). National Fuel Cell Research Center. Web page http://www.nfcrc.uci.edu/

NEDO and NEF. (2000). *New Energy Now*. New Energy and Industrial Technology Development Organization and New Energy Foundation. Japan.

NEF. (1999). *New Energy in Japan - Efforts for Accelerated Switching to New Energy*. (English Translation of "New Energy in Japan - 1999 Edition in Japanese"). New Energy Foundation. Tokyo.

NEF. (2000). "Activity Report." New Energy Foundation. Tokyo.

NEF. (2001). New Energy Foundation. Tokyo. Web page http://www.nef.or.jp/.

NEPO. (1999). Implementation Achievement of the Voluntary Program under the Energy Conservation Program. National Energy Policy Office. Thailand.

NEPO. (2000). National Energy Policy Office. Thailand. Energy Conservation Promotion Fund. Web page http://www.nepo.go.th

New Zealand Energy Data File. (1999). Ministry of Commerce. Wellington. July.

NYSPSC. (2000). "New York State Standardized Interconnection Requirements, Application Process, Contract & Application Forms for New Distributed Generators, 300 Kilovolt - Amperes or Less, Connected in Parallel with Radial Distribution Lines." New York State Public Service Commission. November.

Ogden. (2001). Waste to Energy. Web page http://www.ogden.com/energy/owte/wte.htm

Okazawa, K. and Uto, T. (2000). New Energy Foundation (NEF). Personal communication.

ORNL. (2000). US DOE Oak Ridge National Laboratory. Webpages http://www.ornl.gov/CGES/RFinding/rb5-09.htm, http://bioenergy.ornl.gov/papers/bioam95/perlack.html

Panyathanya, W., Rawiwan, S., and Benjachaya, S. (1993). "A Survey of Industrial Fuelwood Consumption in Thailand." National Energy Policy Office. Thailand.

PETRONAS. (2000). Web page http://www.petronas.com

Philippine DOE. (1995). *Philippine Energy Plan 1996-2025*. Philippine Department of Energy. Manila.

Philippine DOE. (1999). *Philippine Energy Plan 1999-2008*. Philippine Department of Energy. Manila.

Philippine DOE. (1999a). "Pangan-an Island Solar Electrification Project". Philippine Department of Energy. Pangan-an Management Group Presentation to the Lapu-Lapu City Council on 18 August 1999 at Lapu-Lapu City, Philippines.

Philippine DOE. (2001). Personal communication, unpublished data files. Philippine Department of Energy. Manila.

PNOC-EDC. (1997). "The Geothermal Handbook." Philippine National Oil Company - Energy Development Corporation. Manila.

PNOC-EDC. (1999). "Serving the Countries Energy Needs" (brochure). Philippine National Oil Company - Energy Development Corporation. Manila.

Pusat Tenaga. (2000). "Feasibility Study of Grid Connected Power Generation Using Biomass Cogeneration Technology." Pusat Tenaga, Malaysia.

Ramboll, T. (1998). "NEPO/DANCED Report on Biomass Power Producer Investigation." Web page http://www.nepo.go.th

Ramboll, T. (1998a). "Evaluation of Conditions for Electricity Production Based on Biomass." EC-Asean Cogen Programme for Ramboll. Web page http://www.nepo.go.th

RAN. (2000). "Drilling to the Ends of the Earth: The Case Against New Fossil Fuel Exploration." Rainforest Action Network. http://www.ran.org/oilreport

Sachs, J.D. and Warner, A. M. (1995). Natural Resource Abundance and Economic Growth. Harvard Institute for International Development. October.

Secretaria de Energia. (2000). Personal communication with Ms. Leydi Barcelo Cordova of Secretaria de Energia, Mexico. September.

Shell. (2000). "Energy for the future - the issue." Web page http://www.shell.com/royal-en/content/

Siemens. (2001). "Siemens Solar Panels direct from Bullnet." Siemens Solar. Web page http://www.siemenssolar.co.uk/market_potenital.html

Sims, R. (2000). "Renewable Energy Future - an Overview." in *The role of Renewable Energy Technologies in New Zealand's Future*. Proceedings of the Renewable Energy Research Showcase Seminar. March.

Sookkaew, P. (1997). *Rural Electrification Development in Thailand*, 2nd Workshop on Facilitation of Rural Electrification in the APEC Region. Tokyo. June .

SPC. (1997). "97 Energy Report of China." State Planning Commission. China Prices Publishing House.

Tanabe, T. (2001). "NEDO's Strategy of Clean Coal Technology for the 21st Century." Symposium on Pacific Cooperation. Tokyo. February.

Thaddeus, J. (2000). "Complementary Roles of Natural Gas and Coal in Malaysia." Paper presented at the Joint 8th Fossil Energy Technical Seminar and 7th APEC Coal Flow Seminar. Bangkok. Thailand. 30 Oct-3 Nov.

Tietenberg, T. (2000). *Environmental and Natural Resource Economics*. Fifth Edition. Addison-Wesley.

UNDP. UNDESA. WEC. (2000). "World Energy Assessment: Energy and the Challenge of Sustainability." United Nations Development Programme. United Nations Department of Economic and Social Affairs. World Energy Council. September.

United Nations Foundation. (2000). Web page http://www.unfoundation.net/grants/3_14_ biomass.cfm

Union Of Concerned Scientists. (2001) Website: http://www.ucsusa.org/energy/brief.rps.html

US DOE. (2000). Budget Summary. US Department of Energy. Web page http://www.eren.doe.gov/budget/

US DOE. (2001). Photovoltaic Program. US Department of Energy. Web page http://www.eren.doe.gov/pv/

US DOE. (2001a). Distributed Power Program. US Department of Energy. Web page http://www.eren.doe.gov/distributedpower/pages/issue_frame.html

US DOE. (2001b). Wind Program. US Department of Energy. Web page http://www.eren.doe.gov/wind/

USDI. (2000). Bureau of Reclamation - Power Program. US Department of Interior. The History of Hydropower Development. Web page http://www.usbr.gov/power/edu/history.htm.

Van Rest, A. (2001). Personal communication. US Department of Energy. Washington. February.

Van Rest, A. (2001a). Comments to APERC Annual Workshop. US Department of Energy. Tokyo. February.

Valenti, M. (2000). "Local Connections." The American Society of Mechanical Engineers. Web page http://www.memagazine.org/contents/current/features/local/local.html

Weingart, J.M. and Lee, R.F. (2000). "Wide-Spread Implementation of Renewable Energy Projects in APEC Member Economies: Road Maps for Success." APEC Energy Working Group - Expert Group on New and Renewable Energy Technologies. November.

World Bank. (1992). *World Development Report 1992: Development and the Environment.* Oxford University Press. New York. USA.

World Bank. (1996). *Rural Energy and Development: Improving Energy Supplies for Two Billion People*. Development in Practice Series.

World Bank. (1997). *Financial Incentives for Renewable Energy Development.* World Bank Discussion Paper No. 31. Proceedings of an International Workshop. Amsterdam, Netherlands. 17 - 21 February.

World Bank. (1998). "China: A Strategy for International Assistance to Accelerate Renewable Energy Development." WB Discussion Paper Number 388. Taylor, R.P.; Bogach, V.

World Bank. (2000). The World Bank Asia Alternative Energy Program (ASTAE) Status Report #7. February.

WEC. (1993). "Energy for Tomorrow's World." World Energy Council.

WEC. (1994). "New Renewable Energy Resources." World Energy Council.

WEC. (1997). "Financing the Global Energy Sector: The Task Ahead." World Energy Council.

WEC. (2000). "Energy for Tomorrow's World: Acting Now." World Energy Council.

Yearbook of Statistics, Malaysia. (1999). Jabatan Perangkaan Malaysia. Department of Statistics, Malaysia. ISSN 0127-2624. September.

APPENDIX

BIOMASS: DATA ISSUES

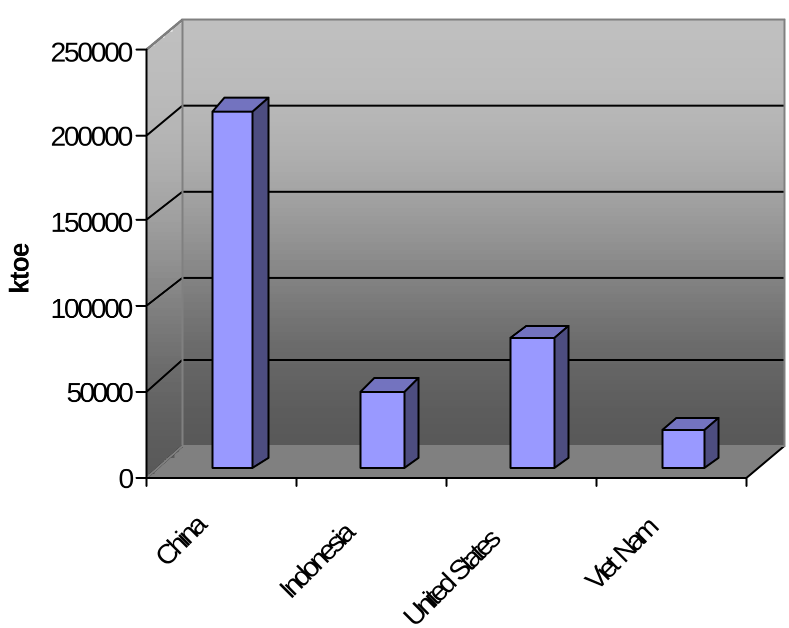
The development of a biomass database is an important issue for the APEC region but problematic because there is practically no complete data available on potential, consumption and supply of biomass for any single economy. The primary reason is because biomass, as an energy resource, has not reached commercial stages in most economies. Considering the concerns with data availability, this study is preliminary. Additional data gathering and analysis could be the focus of future study.

The International Energy Agency (IEA) has the most comprehensive biomass data for almost all of the APEC economies, including Australia, Canada, Japan, Korea, Mexico, New Zealand and the USA (OECD economies); and Brunei Darussalam; Chile; China; Chinese Taipei; Hong Kong, China; Indonesia; Malaysia; Peru; the Philippines; Russia; Singapore; Thailand and Viet Nam (non-OECD economies). The data show that the greatest producers and consumers of biomass in 1998 are China, Indonesia, and the USA. Some economies utilise biomass merely in the residential sector, while other economies use it in the industrial sector as well.

Figure 38 shows biomass production in China, Indonesia, USA and Viet Nam (the four largest producers in APEC region) in 1998. China produced 209,379 ktoe in that year that was followed by the USA, Indonesia and Viet Nam at 75,757, 45,507 and 22,398 ktoe, respectively.

Figure 39 shows that almost all biomass production in China, Indonesia and Viet Nam, was consumed in the residential sector whereas the USA consumed 40.1percent of its production in the residential sector. The USA biomass is mostly used in the industrial sector (50 percent), and the remainder is consumed in the transportation (6 percent) and commercial (3.9 percent) sectors. The USA biomass utilised in the transportation sector was for the production of gasohol fuel for motor vehicles derived

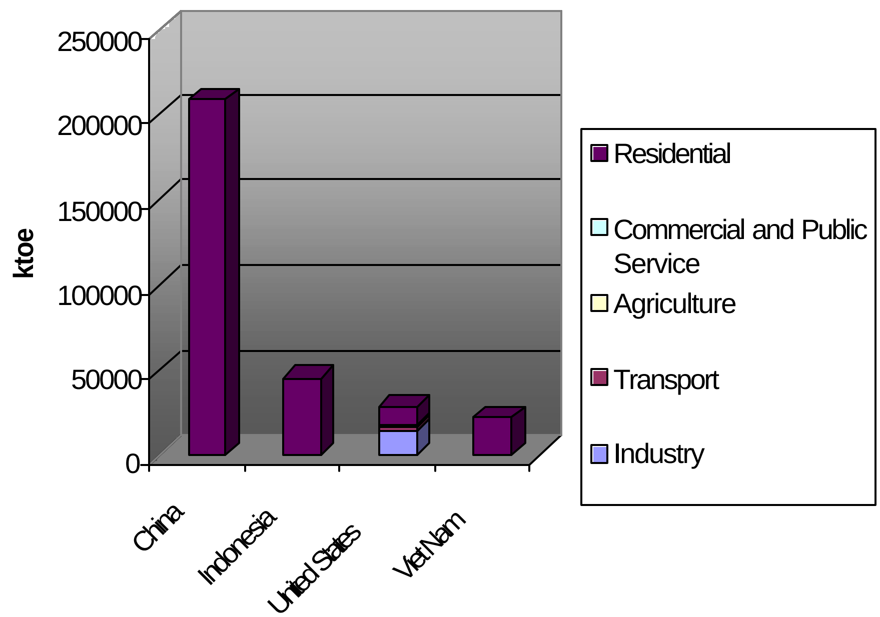
Figure 38 Biomass production in selected APEC economies in 1998



Source: IEA Energy Statistics

from corn.

Figure 39 Biomass final consumption by sector in selected APEC economies in 1998



Source: IEA Energy Statistics

DEVELOPMENT OF BIOMASS UTILISATION IN APEC ECONOMIES

AUSTRALIA

According to the Australian Minister of Agriculture, Fisheries & Forestry, agriculture contributes up to 22 percent of total greenhouse gas emissions. The importance of the utilisation of biomass in the future was discussed during a recent meeting in Canberra, which involved researchers, industry experts and government officials. The meeting advised that improved biomass policy would reduce many agricultural wastes, and provide relief for erosion areas in the form of tree plantings.

The government has announced that an additional two percent of electricity (about 9500 GW) will be provided by renewable energy sources by 2010. Biomass is likely to provide about half of this increase [DOE EIA, 2000a].

CHINA

China has abundant new and renewable energy resources, which suggests a large development potential in the future. Along with increasing environmental concerns, new and renewable energy is viewed as an important substitution for coal in the long-term energy development strategy in China. In 1997, the State Development & Planning Commission developed the "New Energy and Rural Energy Five-Year and 2010 Long-Term Development Plan," to provide a development framework for the future.

Sites with a biomass resource potential of 24,000 to 45,000 dry Mg/year were identified in the Central Yunnan Province. The level of feedstock production would be sufficient to power a 20-MW conversion plant. Feasibility studies show that biomass projects in Yunnan Province are financially and technically viable.

Another site in Jilin Province in northeast China has also been subjected to biomass projects supported by United Nations Foundation (UNF) and led by UNDP. The objectives of these projects are the fulfilment of the demand of electricity in the residential sector, the promotion of economic development through provision of basic needs to operate small business, and improving the local and global environment through more efficient use of biomass in modern food preparation techniques [ORNL, 2000 and United Nations Foundations, 2000].

China has promoted many types of new and renewable energy developments over the years, mainly focusing on rural energy demand. Biogas production has developed significantly, serving 86 thousand households in 1996. [SPC, 1997]. See Chapter 5 for more information regarding China.

INDONESIA

The energy diversification policy of the government, especially in rural (agricultural) areas, will take into consideration the most abundant resources such as biomass. The availability of biomass differs by geographical location. In mountainous and island areas, fuel wood is predominant while in the lowlands, agricultural waste (crop residues) is the most available biomass source. Much of this biomass use is unsustainable, especially for fuel wood that is not part of a forestry management system. Municipal waste is mostly concentrated in the largest urban areas.

The share of biomass in the total energy consumption is approximately 35-40 percent. However, biomass is currently under-utilised for commercial electrical power generation.

One of the existing biomass uses to generate electricity is in the plywood manufacturing industry. Waste wood is used along with diesel generators for electricity production. In addition, plywood mills use wood waste to generate process steam for dryers and hot presses.

Biomass residues are often discarded or burned where they are produced. Crop residue is used in the palm oil industry and bagasse is used in the sugar industry [ACE, 2000].

JAPAN

See Chapter 5 for discussion regarding Japan's current status and future plans for use of solid wastes for power generation.

MALAYSIA

Crop residue utilisation for power generation is to a large extent dominated by the use of waste material in the palm-oil sector. Empty Fruit Bunches (EFB), shells, fibre, and even the palm oil mill wastewater effluent (POME) can be used for the generation of steam and electrical power. Residues in the rice milling industry are not yet used on a large scale, and the very few sugar mills operating, with low rated capacities, offer little scope for further development of power generation. No excess power of this industrial sector is fed into the national grid. However, given the right conditions (for example tariffs), the oil, and possibly also rice mills could become small sized Independent Power Producers (IPPs), since mills are often located in rural areas. See Chapter 5 for more information regarding Malaysia [ACE, 2000].

MEXICO

Biomass contributes to 51 percent of total non-commercial energy sources in Mexico, the remainder consisting of small scale hydro and geothermal. Remote rural communities in Mexico satisfy most of their energy needs with biomass. It is estimated that nearly 75 percent of rural residential energy demand is provided by wood.

Cane bagasse from the sugar cane industry has the potential of more than 3000 GWh of power generation annually. Currently, the Energy Regulatory Commission (CRE) has 12 permits for the installation of 135 MW in biomass power generation.

The Sandia National Laboratory of the United States is currently active in the cooperation to implement renewable energy programmes in Mexico [DOE EIA, 2000 and Secretaria de Energia, 2000].

THE PHILIPPINES

Biomass fuels such as fuel wood, bagasse, charcoal and agricultural waste will account for the bulk of total renewable energy supply, a significant portion of which will be for domestic use such as cooking, heating water and ironing. The supply and viability of biomass fuels will be enhanced by the expected improvement in the performance of the agricultural and industrial sectors, including products such as coconut, rice, sugar and other products.

Households, particularly those in the rural and isolated areas, will continue to be the major consumers of fuel wood and biomass residues that are generally self-collected. See Chapter 4 for more information regarding the Philippines [DOE EIA, 2000].

THAILAND

Thailand has significant renewable energy resources consisting mostly of biomass. Chapter 5 has a case study for Thailand that provides details on the biomass use and potential for electricity generation and other uses.

UNITED STATES

Biomass, as other non-carbon emitting renewable energy, still only supply a small fraction of US energy needs. It is the second most utilised renewable power generation resource in the US with more than 7,000 MW of installed capacity and 37 billion kWh of electricity produced annually. In August 1999, President Clinton issued an executive order calling for a tripling of US use of bio-based products and bioenergy by 2010.

The US DOE BioPower Program supports technology development in co-firing, biomass gasification, modular biomass power systems, and activities to plant the seeds for energy crop industry.

The US DOE funded a US $2.4 million research project for the use of biomass in a combined coal power plant at Willow Island Power Station, in which a combination of 80 percent coal by-products, 10 percent wood waste and 10 percent tire derived fuel (TDF) is burned to produce electricity. This three-year project will meet US Renewable Portfolio Standards, and will reduce fuel costs and nitrogen oxide emissions [DOE EIA, 2000, and The Carbon Trader, 2000].

VIET NAM

Biomass in Vietnam accounts for around 60 - 65 percent of the national primary energy consumption. In the residential sector, around 80 - 90 percent of fuel consumption is from biomass sources such as firewood, charcoal, shrubs, straw, agricultural residues or other organic waste. The main utilisation is for cooking. The overall demand for firewood leads to acute deforestation beyond regenerative limits. Shortage of firewood and the relative high costs of commercial fuels have forced rural households to use leaves, grass, and crop residues in all regions outside the Mekong Delta. Fuel-efficient cooking stove programmes aim to make better use of the available biomass resources. So far, these cooking stove dissemination programmes have been relatively successful [ACE, 2000].