ASIA PACIFIC ENERGY RESEARCH CENTRE

POWER INTERCONNECTION

IN THE APEC REGION

Current Status and Future Potentials

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FOREWORD

I am pleased to present to you the study report "*Power Interconnection in the APEC Region*" which represents the first phase of the study on the potential of expansion of the power supply network in the region. The objectives of this study are to examine the economic advantages and relevant benefits of meeting the electricity demand with the options of potential regional power interconnections within and between participating economies. The study intends to draw up conceptual development plans for the regional power interconnection networks. We wish to identify the obstacles in implementing the power interconnection projects and to propose policy recommendations through this study.

The study was scheduled for two years to be completed by December 1999. However, since APERC had to spend another half year to update its "APEC Energy Demand and Supply Outlook" in 1998 to consider the impacts of the Asian Financial Crisis, the research team commenced this study much behind the initial schedule. Nonetheless, this report shows several conceptual issues and overview of the actual and planned grid interconnection projects in the APEC region. In addition, the work took account of many precious comments and information, provided by participants in the workshops and conferences held by APERC in Japan.

This study will address costs/benefits analysis of Southeast Asia power interconnection using a simulation model developed by the Electric Power Development Co, Ltd, Japan (EPDC) in the next phase. Further, in the subsequent second phase of this study, the comparison with natural gas pipeline options will also be examined. It is hoped that with this study report, we can share ideas and information on the issue of regional power interconnection and receive your further suggestions especially with the forthcoming integration of this project with the natural gas networks interconnection study.

I would like to thank all who have been directly or indirectly involved in this study, including the experts who have helped us through the workshops and conferences with their valuable comments.

Keiichi Yokobori
President
Asia Pacific Energy Research Centre

March 2000

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We also thank the APEC Energy Working Group (EWG), the members of APEC Expert Group on Energy Data and Analysis (EGEDA), APERC Advisory Board members and other government officials for their stimulating comments and assistance in the conduct of 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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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

OVERVIEW

This study on "*Power Interconnection in the APEC Region*" was conducted to examine concepts of benefits and relevant policy issues associated with cross-border power interconnection potential in the Asia Pacific Economic Cooperation (APEC) region and to identify relevant issues and propose policy recommendations.

Strategic cooperation among APEC member economies in the energy sector, through the APEC framework can provide tremendous opportunities for economic and technological improvement of the region. Interconnection of electricity grids is one form of energy integration that can provide vast potential of common benefits of a secure and efficient electricity supply for member economies.

A number of potential benefits resulting from power interconnection in the APEC region include the mutual complementarity of energy resources and power markets, and the implementation of APEC policy principles on energy cooperation.

TECHNOLOGY DEVELOPMENT

The report summarises the technological development related to power interconnection. There are several alternative technologies that are suitable for power system interconnection such as; Alternating Current (AC), High Voltage Direct Current (HVDC) and Hybrid AC/HVDC systems. Since the early stages of development in interconnection, AC system is the most frequently used. However, due to long distances and varying characteristics of individual systems, the HVDC and Hybrid HVDC/AC interconnections are now used increasingly. The Flexible AC Transmission System Technology (FACTS), which makes it easier to control AC transmission (interconnection) system, is also gaining popularity.

Technological development can facilitate power interconnection by reducing project costs.

POTENTIAL BENEFITS OF POWER INTERCONNECTION

Three major factors favour and motivate power interconnection. These are security of supply, economic efficiency and environmental satisfaction. Currently, the first two factors are the major driving forces for interconnection of power systems in the APEC region. However, the increasing concern on air pollution, especially CO_2 emission will induce the power sector to seek cleaner and more environment friendly alternative supply. Environmental protection will require more consideration in future cross border power interconnection projects.

The improvement on reliability against outages and on the stability of voltage and frequency in the interconnected power systems has major significance. Small sized member economies of APEC such as those in Southeast Asia and sub-regional systems of large sized member economies like China and Australia fall in this case. Diversifying energy import through interconnected power grid offers very important means of supply security to the economies that highly rely on imported energy.

Potential economic benefits can arise from the expansion of the power system by allowing economies of scale in power supply. Interconnected grid systems would allow more competition in a power market (system) through freer energy trade.

Considering the geographical distribution of APEC economies, which spans several zones with different time and climate, the complementarity of daily or seasonal load curves could shave the peak load in an interconnected system. The resulting reduced gap in the peak and trough loads will eventually lower the capital burden for capacity expansion.

The investment in generation facilities can be optimised through economies of scale in the interconnected systems instead of individual power systems building independent facilities locally. Utilisation of more economically and environmentally favourable energy sources could be increased. Remote energy resources such as hydropower can be developed. In general, it provides opportunities to support regional economic development.

The environmental aspect in energy production and consumption becomes increasingly important. Any change in the fuel mix for power generation could result in serious environmental consequences. A large interconnected system would offer more opportunities for environmentally favourable energy resource for power generation to be developed than the isolated and smaller ones.

In the case that environment friendly energy resource is not economically available, cleaner fossil energy such as natural gas would be a better option to replace coal or oil. Certainly, the decision on whether power interconnection is more competitive or efficient than natural gas pipeline option needs a detailed and specific study.

EXPECTED RAPID GROWTH OF ELECTRICITY DEMAND

Electricity demand projected in the APEC Energy Demand and Supply Outlook published by Asia Pacific Energy Research Centre (APERC) in September 1998 was used in the analysis of possible interconnection projects.

China and USA will be two major contributors to the APEC region's total increase in demand for electricity. China and Southeast Asia will have higher growth rates in electricity demand than other sub-regions in APEC.

In the outlook, interconnection was assumed not to be developed widely and that electricity trade will be based on the existing interconnections. The future fuel consumption for electricity generation will continue to rely highly on fossil energy resources; coal will still be the dominant source of fuel; the contribution of new and renewable energy resources including hydropower resource will remain relatively low compared to fossil fuels.

Therefore, APEC member economies especially those in Asia will need to consider all possible options in meeting the electricity needs and requirement in the future.

EXISTING POWER INTERCONNECTIONS IN THE APEC REGION

Analyses of the existing power interconnections in North America, Southeast Asia and among three states of Australia show the benefits that could be derived from the integration of power systems as well as related issues in these projects.

In North America, as of 1998, there were 79 transmission lines between the U.S. and Canada and 27 between the U.S. and Mexico. Currently, less than 2 per cent of electricity demand in the U.S. is supplied through cross-border interconnections, mainly from Canada. Initially, the main drivers for power interconnection among the three economies were the provision of emergency backup when domestic resources have been insufficient to meet demand. During the last decades, price differentials among utilities further encouraged electricity trades. The power exchanges between the three economies is expected to grow at a much higher rate than the growth of the total electricity consumption in the region in the next 20 years.

The liberalisation of the electricity markets of the three North American economies could enhance the viability of the proposed “Yukon to Yucatan” electricity grid.

In Southeast Asia, a number of power grid interconnection projects have been implemented and a number of new projects are proposed. In general, they are motivated by the objective to improve the reliability of supply in each of the economies involved. These interconnections have, in some ways, improved political relations at these economies and provided opportunities to develop a closer regional cooperation in energy aspect.

In order to improve efficiency of the energy sector and create a more competitive economy, the government of the Commonwealth of Australia has been pursuing various initiatives with the states to facilitate interconnection and has led to the creation of the National Electricity Market (NEM). NEM is expected to introduce competition in the wholesale supply and purchase of electricity networks across various states and territories of Australia. Currently, some power systems have already been interconnected; several proposals for other interconnection projects are being considered.

POTENTIAL POWER INTERCONNECTIONS IN THE APEC REGION

Power interconnection potentials exist in the three sub-regions of Northeast Asia, Southeast Asia and South America. In Northeast Asia, a number of proposals of grid interconnection between eastern Russia and China, Japan and Korea are discussed. The currently discussed power interconnection project from Irkutsk to North China is reviewed. A future ring of power grid in Northeast Asia may be formed. The abundance of hydropower as well as tidal and fossil energy resources in East Siberia and Far East Russia are important factors that could favour these projects.

Southeast Asia is expected to have very high growth potential of electricity demand. Market expansion and capacity build up of electricity supply including generation, transmission and distribution would be expected. One strategy under the ASEAN vision 2020 is the realisation of the Trans-ASEAN energy network consisting of the ASEAN Power Grid and the Trans-ASEAN Gas Pipeline Projects. There are 14 interconnection projects identified in the ASEAN region at present and three are already operational.

The Great Mekong Sub-Region (GMS) has significant potential for cross-border power trade as the sub-region is well endowed with low-cost hydro resources. The report provides information on the potential power interconnection projects in the area.

The two APEC member economies in South America, Chile and Peru hold significant energy resources. However, several factors limit their availability, especially in the case of Chile. Hydropower is the dominant source of power generation for both economies which are currently not interconnected.

The South of Peru and the North of Chile are expected to have oversupply of electricity in the near future. It could present a barrier to the interconnection of both economies. Nevertheless, in the long term, the energy integration initiatives in South America could ultimately foster interconnections between both economies and with other neighbouring Non-APEC economies, forming part of a proposed continent-wide grid.

POTENTIAL BARRIERS AND RELATED ISSUES

There are some potential barriers and related issues, which could affect the development of power interconnection. They are institutional issues, tariff and pricing, financial availability, development priority and supply security concerns, political uncertainty and the issue of technology acquisition. They would merit further analysis.

Under a deregulated market, Power Purchase Agreements (PPA) may no longer be able to play the same role as in the past. This could adversely affect power interconnection initiatives.

The recent economic crisis makes it difficult to generate sufficient internal fund for investment in electricity sector particularly in the developing APEC economies. The perception on political uncertainty also affects the confidence of investors.

POLICY ISSUES IDENTIFIED

There are potential benefits on power interconnection in the APEC region. However, difficulties in promoting the potential interconnection projects exist. A number of power interconnection proposals are discussed or under study in the APEC region but significant progress in project establishment and engineering will likely to be attained only in the long-term, as many experts believe.

The study recognizes that there is potential competition between power interconnection and natural gas pipeline interconnection. This may require a more in-depth study.

POLICY IMPLICATIONS

Coordination of policy in promoting potential interconnection projects among the related member economies will be important to tackle the barriers or difficulties.

Institutional issues include the need to have mutual harmonisation of regulatory policies in order to promote regional energy security and development including the regional power interconnection.

To reduce the project uncertainty and marketing risks when the traditional PPA is likely to be replaced by bidding mechanism in a deregulated power sector, preferential arrangement to facilitate the access and sale of the power supplied through the interconnection lines may need to be considered.

Regional cooperation and acceptance of mutual dependence of energy supply in a certain degree are prerequisites of regional power interconnection. Political will and support can be a main factor to ease concerns about the security of supply. Power interconnection could facilitate promotion of environmentally friendly energy infrastructure.

Seeking commercial funds or loans and private investment from international capital market will ease financial constraints through market reforms. At the same time, financial assistance from governments of developed economies or international financial institutions through soft loan facility will supplement private financing.

Technical support is a key factor. It is necessary to facilitate technology and know-how transfer at the lowest cost possible.

CHAPTER 1

INTRODUCTION

Strategic cooperation among the Asia Pacific Economic Cooperation (APEC) member economies in the energy sector, through the APEC framework provides tremendous opportunities for economic and technological improvement in the region. The APEC economies are blessed with abundant and diverse sources of primary energy such as coal, oil, natural gas and hydropower. There is also a possibility of harnessing other renewable energy sources such as biomass, solar, wind and tidal energy. As energy becomes more and more essential in the modern lifestyle and also for the production of all kinds of consumer goods for both local and export markets, its continuous availability becomes absolutely important. This leads to the challenge of a stronger cooperation through integration of energy infrastructure among member economies to ensure adequate energy supply. In the APEC region, the interconnection of electricity grids can produce common benefits in terms of providing member economies more secure and efficient electricity supply.

Generally, the driving force for the development of power systems is the growing electricity demand. The continuously increasing demand puts tremendous pressure to the power systems to expand. Interconnection could achieve economic and social benefits for the overall system such as supply stability, lower production cost, and environmental benefits.

Currently, the decentralised power supply systems with small sized gas-fired power plants replacing traditional centralised power plants is becoming a likely trend where the supply of natural gas from established distribution networks is sufficient, cheap and is guaranteed. The technological development in high efficiency combined-cycle gas turbine (CCGT), the environment friendly nature and the relatively lower price of natural gas spur competition between natural gas supply and power networks. On the other hand, the interconnection of the power systems will allow the use of other natural energy resources including the new and renewable energy (NRE) for power generation, which are not physically or economically transportable. Power transmission and interconnection would be the only possible option for the transport of these resources. For these reasons, the potential of power interconnection deserves more careful studies.

RATIONALE FOR THE STUDY

The APEC region has the following outstanding characteristics in economy and energy industry which justify the study of power interconnection potential in this vast region:

Continuous rapid growth of electricity demand is a challenge for regional power supply in the APEC region: Despite the recent economic downturn, the electricity demand growth is projected to remain robust. The Asia Pacific Energy Research Centre's (APERC's) updated "APEC Energy Demand and Supply Outlook" projects that electricity demand in APEC as a whole will increase by more than 60 per cent over the period between 1995 and 2010 (APERC, 1998). Even in the lower GDP growth case, the Protracted Crisis Scenario (PCS), there is a significant increase in demand, at a rate of 2.9 per cent *per annum* or a total of 52 per cent over the next fifteen years. Meeting the demand is a challenging task to APEC member economies.

Power grid development in APEC region has a large potential. In order to meet the projected rapid electricity demand increase, expansion or upgrading of high voltage transmission grids as well as power generation facilities will be required. Both domestic and trans-boundary linkage of subsystems will be needed.

Diversity of natural energy resources: Some APEC economies including Australia, Brunei Darussalam, China, Indonesia, Malaysia and Russia are richly endowed with natural energy resources such as coal, natural gas, hydropower, geothermal and oil. However, economies like Japan, Korea, Singapore and Chinese Taipei do not possess natural energy resources to satisfy their consumption. Their energy supplies are almost solely dependent on imports. The development of cross-border power interconnection may expand their alternatives to meet the domestic demand.

Economic diversity: APEC member economies vary in terms of economic development from developing to developed economies. Some APEC economies having large potential of energy resources are weak in financial strength in developing power industry such as Indonesia, Russia and Viet Nam, while some economies have strong financial capability but limited energy resources. Interconnection of power grids could provide mutually beneficial solutions.

Reform and liberalisation of the electricity sector: Currently almost all APEC member economies are in the process of deregulating their electricity sectors although the respective stages and implementation targets vary. In general, unbundling the traditional electricity sector provides freer access to the electricity supply industry. Currently, APEC is taking the initiative of Early Voluntary Sectoral Liberalisation (EVSL), which includes energy trade liberalisation. These actions may act as catalysts for more cross-border power interconnection with the abolition of access barriers as well as increasing competition on generation, and further on transmission and distribution.

APEC energy policy agenda. Power interconnection can be a policy agenda for energy cooperation among APEC member economies. The APEC Non-Binding Energy Policy Principles (Article 2) call member economies to "*Pursue policies for enhancing the efficient production, distribution and consumption of energy*". As an essential factor of energy distribution, power interconnections could contribute to greater efficiency.

OBJECTIVES

The objectives of the study are: to evaluate major power interconnection potential in the APEC region; to identify associated benefits and barriers of cross-border power interconnection networks; and to identify policy implications and suggestions from the study.

SCOPE OF STUDY

The study aims to assess and examine the potential for power interconnections, which can contribute to generating electricity from untapped hydropower, fossil fuels and other natural energy resources.

In order to have a detailed analysis on economic and environmental benefits, a Case Study on power interconnection in the Southeast Asian region, which covers six APEC member economies, namely: Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore and Thailand is planned in cooperation with the Electric Power Development Company of Japan (EPDC). The costs of cross-border power interconnection and independent systems will be analysed, environmental impacts associated with cross-border power interconnection in the respective economies under study will be investigated. However, this Case Study is still in progress and will be presented in the subsequent report.

CHAPTER 2

TECHNOLOGICAL OVERVIEW OF POWER INTERCONNECTION

During recent years, technological advances have altered the characteristics of transmission networks in terms of design, quality and reliability.

There are several technology alternatives suitable to power system interconnection such as, Alternating Current (AC), High Voltage Direct Current (HVDC) and Hybrid AC/HVDC interconnection systems. In general, designing a transmission system consists of making discrete, albeit numerous choices (for example, which conductor size to use, which route to take). In this way, transmission system design falls naturally into a discrete optimisation problem. To solve a discrete optimisation problem, it is necessary to generate many solution options and pick the best one for implementation. In this chapter these power interconnection technologies are reviewed.

ALTERNATING CURRENT (AC) INTERCONNECTION

Alternating Current (AC) interconnections have been widely used in interconnection systems. AC interconnections have been successfully implemented in the Union for the Coordination of Production and Transmission of Electricity (UCPTE) system in Europe and North America (Canada-USA-Mexico). AC systems are also found in the Southeast Asia region such as the Laos-Thailand, Thailand-Peninsular Malaysia, and Singapore-Peninsular Malaysia interconnection lines.

However, for large and long transmission networks, the AC system may not be economically feasible. Possible technical problems occur in large systems such as load flow problems and/or inter-area oscillations that can cause instability of the interconnected system. The economic advantages of large-scale interconnection are also lower as support from distant generators is very limited in the case of outage in the system (Ni, Y. et. al. 1999).

HVDC INTERCONNECTION

High Voltage Direct Current (HVDC) is a proven technology employed for power transmission. The power is taken from one point in an AC network and converted to DC in a converter station (rectifier) and transmitted over a line and converted back to AC again in another converter station (inverter) before it is injected into the receiving AC network. HVDC interconnection could contribute better to both technical and economic advantages of interconnection system.

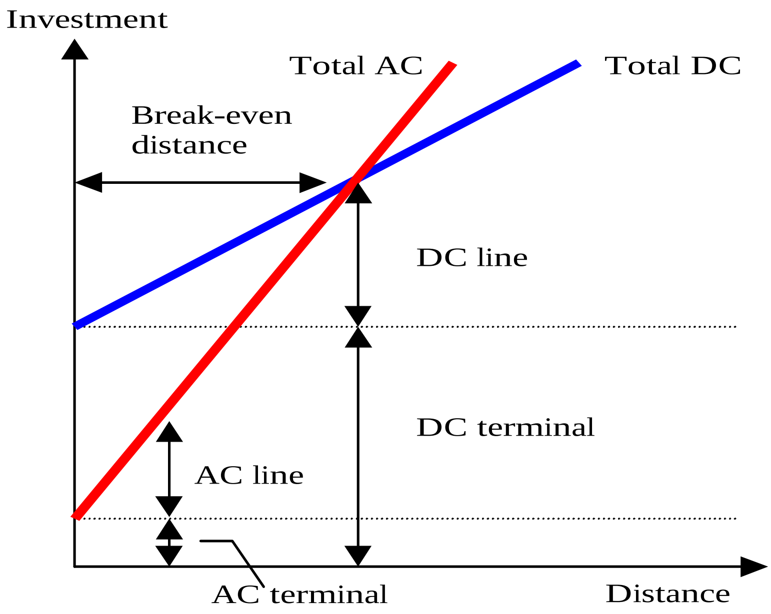
The most common reasons behind the choice of HVDC are:

- Lower line costs – beyond a certain distance (the break-even distance) the DC line will pay for the investment cost for the DC stations (See Figure 1) (ABB, 1998).

- Lower losses - with HVDC, no reactive power is transmitted. The line losses are lower than AC. The losses in the converter terminals are approximately 1.0 – 1.5 per cent of the transmitted power, which is low, compared with the line losses.

- Stable operation at low power flow is also among the other advantages taken into consideration.

Figure 1 Investment Cost versus Distance



Source: ABB, (1998)

However, HVDC has some shortcomings including:

- Additional filters have to be installed to absorb the harmonics occurring in the system;
- A large reactive power requires to be installed in the converter station since the system needs reactive power to be injected to the system to support its normal operation;
- If the controllers are not properly set, the HVDC system may bring about sub-synchronous oscillation (SSO) which can cause instability in the system; and
- Cost of converter station of HVDC system is much higher than that of AC substation.

Interconnections using HVDC system (overhead and submarine cables) can be found in Europe (between UCPTE system and Scandinavian countries), the Southeast Asia region (between Thailand and Malaysia), and China (500 kV-DC at Tiang-Guang and Ge-Shang). Decisions for two new HVDC lines for transmission of the Three Gorges hydropower are expected soon (Fischer *et al*, 1998).

HYBRID AC/DC INTERCONNECTION

The idea of a hybrid interconnection is to exchange HVDC power between neighbouring systems over a direct and shorter AC interconnection route as well as to use HVDC for transmission of large power blocks over long distances. With this combination of AC/DC systems, the interconnected systems become more stable since HVDC can damp oscillations by its fast control. Moreover, a weak AC interconnection (small power exchange) can then be allowed to exchange increased power between interconnected systems supported by HVDC control. Examples for such schemes under development are the Pacific Inter-tie in the USA and the refurbish Cahora Bassa scheme in South Africa.

FLEXIBLE AC TRANSMISSION SYSTEM TECHNOLOGY

The objectives of flexible alternating current transmission system (FACTS) technology are to enhance system controllability and to increase power transfer limit by introducing power electronic devices (at the proper places) of the existing AC system. Such kind of technology can improve system dynamic behaviour and enhance system transfer limit that is desirable in system interconnections.

However, FACTS devices are usually more expensive than conventional devices. Therefore, it is necessary to make an economic comparison with other systems such as HVDC before making decision on whether or not to use FACTS technology. Basically, if the AC system interconnection has already existed, the FACTS controller might be the first choice since asynchronous operation of two or more interconnected system is impossible.

FACTS devices have been successfully used in the state of New York in the United States where the generation is concentrated in the northern and western sides while the load centres are in the southern and eastern parts. Therefore, power transmission is subjected to thermal, voltage and stability constraints under some contingency condition where optimal power dispatch is sometimes hindered and it causes economic penalties. A similar interconnection using FACTS has also been applied for the interconnection between Ontario (Canada) and Minnesota (USA).

FURTHER CONSIDERATIONS

Whether transmitted by alternating current (AC) or by direct current (DC), electricity has two specific characteristics: it cannot be stored, and it does not flow according to the simple laws that apply to fluids and gases. Instead, electricity flows according to Kirchhoff's law, in the path of least resistance – a path that cannot necessarily be determined by contracts. The same holds true during the accidental loss of a means of production. Therefore, correcting the disturbances requires close cooperation and good exchange of information between partners.

Synchronous AC network links are well adapted to short and medium distances and for heavily interconnected networks, but these systems are vulnerable. A major disturbance can lead to a system's complete collapse. Maintaining the stability of such system requires great technical rigor and close cooperation between partners based on instant exchange of information.

DC interconnections and transmissions do not require such rigorous operation and cooperation. But the use of DC is reserved for exchanges over large distances and large transit capacities or for linking systems with different operational frequency or technical standards. Apart from the technical necessity of isolating networks with different technical characteristics, the decisions about whether to use synchronous (AC) or asynchronous (DC) links are often purely economic. In general, a direct current line can be economically justified only beyond a certain distance (about 600 kilometres for aerial lines and 50 kilometres for underwater cables) and for high transit capacities. DC lines require converter stations, which are expensive (about US$250 per kilowatt) (Charpentier and Schenk, 1995).

CHAPTER 3

POTENTIAL BENEFITS OF POWER INTERCONNECTION

As described in chapter 1, there are a number of reasons that could justify power interconnections in the APEC region. With technological development that could make interconnection economically feasible, more interconnection projects could be implemented, which could bring significant impact on the power industry as well as the whole economy.

The existing and potential interconnections, which meet the diversified needs of each economy, have various objectives. Three major factors favour and motivate power interconnection. They are security of supply, economic efficiency and environmental satisfaction. Currently, the first two factors are the major driving forces for the interconnections in the APEC region. However, the increasing concern on air pollution, especially CO_2 emission, forces the power sector to seek alternative clean and environment friendly supply. In this regard, environmental protection could become and important factor in the decision making for cross border power interconnection.

SUPPLY SECURITY IMPROVEMENT

Security and reliability of electricity supply is one of the potential benefits to encourage power interconnection. Interconnection would be able to provide a pool of operational support and additional reserve capacity, which would otherwise demand additional investment for each of the systems involved.

PROMOTING SUPPLY SECURITY OF POWER SYSTEM

When the power system in an individual economy is isolated, the concern on supply security and reliability is serious and needs to be resolved. The development of the economy and improvement of living standard depend on to the security of power supply. Hence, higher supply security and reliability of the power system could be achieved through the linkage with neighbouring system(s) by power interconnections or, alternatively, through additional investment in generation capacity to maintain a reasonable reserve margin. However, in many cases, it is more costly to maintain a desired reserve margin through installation of additional capacity than interconnection. Small sized APEC member economies such as those in Southeast Asia and sub-regional systems of large sized member economies such as China and Australia fall in this case. Although this potential for energy exchange may not be necessarily significant, the improved reliability against outages and stability of voltage and frequency in the interconnected power systems is more important. This is the case of existing interconnections among Singapore, Malaysia and Thailand. In these economies, the sum of energy traded is small compared to the capacity of the system despite significant transmission capacity. Each system provides the necessary capacity required by another as the needs arise (See chapter 5 for more detailed explanation).

PROVIDING A NEW ENERGY SUPPLY OPTION

Another potential benefit of supply security brought about by interconnection is energy trade or exchange through the interconnection lines, which could be viewed as a new form of energy supply. Imported power through interconnection diversifies forms of energy imports to the energy receiving system. A major interconnection transmission linkage will bring a significant amount of electricity (energy) to the destination (receiving system), which is a kind of energy import.

Moreover, this import replaces the import of fossil fuels that otherwise is needed. At the same time it alleviates the constraints of cost and social-acceptance problems, which have become barriers to the addition of power generation capacities.

When the fuels or energy resources are not physically or economically transportable such as hydro and lignite, power interconnection will be a means for development and utilisation of these energy resources. It offers diversification, a better use of all available sources of energy in the region and consequently contribute to the security of supplies overall.

The proposed interconnection in Northeast Asia, for example, could enhance the overall energy supply security in the economies of Japan, Korea as well as China (See chapter 6).

ECONOMICS AND EFFICIENCY

The potential economic benefits are expected from the expansion of the power system to a certain extent. The nature of power supply industry encourages the combination of individual power system to achieve economies of scale. It is also expected that market mechanism may better work in a power market (system) where freer energy trade through interconnection is allowed.

ECONOMIES OF SCALE

Once interconnection is established the power system is expanded by the combination, therefore achieving economies of scale. In this case, interconnection offers the following opportunities:

- Sharing reserve margin is regarded as an additional source of power in addition to the existing generation capacity in those interconnected economies. Large power systems resulting from interconnection can reduce the need for reserve capacity.
- Larger generating units can be introduced for better power quality and lower costs.
- Optimising the investment in the power supply systems.

A power system can obtain backup from its neighbouring connected systems and at the same time achieve higher supply security and reliability. At a required reliability level, reserve margin for a power system can be reduced with this backup power. This effect of economies of scale could be shared by all participating systems.

Optimisation of investment in the interconnected power supply systems through economies of scale would be an opportunity, as it would avoid individual power systems building independent facilities locally. In Great Mekong Sub-region (GMS), the cumulative reduction in generation investment and operating costs for the power interconnection option against the self-supply option could reach USD10.3-13.7 billion by 2020 (World Bank, 1999).

SHAVING PEAK LOAD

The vast size of the APEC region, covering several zones of different time and climate types, results in the different daily and seasonal peak load among power systems. In some cases the peak load curves among neighbouring systems or economies are complementary (See chapter 6). Complementary daily or seasonal load curves in an interconnected system could facilitate peak load shaving. Consequently, the total installed generation capacity required will be reduced since this required capacity is based on the peak load.

On the other hand, a power plant designed for peak-load generation capacity sharing could probably increase the viability through its transmission lines (interconnection project) by increasing utilisation hours. This could be the case for some power generation projects such as huge tidal power plants in Far East of Russia.

Peak Load Shaving in Northeast Asia

Belyaev, *et al* (1998) has shown a prospect to reduce installed generation capacity in each of the interconnected power systems in the North East Asian economies due to time differences in peak load occurrence. The peak load of Japan, Korea and South East China occurs in summer, while in East Siberia, Far East, North and Northeast China and probably North Korea occurs in winter. Therefore, thermal power plants of electric power systems with winter peak load could be used additionally in summer where electricity can be transmitted to another system through interconnected grids displacing half-peak thermal power plants from the power balance. There would be an opposite situation during winter. Thus, the installed capacity of each electric power system could be reduced depending on the interconnected transfer capacity.

Belyaev, *et al* (1998) also showed that the commissioning of the Primorsk nuclear power plant and the interconnection among Far East Russia, China, North Korea and South Korea together with the decreased total required operating reserve would allow saving of 7.2 GW of installed capacity. Out of this saving, 2.4 GW is attributed to this nuclear power plant and 4.8 GW to the effect achieved through the interconnection.

FACILITATING MARKET RESTRUCTURING AND COMPETITION IN POWER SUPPLY

Traditionally, the power industry is considered as a "natural monopoly" due to a number of technical and economic constraints. Among those constraints, the geographically defined supply areas and the general obligation to connect and supply customers exclude other suppliers in the traditional market structure. However, almost every APEC member economy is planning and implementing its own reform programme for power sector, which in general trend favours freer electricity transactions in both domestic and trans-border markets.

Theoretically, free trade could allow benefits of efficiency to be shared between the supplier and user. A particular system within a group, which may be in the position of generating the next increment of another system's demand at lower cost at a given time could supply the incremental energy demand of the latter thereby improving the economic welfare of both. Certainly, the appropriate removal of restriction on the delivery of energy, especially electricity, by transmission is required. This type of benefit motivates the Australian inter-state connection, the Chinese plan for a national integrated grid and the ASEAN power interconnection initiatives. They would help promote and facilitate competition in power supply business and also help break the regional monopoly of utilities.

EXTENSION OF ECONOMIC BENEFITS TO THE REGIONS WITH ENERGY RESOURCES

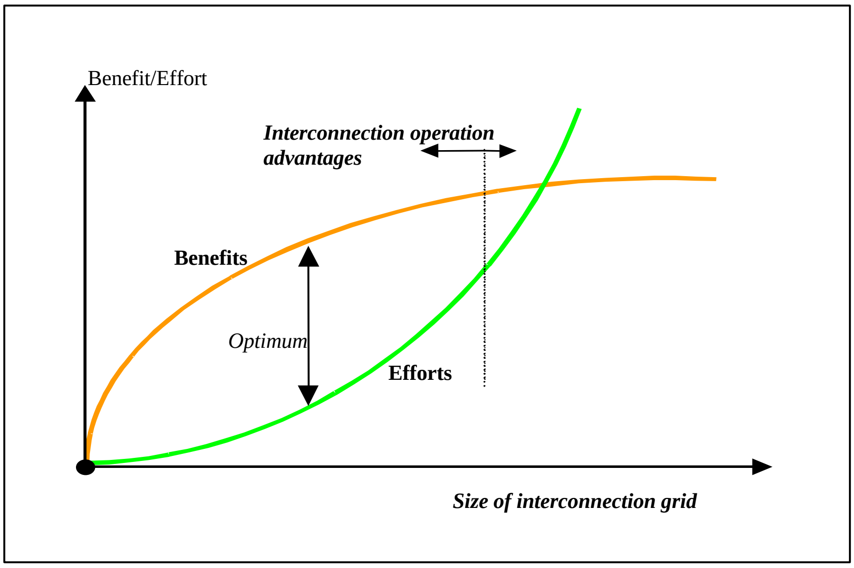
Power interconnection could generate other economic benefits. Remote energy resources like hydropower can be developed. Local economy in remote areas, where energy resources are abundant but in dire economic situation could benefit from the increased business opportunities which include: the supply of locally made equipment and technology, employment, tax revenue from investment and operation of the facilities and foreign exchange savings. It provides opportunities to support regional economic development.

This consideration motivates the Irkutsk to North China interconnection (See chapter 6). Once the project is implemented, Russian electricity supplier will profit from sales of power and the existing excess generation capacity will be better utilised. This will not only increase the rate of return on investment on these assets but also contribute to the recovery of the economy from the current recession. Besides, it will help consolidate future economic development, and possibly generate employment opportunities in East Siberia.

COST AND BENEFIT ASSESSMENT

Figure 2 shows the conceptual dynamic mechanism of cost and benefit of interconnection. The economic benefits result from the extension of system(s) by grid interconnection to an optimum size. However, excessive expansion to an extremely large size is also guided by the principle of diminishing returns as further extension to other systems might require large amount of investment for the improvement of these incoming power systems (Fischer, 1998).

Figure 2 Benefits against Efforts of Interconnection



Source: Fischer, 1998

A number of economic factors have to be taken into account in the economic assessment. Among them, the difference of generation costs, investment in transmission line(s), and transmission losses are the most influencing factors in evaluating the economic feasibility of interconnection projects. The technological development such as HVDC has also largely improved the feasibility of interconnection projects. For a specific interconnection project, detailed feasibility study on cost and benefit needs to be carefully done since power grid interconnection requires not a negligible investment and the transmission losses could be a significant issue if the line spans a long distance.

There is an important factor that may affect power interconnection – the interconnection or networking of natural gas pipelines. When natural gas is supplied for power generation, the option of generating power close to gas field and transmitting the power through interconnection lines *vis-à-vis* the option of sending natural gas to the power stations (whether centralised or decentralised) would be considered to be competing against each other. However, the examination of this issue is deferred to the next phase of this research project.

IMPACTS AND BENEFITS ON THE ENVIRONMENT

The environmental aspect in energy production and consumption becomes increasingly important. As discussed in the chapter 4, the growth of power demand in almost every APEC member economy is much faster than that of the total primary energy demand. Any change in the mix of fuel for power generation would affect the emission contribution from the energy sector in a very significant manner. The option for environmentally favourable energy resource for power generation is more easily achieved in a large interconnected system than in isolated and smaller ones.

The interconnection facilities would certainly have impacts on the environment as other energy facilities do. What is most important is whether the interconnection avoided the worst or worse option and has relatively positive impacts. Although detailed study should be done to evaluate the impacts for a specific interconnection project, potential benefits on environment could be derived from power interconnection.

POTENTIAL NEGATIVE IMPACTS

The magnetic field or electrostatic induction from the high voltage transmission facilities is often considered as a major potential hazard to human and the environment.

The dispute on this issue is not whether there is a hazard but how much and how dangerous the hazard is. The model tests conducted by Ontario Hydro's Research Division showed that no hazard to life or property existed from electrostatic induction under double-circuit 230-kV and single-circuit 460-kV lines (Tyner, 1999). The World Health Organization (WHO) had established threshold limits for magnetic field as 5 kV/m for the electric field strength and 0.1 mT for the magnetic flux density (PLN, 1997). These recommended values are widely respected. Meanwhile, many institutions including WHO itself are still making research efforts on this matter.

Under an HVDC (±500 kV or ±600 kV) line, the magnetic field, which has different nature from that generated by HVAC at ground level is 30-60 per cent of the natural earth magnetic field and has no adverse effect on the environment (Hoville, W., ABB-Canada, personal communication, January 2000).

It will always be a wise choice to select the route of high voltage transmission line away from populous area. The potential adverse impacts on environment may be minimised if it could not be eliminated when this issue is given appropriate attention in the design and route selection

EASING THE PRESSURE OF AIR QUALITY DEGRADATION

Pollutants emitted from fossil energy used to generate electricity, such as SO_x, NO_x and CO_2, attract increasing concerns (see chapter 4). They lead to air quality degradation or to climate change, which could threaten human health and life. The way to mitigate air pollution and Greenhouse Gas (GHG) emission from the power generation sector is to increase energy efficiency and to cut fossil energy use by using air-pollution-free (or less) fuels, such as:

- New and renewable energy (NRE) including hydropower, solar energy, wind energy, tidal power and geothermal;

- Nuclear power; and
- Natural gas instead of coal or oil.

Actually, the NRE is widely utilised but only hydropower has a significant share in the mix of total primary energy supply. However, hydropower and other NRE resources are generally located in remote areas, which are usually far from load centres. Utilisation of huge hydropower resources of East Siberia and Far East of Russia, Southwestern China and the Mekong River are possible only when long distance interconnection lines are constructed. The huge solar energy potential in western China could also be tapped in the future with interconnection (Arakawa and Kato, 1998 and Suzuki, 1998).

Nuclear power is a clean energy resource as it does not emit pollutant under the normal operating conditions. Thus, it will help reduce GHG emissions in Japan and in the Republic of Korea. Interconnected grid ring in Northeast Asia could allow nuclear power generated for example, from the proposed plant of Primorye Krai in Far East of Russia to be sent to Japan and/or Korea (See chapter 6). Then a number of siting issues and social concerns related to domestic nuclear development programs in Japan and Korea could be eased while reducing GHG emissions.

In the case that air-pollution-free energy is not available, cleaner fossil energy, for example, natural gas would be a better option to replace coal or oil if the gas is economically available. There are several regions in APEC where gas reserves are abundant and supply is available. Construction of gas pipeline from some of those sources to consumers is economically and/or technically difficult. Therefore, power generated at the wellhead and transmitted through power grid interconnection to the market becomes an alternative option. Certainly, the decision on whether power interconnection is more competitive or efficient compared with the natural gas pipeline (interconnection) needs a more specific detailed study.

Example of Environmental Gains

On the case of Irkutsk to North China interconnection, the imported electricity from Russia will help China to mitigate local emissions such as SO_x and NO_x (see chapter 6). Although China has no international commitment to reduce CO_2 emission, avoided CO_2 emission (beside avoided SO_x and NO_x emissions) from the coal-fired power plants, that otherwise needed to be built, through the importation of hydro electricity from Russia would be an additional benefit to the global environment.

At present, the coal supplied to power plants in China contains about 1 per cent of sulphur in the average. The total SO_2 emitted from the power sector was close to 8 million tonnes in 1997. 10-15 TWh of imported power through this project could result in a total reduction of 4.6 to 7 million tonnes of coal and consequently, around 90 to 140 thousand tonnes of SO_2 emission reduction per year in China.

- Imported electricity: 10-15 TWh/year and 2-3 GW
- Current average energy efficiency of power output in China: 30 per cent (1996)
- Energy efficiency in new large coal-fired power plants: 37 per cent
- Equivalent coal consumption to 10-15 TWh power: 4.6-7 million tonnes

- Current sulphur contents of coal supplied to power plants: 1 per cent
- Total equivalent SO_2 emission reduced: 90-140 thousand tonnes per year
- Total equivalent CO_2 emission reduction: 25-37 thousand tonnes of carbon per year

The GMS interconnection, as another example, could have also the similar benefits on environment. The World Bank (1999) study expects an emission reduction of up to 31 per cent for SO_2, 12 per cent NO_x, and 17 per cent for CO_2 in the GMS interconnection scenario.

EMISSIONS TRADING

The shifting from potential fossil fuel to air-pollution-free energy will mitigate the CO_2 emission if NRE and nuclear energy is being promoted by the interconnection. Further, from a point of view of power receiving regions CO_2 emission can be avoided through import of power via the interconnection links whether the power is produced with or without burning fossil fuel. The latter case would also generate the global benefits. This way of shifting CO_2 emission could foster international cooperation envisaged under the Kyoto Protocol on GHG emissions such as emissions trading, joint implementation and clean development mechanism.

CHAPTER 4

ANALYSIS OF APEC ELECTRICITY DEMAND AND ENVIRONMENTAL IMPLICATIONS

Although the current financial crisis has slowed down the rate of growth of the overall energy demand in the APEC region, a substantial increase particularly in the demand for electricity is projected in the developing economies in the region.

The forecast for electricity demand in this report is based on the APEC Energy Demand and Supply Outlook (updated in September 1998) developed by APERC. The APERC Outlook, as the Outlook is more popularly known, provides three scenarios, the new 1998 Baseline Scenario (B98), the Protracted Crisis Scenario (PCS) and Environment Friendly Scenario (EFS). The Australian Bureau of Agricultural and Resource Economics (ABARE) provided GDP growth projections for both B98 and PCS. The PCS assumes that the economic turmoil in Asia will continue for a longer period of time with more severe ramifications for APEC economies. Consequently, the PCS energy projections are significantly lower than the B98 scenario. The EFS assumes the same GDP projections as the B98 but postulates that energy efficiencies are improved throughout the region and fuel switching takes place to minimise the use of carbon intensive fuels in response to environmental pressure.

This chapter will analyse the demand growth trend in APEC, which has important implication on future development of electricity sector and also the power grid interconnection, based on the forecast results of two scenarios, B98 and PCS between which differences are more evident.

ELECTRICITY DEMAND

The projected electricity demand in final energy consumption under the B98 and PCS scenarios by region is presented in Table 1 and Figure 3. Electricity demand in the APEC region will increase by 3.2 per cent *per annum* between 1995 and 2010 in B98 and 2.9 per cent *per annum* in PCS. Similar to the APEC region as a whole, the electricity demand growth rates of all sub-regions (groups) in PCS scenario are lower than those in B98 scenario. It reflects the effect of prolonged recession and slower growth in the APEC region.

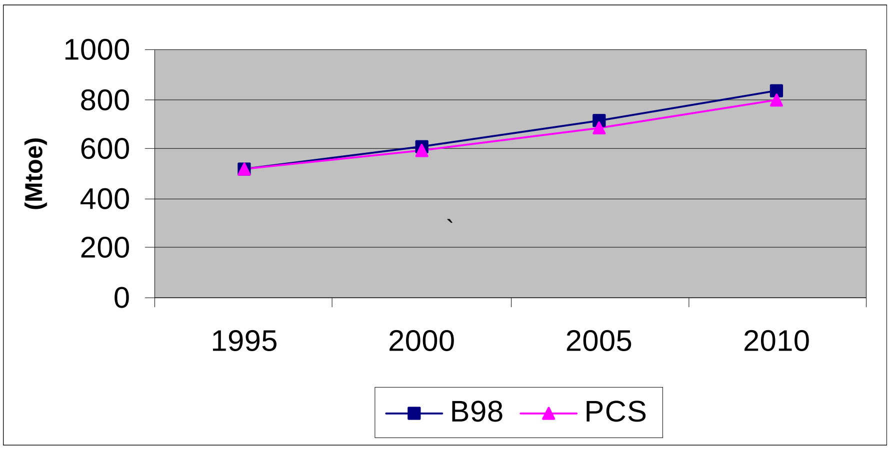
Table 1 Electricity Demand Forecast by Region
Mtoe, Baseline '98 (B98) scenario

	1995	2000		2010		Growth (%) (1996-2010)	
		B98	PCS	B98	PCS	B98	PCS
APEC	521.4	609	597.6	835.9	795.1	3.2	2.9
USA	269.2	297.4	295.3	347.5	340.5	1.7	1.6
Other Americas	52.0	57.7	56.0	80.3	74.5	2.9	2.4
China	67.3	100.3	97.1	179.4	167.5	6.8	6.3
Other East Asia	99.5	112.8	110.0	158.6	148.1	3.2	2.7
Oceania	15.5	18.4	18.3	26.8	26.3	3.7	3.6
Southeast Asia	17.9	22.2	20.9	43.2	38.2	6.0	5.2

Source: APERC, 1998.

However, both scenarios demonstrate very significant growth in electricity demand. B98 shows a 60.3 per cent increase of the total demand over the forecast period while PCS shows 52.5 per cent.

Figure 3 Electricity Demand Forecast for the APEC Region
1995 – 2010, Mtoe

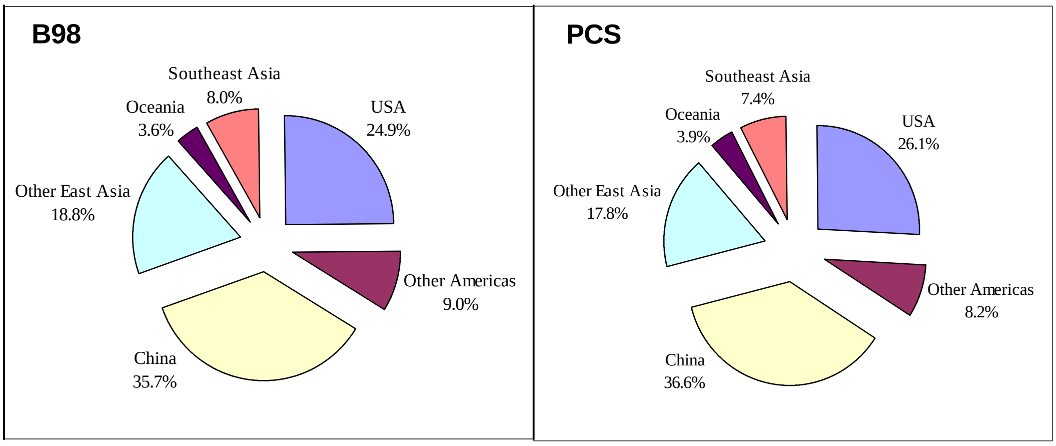


Source: APERC, 1998.

In both scenarios, China and USA are two major contributors to the APEC region's total electricity demand growth. China is expected to be the largest contributor to the total increase with 35.6 per cent (BS98) and 36.6 per cent (PCS) of the total APEC over the forecast period. The USA will contribute to 24.9 per cent for BS98 and 26.1 per cent for PCS of the total APEC increase. Following the two is Other East Asia, which includes Japan, Korea and Chinese Taipei. Other East Asia shares 18.8 per cent in B98 and 17.8 per cent in PCS of total APEC electricity demand increment in the forecast period (Figure 4).

The APERC Outlook also indicates that China and Southeast Asia (which includes Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore and Thailand) have higher growth rates in electricity demand than other sub-regions in APEC. China is expected to have 6.8 per cent annual growth in B98 and 6.3 per cent in PCS over the forecast period 1995-2010 while Southeast Asia is expected to have 6.0 per cent in B98 and 5.2 per cent in PCS.

Figure 4 Share of Additional Electricity Demand
1995 – 2010



Source: APERC, 1998.

GENERATING CAPACITY

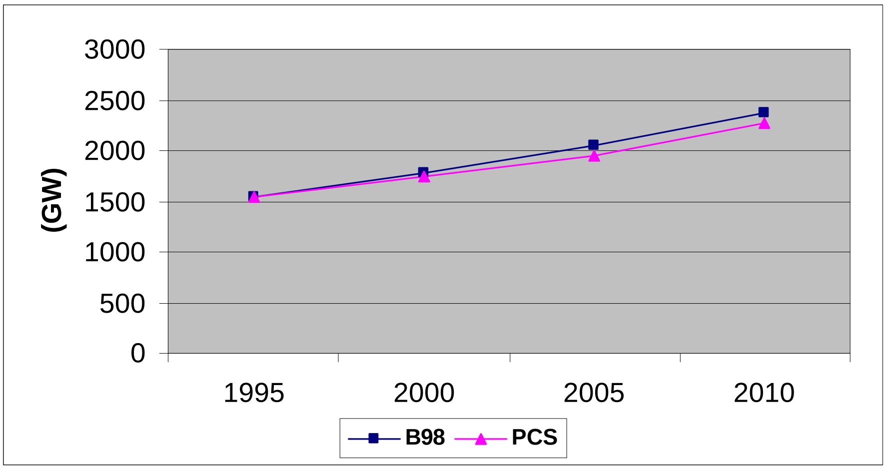
The Outlook indicates that total electricity generation capacity of the APEC 18 member economies would increase from 1,545 GW in 1995 to 2,381 GW under B98 and to 2,263 GW under PCS respectively in 2010. That means 54.1 per cent or 836 GW of increment over the forecasting period under B98 and 46.5 per cent or 718 GW of increment under PCS (see Table 2).

Table 2 Electricity Generation Capacity Requirement by Region
1995 – 2010, GW

	1995	2000		2010		Growth (%) (1996-2010)	
		B98	PCS	B98	PCS	B98	PCS
APEC	1545	1772	1738	2381	2263	2.9	2.6
USA	782	851	845	959	939	1.4	1.2
Other Americas	155	165	160	206	190	1.9	1.4
China	214	321	308	576	538	6.8	6.3
Other East Asia	290	320	312	447	418	2.9	2.5
Oceania	47	48	48	68	67	2.5	2.4
Southeast Asia	57	67	63	125	111	5.4	4.5

Source: APERC, 1998.

Figure 5 Generation Capacity Forecast for the APEC Region
1995 – 2010, GW



Source: APERC, 1998.

Figure 5 shows the power generation capacity growth in APEC region under both scenarios.

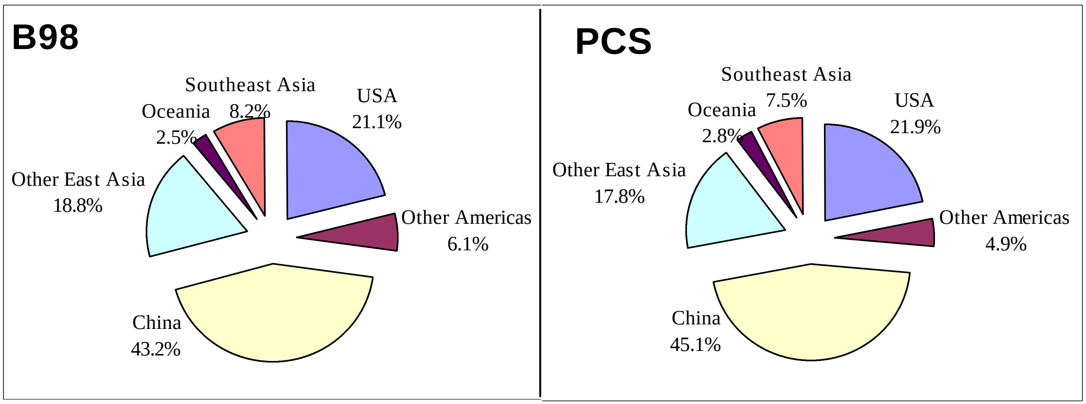
Similar to the results of electricity demand forecast, China, USA and Other East Asia are the three largest contributors to the overall increment of electricity generation capacity in the 15-year forecast. Southeast Asia is expected to have a relatively small contribution to the APEC overall increment but has a high growth rate, at 5.4 per cent and 4.5 per cent *per annum* under B98 and PCS, respectively, second only to China's escalation rate.

Figure 6 displays the share of additional generation capacity in the 15-year forecast.

China's required capacity increase of about 362 GW in B98 accounts for 43.2 per cent of APEC's overall capacity addition, which is higher than the share of China in the electricity demand increase (35.7 per cent). China's share in total APEC additional generation capacity in PCS is 45.1

per cent, a little bit higher than in B98, with the same trend as the electricity demand forecast, which means that China is less affected by the Asian financial crisis.

Figure 6 Share of Additional Generation Capacity
1995 – 2010



Source: APERC, 1998.

Despite having the second largest expected capacity increase of 177GW, the USA is estimated to have a lower share (21.1 per cent in B98 and 21.9 per cent in PCS) in APEC's total generation capacity increase than in electricity demand (24.9 per cent in B98 and 26.1 per cent in PCS). The growth rate of capacity of the USA is only 1.4 per cent in B98 and 1.2 per cent in PCS *per annum*.

Southeast Asia, with generation capacity addition of 68 GW (B98) and 54 GW (PCS), will account for 8.2 per cent and 7.5 per cent of APEC's total capacity increase respectively, which are similar to the shares in additional electricity demand. The generation capacity expansion in Southeast Asia is projected to be fast in spite of the crisis.

Other East Asia with the addition of 157 GW (B98) and 128 GW (PCS), has the third largest capacity addition just next to China and the USA, and will increase by 2.9 per cent and 2.5 per cent *per annum* respectively, over the 15 year-period.

As shown above, even with the more pessimistic scenario of PCS, new capacity requirement over the period from 1995 to 2010 will still be large. East Asia and Southeast Asia will account for 70 per cent of this increase. Better planning and cooperation in investment implementation in the electricity sector including beneficial interconnections could minimise the capacity expansion needs.

In the forecast, interconnection was assumed to have a limited development. The projected electricity trade is based on interconnections that currently exist in the APEC region. It accounts for 1.4 per cent (an increase from 42 TWh in 1995 to 79 TWh in 2010) of APEC's total electricity demand by 2010, including the exchange of electricity between the US and Canada; US and Mexico; China and Hong Kong, China; and Thailand with neighbouring economies.

FUEL CONSUMPTION FOR ELECTRICITY GENERATION

In general, fuel demand for electricity generation follows the trend of the electricity demand in the forecast period. However, the overall growth rate of fuel demand is lower than that of electricity demand because of the improvement in efficiency. The APEC total fuel demand for electricity generation is expected to have annual growth rates of 2.8 per cent in B98 and 2.4 per cent in PCS with absolute increases of 50.4 per cent and 43.3 per cent accordingly over the forecast period of 1995 - 2010. These growth rates are higher than the general growth of the Total Primary Energy Supply of APEC at 2.3 per cent in B98 and 2.0 per cent in PCS respectively. Table 3 shows the forecast fuel consumption for electricity generation in APEC.

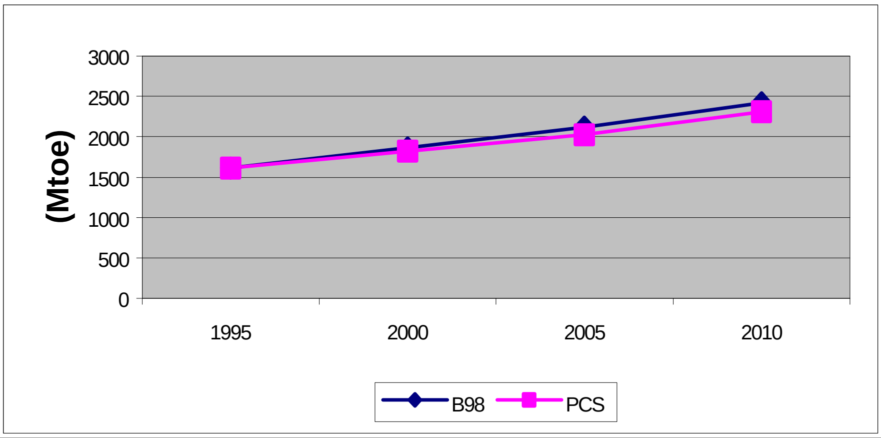
Table 3 Fuel Consumption for Electricity Generation (by fuel)
1995 – 2010, Mtoe

	1995	2000		2010		Growth (%) (1996-2010)	
		B98	PCS	B98	PCS	B98	PCS
Total APEC	1610.7	1861.0	1824.8	2422.0	2307.8	2.8	2.4
Oil	128.9	133.2	124.8	136.2	121.1	0.4	-0.4
Gas	222.0	260.9	255.8	440.9	417.7	4.7	4.3
Coal	801.1	955.1	936.5	1239.7	1183.1	3.0	2.6
Geothermal	29.4	53.8	52.6	60.4	57.1	4.9	4.5
Hydropower	90.0	101.1	99.8	126.5	122.0	2.3	2.0
Nuclear	310.3	322.9	321.9	373.6	362.5	1.2	1.0
Other	29.0	34.4	33.4	44.7	44.3	2.9	2.9

Source: APERC, 1998.

Figure 7 shows the fuel consumption for electricity in APEC under both scenarios.

Figure 7 Fuel Consumption Forecast of the APEC Region
1995 – 2010, Mtoe

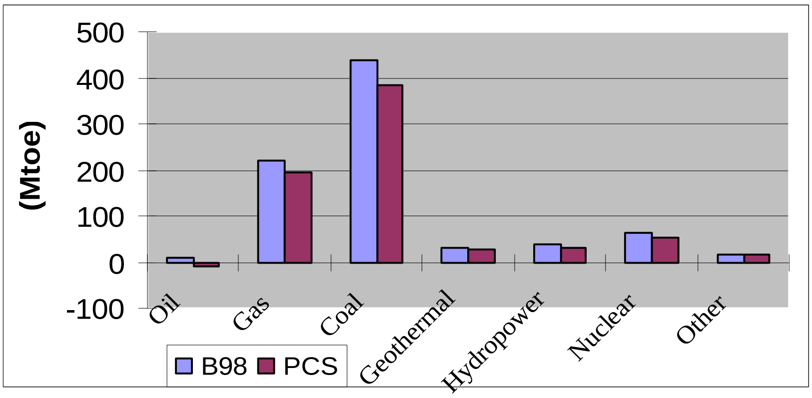


Source: APERC, 1998.

By fuel type, the demand for fossil energy such as oil, natural gas and coal by the electricity sector is expected to grow by 3.1 per cent in B98 and 2.7 per cent in PCS over the forecast period. The share of fossil energy in the fuel mix of electricity generation is expected to grow from 71.5 per cent in 1995 to 75 per cent in B98 and 74.6 per cent in PCS, respectively.

Figure 8 displays the share of additional fuel demand (by fuel type) in the 15-year forecast.

Figure 8 Share of Additional Fuel Demand by Fuel
1995 – 2010



Source: APERC, 1998.

Coal will remain to be the dominant energy source for electricity generation. Its share in the total fuel consumption for electricity is projected to be 51.2 per cent (B98) and 51.3 per cent (PCS) in 2010 from 49.7 per cent in 1995. Total coal demand for electricity generation is expected to increase by 54.7 per cent (B98) and 47.7 per cent (PCS) over the period 1995 – 2010.

Natural gas is the second most important contributor to the incremental fuel for electricity generation. It takes 27.0 per cent (B98) and 28.1 per cent (PCS) of the total fuel demand increase during the forecast period. Natural gas is expected to become the second most important fuel for electricity generation in 2010 with a share in the total of above 18 per cent for both scenarios. Total gas demand for electricity generation is expected to increase by 98.6 per cent (B98) and 88.2 per cent (PCS) over the period 1995 – 2010.

Oil usage is estimated to have slight increase (0.9 per cent in total) in B98 scenario and a slight decrease (1.1 per cent in total) in PCS over the forecast period. In both cases, oil as a fuel for electricity generation is expected to remain a minor component with its share in total fuel consumption of 5.7 per cent to 6.1 per cent in 2010 for the APEC region as a whole.

Hydropower and nuclear are expected to have continuous increase. However their growth is not comparable to natural gas and coal in terms of absolute amount and growth rate. The growth for nuclear power is the second lowest among the fuel groups next only to oil. Regionally, nuclear power expansion is projected mainly in China and Other East Asia.

Despite the expected high growth in electricity supply, the share of geothermal as well as other sources of energy in the total increase is around 4 per cent and 2 per cent, respectively.

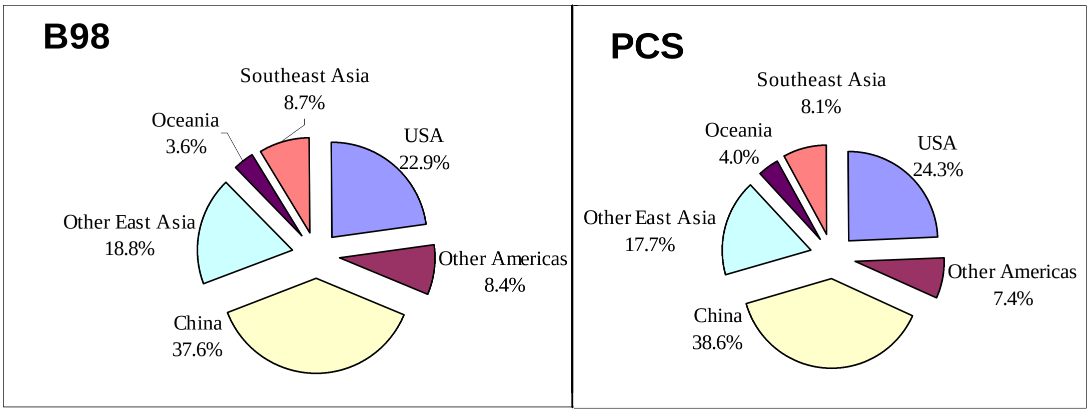
Table 4 Fuel Consumption for Electricity Generation (by region)
1995 – 2010, Mtoe

	1995	2000		2010		Growth (%) (1996-2010)	
		B98	PCS	B98	PCS	B98	PCS
APEC	1610.7	1861.2	1824.9	2422.2	2307.9	2.8	2.4
USA	848	925.8	919.1	1033.6	1017.6	1.3	1.2
Other Americas	121.9	136.9	131.5	190.3	173.3	3.0	2.4
China	241.5	344.6	333.5	546.6	510.4	5.6	5.1
Other East Asia	290.6	322.2	314.1	443.3	414	2.9	2.4
Oceania	50.3	58	57.5	79.6	77.9	3.1	3.0
Southeast Asia	58.4	73.7	69.2	128.7	114.7	5.4	4.6

Source: APERC, 1998.

By region, China and USA will be two largest contributors in the increased fuel consumption with 37.6 per cent and 22.9 per cent (for B98) as well as 38.6 per cent and 24.3 per cent (for PCS) over the period 1995-2010 in both scenarios (Table 4).

Figure 9 Share of Additional Fuel Demand by Region
1995 – 2010



Source: APERC, 1998.

In terms of growth rate, although the Southeast Asian region has been seriously hit by the Asian financial crisis, it is still the region in APEC with second highest annual growth rate just after China from 1995 to 2010. Other East Asia whose weight in APEC is very high, is expected to increase around 2.9 per cent annually in BS98 and 2.4 per cent annually in PCS.

From the above discussion, the future demand for electricity will increase significantly even if the financial crisis is expected to last for a few more years under the PCS. The rate of growth of demand is still 2.9 per cent, and the growth for fuel consumption is around 2.4 per cent annually in PCS. The fuel consumption will continue to rely highly on fossil energy resources with coal being still the dominant source in fuel increase, while the contribution of new and renewable energy resources including hydropower resource will remain low compared to fossil fuels.

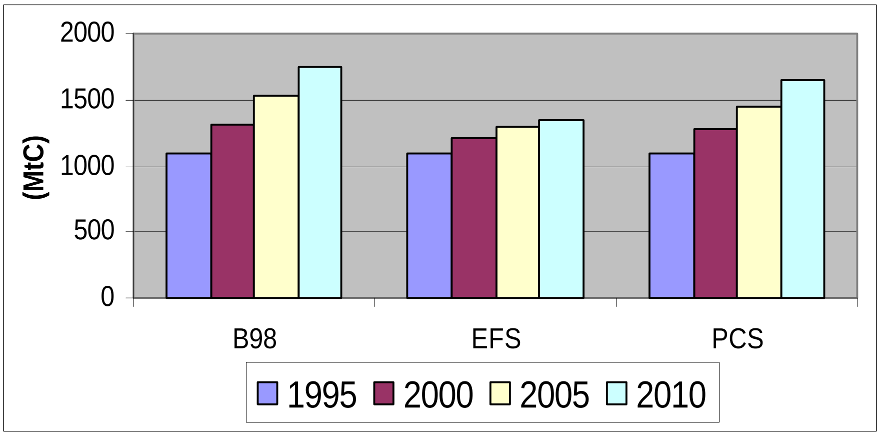
Therefore, it is clear that, APEC member economies especially those in Asia will need to consider all possible options to meet their electricity needs and requirements in the future.

ENVIRONMENTAL IMPLICATION

In any sense, the electricity sector has an important impact to the environment since energy consumed in generating electricity is expected to increase its share in the region's total primary energy supply (TPES) in the forthcoming decade. Pollutant emissions from electricity sector could increase faster than the growth of total energy demand, if fossil fuel consumption by electricity sector continues to grow faster as projected by the APERC Outlook.

The APERC Outlook projects that fuel consumption for power generation in APEC region in all cases encompassing B98, EFS and PCS will increase both its volume and share in TPES. Pollutant emissions from power generation will increase accordingly. Figure 10 and Figure 11 show increasing CO_2 emissions from the electricity sector. Shift to fuels with less carbon content will reduce the pace of increase in emissions in EFS from 2005 to 2010. Both scenarios (B98 and PCS) show very significant and constant rises in CO_2 emissions.

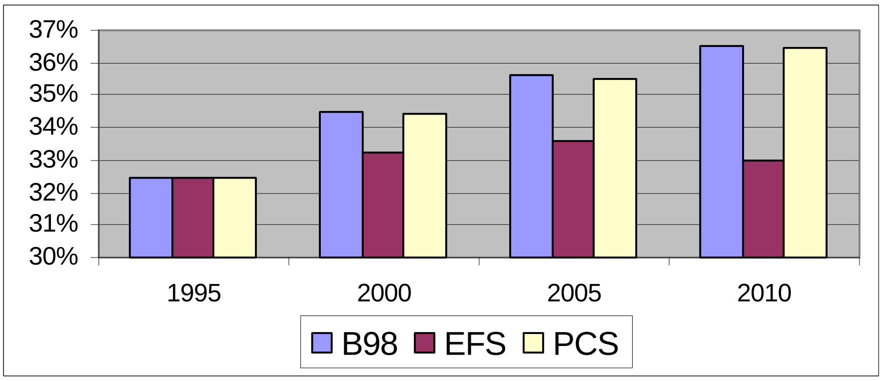
Figure 10 CO_2 Emission from Electricity Generation
1995 – 2010



Source: APERC, 1998.

This implies that other forms of pollutants like SO_2, NO_x and particulates or dusts emitted from electricity generation will increase if proper measures are not taken. Thus, mitigating these environmental impacts becomes a key task facing the sector.

Figure 11 Share of Electricity Generation in Total CO_2 Emission
1995 – 2010



Source: APERC, 1998.

CHAPTER 5

OVERVIEW OF EXISTING POWER INTERCONNECTIONS IN THE APEC REGION

Currently, there is a number of operational power interconnections links among APEC member economies in North America and in Southeast Asia. The electricity exchange through grid interconnection in North America started almost 100 years ago and is now having impacts on power sector deregulation. In Southeast Asia, the existing interconnection routes are rather for the improvement of system security in emergency situations. This chapter presents and analyses detailed information of these existing interconnections. The evolution to a competitive electricity market in Australia is also summarised in the chapter since electricity market reform and deregulation in this economy depends largely on inter-state interconnections.

NORTH AMERICA

HISTORY

The first cross-border power interconnection in North America started operations in 1901. It connected a 90 MW hydroelectric power plant in the Canadian side of the Niagara Falls to Buffalo, New York, some 30 km away. In 1912, the U.S. Northwest started receiving electricity from Western Canada. Interconnections between the U.S. and Mexico were established in 1905, to serve the requirements of border communities (APEC Electricity Regulator's Forum, 1998)[1].

The construction of interconnections has continued through most of the twentieth century. As of 1998, there were 79 transmission lines between the U.S. and Canada and 27 between the U.S. and Mexico. The figures correspond to the cross-border transmission lines for which Presidential Permits have been issued (See "Regulation" below). It must be noted however, that most of these have voltage levels that correspond to sub-transmission or distribution lines (U.S. DOE, 1998).

Table 5 summarises the major transmission lines between these three economies, classified according to the Electricity Reliability Council Regions of the U.S.

[1] Most of the information in North American interconnections used in this study has been taken from APEC Electricity Regulators' Forum (1998) and US DOE (1998).

Table 5 Major Interconnections between Canada, the U.S. and Mexico

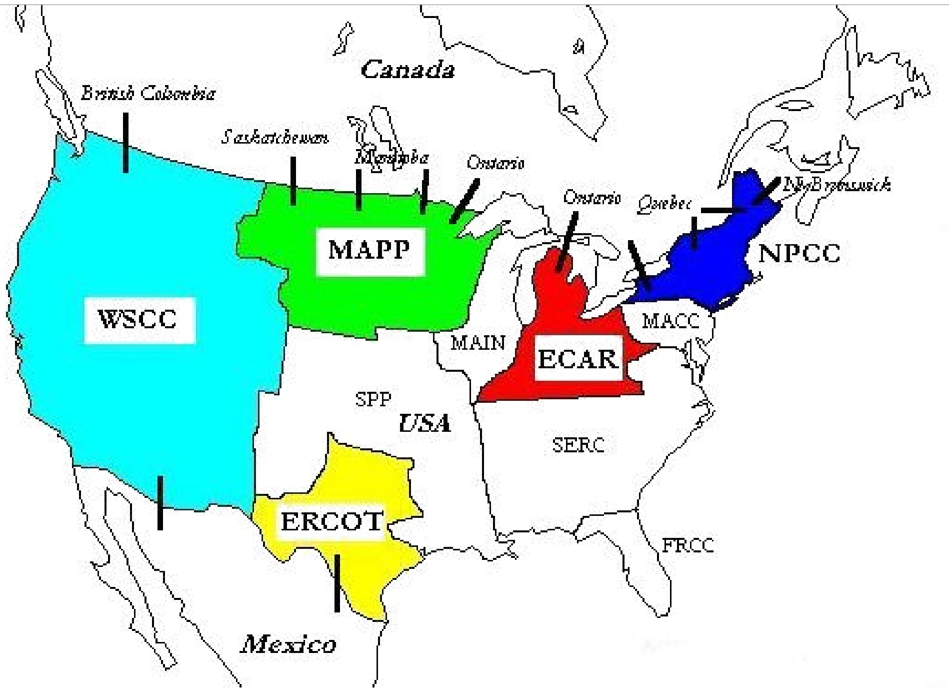
Economies/Regions	Description of major lines
U.S. with Canada[1]	
NPCC-New England	With New Brunswick: 345 kV AC, 138 kV AC, five 69 kV AC With Québec: 450 kV DC, two 120 kV AC
NPCC-New York	With Québec: 765 kV, two 115 kV With Ontario: two 345 kV, four 230 kV, two 69 kV
ECAR	Michigan-Ontario: two 345 kV and two 230 kV
MAPP (North Central)	North Dakota-Manitoba: 230 kV; North Dakota-Saskatchewan: 230 kV Minnesota-Manitoba: 500 kV, 230 kV; Minnesota-Ontario: 115 kV
WSCC (Northwest)	With British Columbia: two 500 kV and two 230 kV
U.S. with Mexico[2]	
WSCC (Southwest)	Three 230 kV and one 69 kV (ordinarily not in service)
ERCOT (Texas)	Several 138 kV lines and other minor lines

Notes: 1) NPCC - Northeast Power Coordinating Council, ECAR - East Central Area Reliability Coordination Agreement, MAPP - Mid-Continent Area Power Pool, WSCC - Western Systems Coordinating Council
2) ERCOT - Electric Reliability Council of Texas, WSCC - Western Systems Coordinating Council

Source: APEC Electricity Regulator's Forum (1998) and U.S. DOE (1998)

Figure 12 is a graphical representation of the previous table. The map highlights the Electricity Reliability Council Regions interconnected to Canada and/or Mexico. The remaining regions are: Mid-America Interconnection Network (MAIN), Mid-Atlantic Area Council (MAAC), Southwest Power Pool (SPP), South-eastern Electric Reliability Council (SERC) and Florida Reliability Coordinating Council (FRCC). Lines show interconnections among regions and do not necessarily reflect their actual geographical location.

Figure 12 Power Interconnections between Canada, the U.S. and Mexico



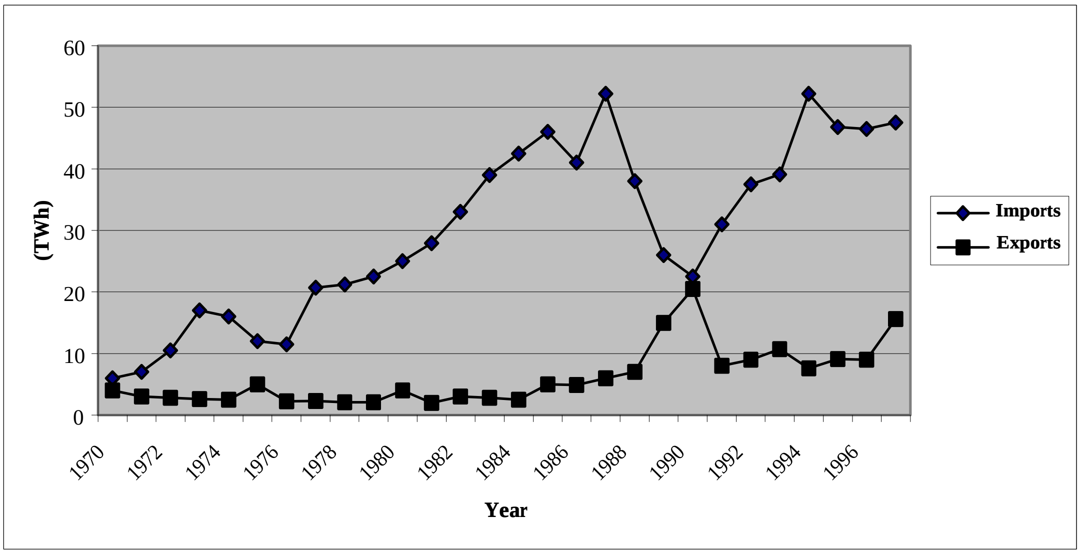
Source: U.S. DOE (1998) and APEC Regulator's Forum (1998)

ELECTRICITY EXCHANGES

Power exchanges have never accounted for a high percentage of the total demand and/or supply of each of the three North American economies despite of the high absolute value and high percentage in the supply of local systems. In fact, less than 2 per cent of the current U.S. electricity demand is supplied by net imports through cross-border interconnections, mainly from Canada.

The United States has been a net importer of electricity from both Canada and Mexico (Figure 13).

Figure 13 Electricity Transactions of the U.S. with Canada and Mexico



Source: U.S. DOE (1998)

Starting in the early 1970s and until 1987, U.S. net imports started to rise sharply from previously low levels. This is closely correlated to the rise in imported oil prices, which apparently triggered a substitution of oil-fired generation in the U.S. for less expensive Canadian hydroelectricity (U.S. DOE, 1998). Meanwhile, U.S. gross imports remained at comparatively low levels.

From 1987 to 1990, U.S. exports rose and imports fell sharply. These were mainly due to electricity shortages faced by Ontario Hydro in Canada, caused by a severe drought, unexpected load growth, outages on several nuclear generating units, and derating of some Canadian coal-fired power plants due to environmental restrictions. After 1990, exchanges recovered the historical trend.

During 1997, almost 100 per cent of the imports of electricity to the U.S. came from Canada. In terms of exports from the U.S., 90 per cent went to Canada and the remaining 10 per cent to Mexico.

On a net basis, the U.S. imported 32.3 billion kWh, which represented only 1.4 per cent of the total U.S. electric energy requirements for that year. However, from a regional perspective the impact becomes greater. For example, electricity imports accounted for 11.6 per cent of New England's 115.9 billion kWh requirements. For the Mid-Continent Area Power Pool (MAPP), imports represented 9.5 per cent of the 149.4 billion kWh requirements (see Table 6).

Table 6 Electricity Transactions of the U.S. with Canada and Mexico
MWh, 1997

Economies/Regions	Imports	Exports	Net Imports[a]	Net Imports as % of Requirements
With Canada				
NPCC – New England	13,418,471	180,674	13,237,797	11.6
NPCC – New York	5,368,669	1,408,342	3,960,327	3.6
ECAR	3,097,274	1,712,100	1,385,174	0.6
MAPP	14,208,046	439,289	13,768,757	9.5
WSCC	11,712,865	10,317,938	1,394,927	2.0
Subtotal U.S.-Canada	47,805,325	14,058,343	33,746,982	
With Mexico				
ERCOT	6,236	2,811	3,425	0.0
WSCC	16,493	1,500,896	-1,484,403	
Subtotal U.S.-Mexico	22,729	1,503,707	-1,480,978	
Grand total U.S.	47,828,054	15,562,050	32,266,004	1.4

Notes: a) Negative values represent net exports.
Source: U.S. DOE (1998)

A regional analysis can give insights into the drivers behind power exchanges among these economies. As seen above, interconnections have provided emergency backups when domestic resources have been insufficient to meet the demand. Likewise, surplus generation capacity has also motivated trade. Furthermore, interconnections have permitted a more efficient supply during peak loads that occur at different hours and/or seasons in each demand centre. However, presumably one of the main reasons during the last decades has been electricity price difference between utilities in the three economies. Suppliers will purchase power if they can obtain it cheaper than they can generate it themselves, a situation that is being facilitated by the deregulation processes currently taking place in the electricity sectors of the three economies (See also APERC, 2000).

Many factors affect these drivers. One of them is the available energy resource base to generate electricity. In the United States, coal and water resources have facilitated relatively inexpensive electric power for most regions. In 1998, coal-fired plants represented 40 per cent of this economy's generation capacity, being concentrated in the South Atlantic, Midwest, Mid-Atlantic, Southwest and Central Regions. Hydroelectric capacity accounted for only about 13 per cent of the total, with most of it concentrated in the Northwest. Natural gas-fired stations accounted for 21 per cent of the generation capacity, being concentrated in the Coastal South. Nuclear capacity represents about 13 per cent of the total generation. Oil-fired accounted for 9.3 per cent, being concentrated in the East, and renewables contributed with 2.8 per cent (APEC Energy Regulator's Forum, 1998; EIA, 1999c).

In contrast, Canada's electricity generation comes mostly from hydropower, accounting for nearly 60 per cent of the total installed capacity. Hydro resources are located mainly in Québec, British Columbia, Ontario, Newfoundland and Manitoba. Coal-fired plants account for nearly 20 per cent of the total generation capacity, being located mainly in Ontario and Alberta. Nuclear power represents more than 13 per cent, while oil-fired and natural gas-fired facilities account for the remaining 10 per cent (APEC Energy Regulator's Forum, 1998; EIA, 1999a).

Oil-fired generation is predominant in Prince Edward Island, New Brunswick and the Northwest Territories, while Alberta and Saskatchewan have natural-gas generation.

While Canada relies mainly on hydropower and the U.S. on coal, nearly half of Mexico's installed capacity is oil-fired. Hydroelectric power plants account for nearly 30 per cent, while natural gas-fired plants represent an additional 12 per cent. Only one nuclear power plant has been commissioned (APEC Energy Regulator's Forum, 1998; EIA, 1999b).

This different resource mix among the three economies has favoured the existence of power interconnections (See Table 5 and Figure 12). For example, most of New England's generation is oil-fired and nuclear, leading to high electricity prices. Cheaper electricity comes from Canada, through New Brunswick and Québec. Hydroelectric generation from Québec and Ontario supplies electricity to the New York/New Jersey region. However, during the 1989-90 drought in Canada, New York was a net exporter to Québec. In the U.S. Midwest, excess capacity of low-cost coal generation during the late 1980's, due to a reduced demand growth, permitted electricity exports to Ontario via Michigan. Similarly, eventual excess capacity of low-cost run-of-river hydroelectric power from Manitoba has been diverted to Minnesota's utilities. Despite abundant and inexpensive hydroelectric power resources, the U.S. Northwest is a major importer from British Columbia, also endowed with abundant hydropower. Imports are consumed internally as well as wheeled to the West Region, mainly California. This last region also imports power from Mexico, under firm power agreements for electricity produced by geothermal resources. However, in recent years it has been a net exporter to Mexico. Finally, the U.S. Southwest region is essentially self-sufficient, with relatively low power exchanges with Mexico. Interconnections have mostly served as backup.

REGULATION

The three economies have regulations that directly or indirectly affect imports and exports of electricity.

In the United States, "*the Federal Government regulates the construction of international transmission lines and the exports of electricity under Federal Power Act Section 202(e). This requires the approval of the U.S. Department of Energy (DOE) before electricity is exported from the United States. There are no comparable requirements for imports. In addition, Presidential Permits are required, pursuant to Executive Order 10485 as amended by Executive Order 12038, to construct and operate electric transmission facilities that cross international borders. The DOE conducts an environmental review under the National Environmental Policy Act before any FERC export authorisations and Presidential Permits are issued*" (Energy Regulator's Forum, 1998). This follows from the Executive Order 12038, which states that before a Presidential permit may be issued, the action must be found to be consistent with the public interest. The two criteria used by the U.S. DOE to determine this consistency are: (a) environmental impact; and (b) the impact on electric reliability, that is, the ability of the existing U.S. generation and transmission system to remain within acceptable voltage, loading and stability limits during normal and emergency conditions. After the authorisation in 1996 for power marketers to export electricity, DOE broadened these considerations (U.S. DOE, 1998).

Regarding international trade, the U.S. DOE has as a policy that it should be subject to the same principles of comparable open access and non-discrimination that apply to transmission in interstate commerce.

Until deregulation (see below), Canadian utilities were allowed to sell power only into U.S. transmission grids immediately adjacent to their provincial borders (U.S. DOE, 1999).

In Mexico, the import of electricity is not considered as a public service (Ayala, 1999). Permits were granted with the condition that imports be aimed exclusively at meeting the requirements of the importers themselves. The Energy Regulation Commission (CRE) is responsible for approving the methodology to calculate charges for transmission services, among which electric power imports and exports are included.

Regarding exports, the criterion is that "they must not affect national consumption, must be technically and economically advisable, tap the common natural resources of Mexico and a border country, and the exchange of electricity with power service deliverers of the other countries take place on the basis of corresponding agreements" (Ayala, 1999).

The Federal Electricity Commission (CFE) holds exclusive rights to import electricity for public service and can participate in exports. However, "importers will be able to use electric power grids, on the basis of agreements drawn up with the CFE, as long as their use does not jeopardise public service delivery or affect third-party rights" (Ayala, 1999).

Both import and export permits are granted by the Secretariat of Energy, Mines and Semi-Public Industry, after making the relevant consultations to the CFE.

FUTURE TREND

According to U.S. DOE/EIA's International Energy Outlook 1999, for the period 1996-2020 both Canada and the United States will have one of the smallest increases in electricity consumption among industrial economies, 1.4 per cent and 1.2 per cent *per annum*, respectively. However, two trends will likely enhance power exchanges at a much higher rate: deregulation in the electricity sector and the reduced reliance on nuclear generation in Canada and the U.S.

DEREGULATION

Deregulation is facilitating power exchanges and permitting the existence of international wholesale markets, with new actors such as the power marketers. In the past, electricity exporters were utilities that also owned and operated transmission lines, which interconnected with similar facilities in Canada and Mexico. Transmission agreements were mainly for long-term sales or emergency backup.

In the U.S., under the Federal Energy Regulatory Commission's (FERC's) vision of open access and comparable transmission service, deregulation has permitted that sellers of electricity are no longer required to own generation, transmission, or a system. The seller of electricity in the foreign marketplace no longer requires the border utility to facilitate international sales, but rather transmit the electricity at a fee or tariff for the seller.

Consequently, currently an increasing number of electricity export authorisation applications in the U.S. are being submitted by power marketers, traditional electric utilities not contiguous to the border, and traditional utilities that seek to export under short term contracts or terms similar to power marketers.

Even though non-traditional exporters and power marketers accounted for only 8.9 per cent of U.S. electricity exports in 1997, their weight is expected to grow significantly, following a similar trend with what happened after the deregulation of natural gas. Currently, natural gas marketers purchasing and selling under short-term, spot market contracts make half of the natural gas transactions in the U.S. (U.S. DOE, 1998).

In the case of Mexico, according to the U.S. DOE Outlook, electricity consumption in the period 1996-2020 is projected to increase at an annual rate of nearly 4 per cent. The need to meet this increase in demand is likely to foster interconnections, aided by deregulation of its electricity sector, the easing of restrictions to international investments, and the need to reduce its environmental problems. Mexico is moving away from oil-fired generation. Natural gas-fired generation and to a lesser extent, power interconnections will likely increase their shares in total supply.

The liberalisation of the electricity markets of the three North American economies could facilitate the implementation the proposed "Yukon to Yucatan" electricity grid (U.S. DOE, 1999).

REDUCED DEPENDENCE ON NUCLEAR POWER

Canada and the U.S. are expected to reduce their dependence on nuclear power over the coming years (U.S. DOE, 1999). From levels of 17 per cent and 20 per cent of total electricity generation in 1996, respectively, the share is expected to drop to 7 per cent and 8 per cent, respectively, by 2020. In the U.S., natural gas and to a much lesser extent, coal will largely supplant nuclear power. In the case of Canada, in a large measure natural gas will make up for the reduced nuclear generation, but also electricity from the U.S., which could revert the historical trend and become a net exporter of electricity to Canada.

INTERCONNECTION PROJECTS

Canada and the U.S. have a fairly developed network of interconnections that may adequately respond to future requirements. However, the situation with Mexico allows for significant increases. One of the main interconnection projects is the Palo Verde Interconnection, requiring 360 million U.S. dollars of investment, and consisting of two transmission lines capable of carrying 800 to 1,000 MW and running from Palo Verde, Arizona to Sonora, Mexico. The link could be completed by June 2002 (EIA, 1999).

Mexico could also interconnect with the planned System of Electrical Integration for Central American Countries (SIEPAC), a project to interconnect six electric grids by 2004. However, currently there is no firm decision in this respect.

SOUTHEAST ASIA

In Southeast Asia, a number of power grid interconnection projects already exist and many new projects are proposed (Chapter 4 Section 2). Among the existing projects are the interconnections between Thailand – Lao PDR which was commissioned since 1968, Peninsular Malaysia – Singapore and the Peninsular Malaysia – Thailand (Stage 1) which was commissioned in early 1980s and the Peninsular Malaysia – Thailand (Stage 2) which is now under construction (Chonglertvannichkul, P., Electricity Generating Authority of Thailand, personal communication, February 2000).

HISTORY

THAILAND – LAO PDR

During 1968 to 1972, the Electricity Generating Authority of Thailand (EGAT) sold electric power to Lao PDR for Nam Ngum Dam construction. The power, which amounted to 5 MW, was supplied from EGAT's grid at Nong Khai Substation to the project site by a 115 kV transmission line. After the completion of first 2x15 MW of the dam, and the additional 3x40 MW generating units that were installed in 1978, almost all of the generated power from this plant was transmitted to Thailand. To provide sufficient transmission capacity as well as to meet the reliability criteria, the 115 kV transmission lines with a total length of 720 circuit-km in EGAT system were reinforced.

Due to the success of the sound cooperation between Thailand and Lao PDR and with the mutual benefits provided by the Project, Lao PDR requested Thailand to supply power to Tha Khek and Savanaket provinces, which are located at the border along the Mekong River in 1972. The power supply was transmitted from EGAT's grid at Nakhon Phanom to Tha Khek and at Mukdahan to Savanaket by 22 kV submarine cables. The demand at Tha Khek and Savanaket was only 0.4 and 1.9 MW respectively.

In 1991, a new small hydropower plant located at the Southern Lao PDR was completed. The small hydropower plant, called Xe Set, having an installed capacity of 45 MW, exports most of the generated power to Thailand. At present, power demand at the Vientiane City that is being served by Nam Ngum power plant is increasing. That has resulted in a decrease in the exported power to Thailand from the Nam Ngum Dam, which currently stands at about 70-75 MW.

On the other hand, the demand at Tha Khek and Savanaket is increasing. The total maximum demand in the areas in 1996 was 8.8 and 6.7 MW respectively. In this regard, the 22 kV line from Mukdahan to Savanaket was upgraded to 115 kV and the overhead tower crossing the Mekong River was built and so was the power supply point at Nakhon Phanom to Tha Khek. The latter is still energised at 22 kV.

In addition to power cooperation mentioned above, hydropower projects in Lao PDR developed by the Independent Power Producers (IPPs) are also integrated with the EGAT system under the Memorandum of Understanding (MOU) signed between the Governments of Lao PDR and Thailand. Two power projects are in operation. The first project, the Nam Theun-Hin Boun Hydropower Project, with a generating capacity of 210 MW is connected to Sakon Nakhon Substation of EGAT via 230 kV, double circuit, transmission line. The other is the Houay Ho Hydropower Project, with a generating capacity of 150 MW, connected with Ubon Ratchathani2 Substation of EGAT via 230 kV, double circuit, transmission line. The Nam Theun-Hin Boun and the Houay Ho Hydropower Projects have been in commercial operation since March 1998 and September 1999, respectively.

PENINSULAR MALAYSIA – SINGAPORE (TNB-SP)

Tenaga Nasional Berhad (TNB) and Singapore Power (SP) are interconnected from Plentong in Southern Peninsular Malaysia to Senoko Power Station in Singapore via 2x250 MVA, 275 (TNB side)/230 (SP side) kV overhead line (12 km) and submarine cables (4 km). The project was commissioned in 1985. The objective of this interconnection was to provide a power supply source during extreme system emergencies for the both interconnected power systems of TNB and SP.

PENINSULAR MALAYSIA – THAILAND (TNB-EGAT) STAGE 1

TNB and EGAT are interconnected between Chuping in Northern Peninsular Malaysia and Sadao in Southern Thailand via a 117 MVA 132 kV 26.7 km long overhead line. The project was commissioned in 1981 with maximum transfer of 80 MW. The objective of this interconnection was also mainly for providing a power supply source during extreme system emergencies for both interconnected power systems of TNB and EGAT. Normally, it is operated radially. The trading of energy between the utilities enables peak shaving and optimisation of production cost.

PENINSULAR MALAYSIA – THAILAND (TNB-EGAT) STAGE 2

TNB-EGAT Stage 2 interconnection is designed for providing more power transfer efficiency with larger volume of power exchange between the two utilities. It is a 112-km long 300 kV HVDC point-to-point link with initial power transfer of 300 MW, expandable to 600 MW later. The project is now under construction and will be completed in the year 2001.

OPERATING EXPERIENCE AND BENEFITS

Generally, the first objective of the interconnections is to improve the reliability of supply of the economies involved, Lao PDR, Malaysia (Peninsular Malaysia), Singapore and Thailand. The generation reserve margin of these economies especially at the areas surrounding the interconnections can be kept low compared to without interconnection and at the same time achieve a better performance and resilience of the power systems from unexpected disturbances. For example, with the interconnection of Malaysia and Singapore with an individual generation capacity of about 12000 MW and about 6000 MW respectively, the resilience of both power systems has improved greatly as a result of their combined system size (Biyaem, 1998).

The second objective is to improve the quality of power supply in the areas concerned especially during disturbances and emergencies at both sides. Actually, on several occasions, the interconnection between these economies, either between Peninsular Malaysia – Singapore, Peninsular Malaysia – Thailand or Thailand – Lao PDR, has enabled these economies to supply each other during the times of need. The interconnections between them had long been considered as a source of power in addition to what they already had in their own economies. Thus, the interconnection has been proven to increase the security of supply.

Like other interconnections that already exist in the other parts of the world such as those in Europe and North America, the interconnections between these economies also bring significant economic benefits. Among them, the interconnections enabled the utilities in these economies, to defer the capital investment for new generation, as a result of sharing of spinning reserve and reserve margins. It has been regularly used for peak shaving as the system peak demand of TNB and that of EGAT's southern network are non-coincidental (Jaafar, 1998). The individual economies may now operate at a lower reserve margin and subsequently defer investment in new plants but can still meet the load demand at a high reliability and security level. Without the interconnections, the additional capital expenditure requirements by the capacity expansion plans would reach billions of dollars. Such a large amount of capital investment would definitely be one of the biggest challenges facing power supply bodies in the three economies.

Furthermore, the interconnections allow the use of larger generating units due to the enlarged power systems in the economies concerned. The above interconnections bring about larger system inertia and a larger distribution of units participating in frequency control such that the tripping of any unit will not affect the frequency performance.

The interconnection will also bring about the possibility of commercial exchange in the future. Though at the moment the commercial arrangement only takes place in the Peninsular Malaysia – Thailand interconnection and Thailand - Lao PDR interconnections, export and import of power between these economies through the existing interconnection will be possible when the economies agree on commercial arrangements in the future.

Apart from those benefits, these interconnections in some ways could improve political relations between these economies and develop a closer regional cooperation in energy aspect. Table 7 shows the details of Thailand – Lao PDR, Peninsular Malaysia – Singapore and Peninsular Malaysia – Thailand interconnections.

Table 7 Existing Interconnections in Southeast Asia

	Thailand - Lao PDR	Peninsular Malaysia – Singapore	Peninsular Malaysia – Thailand Chuping – Sadao (Stage I)	Peninsular Malaysia – Thailand Gurun – Khlong Ngae HVDC link (Stage II)
Date of Commission	1968	1985	1981	Expected to be completed in the year 2001
Details of the Inter-connection	- Between EGAT of Thailand and Power Authority of Lao PDR (EDL). - Nam Ngum Dam. In operation since 1972. Currently, the generating capacity is around 150MW and about half of the power generated is exported to Thailand. - Xe Set Hydropower. In operation since 1991 with capacity of 45 MW. Most of the power generated is exported to Thailand.	- Between Tenaga Nasional Berhad (TNB) of Malaysia and Senoko Power Station of Singapore - The interconnection via 275/ 230 kV transformers, two circuits of 2 x 300 sq. mm overhead lines and 2x 250 MVA submarine cables operated synchronously at 230 kV - Improves the resilience of power system at both sides due to the combined system size. - Maximum power transferred over the past years - No commercial arrangement	- Tie line operated radially at 132kV due to system constraint for synchronous operation. - Between TNB's Chuping 132 kV substation to EGAT's 115 kV Substation at Sadao. - Via 2x66.7 MVA 132/115kV transformer and a 117MVA 115kV overhead lines - Maximum power transferred is 80 MW - Able to provide optimised production costs as well as sharing of reserves during emergencies	- Bukit Keteri to Sadao, to improve and upgrade the current system with HVDC lines. - A point to point HVDC connection of 110 km HVDC lines (85 km in Malaysia and 25 km in Thailand) from TNB's Gurun 500/ 275kV to EGAT's Khlong Ngae 230 kV substation. - Meant to bipolar operation and energised at 300kV DC - Initially the power transfer capability at this stage is 300MW but could be upgraded to 600MW

Source: Jaafar, 1999

AUSTRALIA INTER-STATE POWER INTERCONNECTION

DRIVING FORCE

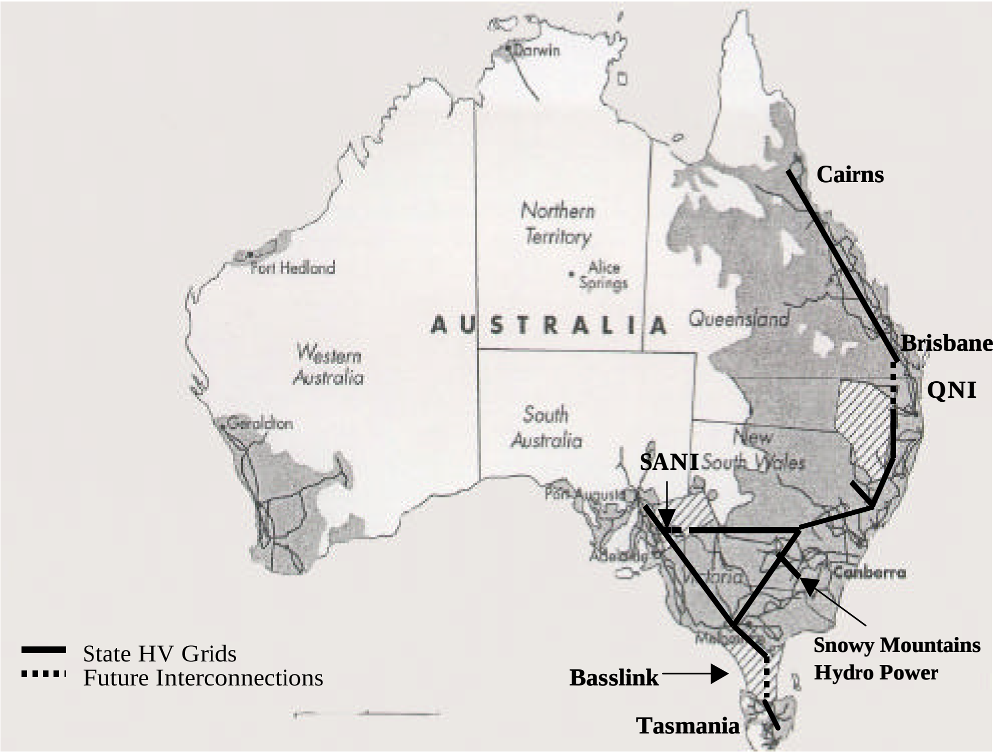
The small extent of electricity interconnection across most state boundaries is among the factors identified by the Industry Commission (1991) and others as impediments to improvement of efficiency in the domestic energy sectors. The Commonwealth government has been pursuing various initiatives with the states to facilitate interconnection. The National Grid Management Council is one of such initiatives.

In addition, Australia's state electric utilities are currently undergoing massive restructuring measures in creating a more competitive economy. The introduction of the National Electricity Market (NEM) began 4 May 1997, NEM1 covers New South Wales (NSW), Victoria, Australian Capital Territory (ACT) and South Australia. The Snowy Mountain hydro scheme allows electricity trading between the state electricity pools of NSW and Victoria. The average wholesale electricity price decreased 40 per cent in the first year of NEM operation (AESIEAP, 1999).

CURRENT SITUATION AND BENEFITS

In the Australian electricity industry, only three states are currently interconnected. NSW and Victoria are linked through the Snowy Mountains hydroelectricity scheme, and Victoria and South Australia are also linked (Figure 14). The link between NSW and Victoria allows the sharing between the two states of hydroelectric power from the Snowy Mountain Scheme. The Victorian grid has been connected with the South Australian grid since 1990, and currently supplies the Electricity Trust of South Australia with additional capacity in the morning and afternoon peak periods. The three interconnected states are a party to a tripartite agreement – the Interconnection Operating Agreement, which provides the basis for electricity exchange between them. There are no interconnections of electricity grids between the remaining states.

Figure 14 Existing and Potential Power Interconnection Links in Australia



Basically, each state of Australia has different primary energy resources (for example, black coal, brown coal, natural gas, hydro, and oil) each with different fuel efficiencies and different production cost. So interconnections between state grids can allow state with cheaper power sources to export power to those states with more expensive power sources.

Interconnection may enhance competition in the interconnected market as more generators compete within an integrated market. The National Electricity Market Management Company (NEMMCO) analysis in the South Australia – NSW Interconnection (SANI) link, for example, clearly agrees that an interconnection between NSW and South Australia would reduce pool prices in South Australia (NEMMCO, 1998). Lower prices may result from a number of factors. First, the merit order dispatch process (whereby the lowest cost generator is dispatched first to meet electricity demand requirements) would facilitate enhanced competition among generators in the national electricity market. Australia's electricity prices are among the lowest in the developed economies.

Another implication of interregional trade is the possibility of change in the mix of fuels used to generate electricity. The merit order dispatch process means that the fuel mix may change following the response of local generators to competition from generators in other regions. By widening the range of generation technologies available, integration of regional markets through interconnection could alter the generation mix. The proposed Tasmania – Victoria interconnection, Basslink, for example, could lead to the export of hydroelectric peak power from Tasmania (subject to the availability of stored water), and a reverse flow of brown coal fired power from Victoria in off peak period.

FUTURE TRENDS

The national or the Southeast grid covers the interconnected jurisdictions of NSW, Victoria, South Australia and Australian Capital Territory, which accounted for 62 per cent of electricity consumption in Australia in 1997-1998 (Melanie, 1999). In addition to increasing the capacity of the existing interconnections, several proposals for interconnection development are likely. Queensland is already a part of the national electricity market but not physically connected to the national grid. It will be linked to the national grid (through Queensland - New South Wales Interconnection – QNI) by the end of 2000, with a northbound capacity of 500 MW and a southbound capacity of 1000 MW. There is a parallel proposal for the Directlink project which will link the Queensland and NSW power networks through an under ground cable of 180 MW, starting in January 2000. Plans for linking Tasmania to the mainland are also well advanced, with expectations that Basslink will be commissioned by late 2002 with capacity of 300-400 MW. The proposal to link NSW and South Australia through the SANI link is still on the agenda.

CHAPTER 6

OVERVIEW OF POTENTIAL POWER INTERCONNECTIONS IN THE APEC REGION

In the APEC region, member economies are in different stages of development analogous to the development of each electrical system. As analysed in Chapter 4, power industry in APEC is expected to have a continuous growth in the future. For the already industrialised economies, like Japan, North America and Oceania, electricity demand growth is expected to be low but based, however, on a very high present consumption level. For the other member economies that are in the developing stage, electricity demand growth is expected to be high and needs rapid development of electric systems.

The APEC region possesses also abundant natural energy resources for power generation, which are not evenly distributed geographically. With this disparity in energy resources, member economies engaged in trade of primary fossil energy such as coal, oil and natural gas. This disparity likewise pinpoints the potential for electricity trade through interconnection of individual power grids. Given the trend of rapid power system development and the great potential of power trade, the APEC region has a number of important power interconnection opportunities in the future.

Taking into account the benefits of existing power interconnections in North America, Southeast Asia and Australia in the APEC region, this chapter examines the other potential interconnections at the Northeast Asia, Southeast Asia and South America sub-regions of APEC.

NORTHEAST ASIA

Northeast Asia is a very dynamic region in terms of economic development and electricity market. Russia, China, Korea (ROK) and Japan are all APEC member economies. Together with two non-member economies, Mongolia and North Korea (DPRK), Northeast Asia is a very promising integrated power market in the future.

Meanwhile, Hong Kong, China and Chinese Taipei, who are also APEC member economies in Northeast Asia, are not included in the study. The power system in Hong Kong, China is already connected to mainland China through the interconnections between the system of China Light & Power Company (CLP) and Guangdong provincial power grid and Daya Bay nuclear plant. There are eight 132 kV transmission lines and four 500 kV/400 kV interbus transformers interconnected with Guangdong with a total capacity of over 3,000 MVA (CLP, 2000).

Chinese Taipei, who has a total generation capacity of 26.7 GW in 1998, is isolated. It is about 150-180 km away from Fujian province of the mainland China across the strait. The development of new power plants is facing difficulties on siting in Chinese Taipei. However, the interconnection between two sides of the strait is not yet an issue being considered because of sensitive political reasons.

CURRENT SITUATION

The Eastern part of Russia, East Siberia and Far East is geographically connected to other economies in the Northeast Asia region, namely China, Japan and Mongolia. The northern part of China, namely North China and Northeast China is the area connected to Russia and North Korea (DPRK).

Initial integration between China and Russia is already being realised in the form of near-border effective power cross flows, after which these could be succeeded by bulk-scale power transfer.

Republic of Mongolia used to be a Siberian electric power consumer for a long time. The Central Electricity System of Mongolia operates in parallel with United Energy System (UES) of Siberia at 220 kV voltage. There also exist small power interconnections such as: the Energy System (ES) Chita – Eastern Mongolia and the Krasnoyarskaya ES – Western Mongolia. In the previous years electric power transfer to Mongolia was about 0.1 to 0.3 GWh, the interconnections' capacity was insufficient.

In the case of further power demand increase in Mongolia exceeding the present lines capacity two options are considered: construction of 220 kV HVAC transmission line Irkutsk – Erdenet, or 500 kV HVAC Gusinoozerskaya thermal power plant – Ulan-Bator, which could provide additional 450 – 600 MW depending on the Mongolian grid development.

Over the border between China and DPRK, the two jointly developed hydropower stations are the geophysical bridges of the neighbouring power systems. However, there is no physical linkage between the power systems. Therefore no electricity exchange happens between China and DPRK.

The Japanese power system, which is actually integrated by interconnections between its 60 Hz system in the west and 50 Hz system in the east and north, has no power linkage to other economies. Korean (ROK) power system is likewise isolated at the moment.

NATURAL RESOURCES

In Northeast Asia region, two different groups of economies in terms of energy resources could be found. Russia and China are quite rich in energy resources while the others including Japan and Korea have much less (Table 8– Table 11).

Table 8 shows that compared to the technical potential of hydropower in East Siberia (661 TWh/y) and Far East Russia (684 TWh/y), that of North China (23.2 TWh/y), Northeast China (38.4 TWh/y), Japan (64.9 TWh/y) and Korea (7.6 TWh/y) is very limited. In addition, Japan and Korea have almost fully developed their hydropower resources.

Total potential resources of hydropower in East Siberia and Far East of Russia amounts to 134.5 GW, which accounts for 81 per cent of Russian total and so far only 7.6 per cent, had been developed. Likewise, these areas have abundant fossil energy including natural gas, oil and coal. In addition, the potential tidal energy in the Far East was estimated to have potential for two large tidal power plants, Tugursk and Penzhinsk that could have power generation capacity of about 7 GW and 80 GW, respectively.

Table 8 Hydropower Resources in Northeast Asia

	Gross Potential		Technical Potential		Generation		Use of Technical Potential
	TWh/y	%	TWh/y	%	TWh/y	%	%
Total Russia	2396	100	1670	100	168.4	100	10
East Siberia	849	35	661	40	91.8	55	14
Far East	1008	42	684	41	10.8	6	2
Total China	5922		1923	100	188	100	10
North China			23.2	1	3.1	2	13
Northeast China			38.4	2	11	6	29
Southwest China			1305	68	52.6	28	4
Japan	596		>64.9		82.9		
Korea	77		7.6		5.2		68

Note: Hydropower Generation of Russia is in 1992, others in 1996.
Sources: Balyaev, L.S. *et al*, (1998); State Planning Commission (SPC) of China, (1997); World Energy Council, (1995); APEC Energy Database.

Table 9 displays the absolute dominance of Russia in natural gas reserves. Reserves and production of China, on the other hand, are in fact not distributed to its North and Northeast but to the Southeast area.

Table 9 Natural Gas Reserves in Northeast Asia

	Proven reserves		Production		R/P ratio
	(Tcm)	%	(Bcm)	%	
Total Russia	48.14	100	571.1	100	82.7
East Siberia & Far East	2.1	4.4	8.2	1.4	256.1
China	1.37		22		62.3
Japan	0.03		2.28		13.2
Korea	-		-		-

Note: R/P ratio – Reserves/Production ratio
Sources: Saneev, B.G., (1999); BP Amoco, (1999); World Energy Council (WEC), 1995; APEC Energy Database.

In Northeast Asia, oil reserves and production are mainly in the Northeast China and Russia (East Siberia and Far East). However, the production expansion potential in East Siberia and Far East seems to be much larger than China because of the high R/P ratio (Table 10).

Table 10 Oil Reserves in Northeast Asia

	Proven reserves		Production		R/P ratio
	(B ton)	%	(M ton)	%	(year)
Total Russia	6.7	100	304.3	100	22.0
East Siberia & Far East	1.6	24	1.5	0.5	1044
China	3.3		159.9		20.6
Japan	0.0076		0.7		10.3
Korea	-		-		-

Note: R/P ratio – Reserves/Production ratio

Sources: Saneev, B.G., (1999); World Energy Council (WEC), (1995); APEC Energy Database.

The coal reserves in East Siberia and Far East is huge and even much larger than that of whole of China where coal is the dominant fossil energy resource (Table 11).

Table 11 Coal Reserves in Northeast Asia

	Proven reserves		Production		R/P ratio
	(B ton)	%	(M ton)	%	(year)
Total Russia	240	100	262.8	100	913
East Siberia & Far East	161	67	105.3	40	1529.0
China	114.5		1372.8		83.4
Japan	0.821		5.3		-
Korea	0.183		4.5		-

Note: R/P ratio – Reserves/Production ratio

Sources: Netherlands Energy Research Foundation ECN, (1999); Saneev, B.G. *et al*, (1998); World Energy Council (WEC), (1995); APEC Energy Database.

Generally speaking, Japan and Korea hold very limited energy resources. Compared with their considerable energy demand, the indigenous reserves of energy are negligible. The hydro resources in Japan and Korea are relatively important but there is no longer much room for further development. Compared to East Siberia and Far East of Russia, energy resources that northern part of China possesses is not significant and especially not as clean.

Therefore, within Northeast Asia region, the energy-rich but weak economies can complement the energy needs of the economically prosperous economies that are wanting in energy resources.

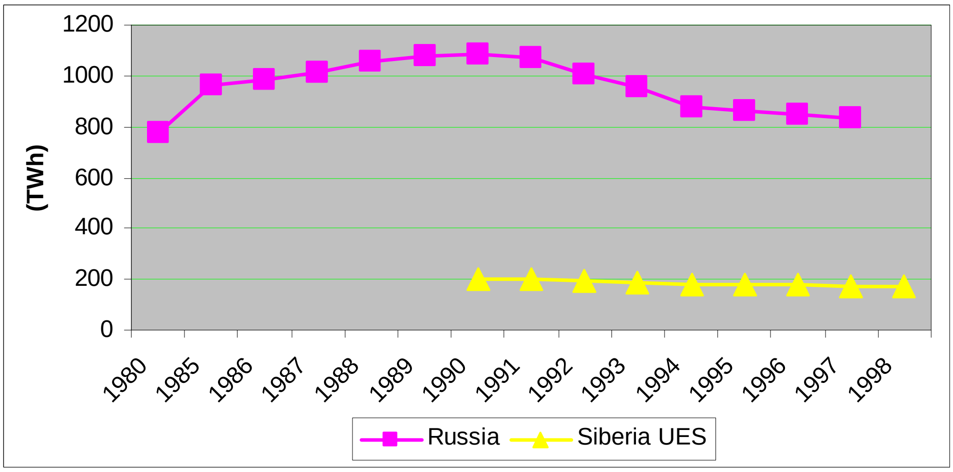
POWER INDUSTRY AND MARKET

The electricity demand in Northeast Asia is very promising except in East Siberia and Far East of Russia, which is experiencing economic slowdown and electricity supply surplus. In a longer-term view, northern China, Japan and Korea could be the potential markets of electricity from both the existing plants and future new plants in East Siberia and Far East of Russia.

POWER SUPPLY SURPLUS IN SIBERIA

Since the economic downturn from early 1990s, electricity supply capacity has become excessive in Russia.

Figure 15 Power Generation Dynamics of Russia



Sources: Ministry of Fuel and Energy of Russia Federation, Institute of Energy Strategy, (1999).

Recently, the power sector in Siberia faced a difficult situation. The economic recession in the region has caused a decline in electricity demand. Figure 15 shows the recession trend of demand in whole Russia and in the United Energy System (UES) of Siberia or the Siberia Interconnected Electric Power System, to 1997.

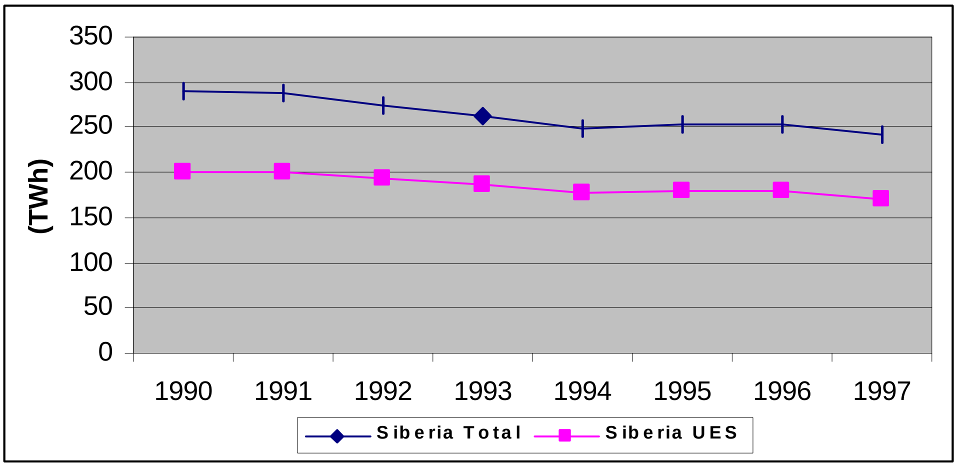
UES OF SIBERIA

The United Energy System (UES) of Siberia includes only the power plants controlled from the Common Dispatching Centre, situated in the city of Kemerovo. The UES of Siberia does not include one of the largest power systems of Siberia - Tyumen power system, which, in turn, belongs to UES of Ural, and the power plants of so called "isolated" territories, such as the territories that have no tie lines with UES of Siberia. In 1997 power generation in Tyumen power system made up 58.9 TWh.

The Siberia UES grid consists of 10 utilities (or systems) with a total installed generating capacity of 46.2 GW in 1995, of which 23.3 GW or 50.4 per cent was hydro. Peak load was about 28 GW and the total power generated was 179.5 TWh in 1995. Hydropower output in this grid was 106.8 TWh during the year accounting to about 60 per cent of total output of the interconnected grid (UES).

The Siberia UES is suffering from depression in demand from the beginning of 1990s (Figure 16). The margin of generation capacity was about 40 per cent in 1995, which is believed to be being the highest in recent years. Abundant hydropower was discarded through dams that could amount to a few TWh per year.

Figure 16 Power Generation Dynamics in Siberia



Sources: UES of Siberia, (1990-1998).
State Committee on Statistics of Russia, (1997).
State Committee on Statistics of Russia, (1998).

IRKUTSK SYSTEM

Irkutsk is one of the 10 utilities of Siberia UES. Total installed generating capacity of Irkutsk system in 1995 was 13.1 GW, of which hydro takes 9 GW or 68.7 per cent of the total. There are three large hydropower stations, namely Ust-Ilimskaya (3.84 GW), Bratskaya (4.5GW) and Irkutskaya (660 MW) on the Angara River which goes to the world largest fresh water lake, Lake Baikal.

Output of electricity generated in this system was decreasing since 1989 from 75 TWh down to 58.8 TWh in 1995. The reduction of output included a discarded volume of water through dams. Margin of installed generation capacity was about 80 per cent in winter and about 180 per cent in summer in 1995. Internal market recession of power consumption within the system was the main cause of generation downturn. Potential power export capacity could be up to 3 GW and potential volume of electricity that could be exported in 1995 was about 16.2 TWh if we set the output of 1989 as a benchmark.

Since the trend of economic development doesn't show sign of gaining strength, power demand in the local market and installed capacity of power generation are expected to remain constant in the Irkutsk power system. Installed capacity is not expected to dramatically change from the current level in 2010.

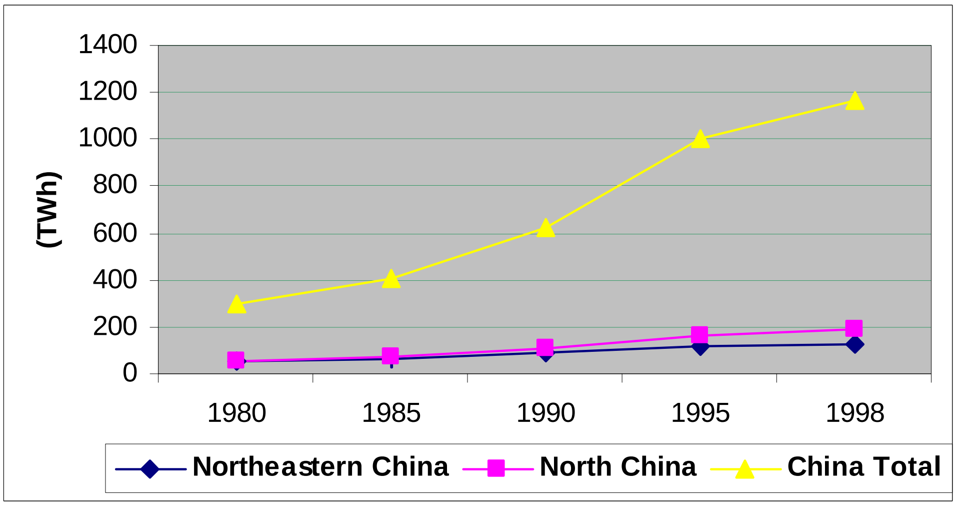
Krasnoyarsk in the west and Buryatia in the east are two receiving utilities that were expected to receive power from Irkutsk system. In the Krasnoyarsk power system, Boguchanskaya hydro station, the fourth station on the Angara River with designed capacity of 3 GW, have started construction before 1996 and was planned to be completed in 2002 (however, it is now indefinitely delayed). Together with the coming on stream of the Berezovo thermal power plant-1 to full capacity of 6.4 GW, an excess of 13-15 TWh of electricity output by 2005-2010 in Krasnoyarsk power system (Voropai *et al*, 1998) may be expected. The Chita power system, which is connected to Irkutsk system, will also have excess power after the completion of construction of Kharanor thermal power plant. This new generation capacity will ensure the internal supply and provide excess power to Irkutsk system in the future.

Voropai *et al*, (1998) expected that, the excess power would be around 25-30 TWh by 2005-2010 from Irkutsk, Krasnoyarsk and Chita systems. It is also said that this figure may further reach to 40-50 TWh if the excess capacity and power from Yakutia after the completion of the construction of a cascade of Uchursk hydro power plants is considered.

PROSPECT OF CHINA'S POWER MARKET

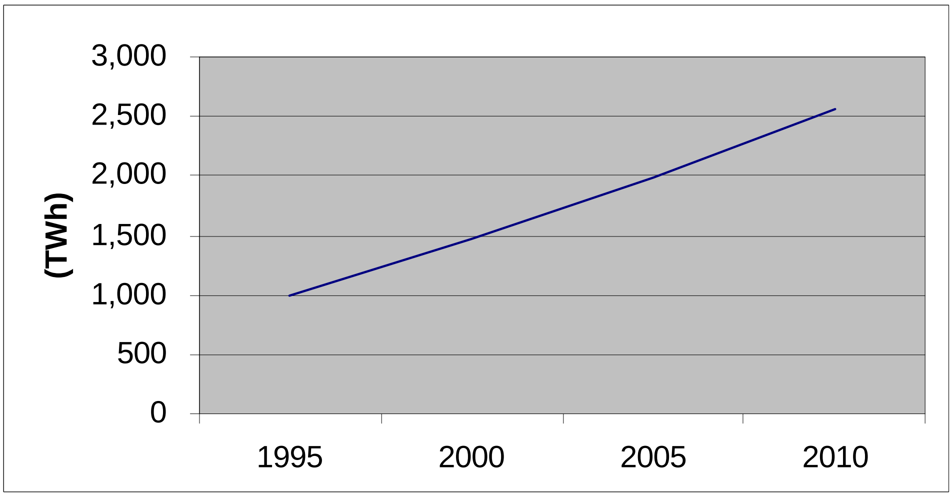
China has achieved strong growth of power demand and supply in the last two decades (average 8 per cent *per annum* over 1978 – 1998) (Figure 17). Until 1997, power supply shortage was always considered as a bottleneck of economic growth and also a social concern. The growth rate in 1998 was slowed down because of the impacts of lower economic growth. It is likely picking up in 1999. The forecast done by APERC in 1998 shows that more than 1,500 TWh of additional power supply *per annum*, which is 1.5 folds of the base year 1995, would need to be added over the period of 1995 – 2010 (Figure 18).

Figure 17 Power Generation Dynamics of Northern China
1980 - 1998



Sources: State Planning Commission (SPC), (1997); Collected from other articles.

Figure 18 Power Generation Forecast – China
APERC (B98)



Source: APERC, (1998).

Although the Chinese power industry has experienced very strong growth in a period of about 20 years with total installed capacity and electricity generation reaching 277 GW and 1167 TWh, respectively at the end of 1998, per capita electricity consumption is still very low. Per capita installed capacity and electricity generated was about 0.22 kW and 933 kWh respectively in 1998. These per capita shares are far lower than OECD and APEC average in 1995 (see Table 12). In a long-term view, electricity demand will grow at a quite high level in the next decades.

Table 12 Per Capita Electricity Generation Capacity Comparison
(in 1995)

	Population (million)	Installed Capacity (GW)	Generation (TWh)	Per Capita Capacity (kW)	Per Capita Generation (kWh)
China	1203	217.2	1007	0.18	837
APEC	2173	1544.7	6822	0.71	3139
OECD	1081	1814	7978	1.68	7380

Sources: EDMC, (1999)
IEA, (1998)
APERC, (1998)

On the other hand, the parts connected with Russia such as, North and Northeast China, have a serious problem of environmental pollution caused by coal burning. Coal is used in these areas as a major fuel of power generation. Some big cities, which are power-consuming centres, such as Beijing, Tangshan, and Shenyang are severely affected by this problem and have issued some regulations to ban coal burning in specific urban areas to limit pollutant emissions. This makes the idea of introducing Russian Siberian power even more interesting.

While both the central and local Chinese authorities are struggling with the problems of emission from coal burning, the power industry in the northern regions is facing more and more serious challenges of environmental protection. But choices are not many if the only fuel for generating power is coal. Recently, natural gas that was found in central China and introduced into Beijing becomes a cleaner fuel option for power generation. But considering the total volume of natural gas that can be available for all consumers in Beijing as well as those in the region, the availability of gas supply for the power industry is quite limited even with the potential natural gas import from Russia in the future. Natural gas as fuel for power generation is so far only used or planned to be used within urban areas or for co-generation.

Therefore, imported electricity from Russia will be a very potential solution to meet fast growing market demand of North China and Northeast China in an environment friendly way.

NORTH CHINA AND NORTHEAST CHINA POWER INDUSTRY

North and Northeast China are areas close to Russia. These areas are traditionally industrial regions in China. Total installed power generating capacity in 1996 was 63.5 GW accounting for about 26.8 per cent of the nation's total. The growth rates from 1991 to 1997 of power generation in the regions were around 9 per cent and 6 per cent, respectively.

Among the installed power generating capacity in these regions, 90 per cent is thermal power. Coal-fired power is the dominant source that accounts for about 95 per cent of thermal power. Hydropower, oil and gas fired power takes only a few percentage in the total.

In the total output of 307.1 TWh in 1996, thermal power takes 95.4 per cent. Coal-fired power accounts for 97.2 per cent of thermal power.

Both regions, especially North China, are very much limited in hydro resources. Similarly, other NRE power is insignificant in terms of share. On the contrary, coal reserves, which are abundant in the regions, become the only reliable indigenous fuel for power generation. Extensive use of coal as fuel in these regions has caused environmental problems.

However, despite the large size of installed generation capacity, the per capita electricity consumption in these regions is still very low. The North China Network is serving a population of about 140 million while Northeast China Network serves about 110 million. Installed power generation capacity per capita was about 0.25 kW in both regions in 1996. With further economic development, the potential of power industry development would be high in these highly populous regions.

In order to meet future power demand, a number of big power projects are either being implemented or will be implemented. For example, the North China Power Group (NCPG) which is operating the North China Network has announced 10 big power plant projects with a total capacity of 10,180 MW (NCPG, 1999) along with smaller projects in 1998-2000 and later (see Table 13). All of these power projects will be coal-fired.

Table 13 Power Projects Planed in North China Network

Sanhe (coal-fired)	350MW × 2
Hanfeng (coal-fired)	660MW × 2
Xibaipo phase-2 (coal-fired)	300MW × 2
Hejin (coal-fired)	300MW × 2
Yangcheng (coal-fired)	350MW × 6
Dalate phase-2 (coal-fired)	330MW × 2
Hengshui phase-2 (coal-fired)	300MW × 2
Shalingzi phase-2 (coal-fired)	300MW ×4
Panshan phase-2 (coal-fired)	600MW ×2
Tokto (coal-fired)	600MW × 2

Source: NCPG, (1999).

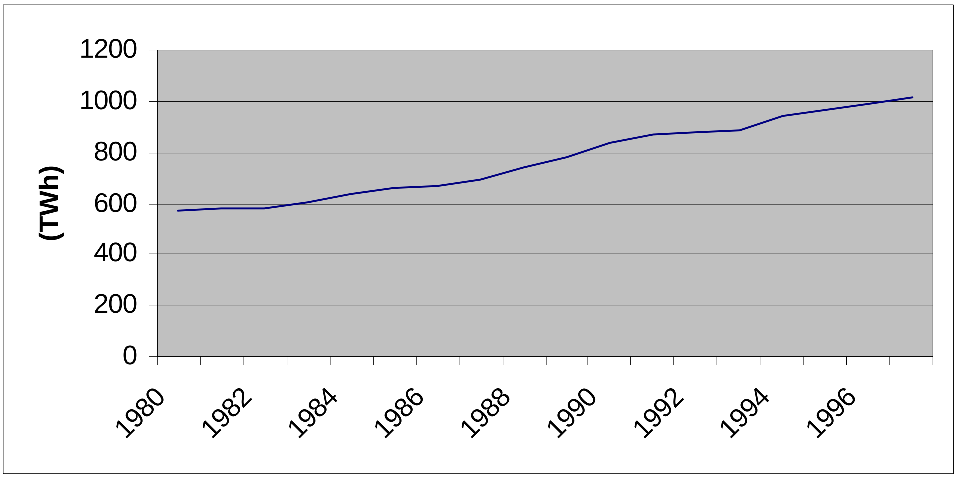
PROSPECT OF JAPAN'S POWER MARKET

Actually, the electricity market of Japan is isolated without any connection to other economies. Electricity demand and generation in Japan have enjoyed steady increase in the past decades (Figure 19). According to various forecasts, the energy demand of Japan will continue to increase in the future. APERC has projected that the power generation in Japan would increase by 40 per cent over the period 1995 to 2010 (See Figure 20).

However, Japan is actually struggling to achieve its commitment in reducing GHG emission under the Kyoto Protocol. The efforts to contain GHG emissions would be defeated if the use of fossil fuel keeps on increasing.

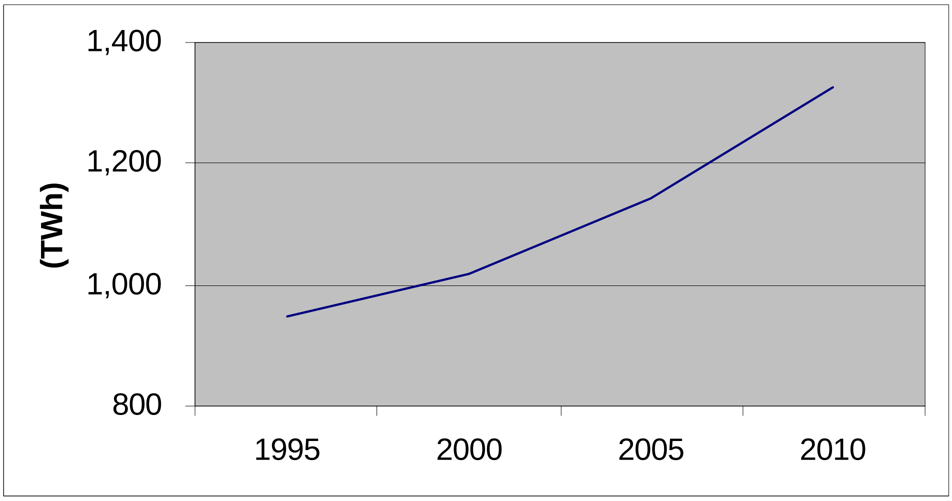
Electric power imported from outside of Japan could be treated as a clean supply of energy, especially if this power is generated by hydro, nuclear or other renewables. Therefore, electric power grid interconnection for energy supply purpose is an important alternative for Japan.

Figure 19 Power Generation Dynamics of Japan
1980 - 1998



Source: APERC Database

Figure 20 Power Generation Forecast – Japan
APERC (B98)



Source: APERC, (1998).

CHALLENGES TO JAPAN'S ENERGY INDUSTRY

According to the forecast issued in June 1998 by Japanese Government (Ministry of International Trade and Industry, MITI), primary energy demand of Japan will be 693 million kl of oil equivalent (Mkloe) in 2010 from 597 Mkloe in 1996 in a "business as usual"(BAU) scenario. This assumes an average growth rate in primary energy demand of 1.1 per cent annually while GDP is growing by an annual average of 2.3 per cent. Under this scenario CO_2 emission from energy use in 2010 will be about 10 per cent higher than in the year 1996 when the CO_2 emission had already increased by 9.6 per cent from 1990 base. Therefore, this BAU scenario projects about 20 per cent increase of CO_2 emission from energy use over the period 1990 to 2010 (Nonaka, 1998).

However, Japan is required to reduce GHG emission by 6 per cent from the 1990 level by the period 2008 - 2012 under the Kyoto Protocol adopted at the Third Conference of Parties of the United Nations Framework Convention of Climate Change (COP3). Japan is actually an outstanding economy with low energy consumption intensity. Any further reduction on energy consumption or intensity would be a very challenging task. In order to achieve this goal, a "Policy Target" scenario was then proposed by the government forecast. It produced a total primary energy demand of 616 Mkloe in 2010 assuming a 0.1 per cent of annual primary energy demand growth over the forecasted years. In the supply side, this scenario outlines top priorities on nuclear power and new and renewable energy development while reducing fossil energy consumption. Thus the "Policy Target" scenario will achieve a zero increase in CO_2 emission from 1990 to 2010 in energy use.

Major challenges facing this "Policy Target" scenario may come from two aspects. One is about the reality of keeping energy demand growth low while GDP is going to grow at 2.3 per cent annually and the second is the possibility of development in nuclear power and new and renewable energy. The former supposes an energy consumption elasticity coefficient of about zero in the next 15 years while it was 1.23 in the past 7 years (FT Asia Gas Report, 1998). The latter suggests a 3.4 per cent annual increase of power output from nuclear while the public opposition in Japan to nuclear projects is growing. The 7.75 per cent average annual growth of new and renewable energy utilisation suggested by the scenario is likewise very ambitious to achieve due to very high cost.

Therefore, CO_2 emission reduction is in any sense a very challenging task for Japan.

Is Nuclear Power the Solution?

According to the above mentioned "Policy Target" scenario, total installed electric generating capacity by 2010 will be 255.9 GW, an increase of 48.02 GW from the end of FY 1996 (namely, March 31 1997) level. Of the total increase in capacity, 23.5-27.5 GW is expected to come from new nuclear projects. A study of the Institute of Energy Economics, Japan (IEEJ) shows that nuclear power development could not allow Japan to meet the target set by government forecast even with additional reactors whose construction are definite by now (Kawai and

Oda, 1998). IEEJ assumes that a nuclear power shortage from the goal set by the "Policy Target" will amount to 160 TWh in 2010 in the case of no additional reactors, and 40 TWh even in the case with addition of reactors whose construction is confirmed.

On the other hand, the IEEJ study shows that all the photovoltaic, geothermal and conventional hydropower (excluding pumped-storage) projections in 2010 in the "Policy Target" are somehow ambitious.

Recently, nuclear power related accidents in the past years have increased public concerns on security of nuclear power plants. On 22 February 2000, the third largest Japanese power company, Chubu Electric Power Company scrapped its plan of building a nuclear power plant in Mie Prefecture forced by the objection of local authorities. This is alarming to the Japanese energy policy, which highly relies on nuclear power development. Some industry experts also believe that even half of the targeted number of reactors would be difficult to be built in the planned period. MITI has decided, on 10 February 2000, to review its overall energy policy from April 2000, taking into account the changing circumstances (Watanabe, 2000).

All these factors suggest a very difficult and challenging situation for Japan in dealing with both targets of satisfying power demand and GHG reduction commitment.

Hence, imported electricity could be a possible option to make up for the potential shortage of nuclear and other low CO_2 emitting power sources to meet Japan's power demand as well as CO_2 mitigation target.

PROSPECT OF KOREA'S POWER MARKET

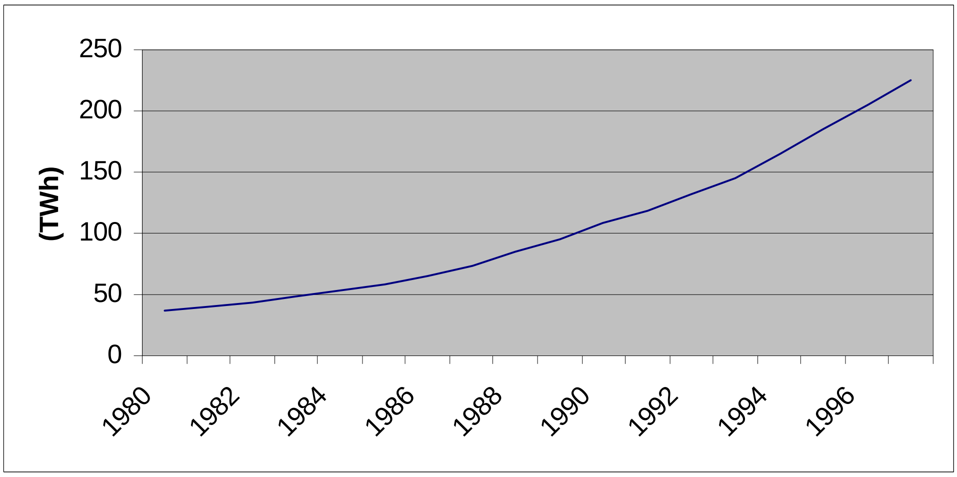
Similar to Japan, the power system of Republic of Korea is isolated. The power system in the Korean Peninsula has been separated into two independent systems since 1948 due to political reason. The Republic of Korea's power market has experienced steady and high growth of electricity demand and generation in the past decades (Figure 21) and could hardly deal with its future increase in energy demand. Actually, the isolated power system of Korea became quite large with an installed generation capacity of about 43.77 GW at the end of 1998 (Lee, 1999). Transmission voltage in this system has been upgraded to 345 kV and a new 765 kV transmission system will be in operation by early 2000s.

According to the national energy plan of the Korean Government, total installed generation capacity in the Republic of Korea will be 80.83 GW in 2015 of which 115 new generating units with total capacity of 51.59 GW will need to be added. This requires total investment, including transmission and distribution facilities, of about 58.8 billion US dollars at 1997 constant prices (Park *et al*, 1998).

APERC projected that power generation in Korea would be doubled over the period of 1995 to 2010 (Figure 22) (APERC, 1998).

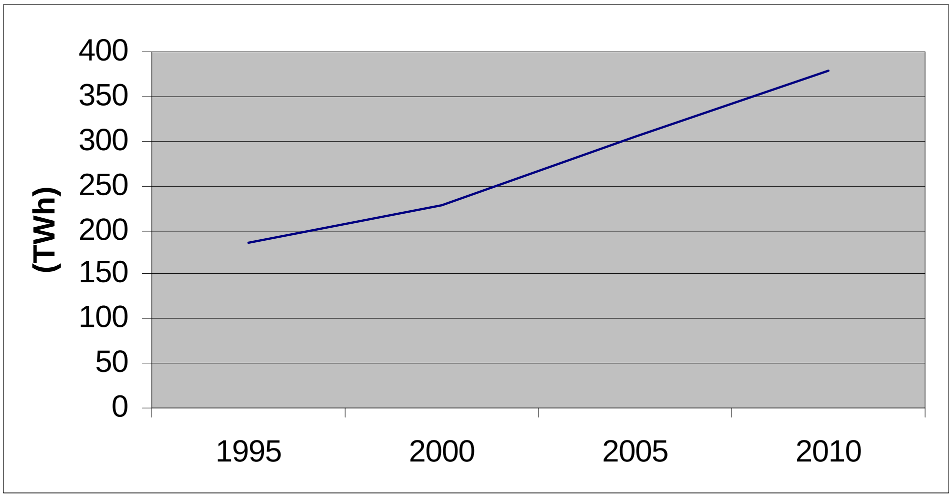
The energy demand growth rate and the difficulties to build up a cleaner power industry relying on nuclear power will be a serious challenge to Korea. The electric power from Russian Far East or East Siberia could arrive at Korea through interconnections via China and North Korea.

Figure 21 Power Generation Dynamics of Korea



Source: APERC Database

Figure 22 Power Generation Forecast – Korea
APERC (B98)



Source: APERC, (1998)

CHALLENGES TO KOREA'S ENERGY INDUSTRY

The primary energy demand in Korea is expected to increase quite slowly compared to the previous years. Since 1985, energy consumption in Korea had increased by more than 10 per cent *per annum* to 1997 just before the current Asian financial crisis. A study named Long Term Energy Demand under IMF in 1998 implemented by KEEI shows an average annual growth rate at 3.74 per cent between 2001 and 2010 and 2.33 per cent between 2011 and 2020 (Jung, 1999). The study made by LG Economic Research Institute (LGERI) shows an average annual increase of 3.2 per cent between 2001 and 2010 and 2.1 per cent between 2011 and 2020.

Derived from the projected primary energy demand, CO_2 emission was calculated by LGERI study as follows:

The CO_2 emission from energy use in Korea will increase to 230 per cent in 2010 from the 1990 level and to 280 per cent in 2020. These forecasts are all based on an orientation of optimising primary energy mix by increasing significantly the share of LNG and nuclear in order to reduce GHG emission.

Korea became an OECD member a few years ago. Under the Kyoto Protocol, Korea still holds the status of developing economy and does not take a commitment to reduce its GHG emission. Looking forward to the future, however, Korea will face a very serious challenge if it is going to reduce GHG emission.

Is Nuclear Power a Matter of Consideration?

Nuclear power is considered as a way to ease GHG emission and ensure energy supply. Under the aforementioned national energy plan, nuclear energy is expected to take a share of 34.2 per cent in total installed power generation capacity in 2015, ranking first in the mix supplied to power sector, from 27.5 per cent in 1998 when nuclear ranked second next to LNG (27.9 per cent). The total generation capacity of nuclear power will increase from 12.02 GW in 1998 to 27.65 GW by 2015 with a net addition of 15.63 GW over the plan period. Like Japan, the increasing concerns for the environment in Korea make it difficult to find locations for environment-polluting facilities such as power plants. In the case of nuclear power plants, the issue of siting is worse than other facilities. First of all, suitable sites for nuclear power plant are very limited considering its safety and operational aspects. In addition, siting of nuclear power plants confronts public opposition, a major stumbling block. Due to these difficulties, 18 nuclear reactors are planned to be built in 6 locations, under the government's long-term electricity demand/supply plan, of which 3 locations for 10 reactors have not yet been decided (Lee, 1999). Construction works are also delayed under current financial crisis.

Table 14 Primary Energy Demand Forecasts of Korea
Mtoe

	1990	1995	2000	2010	2020
KEEI (1998.6)		150.4	178.4	257.5	324.2
LGERI (1998)	93.1	150.4	168.3	231.7	285.2

Source: Jung, 1999; Lee, 1999

Table 15 CO_2 Emission Forecast of Korea
Million tonnes of carbon

	1990	1995	2000	2010	2020
LGERI	65.1	101.1	109.4	149.9	182.7

Source: Lee, 1999

INTERCONNECTIONS POTENTIAL

In the context that Northeast Asia needs an enormous amount of new supply capacity, two tasks would need to be done. The first is to create enough or adequate supply sources and the second is to find better options of supply.

Considerations for matching needs of resources and market demand between eastern Russia and other economies in Northeast Asia have resulted in the initiatives of power interconnection between the economies recently.

EAST SIBERIA – NORTH CHINA

China and Russia have initiated a power interconnection proposal for transmitting Russian electricity from Siberia to northern China since 1995. The governments of both sides have also engaged in the discussion under the framework of Energy Sub-Commission of Regular Premiers Meeting Commission. Investigations and initial negotiation have been undertaken by related utilities, assigned grid companies and international interests.

According to investigations and preliminary studies conducted by two sides of the concerned authorities, Irkutsk utility or system, which is one of the ten parts of the Siberian UES Grid, is the most possible, major and suitable exporter of electricity to China.

THE PROJECT OUTLINE

An initial proposal suggests the construction of a transmission corridor between one of the major hydropower stations of Irkutsk system, for example Bratsk, and Tangshan City – a hundred and fifty kilometres northeast of Beijing, *via* Mongolia. Total distance of this corridor will be around 2,500 km. Then the power can further go to either Beijing in North China or Shenyang in Northeast China or both. Initial transmission capacity using 600 kV HVDC lines could be at 2-3 GW level with an annual volume of power flow of 10-15 TWh.

KEY ISSUES

Actually, the average power generation cost in China is quite low by international standards. Along with the progress on deregulation, China is going to apply a bidding mechanism in power dispatching systems to select the lowest cost of power to the grid to keep prices as low as possible.

The current electricity price in North China and Northeast China was about 0.3 – 0.55 Yuan of Chinese RenMinBi (RMB) for the normal industrial and 0.3 – 0.4 Yuan to residential users per kWh respectively, in mid 1999 (CPIN, 1999). These prices are equivalent to about 4 - 6 ¢ per kWh in US dollar term. The price in foreign currency term would vary if the exchange rate fluctuates.

The local generation cost and the level of power retail prices would be the benchmarks for imported power. Competition among suppliers in Chinese power markets will become stronger along with the introduction of a bidding mechanism. This competition is basically based on price and quality.

Imported power is the supply option that will not bring an impact on air degradation unlike burning of fossil fuel and could be regarded as an environment friendly supply. However, such externality or benefit that is beyond direct cost of generation and transmission may be difficult to be reflected in prices.

Therefore, the price and purchase arrangement of imported power would become key issue in promoting this project.

FAR EAST OF RUSSIA – JAPAN

Under these interconnection concepts, power generated in Russian Siberia and Far East regions will be transported directly to Japan through Sakhalin to Hokkaido connection, or via China and then to Korea and finally to Japan through interstate ties.

Nuclear power is being considered as one of the major measures to mitigate CO_2 emission and guarantee future energy supply in Japan as well as in the Republic of Korea. But many difficulties exist for implementation of their nuclear programmes. It is proposed to construct nuclear power plants in Primorye Krai of Russian Far East and transfer the nuclear power to Korea or to Japan through interstate interconnection ties (Belyaev *et al*, 1998).

These proposed interconnection projects would especially provide an environment friendly power supply to Japan. Power supplied to the interconnection system will be cleaner than traditional sources in the area. The potential benefit of reducing CO_2 emission is considered very important.

The load curves in Japan and in eastern Russia peak during opposite seasons. The peak load in eastern Russia is in winter while it is in summer in Japan. Figure 23 displays the load curve of Irkutsk system, which represents the typical load curve in the eastern Russia systems. Figure 24 shows the load curve of Japan as a whole in 1997 (FEPC, 1999). A number of GW of generation capacity could be shared potentially if the power systems would be interconnected.

As the peak load shift effect is achieved by the interconnection in this region, a new power plant to be commissioned in the interconnection system will also generate benefit by this effect. It can be loaded to balance demand in one system in summer and in another system in winter. This effect will favour building some power plants using non-traditional technologies and less economically feasible but more environment friendly such as new and renewable energy generated power, like tidal power.

Figure 23 Forecasted System Load Curve of Irkutskin
2010

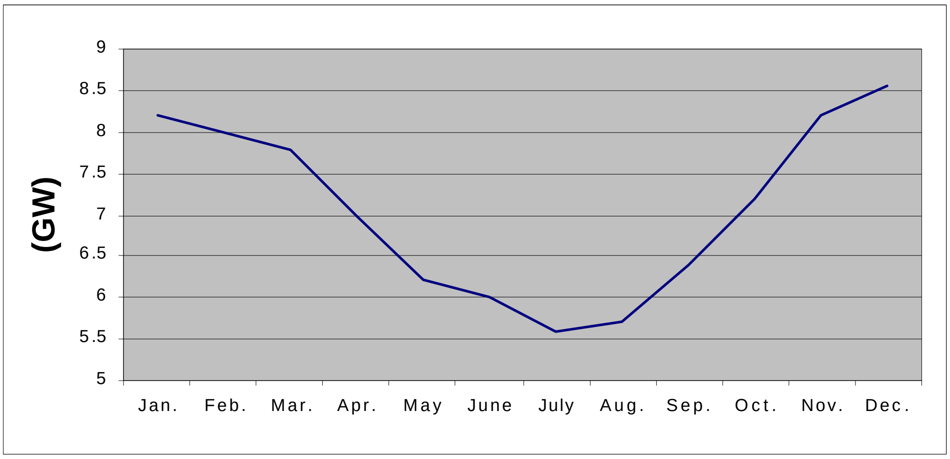
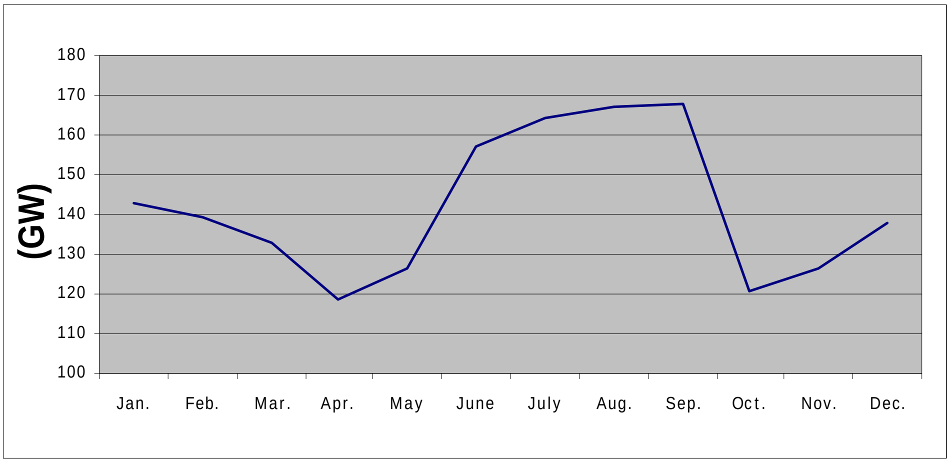


Figure 24 Load Curve of Japan
1997



Source: FEPC, (1999)

The Far East of Russia to Japan interconnection could involve Yakutian hydropower stations (rivers Uchur and Timpton), gas and coal fired power plants in Sakhalin island, the integrated system of Japan, and then probably extended to the power systems of ROK. Submarine power transmission cables could close this route: Sakhalin – Hokkaido (50 km), Honshu – Korea (200 km), Maritime Territory – Sakhalin (20 km).

This concept has been worked out in 1997 in the Russian Joint Stock Company (RAO) - the Unified Energy System of Russia (UESR) and the Russian Academy of Sciences. RAO UESR's intentions were recently (August 1999) confirmed by its top officials. The project's target is electricity export from Russia (Sakhalin) to Japan. It is supposed to construct two clean thermal power plants (TPP) in the middle of Sakhalin island: 1) 4 GW Sakhalinskaya TPP fuelled by Sakhalin shelf gas, and 2) 2 GW Solntsevskaya TPP fuelled by coal from Solntsevsky coal field. Both TPP's are near to 100 per cent export oriented. Power could be exported through a 500 kV HVDC transmission line along Sakhalin (420 km) plus a submarine cable (50 km) through the Laperuza channel with capacity of 6 GW. Realisation period is 6 – 8 years; investments are estimated at total US$ 11.9 billion. Power export potential is up to 36 TWh per year.

KOREAN PENINSULA AND TO NEIGHBOURING ECONOMIES

As mentioned earlier in the last section, Korean power industry needs a very significant input of new generation capacity. However, two factors may encourage Korea to consider power interconnection with its neighbouring economies. One is the existing constraint on costs, siting and emission limits for the capital-intensive projects. The other is to facilitate the relaxation of political and military tension in the Peninsula through cooperation in power interconnection with the North Korea – Democratic People's Republic of Korea (DPRK).

The DPRK's power system, isolated basically, has an installed generation capacity of about 6.3 GW, of which about 3.2 GW is hydropower, according to an announcement made by a DPRK's authority (Park *et al*, 1998). It is believed that DPRK has important potential of hydropower to develop and has or will have supply shortage of power. Therefore, an interconnection to Republic of Korea will probably help to optimise the system with high hydropower proportion and alleviate power supply shortage and at the same time help the Republic of Korea to utilise hydropower as well as to develop further supply sources in the North.

In a longer term, the interconnection in the Peninsula will be extended to China and Russia to the north and probably Japan to the south resulting in the total interconnection of Northeast Asia. This interconnection might likewise support a relaxation of the political and military tension. The government of the Republic of Korea launched in June, 1999 a research project on Northeast Asia Region System interconnection (NEAREST), namely "Pre-feasibility Study on NEAREST". The main objective of this research project is to roughly evaluate the potential economic effects of NEAREST. The results will be used for making decisions on policies relating to NEAREST (Park, 1999).

This interconnection proposal provides an important prospect, as further steps, to facilitate the idea of forming an integrated power system – the ring, which includes Korea Peninsula, China, Russia and perhaps, Japan.

THE FUTURE RING OF POWER GRID IN NORTHEAST ASIA

The Northeast Asia region enjoys high demand growth in electricity. The projected demand growth rate in the future is still very significant. To meet the potential electricity demand, challenges of energy sources, environmental protection and social conflicts are emerging. As analysed above, joint efforts on regional power grid interconnection would be for the common interests and will be mutually beneficial.

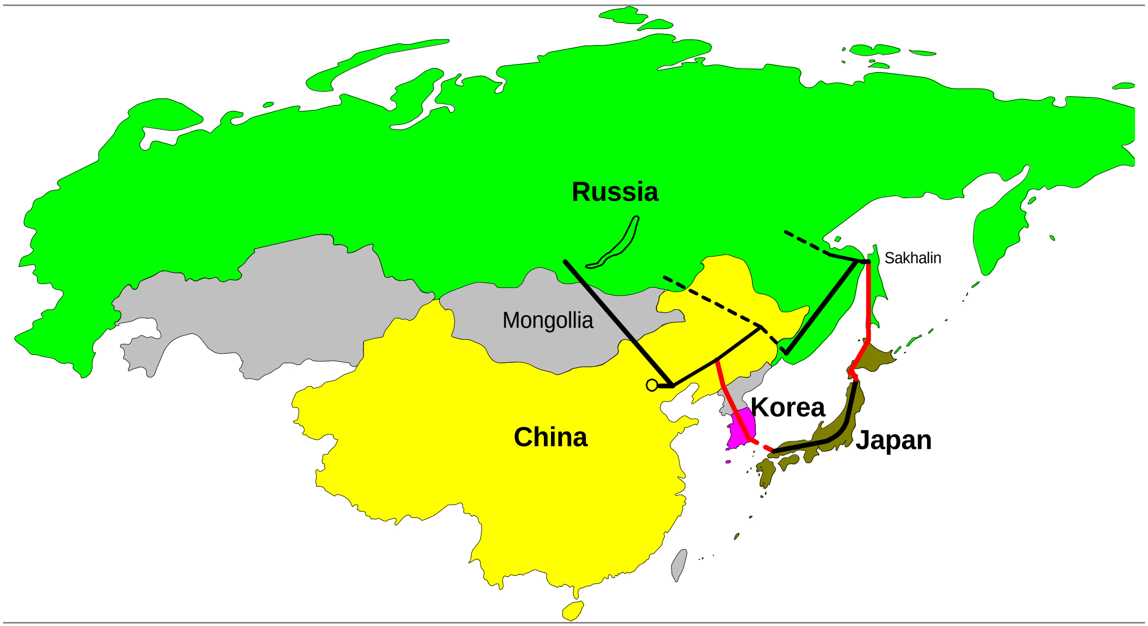
Considering the vast territories of Northeast Asia, a future ring of integrated power grid (system) in the region through cross border interconnections would be potentially formed along the following major routes:

- East Siberia of Russia to China through Mongolia;
- China to DPRK and Then to Republic of Korea (and Japan); and
- Far East of Russia to Japan.

There is a significant interest for installation of power interconnection between UES Siberia and UES of Far East (its power deficient part – Maritime ES) through the Northeast China, which is 1,400 km shorter than the route along Russian-Chinese border.

Moreover, a long-term prospect looks forward to a possibility of conveying a large amount of solar power generated in Western China's Gobi desert to the East through this interconnection system (Arakawa and Kato, 1998 and Suzuki, 1998).

Figure 25 Potential Power Grid Interconnections in Northeast Asia



SOUTHEAST ASIA

CURRENT SITUATION

In considering the potential for interconnection of the power grids in Southeast Asia, the non-APEC economies in the region, particularly those in the ASEAN namely, Cambodia, Lao PDR and Myanmar, should be included.

As discussed in the chapter 5 (Section "Southeast Asia"), a part of Southeast Asian APEC member economies have, at a certain level, integrated their power networks through existing interconnection links. However, more extensive integration of power supply network in Southeast Asia must be implemented in the near future.

Meanwhile, the Great Mekong Sub-regional (GMS) power interconnection proposal is also promoted by the Asian Development Bank (ADB) and the World Bank (WB). This chapter will provide related information and make an analysis on the two proposals.

ENERGY RESOURCES

With the exception of Singapore, which has no indigenous energy resources, ASEAN economic region is blessed with energy resources from fossil fuels to hydropower. Coal is found in Indonesia, Thailand, Philippines, Lao PDR, Viet Nam and small amount in Malaysia and Myanmar.

Oil and gas are abundant in some economies such as Indonesia, Brunei, Malaysia and Viet Nam. Indonesia, Brunei and Malaysia are the major producers of gas. Myanmar, Philippines and Viet Nam have gas reserves that are intended to be exploited for electricity generation.

Significant exploitable hydropower reserves are found in most ASEAN economies such as Indonesia, Malaysia, Viet Nam, Myanmar and Lao PDR. Lao PDR would like to exploit its hydropower resources as a source of revenue by exporting power to neighbouring economies such as Thailand, Myanmar and Viet Nam. Malaysia also plans to exploit its hydropower potential in Bakun, Sarawak to meet future electricity demand.

New and renewable energy (NRE) offers a valuable source for electricity generation but its exploitation has no significant progress beyond a few pilot projects due to the high technology costs compared to other energy sources.

COAL

Most coal reserves in the region are classified as a low rank coal, lignite accounts for 74.6 per cent while bituminous and sub-bituminous account for 3.5 per cent and 21.9 per cent, respectively. The biggest coal reserve is located in Indonesia. Thailand, Philippines and Viet Nam also have significant amount of coal reserves. Although the potential of coal reserves in Cambodia is not known, it is estimated to be very small (based on the geology of the region). The proven recoverable reserve of coal is shown in Table 16.

Table 16 Proven Recoverable Reserves of Coal in Southeast Asia
1996, Million tonnes

	Bituminous	Sub-bituminous	Lignite
Brunei Darussalam	-	-	-
Cambodia	-	-	-
Indonesia	770	1390	3060
Lao PDR*	56	-	170
Malaysia	4	-	-
Myanmar	2	-	-
Philippines	24	187	88
Singapore	-	-	-
Thailand	-	-	2000
Viet Nam	150	-	-

Source: WEC, (1998)

Focusing on the indigenous resource dimension of the fuel diversity for electricity generation, the locations of coal reserves appear to be widely distributed to offer an appropriate level of fuel diversity. Taking into account that most of coal reserves in the region are low rank coal, mine-mouth power generation is considered as the most economic choice for generating electricity. However, appropriate measures should be considered in order to limit the impact of coal utilisation into the environment such as emission of CO_2, NO_x, SO_x and particulates.

OIL

Oil is known as the most flexible fuel for electricity generation for a century. It is found abundant in the ASEAN region. Brunei, Indonesia and Malaysia are three major economies having large oil reserves in the region. These economies are oil exporters. Table 17 shows the proven recoverable reserves of oil and natural gas liquid in the ASEAN economic region. A considerable amount of oil reserve is also found in Viet Nam and the Philippines. All domestic production of oil in Viet Nam is for export while in Philippines, production is not sufficient for its own domestic demand.

Table 17 Proven Recoverable Reserves of Oil and Natural Gas Liquids in Southeast Asia
1996, Million tonnes

	Crude oil and Natural Gas Liquids
Brunei Darussalam	184
Cambodia	-
Indonesia	677
Lao PDR	-
Malaysia	526
Myanmar	7
Philippines	28
Singapore	-
Thailand	28
Viet Nam	82

Source: WEC, (1998)

Since oil basins are in diverse locations and sizes, the ASEAN economies will be able to maintain geographic diversity of oil. Oil will continue to be consumed in the electricity sector due to this factor. Moreover oil is easily transportable fuel and there are no serious transportation constraints under the current condition. However, a special measure should be taken into consideration for traffic congestion in the Straits of Malacca.

NATURAL GAS

Natural gas is generally the fuel of choice for generating electricity due to its highly favourable economic factor, brought about mainly by highly efficient CCGT technology that utilises natural gas as fuel. It is also considered a clean fuel as far as environmental impact is concerned.

Table 18 shows the proven recoverable reserves of natural gas in the ASEAN region. Brunei, Indonesia and Malaysia, which are rich in oil resources, also have major natural gas reserves. A small amount of natural gas reserves are also located in some economies of ASEAN namely: Philippines, Thailand and Viet Nam.

Table 18 Proven Recoverable Reserves of Natural Gas in Southeast Asia
1996, Billion cubic meters

	Billion cubic metres
Brunei Darussalam	399
Cambodia	-
Indonesia	2046
Lao PDR	-
Malaysia	2271
Myanmar	311
Philippines	80
Singapore	-
Thailand	188
Viet Nam	142

Source: WEC, (1998)

HYDROPOWER RESOURCES

Hydropower resources are available in many economies in the region such as Indonesia, Malaysia, Viet Nam, Myanmar and Lao PDR. Hydropower represents a major resource of electricity generation in Lao PDR and there are plans to export electricity generated by hydropower to neighbouring economies such as Thailand. Malaysia also plans to exploit its hydropower potential in Bakun, Sarawak to meet future electricity demand in Malaysia. Table 19 shows the hydropower resources in the ASEAN economic region.

Table 19 Hydropower Resources in Southeast Asia
1996, TWh/ year

	Gross Theoretical Capability	Technical exploitable capability	Economically Exploitable Capability
Brunei Darussalam	-	-	-
Cambodia	83	83	
Indonesia	2147	402	40
Lao PDR	232	63	42
Malaysia	230	72	
Myanmar	366	130	-
Philippines	47	20	18
Singapore	-	-	-
Thailand	56	19	18
Viet Nam	300	90	-

Source: WEC, (1998)

Unlike other fuels, the only way to exploit hydropower resources is through electricity generation on site and transmission of electricity to load centres. Several studies have been conducted in order to exploit hydropower particularly in the Greater Mekong Sub-region (GMS), which includes Myanmar, Lao PDR, Thailand, Viet Nam and Yunnan province of China. The studies indicated that comprehensive development is still a long way to materialise. One potential source of conflict is cross-border water management where economies on the upstream side of the river may affect river conditions downstream by building hydropower projects in the parts of the river they control.

GEOTHERMAL RESOURCES

Geothermal is another resource that cannot be transported. Like hydropower, it can only be transmitted over the electricity grid. Currently, geothermal resources are located in Indonesia, Malaysia, Myanmar, Philippines, Thailand and Viet Nam.

The development of geothermal resources has not been significant except those in the Philippines, which had an installed capacity of more than 1900 MW, in 1999. Indonesia only has installed capacity of about 308 MW (less than 2 per cent of its total resource potential). A small geothermal plant of 300 kW is being harnessed out of 200 MW estimated potential in Thailand. There is no a substantial indication of geothermal development in Malaysia, Myanmar and Viet Nam although the government of these three economies have planned to investigate their resources for electricity generation.

Geothermal is a complex resource with economics driven by forces similar to those driving oil or other extracted resources. The risks inherent in exploration are substantial where many efforts lead to unproductive discoveries with low or nearly non-existent flow rate. A set of incentives through the government is required to stimulate the exploration of geothermal resources in the region.

NEW AND RENEWABLE ENERGY (NRE)

The potential for NRE (other than hydropower and geothermal) is under-utilised. Small-scale NRE systems are not good candidates for electricity generation. Generally, NRE resources are only economic when used in isolated rural areas and they can be deployed as a means of avoiding transmission and distribution investment. With the costs still relatively high there is a small possibility of its extensive utilisation in the near future.

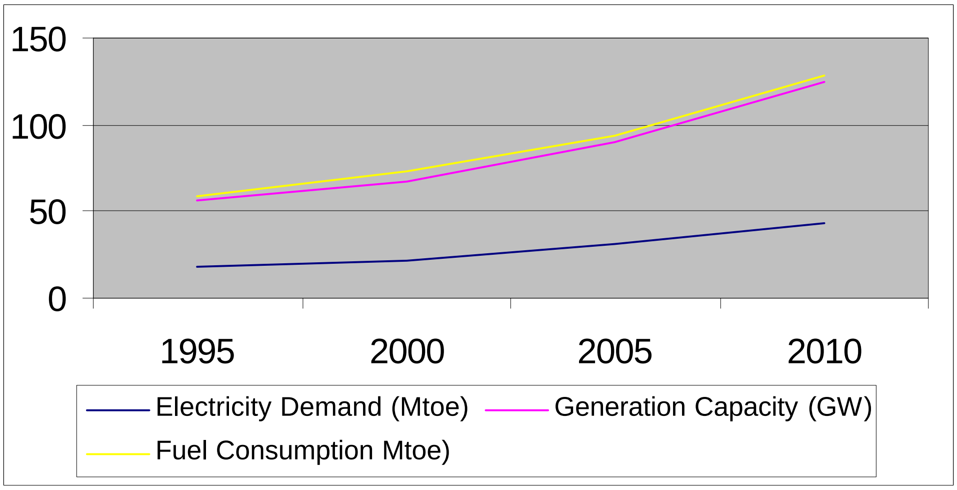
POWER INDUSTRY AND MARKET

Energy is essential to the ASEAN (Southeast Asian APEC and non-APEC) economic and social development and particularly critical to the region's industrialisation efforts. Even with the economic slowdown, electricity demand growth rate is projected to be more than 5 per cent annually over the period of 1995 – 2010 (APERC, 1998).

The total electric power generating capacity in ASEAN of 56 GW (1995) is the third largest in Asia behind China, and Japan. With the abundance of rich energy resources like oil, gas, hydro, coal and the special emphasis on renewable energy technologies, power development gained leading prominence in the overall growth of the ASEAN energy sector, and has become the flagship programme for ASEAN energy cooperation.

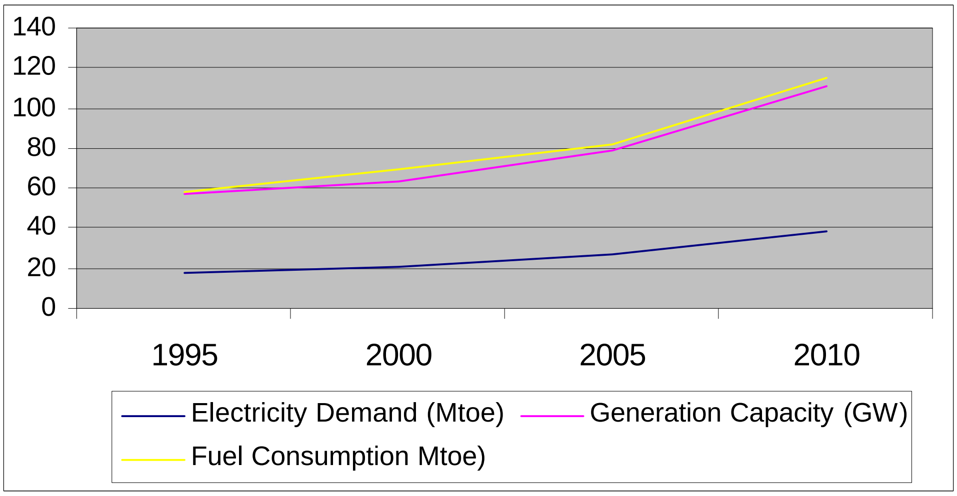
As analysed in chapter 4, Southeast Asia as sub-group of APEC is expected to have very high growth potential in electricity demand. Market expansion and capacity build up of electricity supply including the generation, transmission and distribution would be expected.

Figure 26 Electricity Projection of Southeast Asia – Baseline Scenario
Based on APERC Baseline '98 (B98)



Note: In the projection, Southeast Asia includes 6 APEC member economies, Viet Nam was not included since it joined APEC later.
Source: APERC, (1998)

Figure 27 Electricity Demand Projection of Southeast Asia
Based on APERC Protracted Crisis Scenario (PCS)



Note: In the projection, Southeast Asia includes 6 APEC member economies, Viet Nam was not included since it joined APEC later.
Source: APERC, (1998)

Figure 26 and Figure 27 display the rapid growth trends of electricity sector in the Southeast Asia for both B98 and PCS scenarios.

Moreover, power sector reforms (such as, privatisation, deregulation and/or restructuring of the electric supply industry) and the conducive policy environment for the domestic and private investment in power generation and supply (such as IPPs and BOOTs/ BOOs) are in place in some member economies. This could generate the much-needed capital requirement for power infrastructure build-up.

One plausible strategy under the ASEAN vision 2020 is the realisation of the energy interconnection infrastructures for the Trans-ASEAN energy network consisting of the ASEAN Power Grid and the Trans-ASEAN Gas Pipeline Projects, which will require business synergy between and among the private sectors in ASEAN.

STATUS OF THE ASEAN POWER GRID PROJECTS

There are presently 14 interconnection projects being identified in the ASEAN region and only three are already operational, such as, Thailand-Lao PDR, Peninsular Malaysia-Thailand Stage 1 and Peninsular Malaysia-Singapore (as discussed in chapter 2). Peninsular Malaysia-Thailand Stage II involving HVDC interconnection is being implemented, but target completion date is deferred to the year 2001. The interconnection project for the Sarawak-Peninsular Malaysia HVDC (under the Bakun Hydro Electric Project) has been deferred indefinitely, due to the current economic slowdown. The ASEAN power interconnection projects are presented in Figure 28.

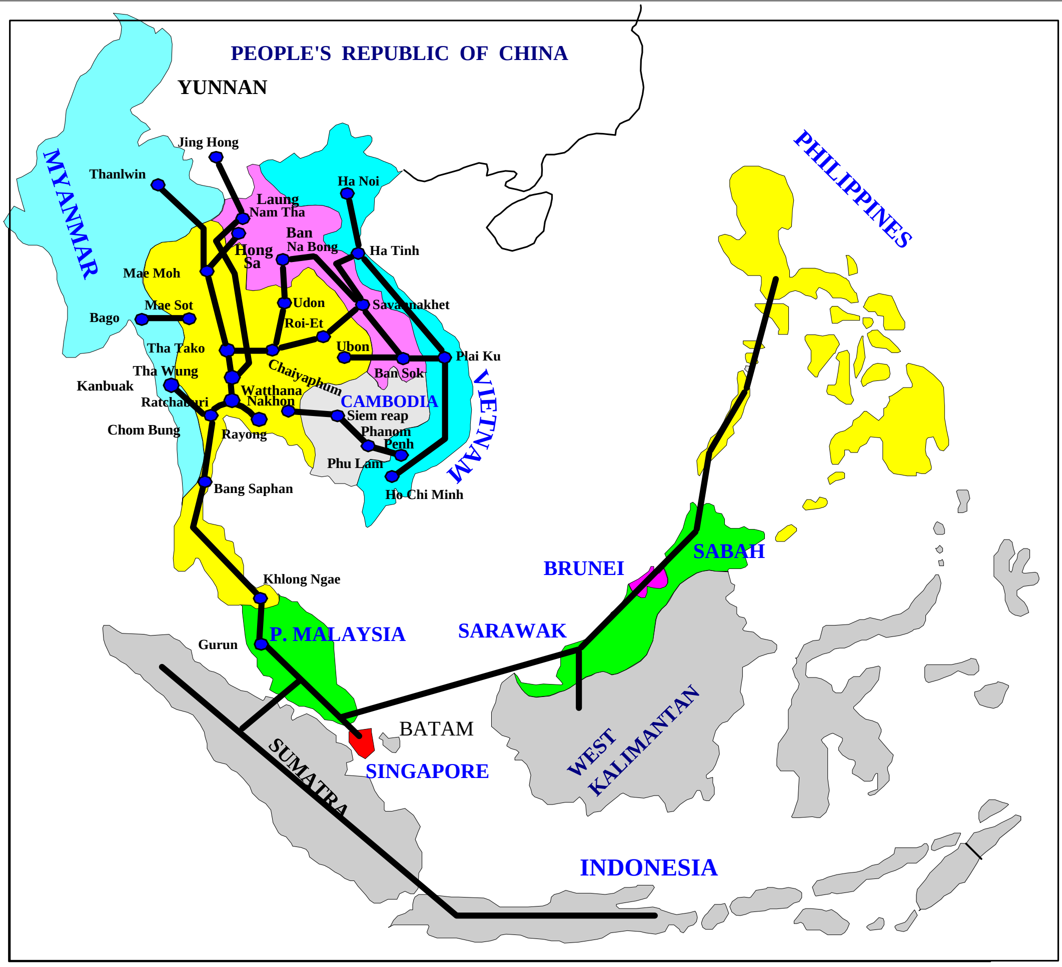
Apart from the interconnections between Thailand-Lao PDR, Peninsular Malaysia-Thailand and Peninsular Malaysia-Singapore, the implementation of other ASEAN power interconnection projects have been delayed due to financing constraints and the presently unfavourable economics of some of the projects which require the construction of transmission lines over long distances. This became worse by the slowdown in the load demand of some utilities in the region. The status of the projects is presented in Table 20.

Table 20 Status of Interconnection Projects in Southeast Asia

	Projects	Status
1	Peninsula Malaysia – Singapore	Operating synchronously since 1985 under zero electricity exchange Improve system resilience due to larger combined size and short time transfer during emergency
2	Peninsula Malaysia – Thailand	
	Bukit Keteri – Sadao	In operation since 1981 with power transfer capability up to 80 MW
	Gurun – Khlong Ngae (HVDC)	Project in progress and targeted for completion in 2000
3	Sarawak – Peninsula Malaysia (submarine cable HVDC 500Kv and HVAC 275 kV)	This project originally planned to transmit to Peninsula Malaysia 2100 MW of electricity from a 2400 MW Bakun hydropower project in East Malaysia. However the Bakun project has been scaled down for domestic consumption due to financial crisis that hit ASEAN region recently and the interconnection project has been deferred indefinitely
4	Sumatra, Indonesia – Peninsula Malaysia (submarine cable)	Project aimed for bi-directional electricity flow. MOU has been signed by both parties for the development of a mine power plant in Sumatra, Indonesia Funding is the constraint for project implementation (private participation as an alternative)
5	Batam, Indonesia – Bintan, Indonesia – Singapore – Johore, Malaysia	Seeking sponsors for financing the study
6	Sarawak, Malaysia – West Kalimantan, Indonesia (150 kV, 250 MW overhead line)	Implementation being prepared with options for the private participation
7	Sabah, Malaysia – Philippines	Seeking sponsors for financing the study
8	Sarawak, Malaysia – Brunei – Sabah Malaysia (275 kV overhead line)	Pre-feasibility study completed and seeking sponsors for financing the feasibility study
9	Thailand – Lao PDR	
	Nam Ngum Dam	In operation since 1972. Currently, the generating capacity is around 150MW and about half of the power generated is exported to Thailand.
	Xe Set Hydro power	In operation since 1991 with the capacity of 45 MW. Most of the power generated are exported to Thailand.
	Hongsa – Mae Moh	No progress has been reported.
	Ban Na Bong – Udon Thani	Discussed in details in the section “GMS Interconnections”
	Savannakhet – Roi Et	
	Boloven – Ubol Ratchathani	
10	Viet Nam – Lao PDR	Possibility of inclusion of interconnection between Thailand – Myanmar, Thailand – South China, Viet Nam – Cambodia
	Central Viet Nam – Central Lao PDR	
	Central Viet Nam – Sauthern Lao PDR	Discussed in details in the section “GMS Interconnections”
11	Thailand – Myanmar	New project – details of the project will be studied by the relevant power authorities/ utilities Discussed in details in the section “GMS Interconnections”
12	Viet Nam – Cambodia	New project – details of the project will be studied by the relevant power authorities/ utilities Discussed in details in the section “GMS Interconnections”
13	Lao PDR – Cambodia	New project – details of the project will be studied by the relevant power authorities/ utilities
14	Thailand - Cambodia	New project – details of the project will be studied by the relevant power authorities/ utilities

Sources: Biyaem, *et al* (1998)
Chonglertvanichkul, P., (2000)
Jaafar, Z., (1999)

Figure 28 Southeast Asia Power Interconnection Projects



Source: Chonglertvanichkul, P., (2000b)

GMS INTERCONNECTIONS

The Great Mekong Sub-Region (GMS) – Cambodia, Lao People's Democratic Republic (PDR), the Yunnan Province of China, Myanmar, Viet Nam and Thailand has significant potential for cross-border power trade. The power networks of these economies are almost independent. The economy of this region is very diverse and the electricity demand growth is high. According to the recent study by World Bank on "Power Trade Strategy for the Greater Mekong Sub-Region" (World Bank, 1999), under the base case scenario the power demand of GMS will grow from 131 TWh (21 GW) in 1997 to 597 TWh (92 GW) by the year 2020 with annual average growth at 6.8 per cent.

The sub-region is well endowed with low-cost hydro resources, such as those in Lao PDR, Myanmar, and Yunnan Province of China. Amongst GMS economies, Thailand has the largest increase in electricity consumption accounting for more than 65 per cent of the GMS total demand (411 TWh) by the year 2020.

Table 21 shows a total exploitable hydroelectric energy estimated at 837 TWh, of which only 21 TWh (3 per cent) of the total hydroelectric energy in GMS has been exploited.

Table 21 Natural Energy Resources Potential in GMS

	Crude Oil (Billion bbls.)	Natural Gas (Tcf)	Coal (Billion ton)	Hydropower* (GW)	Hydropower* (TWh)
Thailand	0.6	14	2.3	10	49
Viet Nam	2.3	12.7	3.5	15	70**
Myanmar	1.4	7.4	0.3	25	125**
Cambodia	Na.	Na.	Na.	8	41
Lao PDR	0	0	0.9	20	102
Yunnan	Na.	Na.	23.5	90	450
Total	**4.3**	**34.1**	**30.5**	**168**	**837**

Notes Exploitable capacity and generation; APERC estimates

Sources: ASEAN – EC Energy Management Training and Research Centre (AEEMTRC), World Bank and Institute of Energy, Viet Nam (IE-Viet Nam)

HISTORICAL BACKGROUND.

Since 1970s, the six GMS member economies began deliberating ways of coordinating electricity infrastructure investment and various social and economic activities to strengthen their competitive position and growth prospects.

The first agreement was the power purchase between Lao PDR and Thailand when the Nam Ngum 1 hydropower plant in Lao PDR with 150 MW of installed capacity was completed in 1971.

In 1990, the Thai Government appointed Thailand-Myanmar Border Hydroelectric Project Committee that has been responsible for the coordination with the Myanmar Government in the development of hydroelectric projects. Thailand and Myanmar formally signed a memorandum of understanding (MOU) in 1997 for Thailand to buy power from Myanmar by year 2010 and in the following year, a series of hydroelectric projects were considered for electricity sales to Thailand with the total 4460 MW of the installed capacity.

In June 1993, the Thai Government and the Lao PDR Government signed an MOU agreeing upon the development of power projects in Lao PDR to export 1500 MW – 3000 MW power capacity to Thailand in the period 2000-2006 through 230 kV and 500 kV transmission line (subject to the receiving points).

In 1993, the Yunnan Provincial Electric Power Cooperation (YPEPC) of China and The Electricity Generating Authority of Thailand (EGAT) discussed in a meeting the development of hydroelectric projects in Yunnan and the planned sale of electricity to Thailand (Biyaem, 1998). Two hydropower projects, Jinghong and Mensong were suggested to be studied for power export to Thailand through interconnection across Lao PDR. Under the development plan, about 1200 MW of power with 5700 GWh would be exported to Thailand by 2005 for the first stage.

In 1998, Viet Nam and Lao PDR Government signed an MOU to supply 2000 MW of power from hydropower plants in Lao PDR to Viet Nam by 2010.

In 1999, an MOU was signed by Vietnamese and Cambodian governments to supply power from Viet Nam to Cambodia through 230 kV transmission line.

In general, it appears that the Greater Mekong Sub-region member economies are increasing their power trade. Also, they are supported by regional and multilateral agencies in their integration efforts.

PROSPECT OF GMS POWER NETWORK

Thailand-Lao PDR Interconnection: The first three GMS regional power interconnection projects in operation were Nam Ngum1-EGAT, Xeset-EGAT and Nam Theun Hin Boun –Sakon Nakhon, which supplied electricity to Thailand with the total export capacity about 380 MW through 115 kV and 230 kV transmission lines. (Please also refer to Chapter 3)

In addition, two other transmission lines under construction are Nam Leuk-EGAT (115Kv) and Houay Ho-Ubon Ratchathani, Thailand (230 kV) with the total 126 MW from Houay Ho hydroelectric power.

The 500 kV transmission links would be designed to receive electricity from power plants in Nam Theun Basin and in southern Lao PDR (Roi Et-Savanakhet) and from hydroelectric plants, Nam Ngum 2, Nam Ngum3 and others in the northern Lao PDR (Udon Thani-Ban Na Bong (Longsan)), as well as from Hong Sa thermal power plant (Mae Moh-Hong Sa).

Viet Nam-Lao PDR Interconnection: The main connection between Viet Nam and Lao PDR would be two 500 kV transmission lines in Nam Theun (central Lao PDR) - Hatinh (central VN) and Ban Soc (southern Lao PDR) – Playcu (central Viet Nam).

Viet Nam-Cambodia Interconnection: In the medium-term, 115 kV and 230 kV transmission lines from the south of Viet Nam would connect these two economies.

Viet Nam-China Interconnection: A 500 kV transmission line would be connected from Sonla (northern Viet Nam) hydropower plant to the south-eastern Yunnan beyond 2010.

Yunnan (China)-Thailand Interconnection: 1,200 MW power out of Jinghong hydroelectric plant's 1,500 MW would be transmitted by a 500 kV line via northern Lao PDR (Luong Nam Tha) and probably connected to the 500 kV substation at Tha Wung near Bangkok.

Thailand-Myanmar Interconnection: Depending on the power exported from hydropower plants in Myanmar, 230 kV or 500 kV lines will be built toward Northern Thailand.

In summary, the 500 kV transmission lines from Myanmar, Lao PDR and Yunnan hydroelectric resources to Thailand and Viet Nam would form a GMS power network, namely:

- South-eastern Yunnan to northern Viet Nam and central Viet Nam via central Lao PDR to north-eastern Thailand;
- Yunnan through northern Lao PDR to Thailand; and
- Myanmar to north-western Thailand (Chieng Mai area)

APEC MEMBER ECONOMIES IN SOUTH AMERICA

CURRENT SITUATION

Power interconnection among South American economies is an on-going process (Ayala, 1999; de Paula, 1998)[2]. Many factors have favoured this integration, such as:

- Different hydrological conditions;
- Imbalance between energy resources and demand;
- Different time zones;
- Binational and subregional integration agreements (see Ayala, 1999); and
- Reform of the power sector, a process already undertaken or underway in most of the continent.

Historically, power integration in the Region has materialised in binational hydropower generation plants and numerous power lines, which responded - to a greater extent - to the first four factors mentioned.

As Figure 29 shows, some of the more active economies in this respect have been Argentina, Brazil, Paraguay and Uruguay, which currently are members of the Common Market of the South (MERCOSUR).

Chile and Peru, the two South American APEC economies, have not shown the same dynamism. Despite the existence of numerous interconnection projects, currently only one has materialised, between Chile and Argentina. This interconnection - completed in 1999 - corresponds to a 345 kV line between two natural gas combined-cycle plants in Salta, Argentina (632.7 MW total capacity) and the Atacama substation of the Interconnected System of the Great North (SING), in northern Chile.

Even though interconnections between Chile and Peru are not foreseeable in the near future, this situation may change in the long term as a result of numerous initiatives, some of which are discussed in this chapter.

[2] The main sources of information used are Ayala (1999) and de Paula (1998).

Figure 29 Existing and Projected Power Interconnections in South America

Note: The location of lines is not necessarily geographically accurate.
Sources: Ayala (1999), de Paula (1998) and Moraga (1999).

ENERGY RESOURCES AND DEVELOPMENT OF THE POWER INDUSTRY

Both Chile and Peru have important energy resources in place.

Table 22 Natural Energy Resources in Chile and Peru

	Coal (Mt)	Oil (Mt)	Natural Gas (Bcm)	Hydropower (TWh/y)
Chile	1,181	41	110	132
Peru	1,060	109	200	1,091

Source: WEC, (1995)

Table 23 Energy Production and Consumption in Chile and Peru

	Coal (Mt)		Oil (Mt)		Natural Gas (Bcm)		Hydropower (TWh/y)	
	Prod.	**Cons.**	**Prod.**	**Cons.**	**Prod.**	**Cons.**	**Prod.**	**Cons.**
Chile	0.7	3.8	0.8	10.8	2.5	2.5	19	19
Peru	0.015	0.3	5.9	7.9	0.5	0.5	13.2	13.2

Source: APEC Database < http://www.ieej.or.jp/apec/database>

However, long distances between the location of these resources and the demand centres, market conditions for their exploitation, variable hydrological conditions, environmental restrictions and/or opposition and other factors reduce the actual exploitable resources significantly.

This is especially the case of hydro resources, which represent a considerable percentage of the generation in both economies. Hydrological conditions are inherently variable, causing severe disruptions in the generation systems during droughts. Furthermore, in Chile for example, the main unexploited hydro resources are located in the South, thousands of kilometres from demand centres; desert conditions prevail in the North and most of the centre.

Fossil fuel resources are also unevenly distributed. In the case of northern Chile, no resources have been found.

In Peru, coal reserves are significant in relation to its current production level. However, the lack of adequate transport infrastructure to consumption centres has been a major obstacle (de Paula, 1998).

Gas reserves in Peru are also important. The Camisea gas field, with proven reserves of between 109-183 bcm and located in the South has attracted considerable interest. However different circumstances have prevented its development.

CHILE

Chile's installed capacity by the end of 1999 was 9,183 MW, of which hydroelectric plants represented nearly 43 per cent and thermal plants the remaining 57 per cent (CNE, 2000)[3]. This is a reversal of the historic trend where traditionally hydroelectricity accounted for most of the capacity and generation. The main driver behind this reversal has been the introduction of natural gas from Argentina, which has permitted the construction of numerous combined cycle plants.

Chile has two main grids, which are not interconnected: the Central Interconnected System (SIC) -with approximately 73 per cent of the installed capacity and supplying the majority of the population- and the Interconnected System of the Great North (SING). Additional isolated grids are Aysen and Magallanes, which account for a low percentage of the installed capacity and the demand.

Chile's North, served by the SING, has an oversupply condition due to the construction of natural-gas fired combined cycle plants supplied by two competing natural gas pipelines from Argentina, together with a competing power transmission line, also from Argentina. Electricity demand has risen sharply in the last 6 years –almost 2.7 times, or almost 28 per cent *per annum*– mainly due to the increase in copper production. However, it is expected to slow down

[3] The figures for installed capacity and generation mix correspond to the two major interconnected systems, SIC and SING, which account for over 99% of the installed capacity, and do not include autoproducers. The total installed capacity is 9,887 MW.

considerably due to the comparatively slow increase in copper production forecasted for the next decade (Sanchez Albavera *et al*, 1999).

Chile's power industry was restructured in 1982. Its main characteristics are competition in generation, a coordinating dispatch entity, open access to transmission lines, regulated retail prices and the existence of contestable consumers (APERC, 2000).

Currently, a regulatory framework for cross-border power interconnections is being discussed, which will complement the treaties and agreements that Chile has signed with its neighbours (Chilean National Energy Commission, 2000).

PERU

As of 1998, Peru's installed generation capacity was 5,513.6 MW. Nearly 47 per cent of this capacity consists of hydroelectric plants. However, hydropower accounted for 74 per cent of the generation, given unusually favourable hydrological conditions produced by the El Niño phenomenon's southern oscillation. Thermal generation is based on coal, diesel, fuel oil and natural gas. There is a negligible percentage of wind power generation in isolated regions (MEM, 1999; Campodonico, 1998).

The electricity sector was restructured in 1992, adapting the Chilean model.

Until 1999, Peru had two non-interconnected systems, the Centro-Norte Interconnected System (SICN) –with 66 per cent of the installed capacity and 74 per cent of the generation– and the Sur Interconnected System (SIS) –with 14 per cent of the installed capacity and of the generation (EMM, 1999); isolated systems accounted for 20 per cent of the installed generating capacity and 12 per cent of the generation. Both demand and power generation capacity had considerable growth rates in recent years (average annual growth rates for the period 1995-1998 have been 7.3 per cent and 6.9 per cent, respectively) (APEC database). According to the Electricity Tariff Commission, the power reserve margin in 1998 was 45 per cent. For that year, the Minister of Energy and Mines estimated the excess capacity to be in the order of 1,500 MW, sufficient to cover demand growth for 6 or 7 years if it grows at 5 to 6 per cent per annum. In an earlier study undertaken by the same Ministry ("Plan Referencial de Energía 1997", cited in Campodonico, 1998), the projections for the period 2000-2013 indicate annual deficits in capacity of 41 MW starting in 2002 and 147 MW starting in 2004, for the low scenario, and deficits of 354 MW in 2001 and 263 MW from 2002 onwards in the high scenario (Campodonico, 1998)[4]. However, these deficits may be amply offset by capacity additions that were not considered in the projections of the 1997 Reference Plan. Thus, in the medium term an over capacity condition is likely to continue. Currently, legislation does not mention cross-border power interconnections (Ayala, 1999).

INTERCONNECTION POTENTIAL

Power interconnections in South America must be put in the broader context of economic integration agreements, notably the Common Market of the South (Mercosur), formed by Argentina, Brazil, Paraguay and Uruguay, with Bolivia and Chile as associated members, in which energy integration is a significant element. This new scenario, together with reformed electricity sectors, will favour the transition to a regional wholesale market and possibly to a coordinated operation of an interconnected system.

4 Projections were made for the National Integrated System, since the Mantaro-Socabaya transmission line was expected to interconnect both systems by the end of 1999.

Figure 29 shows the projected power interconnections in South America. Projects are in various phases of development, thus their feasibility is not yet determined and their geographical locations are not accurate. For clarity, gas and oil pipelines are not included, even though they are significant elements in the energy integration process of the continent.

POTENTIAL INTERCONNECTIONS BETWEEN CHILE AND PERU

Several favourable conditions indicate that power interconnections between Chile and Peru could materialise, such as: a) the Energy Ministers of Chile and Peru signed the Memorandum of Understanding at the Latin American Energy Organization (OLADE) meeting held in Quito in November of 1995, to foster integration; b) Peru's South suffers from droughts, which affect its hydroelectric generation; c) currently Chile's Northern Interconnected System has an oversupply of electricity, as a product of natural gas pipelines that supply power plants and a power transmission line from Argentina; d) the similarity in the electricity regulatory frameworks of both economies; e) the future enactment of the legal framework that regulates power interconnections between Chile and its neighbours, clarifying the rules for potential investors which is currently under discussion, and f) the recent expansion of Chilean electricity companies into Peru, which could facilitate the materialisation of projects, even strictly from a business point of view.

However, to date, only two projects have been formulated, the first connecting Arica, in the North of Chile, with the nearby city of Tacna, in the South of Peru, and the second consisting of a hydroelectric project in Southern Peru, on the border with Bolivia and Chile (de Paula, 1998).

The first project saw its major impulse with the drought that Peru's South suffered in the beginning of the 90's, and merited the signing of a decree by the presidents of each economy. The project, developed by Emelari S.A. in Chile and Electrosur S.A. in Peru, envisioned the export of 10 MW through a 70 km transmission line to Peru. The possibility of increasing the power to 20 MW was envisaged, provided that excess capacity in the Chilean system would permit it. Likewise, flows from Peru to Chile were also considered, in the event that Peru's hydrological conditions resulted in power surpluses.

The major potential benefits of the project would have been a relief to Tacna's power shortages during droughts and a means of coping with unexpected increases in demand in both systems. However, interest in the project ceased together with the drought.

The second initiative considers a total installed capacity of 87 MW, generated in five hydroelectric plants in equal number of dams. According to the available information, the project is in the technical and economic studies phase.

However, as discussed previously the current oversupply of electricity in the South of Peru and the North of Chile could present a barrier to the interconnection of both economies, at least in the short or medium term.

Nevertheless, in the long term, the energy integration initiatives in South America could ultimately foster interconnections between both economies, forming part of a proposed continent-wide grid. Given this situation, some integration proposals with other South American economies are briefly outlined in the following section.

INTERCONNECTION PROJECTS BETWEEN PERU AND ITS NON-APEC NEIGHBOURS

Several lines have been envisaged between the provinces of El Oro and Loja in southern Ecuador and the provinces of Tumbes and Piura in northern Peru. For example, 1.5 and 5 MW could be transferred between Huaquillas in Ecuador and Aguas Verdes in Peru through a 13.8 kV line. A 69 kV line between Arenillas and Huaquillas would permit a transmission capacity of 20 MW to Tumbes in Peru. The district of Piura in Peru has a shortage of supply that could be satisfied through a 230 kV line from the province of El Oro in Ecuador. Even though these connections are technically feasible, according to the available information no specialised studies are underway (de Paula, 1998). Some authors have suggested that political factors, together with low electricity demands and over-optimistic electricity development plans have played against integration initiatives in the past (Vargas, 1993).

Negotiations with Bolivia have involved the purchase of energy to supply the provinces of Yunguyo and Chucuito. The first phase involved the extension of a transmission line from Copacabana, delivering 400 kW to Yunguyo and 100 kW to Desaguadero. The second phase considers the construction of three other lines in the frontier and a 69/25 kV substation in Bolivia. Technical and economic feasibility studies are underway.

No information is available with respect to interconnection projects with Colombia and Brazil.

INTERCONNECTION PROJECTS BETWEEN CHILE AND ITS NON-APEC NEIGHBOURS

The idea of interconnecting the power systems of Chile and Argentina dates back to 1967, and was proposed by the Regional Electricity Integration Committee (CIER). An Argentinean-Chilean committee was formed to elaborate the feasibility studies. The project considered a 220 kV line capable of transporting 200 MW between Mendoza, Argentina, and Santiago, Chile, crossing the Andes Mountains through an international tunnel. Energy exchanges would go in both directions. In spite of the forecasted benefits, numerous factors resulted in the cancellation of the project.

No information is available concerning transmission lines with Bolivia.

CHAPTER 7

POTENTIAL BARRIERS AND RELATED ISSUES

Although power interconnection provides a potential option to meet energy demand in an economic and environment friendly manner, several issues need to be addressed before interconnection projects could be justified. Any project or proposal for large interconnection could be promoted and implemented only when a number of potential barriers are removed even when the project's economic and technical viabilities are confirmed. This chapter gives an overview of the major potential barriers and related issues that affect the implementation of power interconnection projects.

INSTITUTIONAL BARRIERS

Implementation of potential power interconnection could be hindered with the absence of appropriate institutional arrangements.

Member economies in APEC region have their own regulatory frameworks, which could be different from each other. Most of APEC member economies are in the process of restructuring the power sector through deregulation and privatisation. The different regulatory frameworks and the desired transition processes result in market uncertainties or risks that could be too high for power suppliers especially those who supply power from outside the border through long distance lines.

MARKET ACCESS

As mentioned in chapter 3, power interconnection, being the bridge for energy trade across borders would require market access to facilitate trade. Currently, no APEC economy could claim that "free trade" of electricity exists in the existing interconnection links. Even in the case of the most open electricity market in North America, electricity trade (export and import) requires permits and approvals from federal regulatory and other government bodies. The "regulated electricity trade" could be a more realistic description than the "free trade" concept.

Specific regulatory arrangement needs to be settled for market access. The first is the general access of power brought by interconnection lines to the receiving system. Once an economy is going to push all power generators to a competitive market, power purchased by the network will be theoretically through an open bidding system in the pool market.

One issue that arises though is how the above-mentioned imported power could fare in the bidding system. Should a special arrangement, such as the traditional Power Purchase Agreement (PPA) be needed to provide a certain degree of certainty or guarantee for return on investment in order to facilitate the decision making on the project implementation? The open access of power dealers to the interconnected grid requires transparent and non-discriminatory regulation for establishing favourable cross-border electricity trade in a fairly competitive power market.

The traditional PPA was and is the usual way to encourage participation from outside of the local utility franchise and to provide a return guarantee to this participation in power market. However, in a more sophisticated deregulated power supply market, PPA may no longer be able to play the same role as in the past. This could be an issue that may adversely affect power interconnection initiatives.

ADMINISTRATIVE COOPERATION

The administrative system is also different from each APEC member economy. Governments could play very important roles to overcome difficulties in initiating and implementing the cross border projects. Effective coordination at high administrative level to form and operate cross border (joint) venture is essential for success. An appropriate bilateral or multilateral coordinating body is desired to carry out specific and detailed programme and study of power interconnection. Actually, such kind of coordinating body is missing.

Unlike the ASEAN power interconnection initiative, in many other cases, for example the GMS there is no general official agreement at the government level on the feasibility study, development planning and electricity trading among all economies being involved. Likewise, there is no regional master plan study on energy development and not all of GMS economies took into account this possible energy trade in their energy master plan studies.

OWNERSHIP AND OPERATION

To initiate any power interconnection proposal commercially, or to realise such long-term heavily invested cross-border projects, the structure of project management, ownership and relations among investors, operators and dispatchers required by laws or regulations for the power interconnection are very important in many instances. Lack of appropriate rules on these matters, which take care of mutual interests of the partners involved, and transparency of such rules will affect the confidence and capability of risk management of all potential developers of interconnection projects.

Many economies' authorities are hesitant to recognise the right of a private party to own transmission facilities, for example through BOO (Build-Own-Operate) or BOT (Build- Operate-Transfer). This recognition requires appropriate legal and regulatory framework to allow private ownership of transmission facilities.

TARIFF AND EXTERNAL COST

Certainly, one interconnection project between two power systems can be established only when it delivers a net positive economic value. For the interconnection planned mainly for security purposes, the net economic benefit should be the avoided social and economic cost of potential interruptions against the cost of construction and maintenance of this interconnected system.

For the interconnection planned mainly for energy exchange purposes, the economic benefit will come from the sales of energy and power (capacity) against the cost of investment and operation of the interconnection link and the cost of avoided investment in new generation capacity in the energy receiving system. Therefore, costs of power supplied by interconnection route compared to local supply needs to be analysed. However, to allocate properly the cost in order to promote environmental and social benefits, substantial efforts by concerned economies are needed.

An interconnection project could only be successfully carried out, implemented and operated when all parties involved gain mutual interests or benefits. Basically, the project should be first economically viable.

On the other hand, imported power should not get preferential treatment and should compete in the market of receiving system that is already deregulated. Large arguments remain whether and to what extent, the environmental and social benefits derived from the cleaner energy supply and avoided social contradictions, should be internalised to the price of electricity. The price of the imported electricity by interconnection could be paid at a higher premium if these external benefits are internalised. However, in a market where electricity moving on the grid could not be identified by its source or origin, this higher price would result in a low marketing competitiveness unless the electricity costs of all sources have embedded environmental and social costs.

In fact, the interconnections such as the Russian proposals to other Northeast Asian economies would probably fall on the applications of above-mentioned prerequisite on environmental and social costs.

Meanwhile, the other cases may survive economically just in the existing power market. The existing interconnections in North America, Southeast Asia, and some of the future projects such as Irkutsk to North China and some new proposals in Southeast Asia would probably have no problem in economic competitiveness.

Tariff is a core issue for a new project. The average generation cost and the level of power prices in the receiving market would be the benchmark for imported power. Competition among suppliers in power market will become stronger along with the introduction of bidding mechanism. However, when electricity tariff does not include externality costs such as environmental costs associated with generation and transmission, the competition could be distorted.

FINANCIAL AVAILABILITY

The financial issue is essential for the power interconnection projects. Massive capital investment will be required for the development of regional power interconnection network and the recent economic crisis is not likely to generate sufficient internal fund for investment in electricity sector particularly in the developing APEC economies. The investment requirement for such long-term and capital-intensive projects is still difficult to be met.

The financial crisis that hit a number of Asian economies has provided a shocking experience to these economies. In general the economic crisis had resulted in the following impacts on power sector:

- Increased operational costs primarily through higher fuel and spare parts costs;
- Higher financing charges on foreign loans due to the depreciated local currencies and also an increase in the servicing of interest rates;
- Higher capital expenditures for new projects and those still in progress;
- Restricted access to foreign loans as the economy's creditworthiness rating has been downgraded while funding spread has widened; and
- Lower revenue growth and lower electricity demand as the economy contracts.

Although some interconnection projects are technically and economically feasible, financing turns out to be a formidable constraint to the projects. To ASEAN, for example, ways should be found, as the economic benefits of interconnection will never be matched by the existing individual systems of the member economies.

DEVELOPMENT PRIORITY AND SUPPLY SECURITY CONCERNS

Priority of each economy is considered first in any development plan, domestic or regional in nature.

One has to acknowledge that no economy will want to face the extra financial burden as a proponent in a regional infrastructure project if the project will not benefit its own economy. In electricity trading, if power can be wheeled from source A to D, passing through geographical boundaries B and C, then all four parties should join efforts in making the trading works. The first step is for each economy to recognise and endorse international trading in electricity to be an integral part of their development, economic or energy policies to strengthen the electricity sector.

The net benefits from import - net gain from trade minus foregone benefits from domestic production – must be carefully examined.

When the supply security is concerned, contradictory implications could derive from the power interconnections. One is that power interconnection could be a means to enhance the energy supply security to the receiving system through the new form of power supply diversifying energy sources if it is designed for energy exchange.

The second is the concern related to the dependence on imported power and the possible supply disruption. Actually, the existing power interconnections in APEC region do not bring significant impact of high import dependency on power supply to interconnected power systems. It is not likely to pose a real problem in APEC region if all parties appreciate the mutual benefits of interconnection.

However, in a technical point of view, a well integrated power supply, where all power plants operate under a “primary control assistant”, with each utility providing participating spinning reserves, would require inherently a minimal but necessary loss of freedom (Montfort, 1991). These could be offset however, by the overall benefits to be gained from “pool” operation. While a less integrated interconnected system, linked through a fewer energy transmission ties, would not have to be so highly dependent or less free on operation.

POLITICAL UNCERTAINTY

This is a key issue for trans-border power interconnections. As described in last section, power interconnection requires regional mutual dependence on energy supply to a certain extent. The perception on political uncertainty will affect the confidence of investors. The establishment of a regional interconnection project would be difficult to be realised or might be troubled if the political situation in related economy/(ies) is not stable or the relation among them is expected to be unstable. In the APEC region, this concern is still a major factor to contend with in some cases. On the other hand, the growing interdependence may limit the impact of political uncertainty.

TECHNICAL SUPPORT AND EXPERTISE ACQUISITION

This is essential to the systems or the economies, which do not have much experience on managing high-tech equipment and control software of advanced transmission or networking technologies. The lack of such technology and expertise would be a potential barrier.

CHAPTER 8

CONCLUSIONS AND POLICY ISSUES IDENTIFIED

As discussed in the previous chapters, power interconnection in the APEC region could offer many potential advantages in the future. However, promoting the potential interconnection projects is still challenging. A number of power interconnection proposals are discussed or under study but significant progress in project establishment and engineering will likely take a longer time as many experts believe.

CONCLUSIONS

Despite the recent Asian financial crisis, which slowed down the pace of regional economic development and led to an energy demand decline or stagnation, energy demand growth in the APEC region in the longer term is expected to again increase significantly. In the course of 1999, some Asian economies in APEC declared recovery from the financial crisis. Energy demand in most of the APEC member economies is again increasing.

The electricity demand is expected to grow faster than rest of total primary energy. Progress and improvement in electrification in member economies result in this higher growth of electricity demand, particularly in developing economies. However, the development of power sector in some economies are constrained by the environmental and social conflicts, which make securing sites for new power generation projects limited and costly.

Technological development has given the power supply industry more flexibility to serve its consumers. The HVAC, HVDC, Hybrid AC/DC and FACTS technologies are either widely used or in fast progress. These technologies provide technical and economic feasibility for power grid interconnection projects.

Power interconnection could be motivated by three major factors: supply security, economic efficiency and environmental satisfaction, and then can be classified as for system security-oriented and energy exchange-oriented or hybrid of both. The former is especially desired by small power systems or small sized economies whose power systems are generally weak. The latter is considered as a means of clean energy supply with economic advantages. Power grid interconnection could offer extra supply in an emergency as well as expand a potential supply of power resource. The nature of power supply industry encourages the combination of individual power system to achieve economies of scale to a certain extent. Market mechanism may better work in a power market (system) where freer energy trade with competition through interconnection is allowed. In a wide regionally integrated power system with interconnection, seasonal and daily peak load shaving could provide additional attractiveness. In APEC, specifically, interconnection can significantly promote the development of abundant hydropower resources in the region and help to ease environmental pressure and improve air quality.

The APEC region has several interconnection systems creating integrated grids in North America, South America and Southeast Asia. Experiences from these existing interconnections show a wide range of benefits including sharing of supply sources or reserves, lower cost power sources and enhanced system security. Likewise, the Australian Inter-state interconnection initiative intends to advance power market restructuring which was facilitated by power grid interconnection.

With recognition of the potential advantages and benefits, there are a number of power interconnection proposals and studies by initiatives from governments of APEC member economies. In Northeast Asia, China and Russia are discussing potential interconnection projects while the Korean government is seriously pursuing its own study on the Northeast Asia regional power interconnection. The potential complementarity in power generation and in electricity market among Northeast Asian economies is very significant. Likewise, the ASEAN is promoting its power interconnection programme with detailed proposals on probable routes. The GMS interconnection initiative appears attractive. In South Latin America a very ambitious strategy on energy integration, which includes cross-border power interconnections, is under progress.

However, for any of the above-mentioned interconnection projects or proposals to materialise, major impediments and concerns have to be addressed. This study has identified a number of policy issues and their implications concerning these matters.

The study also recognised that there is a potential competition between power grid and natural gas pipeline interconnection as well as complementarity between them. The Northeast and Southeast Asia have important gas reserves but unsubstantial infrastructure to transport natural gas within the region. The development of Combined Cycle Gas Turbine (CCGT) has enabled high efficiency and low cost gas-fired power generation. Therefore, in order to exploit natural gas development effectively for generating electricity, the comparison of natural gas pipeline network with the power grid interconnection should be examined.

POLICY IMPLICATIONS

To tackle the barriers or difficulties, policy coordination in promoting potential interconnection projects among the related member economies is important. APEC is suggested to be as a potential advantageous forum to address these issues.

INSTITUTIONAL COOPERATION

Institutional issues need to be addressed. Harmonisation must be considered on the individual regulatory frameworks and the opportunities for deregulation of the power sector in member economies in order to promote regional energy security and development including regional power interconnection.

FACILITATING ACCESS

To reduce project marketing uncertainties and risks, the traditional PPA mechanisms may no longer be useful under a deregulated power sector. Preferential arrangement to facilitate the access and sale of the power supplied by interconnection lines to the targeted market may need to be considered. As the interconnection of grids could encourage electricity supply from environment friendly sources, consumers may accept such special terms.

CLOSER CONSULTATION

Closer consultation with more bilateral or multilateral information exchange through official contact would be necessary for real progress in developing interconnection project.

BALANCED PARTICIPATION

To encourage the development of power interconnection project, internationally founded consortia, through BOO or BOOT, may be a practical option, which would provide more balanced control in equity, debt, operation, and dispatch. This structure might, in some cases, help to neutralise the political position of the parties concerned if political stability is considered a major concern. Consequently, appropriate accommodation of related laws and regulations on ownership and operation of power transmission system would be needed.

POLITICAL SUPPORT

Regional cooperation and recognition of need for mutual dependence of energy supply in a certain degree are prerequisites for regional power interconnection. Political will and support is the main factor to ease concerns about the security of these transmission lines.

The authorities in the region should promote closer cooperation in power interconnection as well as in other energy sub-sectors since power interconnection can play a strategic role in the current efforts for APEC economic cooperation.

On the other hand, promoting power interconnection could constitute a part of the policy initiative of promotion of environment friendly energy infrastructure.

FINANCIAL COOPERATION

Many potential interconnection projects are considered among the economies where funds for investment on infrastructure are limited. The prospect for this investment became worse when the Asian financial crisis happened. In a longer-term view, financial issue will remain important specially, for capital-intensive projects. The alternative is to seek commercial funds or loans and private investment from international capital market as well as in domestic markets. However, investors will invest in an economy or economies only when they are confident of a satisfactory return, and such confidence often depends on the existence of sound and transparent structural and institutional framework. Being an important infrastructure that requires long term commitment and relatively low return, interconnection projects may require the assistance and support of the governments of developed economies or international financing institutions through soft loan packages and other favourable financing instruments.

TECHNOLOGY TRANSFER

It is evident that technical support is a key factor in setting up and maintaining high technology and know-how in interconnection projects and interconnected power systems. The transfer of good practices and technology and know-how would facilitate and encourage the developing economies to accept and promote interconnection. In this aspect, as a common issue in other sectors, the means to encourage transfer of such technologies and know-how at a reasonable price requires serious policy efforts and cooperation inside the APEC region.

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APPENDIX

SELECTED SOCIO-ECONOMIC AND TECHNICAL INDICATORS OF MEMBER ECONOMIES

AUSTRALIA

Area	7,682,300 sq km	Installed Electricity Capacity (‘98)	39,017 MW
Population (‘98 est.)	18.8 million	Gross Generation (‘98)	183,643 GWh
GDP (‘98)	US$347.3 billion	Population Electrified	100%
GDP per capita (‘98)	US$18,473	Main Voltages (kV)	500, 330, 275, 132, 66
Total line length (‘98)	817,214 km	Peak Demand	N/A

Sources: EDMC, IEEJ, (1999)
AESIEAP, (2000)

BRUNEI DARUSSALAM

Area	5,765 sq km	Installed Electricity Capacity (‘98)	770 MW
Population (‘97)	305,000	Gross Generation (‘98)	1,528 GWh
GDP (‘97)	US$4,815 million	Population Electrified	100%
GDP per capita (‘97)	US$15,782	Main Voltages (kV)	66
Total line length (’98)	269.2 km	Peak Demand (98)	251 MW

Sources: EDMC, IEEJ, (1999)
Brunei Darussalam Statistical Year Book, (1996/1997)
EGAT, (1999a)

CANADA

Area	9,215,430 sq km	Installed Electricity Capacity (‘97)	105,176 MW
Population (‘97)	30.29 million	Gross Generation (‘97)	587,475 GWh
GDP (‘97)	US$612.02 billion	Population Electrified	100%
GDP per capita (‘97)	US$20,205.4	Main Voltages (kV)	735, 500, 333, 220, 145, 71, 24.5, 11
Total line length	N/A	Peak Demand	N/A

Sources: EDMC, IEEJ, (1999)
Statistics Canada, (1999)
Hoville, W., ABB-Canada, personal communication, February 2000

CHILE

Area	756,252 sq km	Installed Electricity Capacity ('99)	9,183.35 MW
Population ('97)	14.622 million	Gross Generation ('99)	35,858 GWh
GDP ('97)	US$74.96 billion	Population Electrified (est.)	95%
GDP per capita ('97)	US$5,127.56	Main Voltages (kV)	500, 220, 154, 110
Total line length ('98)	14,110 km	Peak Demand ('99):	
		SIC	4,186 MW
		SING	1,175 MW

Sources: EDMC, IEEJ, (1999)
National Energy Commission of Chile, (1999)
World Bank, (1999)

Note: 1, SIC - Central Interconnected System; SING - Interconnected System of the Great North
2, The figures for installed capacity, generation and peak demand correspond to the two major interconnected systems, SIC and SING, which account for over 99% of the installed capacity, and do not include autoproducers. The total installed capacity is 9,887 MW.

CHINA

Area	9.6 million sq km	Installed Electricity Capacity ('98)	277 GW
Population ('98)	1,248.1 million	Gross Generation ('98)	1167 TWh
GDP ('98)	US$960.9 billion	Population Electrified	95%
GDP per capita ('98)	US$770	Main Voltages (kV)	50, 500, 330, 220
Total line length ('98, until 220kv)	130,169 km	Peak Demand	N/A

Sources: State Statistical Bureau of China, (1999)

Note: GDP in US dollar term is converted by using GDP in Chinese currency and the annual average exchange rate to US dollar

HONG KONG, CHINA

Area	1,095 sq km	Installed Electricity Capacity ('98)	10,593 MW
Population ('98)	6.687 million	Gross Generation ('98)	28,932 GWh
GDP ('98)	US$166.3 billion	Population Electrified	100%
GDP per capita ('98)	US$24,870	Main Voltages (kV)	400, 132, 66
Total line length ('98)	8,386 km	Peak Demand ('98)	7484 MW

Sources: EDMC, IEEJ, (1999)
AESIEAP, (2000)

INDONESIA

Area	1,919,440 sq km	Installed Electricity Capacity ('97)	21,312 MW
Population ('98)	212,94 million	Gross Generation ('97)	75,030GWh
GDP ('98)	US$94.2 billion	Population Electrified	55%
GDP per capita ('98)	US$442	Main Voltages (kV)	500, 150, 70, 20
Total line length ('97)	19,516 km	Peak Demand ('97)	12,618 MW

Sources: EDMC, IEEJ, (1999)
Badan Pusat Statistic (BPS), Republic of Indonesia, (1999)

JAPAN

Area	377,765 sq km	Installed Electricity Capacity ('97)	242,447 MW
Population ('97)	125.64 million	Gross Generation ('97)	1018,328 GWh
GDP ('97)	US$5384.13 billion	Population Electrified	100%
GDP per capita ('97)	US$42853.62	Main Voltages (kV)	500, 275, 187, 132
Total line length ('97)	90,139 km	Peak Demand	N/A

Sources: EDMC, IEEJ, (1999)
AESIEAP, (2000)

KOREA

Area	98,480 sq km	Installed Electricity Capacity ('97)	41,042MW
Population ('98)	46.4 million	Gross Generation ('97)	224,444 GWh
GDP ('97)	US$631.2 billion	Population Electrified	100%
GDP per capita ('97)	US$13,700	Main Voltages (kV)	765 (from '99), 345, 154, 66, 22
Total line length ('97)	134,720 km	Peak Demand	N/A

Sources: EDMC, IEEJ, (1999).
AESIEAP, (2000)
Ministry of Commerce Industry and Energy, Republic of Korea, (1998)

MALAYSIA

Area	329,733 sq km	Installed Electricity Capacity ('98)	13,781.6 MW
Population ('98)	20.93 million	Gross Generation ('98)	60,593 GWh
GDP ('97)	US$227 billion	Population Electrified:	
		Peninsula	99%
		Sabah / Sarawak	75%
GDP per capita ('97)	US$11,000	Main Voltages (kV)	500, 275, 132, 66
Total line length ('98)	22,822 km	Peak Demand ('98)	9,106 MW

Sources: Ministry of Energy, Communication and Multimedia, Malaysia, (1997)
AESIEAP, (2000)
TNB, Malaysia, (1999)

MEXICO

Area	1,909,000 sq km	Installed Electricity Capacity ('99)	35,675.1 MW
Population ('97)	96.4 million	Gross Generation ('99)	191,888 GWh
GDP ('97)	US$321.96 billion	Population Electrified	95%
GDP per capita ('97)	US$3339.8	Main Voltages (kV)	400, 230, 115
Total line length ('98) ('99,T&D)	77,310 km	Peak Demand	N/A

Sources: EDMC, IEEJ, (1999)
World Bank, (1999)
Secretariat de Energia, Mexico, (1999)

NEW ZEALAND

Area	268,680 sq km	Installed Electricity Capacity ('97)	7,900 MW
Population ('98)	3.8 million	Gross Generation ('99)	36,675.3 GWh
GDP ('98)	US$45.72 billion	Population Electrified	100%
GDP per capita ('98)	12,031	Main Voltages (kV)	220, 110, 66, 50
Total line length ('98)	17,616 km	Peak Demand	N/A

Sources: EDMC, IEEJ, (1999)
AESIEAP, (2000)
Ministry of Commerce, New Zealand, (1999)

PAPUA NEW GUINEA

Area	462,840 sq km	Installed Electricity Capacity ('97)	262.8 MW
Population ('98)	4.6 million	Gross Generation	607.7 GWh
GDP ('96)	US$11.6 billion	Population Electrified	7.5%
GDP per capita ('96)	US$2,650	Main Voltages (kV)	132, 66, 33, 22, 11
Total line length ('97)	3,373 km	Peak Demand ('97)	139.7 MW

Sources: EDMC, IEEJ, (1999)
AESIEAP, (2000)
Electricity Commission, Papua New Guinea, (1998)

PERU

Area	1,280,000 sq km	Installed Electricity Capacity ('98)	5,514 MW
Population ('98)	24.8 million	Gross Generation ('98)	17,950 GWh
GDP ('98)	US$63.0 billion	Population Electrified	72%
GDP per capita ('97)	Us$2,544	Main Voltages (kV)	220, 138, 66
Total line length ('98)	8,477 km	Peak Demand	N/A

Sources: EDMC, IEEJ, (1999)
Ministerio de Energia y Minas, Republica del Peru, (1999)
Commission for the Promotion of Peru, (1999)

PHILIPPINES

Area	300,000 sq km	Installed Electricity Capacity ('98)	12,069 MW
Population ('97)	73.53 million	Gross Generation ('98)	41,065 GWh
GDP ('97)	US$82.51 billion	Population Electrified	73.4%
GDP per capita ('97)	US$1,122.1	Main Voltages (kV)	500, 230, 138, 115, 69
Total line length ('98)	19,173 km	Peak Demand ('98)	6,448 MW

Sources: EDMC, IEEJ, (1999).
National Power Corporation (NPC), Philippines, (1999)

RUSSIA

Area	16,889,000 sq km	Installed Electricity Capacity ('97)	214,200 MW
Population ('97)	147.3 million	Gross Generation ('97)	834,000 GWh
GDP ('97)	US$338.2 billion	Population Electrified	99%
GDP per capita ('97)	US$2,295.7	Main Voltages (kV)	750, 500, 220, 110
Total line length ('97, T&D)	3,018,000 km	Peak Demand	N/A

Sources: EDMC, IEEJ, (1999)
World Bank, (1999)
Mactepakoba, A.M., (1998)

SINGAPORE

Area	646 sq km	Installed Electricity Capacity ('98)	5,521 MW
Population (98)	3.87 million	Gross Generation ('98)	28,200 GWh
GDP ('97)	US$97.89 billion	Population Electrified	100%
GDP per capita ('97)	US$26174	Main Voltages (kV)	400, 230, 66
Total line length (98)	4,100 km	Peak Demand ('98)	4,307 MW

Sources: EDMC, IEEJ, (1999)
AESIEAP, (2000)
Lau and Yong, (1999)

CHINESE TAIPEI

Area	35,980 sq km	Installed Electricity Capacity ('98)	26,680 MW
Population ('98)	21.9 million	Gross Generation ('98)	142,964 GWh
GDP ('97)	US$281.08 billion	Population Electrified	99.97%
GDP per capita ('97)	US$12,963	Main Voltages (kV)	345, 161, 69
Total line length ('98)	12,813 km	Peak Demand ('98)	23,830 MW

Sources: EDMC, IEEJ, (1999)
AESIEAP, (2000)
Energy Commission, Ministry of Economic Affairs, Chinese Taipei, (1998)

THAILAND

Area	514,000 sq km	Installed Electricity Capacity ('98)	17,261 MW
Population ('98)	61 million	Gross Generation ('98)	93,134 GWh
GDP ('97)	US$176.65 billion	Population Electrified	82%
GDP per capita ('97)	US$2915	Main Voltages (kV)	500, 230, 132, 115, 69
Total line length ('98)	23,957 km	Peak Demand ('98)	14,180 MW

Sources: EDMC, IEEJ, (1999)
AESIEAP, (2000)
EGAT, (1999b)

U.S.A

Area	9,159,000 sq km	Installed Electricity Capacity ('98)	775,861 MW
Population ('98)	274.1 million	Gross Generation ('98)	3,526,756 GWh
GDP ('97)	US$7,786,57 billion	Population Electrified	100%
GDP per capita ('97)	US$29,065.2	Main Voltages (kV)	765, 500, 450, 345, 240, 230, 138, 120, 115
Total line length ('98,approx.)	320,000 km	Peak Demand	N/A

Sources: EDMC, IEEJ, (1999)
World Bank, (1999)
EIA, (1998)

VIET NAM

Area	329,560 sq km	Installed Electricity Capacity ('99)	5,559 MW
Population ('98)	77.0 million	Gross Generation ('98)	21,654 GWh
GDP ('97)	US$24.5 billion	Population Electrified	71%
GDP per capita ('97)	US$318	Main Voltages (kV)	500, 220, 110, 66, 35
Total line length ('98)	209,457 km	Peak Demand ('98)	3,774 MW

Sources: EDMC, IEEJ, (1999)
AESIEAP, (2000)
Institute of Energy, Viet Nam, (1999)

LIST OF ABBREVIATIONS

ABARE	Australian Bureau of Agricultural and Resource Economics
AC	Alternating Current
ADB	Asian Development Bank
APEC	Asia-Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
ASEAN	Association of Southeast Asian Nations
BAU	Business-as-usual
B98	Baseline Scenario 1998
BOO	Build-Own-Operate
BOT	Build-Operate-Transfer
CCGT	Combined-Cycle Gas Turbine
CFE	Federal Electricity Commission, Mexico
CNE	National Energy Commission, Chile
CRE	Energy Regulation Commission, Mexico
DC	Direct Current
DPRK	Democratic People's Republic of Korea
EDMC	Energy Data Modelling Centre, The Institute of Energy Economics, Japan
EFS	Environmentally Friendly Scenario
EGAT	Electricity Generating Authority of Thailand
EIA	Energy Information Administration, Department of Energy, USA
EPDC	Electric Power Development Company, Japan
ES	Energy System
EWG	Energy Working Group
FACTS	Flexible Alternating Current Transmission System
FEPC	Federation of Electric Power Companies, Japan
FERC	Federal Energy Regulatory Commission, USA
GDP	Gross Domestic Product
GHG	Greenhouse gas
GMS	Great Mekong Sub-region
GW	Gigawatt
GWh	Gigawatt hour (= one million kilowatt hours)
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IEA	International Energy Agency
IEEJ	Institute of Energy Economics, Japan
IE-Viet Nam	Institute of Energy, Viet Nam
KEEI	Korea Energy Economics Institute
KV	Kilovolt (= 1,000 volts)
KW	Kilowatt (= 1,000 watts)
KWh	Kilowatt hour (= 1,000 watts hour)
LGERI	LG Economic Research Institute, Korea
LNG	Liquefied natural gas
MITI	Ministry of International Trade and Industry, Japan
MOU	Memorandum of Understanding
Mkloe	Million kilolitres of oil equivalent
Mtoe	Million tonnes of oil equivalent
MVA	Megavolt Ampere
MW	Megawatts (= 1,000 kilowatts)
MWh	Megawatts hour (= 1,000 kilowatts hours)
NCPG	North China Power Group
NEM	National Electricity Market

NEMMCO	National Electricity Market Management Company
NO_X	Nitrogen oxides
NRE	New and renewable energy
OECD	Organisation for Economic Cooperation and Development
OLADE	Organizacion Latinoamericana de Energia (Latin American Energy Organisation)
PCS	Protracted Crisis Scenario
PLN	Perusahaan Listrik Negara (State-owned Electricity Enterprise, Indonesia)
PPA	Power Purchase Agreement
QNI	Queensland – New South Wales Interconnection
SANI	South Australia – New South Wales Interconnection
SO_X	Sulphur Oxide
TNB	Tenaga Nasional Berhad (National Power Limited, Malaysia)
Toe	Tonne of oil equivalent
TPES	Total Primary Energy Supply
TPP	Thermal Power Plant
TWh	Terawatt hour
UCPTE	Union for the Coordination of Production and Transmission of Electricity
UES	United Energy System
UESR	Unified Energy System of Russia
US DOE	Department of Energy, United States
WB	World Bank
WEC	World Energy Council
WHO	World Health Organisation
YPEPC	Yunnan Provincial Electric Power Company, China