Coal and Natural Gas Competition in APEC Economies

Asia-Pacific Economic Cooperation
Clean Fossil Energy Expert Group

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Center for Energy-Environment
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CEERD

Coal and Natural Gas Competition In APEC Economies

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Foreword

Coal and natural gas are closely competing as fuels for power generation. Natural gas use in the power sector has increased remarkably during the last several years. The advent of cost-competitive gas-fired generation technology and the environmental qualities of natural gas have made it a preferred fuel for power generation. Coal, however, remains attractive because of its abundant supply and stable prices. Moreover, the continued development of clean coal technologies is reducing the negative environmental consequences associated with coal burning. *Coal and Natural Gas Competition in APEC Economies* examines the factors that drive the competition between these two fuels in the APEC economies.

In an attempt to gather information and begin the analysis at the national level before coming up with a regional synthesis, detailed survey questionnaires were sent to various public and private sector organizations in all the 21 APEC member economies. Of the 230 selected respondents, only 30 returned answered questionnaires. Some chose to send documents providing the required information and others referred to sources of information, including especially the Internet, instead of answering the questionnaires. Members of the study team also visited a few countries to get first hand information to gather national agency statistics and reports. Thus, the analysis of the study drew heavily on official documents and published sources as well as from information available in the Internet.

The study confirms the following as the main factors driving the competition between coal and natural gas as fuels for electricity generation: resource availability, relative fuel prices, technology, environment, and the increasing role of independent power producers as a result of electricity sector privatization and restructuring.

The Center for Energy-Environment Research and Development (CEERD) would like to thank APEC Experts Group on Clean Fossil Energy for their support and all the national agencies and private companies that provided information, in one way or another, for this study.

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Abbreviations

AAQS	Ambient air quality standards
ACCGT	Advanced Combined Cycle Gas Turbine
ADB	Asian Development Bank
APEC	Asia-Pacific Economic Cooperation
bbl	barrel
Bcf	Billion cubic feet
Bcm	billion cubic meters
BOO	Build-Own-Operate
BOT	Build-Own-Transfer
Btu	British thermal unit
CCGT	Combined Cycle Gas Turbine
CDM	Clean development mechanism
CFBC	Circulating Fluidized Bed Combustion
DeNOx	Unspecified NOx control system
GHG	Greenhouse gas
GJ	Giga joule
GTCC	Gas turbine combined cycle
GWh	Gigawatt - hour
IFC	International Finance Corporation
IPP	Independent Power Producers
ISIGT	Intercooled Steam Injected Gas Turbine
Km	Kilometer
Ktoe	Kilo tons of oil equivalent
KWh	Kilowatt-hour
LDCs	Local distribution companies
LNG	Liquefied natural gas
MBI	Market based instrument
MMBtu	Million British thermal unit
MMSCFD	Million Standard Cubic Feet per Day
Mtoe	Million tons of oil equivalent
MW	Megawatt
NOx	Nitrogen Oxides
O&M	Operations and Maintenance
OL	Operate-Lease
PM	Particulate matters
R&D	Research and Development
ROL	Rehabilitate-Operate-and-Lease
ROM	Rehabilitate-Operate-and-Maintain
Scf	Standard cubic feet
SOx	Sulphur Oxides
Tcf	Trillion cubic feet
TPES	Total primary energy supply
US$	Us dollars
USC	Ultra-supercritical combustion

EXECUTIVE SUMMARY

The shares of coal and natural gas in the energy mix, particularly for electricity generation, in the APEC economies as a whole have increased tremendously during the last several years. Coal has been a mainstay fuel because of proven abundant regional supply, but its importance has grown for energy security reasons. Oil is becoming less attractive because of supply and price volatility. The increase in the share of natural gas, on the other hand, has been more remarkable. Natural gas is a newcomer relative to other major fuels, and its development and utilization is still growing.

The study focuses on the technical, economic and policy issues affecting the competitive position between coal and natural gas in the power sector of the APEC economies. In order to provide insights to the changing roles of these two important energy resources, the study examines several factors that affect fuel and technology choices. These are the competing sources of coal and natural gas, coal and gas prices, environmental constraints, technology options, and privatization and restructuring in the electric supply industry.

Chapter 1 examines **coal and natural gas as competing fuels** in the APEC economies. The general trends observed in the study are the following:

- The relative importance of coal and natural gas in both the total primary energy consumption and power generation in APEC economies varies, influenced mainly (but not entirely) by the availability of the said resources. The shares of coal and natural gas are respectively high in major coal (Australia, China and United States) and natural gas producing economies (Brunei, Indonesia, Malaysia).

- Coal and natural gas competition exists in the total primary energy consumption and the power generation sector, with the following trends: natural gas consumption grew rapidly than coal (Hong Kong, Indonesia, Vietnam, Malaysia, Singapore, Thailand, Brunei, New Zealand); coal demand increased faster than natural gas (Philippines, Chile); both coal and natural gas consumption grew at comparable rates (Korea, China, Japan, Australia, United States).

- Coal and natural gas consumption are also projected to rise further in the future, though the strength of their growth rates will differ from economy to economy. It appears however that gas consumption is expected to grow faster in those economies with high initial utilization rate of coal. Conversely, coal demand is projected to increase at relatively higher rates in those economies whose utilization rate of natural gas is high.

While reasons for such changes appear to be obvious for some economies, the remaining chapters attempt to investigate several key parameters that could potentially affect the changes in the relative shares of coal and natural gas in the power sector of the APEC economies.

One of the main factors affecting fuel choice is the availability of a given fuel. **Chapter 2** surveys the **competing sources of coal and natural gas** in the APEC economies.

- The APEC region is a grouping of economies with wide disparities in energy resource endowment. Several economies are rich in coal resources (Australia, China), others in natural gas (Canada, Mexico, Indonesia, Malaysia), and some others, in both (USA, Indonesia, Russia).

- With respect to the balance between demand and supply, the region enjoys a comfortable balance as far as coal demand-supply relationship is concerned. The proven reserves are more than adequate to meet anticipated demands for coal. Coal reserves are widely distributed and the presence of several exporters ensures stability of supply. Coal production has been higher in the region but the projected demand in 2010 is expected to slightly exceed production which would imply an increase in exports to the region. The demand-supply balance of natural gas is however less comfortable compared with that of coal. Gas reserves are far smaller than demand, and non-APEC economies play an important role in meeting the demand. The outlook for gas in 2010 is more critical because there will be a larger gap between production and demand. Gas exports from non-APEC economies are expected to fill up the deficit.

- APEC economies play an active role in the trade of coal and natural gas in the international markets, both as buyers and sellers of these resources. Obviously, resource rich economies are the major sellers while those resource poor economies are the major buyers. Moreover, in order to keep up with their competitive edge, coal and natural gas suppliers have prioritized their upstream development programs and necessary infrastructures to bring these commodities to the international market (e.g. ASEAN and Northeast Asian gas grids).

- Coal and natural gas availability either in the local market or international market has influenced the relative importance of these fuels in the total primary energy consumption and power generation. Coal has long been established as a major fuel in the power sector of many economies, even those with limited coal resources. On the other hand, the use of gas is fast expanding due to its increasing availability and more advantageous use in terms of performance and environmental considerations. In the long-term, however, coal will remain as the primary fuel in the power sector of many APEC economies in view of its greater abundance compared to natural gas.

- The increased development and use of coal and natural gas in the APEC region has been supported by existing and emerging government policies as a matter of energy security or economic development. These policies affect the exploration, development and production of local resources, and the necessary impetus to support the coal and gas industries, such as investments, infrastructure, trade, and consumption.

Central to the analysis in **Chapter 3** is the **relative prices of coal and natural gas** as determinants of fuel choice. The chapter reviews pricing of coal and natural gas in the international and domestic markets of APEC economies.

- APEC economies are major players in both the Atlantic and Pacific markets of coal. Despite the division of the market into two, coal prices are linked and have converged. Coal prices in the Atlantic market are based on spot sales while those in Pacific markets are determined through bilateral negotiations with reference to benchmark prices. The international coal prices have declined in both nominal and real terms and have been stable in the last 20 years due to improvements in productivity and increasing competition among suppliers.

- International trading of natural gas is done in three distinct markets: Europe, North America, and Asia-Pacific – with the two latter markets within the APEC region. The North American market trades piped gas while LNG is mainly traded in the Asia-Pacific market. Prices in these two markets are not linked, and obviously the average gas prices in North America is relatively lower than those in Asia-Pacific due to higher cost of transporting and processing LNG.

- The international prices could serve as the benchmark in fuel pricing, but the pricing policies adopted by the economies are the main factor that influence fuel choice. In some developing APEC economies, national coal and natural gas industries are protected from international competition. Prices for domestic coal in several countries – which are mainly determined from cost plus methodology – are highly subsidized, or prices of imported coal are heavily taxed, and/or non-price trade barriers exist to discourage the use of imported coal. While the North American domestic natural gas pricing is market based, those of many other economies are either cost plus based or based on their netback value, and are also subsidized. Also in these economies differential prices of natural gas exist among economic sectors and that gas prices for power generation are the cheapest.

- The relative price between coal and natural gas is one of the most important determinants of the extent of competition between these two fuels. At the international market, coal prices are cheaper than natural gas (LNG) based on their costs per calorific value. Domestic prices of coal and natural gas however deviate from this international trend. Natural gas prices tend to be lower than coal in countries with huge reserves of natural gas while coal prices tend to be lower than gas in coal-rich economies. Price expectations also influence the choice between coal and natural gas. Coal price expectations have been relatively stable and low while those of natural gas are increasing. This makes coal a mainstay fuel in the overall energy and power generation mix of many APEC economies. The higher prices of natural gas however have not been a stumbling block for its increase in consumption. Gas use is increasing faster than coal in many APEC economies.

- The pricing reforms introduced by many developing countries in conjunction with structural reforms and privatization in the energy sector in several APEC economies could also affect the relative prices of coal and natural gas. With reforms however, domestic prices of these fuels would eventually converge to the prices in the international market.

Another determining factor that affects competition between coal and natural gas is the environment. **Chapter 4** reviews **environmental concerns** in APEC economies and discusses how environmental issues affect competition.

- Several environmental concerns in many APEC economies are linked with the power sector and the utilization of coal. Air quality problems are worst in many developing APEC economies due to intensive use of low quality coal in the power sector. Moreover, carbon emissions are of particular concern to several developed APEC economies due to their commitments to stabilize their emissions of global warming gases under the Kyoto Protocol.

- Environmental regulation for local pollutants in the APEC economies has evolved in two directions: increase in the stringency of environmental standards and increase in the use of economic instruments.

- Ambient air quality standards (AAQS) were once the main instruments in regulating atmospheric emissions in the power sector in most APEC economies. With increasing problems on air pollution, AAQS were first reviewed in several economies to meet international requirements on air quality. But as environmental quality could not be satisfied, some APEC economies have adopted stack emission standards to control emissions in the power sector. In some developing APEC economies, emission standards in the power sector have only been issued in the 1990s. There exists differences in the emission standards among APEC economies, due mainly to the difference in the types of fuel that are being used. Some economies allow local or regional governments to set up their emission standards based on national guidelines – and most of the local standards are more stringent than the national. In few economies, stricter standards are imposed only to plants yet to be built, but the control on existing plants is relatively lenient. In general however, the emissions standards in the region are progressively being tightened.

- Aside from emission limits at the burner tip, several economies have also imposed standards on fuel quality, particularly in the control of sulfur emissions from coal. While the majority of APEC economies rely on the command and control type of policy measures, few economies have experimented in the use of economic instruments such as emission trading and taxes on emissions of pollutants in the power sector.

- Several APEC economies are among the Annex-1 countries of the Climate Change Convention that have a long-term commitment to reduce greenhouse gas emissions. Other developing countries are required to formulate and implement climate change mitigation and adaptation programs. However, some developing Asian APEC economies have expressed interest to a long-term reduction in the emission of climate change gases.

- The implications of these changes in environmental standards and the commitment to global warming gas emission reductions is that, there is pressure on power utilities to either shift to clean fuels or adopt clean technologies. On environmental grounds, natural gas becomes more attractive than coal. However, coal continues to maintain its competitive position. The development of Clean Coal Technologies has enabled coal to be used to generate electricity while complying with strict environmental standards.

- Environmental policy reforms could affect the competition between these two fuels. One of the issues in the reforms is on the flexibility and cost effectiveness in complying with environmental requirements. The command and control approach in environmental regulation could in fact potentially facilitate a faster penetration of natural gas and abrupt reduction in the use of coal. The use of economic instruments could potentially retard interfuel substitution since a cost effective approach in mitigating emissions may not be a shift to cleaner technologies and fuels.

With fuel economics and environmental regulation, another important parameter affecting fuel competition is the economics of electricity generation. **Chapter 5** discusses **technological choices** given the environmental constraints in power generation.

- Technological development has intensified the competition between coal and natural gas. A coal-based electricity production is considered to emit more air pollutants than any other fuels; several clean coal technologies have been developed to make coal-fired power technologies comply with existing environmental standards. These technologies provide a wide range of options to the utility, both in relative cost and point of application in the process (i.e. pre-combustion, combustion and post combustion). They can be used to raise conversion efficiencies while substantially reducing the amounts of pollutant emissions generated. Similarly, there is also a parallel trend in the development of gas technologies. More efficient gas technologies are being developed but are more expensive than coal technologies.

- With coal and natural gas competition in power generation, and given the environmental constraints, APEC economies have adopted different technologies. Some economies (China for example) have engaged in coal-cleaning; others have invested in advanced as well as clean coal combustion technologies; several others have installed post combustion technologies to existing as well as new conventional coal power plants. Several economies have also invested on gas and advanced gas technologies.

- Clean coal and gas technologies are also adopted not only for environmental reasons but also to improve power generation efficiencies. Other approaches adopted by APEC economies include retirement of inefficient plants, increasing the scale of the plant unit, improvement of fuel quality, continuous operation, retrofitting, repowering and cogeneration.

- The economics of electricity generation in the same manner with fuel economics moves in either direction. The levelized cost of electricity generally favors coal as input fuel. This is true for some APEC economies. But for others, with certain price expectations, discount rate and technical assumptions, the levelized cost of electricity from natural gas is lower than from coal. There are furthermore other cost components that must be considered for which natural gas-fired technologies have a cost advantage over coal-fired technologies. These are capital costs, non-fuel O&M costs, and fuel efficiency.

In many APEC economies, power sector reforms and privatization have been introduced. With this, independent power producers (IPPs) proliferate in the region. **Chapter 6** reviews the **restructuring and privatization in the power sector** of the APEC economies and discusses its **impacts** on coal and natural gas competition.

- The electricity sectors in the APEC economies are at different stages of restructuring and privatization. A vertically integrated monopolistic industry structure exists in Papua New Guinea, Russia and Hong Kong; a purchasing agent model (and its variants) in Brunei, Indonesia, Malaysia, Philippines, Thailand, South Korea, China, Mexico, Vietnam, Canada, Chinese Taipei and Japan; wholesale and retail competition in Alberta (Canada), United States, New Zealand, Australia, Chile, Singapore and Peru. Though at different stages, common to most of these economies is the presence of independent power producers.

- Most IPPs prefer either coal or natural gas for power generation. Natural gas is the main preference fuel by IPPs in the US, Australia and South Korea; coal is preferred by IPPs in China; neither coal nor natural gas are preferred in Mexico, New Zealand and the Philippines. In terms of technology additions, a recent survey shows that gas turbines appear to be the preferred technology worldwide. The fuel and technology choice by IPPs is driven by the availability of fuels, relative fuel prices, attractiveness of the corresponding generation technology (in terms of cost, efficiency, construction/installation lead times, environmental compliance), environmental considerations and costs of generation.

- Gas-fired power plants are often the attractive option for IPPs because of their relative low capital construction cost; the use of well-established technology; their construction lead times; their relatively higher fuel conversion efficiency and their lower environmental impacts.

- Privatization and restructuring cause at least three issues that can directly affect fuel and technology choice of IPPs. First, it creates uncertainty in terms of the development of new generation technologies. Second, it affects the competition not only in terms of fuel choice but also in terms of its implications on the fuel supply industries. Third, the convergence between the natural gas and power industries could tilt the competition in favor of natural gas.

The study **concludes** that the competition between coal and natural gas is a complex process that involves the interplay of several parameters. It is found that the competition between coal and natural gas is a result of an interaction among the above factors inextricably intertwined with the historical development of the energy sector.

- The relative importance of these fuels in the total energy mix is determined by the availability of coal and natural gas as indigenous resource. Economies with high reserves of coal tend to have higher shares of coal in power generation; economies with high reserves of gas use more gas; those with substantial reserves of both coal and gas tend to use both. Energy exporting countries however deviate from these trends due to the priorities of energy resources for exports. Economies without or less endowed with coal and natural gas, but with access to the international market tend to have balanced utilization of these fuels, though some economies prefer to use coal than gas.

- The growth in the consumption of coal and natural gas were supported by those economies with local resource base of these fuels, and some net energy importing economies with access to these fuels in the international market. Unlike coal which has been a mainstay fuel in power generation, gas discoveries and development in most APEC economies (except in North America) have been recent. The momentum gained in gas consumption would likely be sustained in the medium and long term since national and regional gas infrastructures are currently being planned or developed.

- The above trends are partly explained by fuel economics and the economics of electricity generation. Coal is cheaper than natural gas in the international markets. The domestic prices of these fuels however deviate from the international trend. Countries with huge reserves of coal tend to have coal cheaper than natural gas and those economies with big reserves of natural gas tend to have gas cheaper than coal. Similarly, for some APEC economies with certain price expectations, discount rate and technical assumptions, the levelized cost of electricity from coal is lower than from natural gas while for some others electricity generated from natural gas have lower levelized cost than from coal. There are furthermore other cost components that must be considered for which natural gas-fired technologies have a cost advantage over coal-fired technologies, and these are capital costs, non fuel O&M and fuel efficiency.

- One of the main reasons why the governments support the development of natural gas resource as well as for some economies to continue to use imported but expensive natural gas, is the environment. Moreover, the rigidity of the command and control approach in environmental regulation (on which most of the APEC economies rely) favors an increase in natural gas utilization. Furthermore, the development of more efficient and cost-competitive gas-fired technologies makes natural gas an attractive fuel. The attractiveness of natural gas on environmental grounds did not diminish that of coal. The development of clean coal as well as advanced technologies that comply with stringent environmental standards retains coal as the fuel choice of those economies traditionally dependent on coal and those with huge coal reserves. Though the capital costs of these technologies are relatively higher, lower coal prices can offset this resulting in still lower levelized cost of electricity. The global warming concern especially for those member economies with international commitments under the Kyoto protocol is not being resolved with these technological developments related to coal. The development of flexible and clean development mechanisms and global emissions trading could however maintain the level of coal use in APEC economies that are highly dependent on coal.

- In addition to the above factors, the liberalization in the electricity supply industry indirectly contributes to the above competition. IPPs tend to select fuel based on the availability of the resource in the economy. Thus, economies with huge reserves of coal IPPs invest in coal-fired technologies while in gas-rich economies natural gas-fired technologies. Other factors that influence the fuel choice of IPPs include relative fuel prices, attractiveness of the technology, environmental considerations and the costs of generation. However, IPPs tend to prefer natural gas when it is available since natural gas-fired technologies have relatively low capital construction cost, a well-established gas technology, short construction time, higher conversion efficiency and lower environmental impact.

1. COAL AND NATURAL GAS AS COMPETING FUELS IN APEC ECONOMIES

The share of coal and natural gas to the total APEC primary energy consumption as well as in the power sector is expected to increase in the future. Fuel preferences among the APEC economies vary differently depending on the various factors such as availability of supply, market and prices, technology and environmental implications of these fuels. However, government's policies also play a major role in the choice of fuel. Generally, those economies whose share of coal in the energy mix and fuel mix for power generation is high are those countries that are expected to increase the use of gas in the future. Also, those economies where gas plays a major share in the total primary energy supply and in the economies' power sector are those countries that will consume more coal in the future.

1.1 Coal and Natural Gas Competition at the National Level

The APEC economies account for about 60% of world total primary energy consumption as well as world total oil and natural gas consumption, respectively (see Figure 1.1). Their share in world total coal consumption is even higher at close to 70%.

Figure 1.2 also shows that the APEC region as a whole is dependent primarily on oil, but coal and natural gas are in not so distant second and third place, respectively, in terms of contribution to total primary energy consumption. However, the close competition among these three fuels is mainly because of the U.S., which accounts for more than 40% of the APEC economies' total primary energy consumption. Outside the U.S., oil is still the dominant fuel in most APEC economies. The only exceptions are Russia and Brunei where gas is the main primary fuel (Figure 1.3), China and Australia where indigenous coal is the main fuel (Figure 1.4), and Canada and New Zealand where natural gas is catching up with oil as a main fuel.

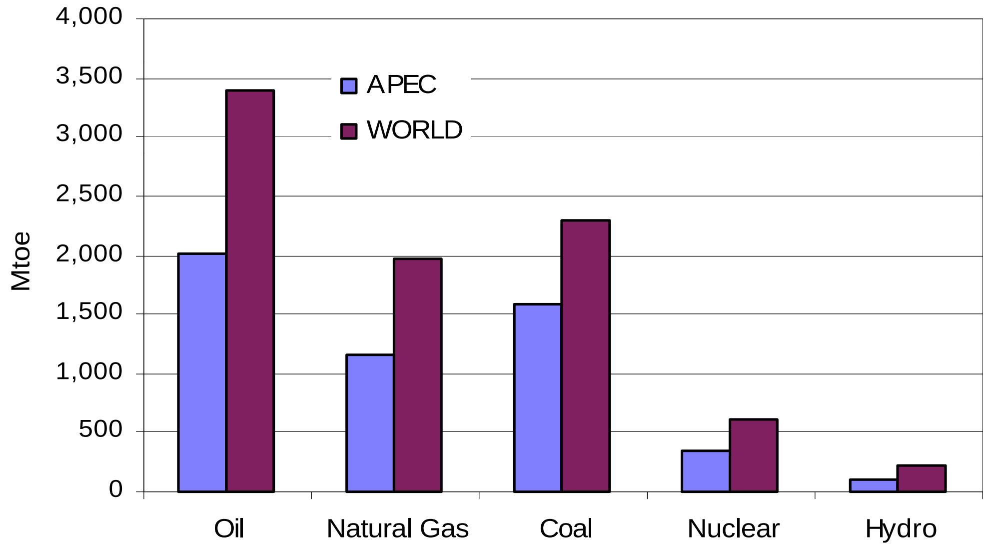


Figure 1.1: Primary Energy Consumption of APEC vs. World, 1977
Source of data: BP (1999), IEA (1998e)

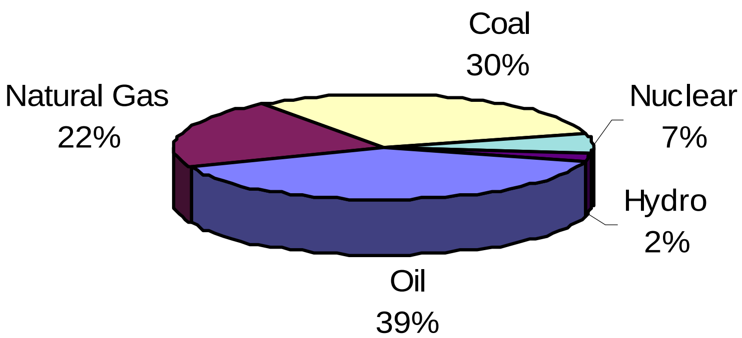


Figure 1.2: Structure of Primary Energy Consumption in the APEC Region, 1977
Source of data: BP (1999), IEA, (1998e)

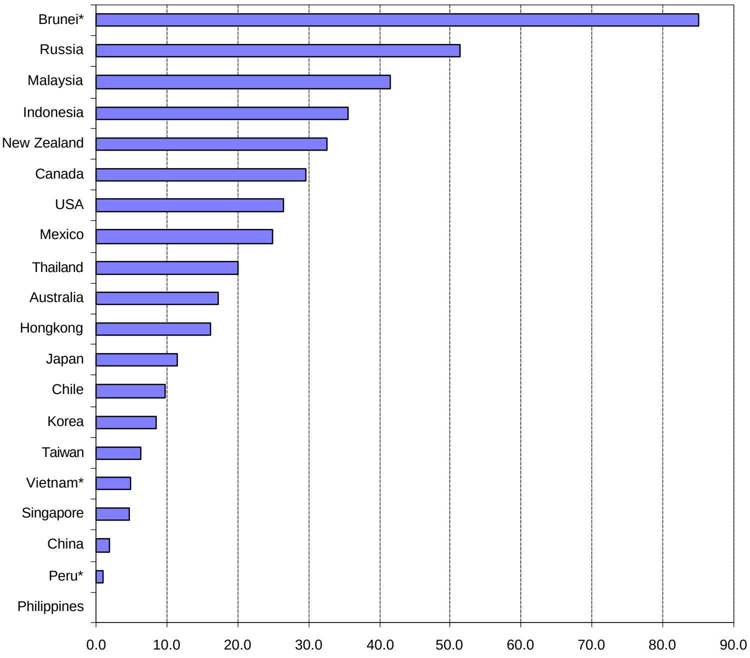


Figure 1.3: Share of Natural Gas Consumption to Total Primary Energy Consumption, 1997 (%)

* 1995 figures
Source of data: BP (1999), IEA, (1998d), IEA (1998e)

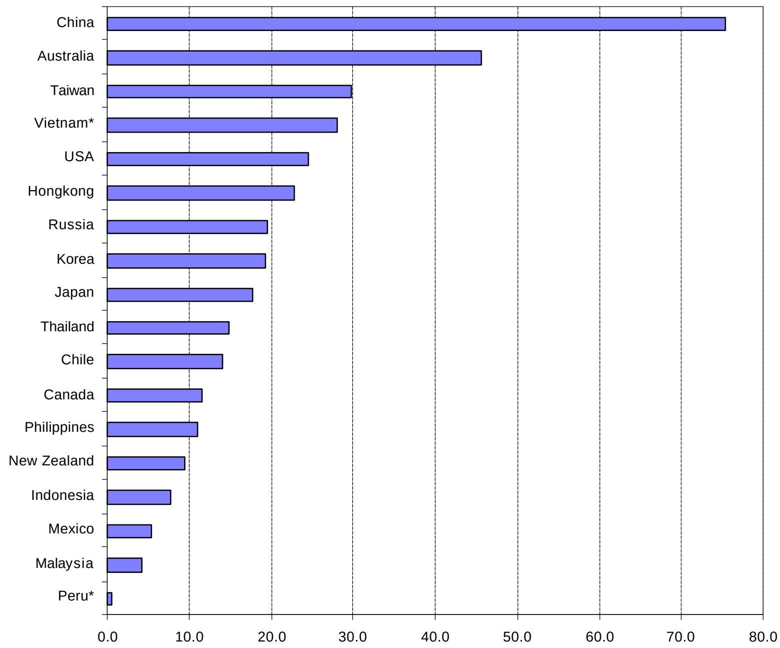


Figure 1.4: Share of Coal Consumption to Total Primary Energy Consumption, 1997 (%)

* 1995 figures
Source of data: BP (1999), IEA, (1998d), IEA (1998e)

But the present picture, however, is likely to change in the future. APEC's concern on security of oil supplies and oil price volatility has driven them to diversify fuel sources and consider coal and natural gas as alternative long-term sources of energy. This is demonstrated by the slower growth of oil demand which grew only by 1.3% per annum from 1980 to 1995, while that of coal has increased significantly by 3.4% per year during the same period with the Americas and East Asian economies consuming the most. Gas, on the other hand, grew moderately by 1%, per annum, from 603 Mtoe in 1980 to 1385 Mtoe in 1995 (Figure 1.5). Natural gas demand, however, is expected to have the fastest growth rate among primary energy sources, growing by 3.3% per year from 770 Mtoe in 1995 to 1,249 Mtoe in 2010. Growth in coal and oil use during this period will be slower at 2.5% and 2.4%, respectively, although oil is still expected to remain as the dominant fuel in the future.

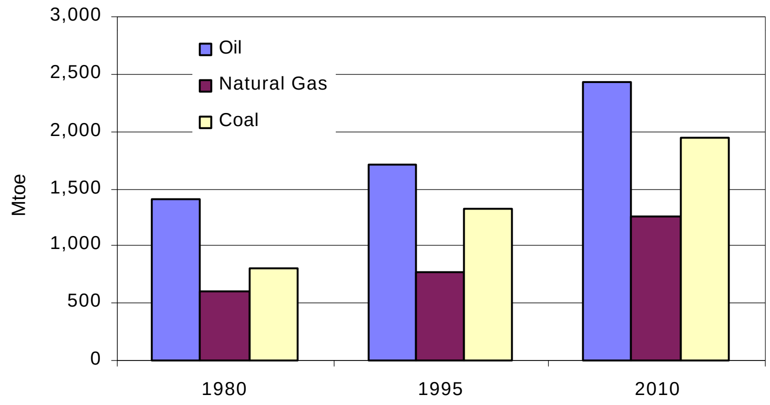


Figure 1.5: Coal and Gas Consumption vs Oil, 1980-2010
Source of data: APERC (1998)

Table 1.1 shows that the growth in natural gas consumption, will be highest in East Asia and Southeast Asia even after the Asian financial crisis, increasing annually by 6.8% and 6.5% for the period 1995 to 2010 compared with those of Oceania (4.9%) and America (2.1%). In East Asia, Japan will remain as the major consumer of gas, despite the anticipated significant decline of its share in the region's natural gas consumption from 66% in 1995 to 45% in 2010. Meanwhile, China is anticipated as the main source of growth of natural gas consumption in this region, its corresponding share growing from 19% in 1995 to 27% in 2010. In Southeast Asia, Indonesia and Malaysia are the dominant users of gas, accounting for 45% and 34% of Southeast Asian gas consumption, respectively, but their shares are expected to decline to 41% and 28%, respectively, by 2010. The source of growth in gas consumption in Southeast Asia will be Thailand whose share is anticipated to increase from 16% in 1995 to 23% in 2010. However, despite the rapid growth in gas consumption in East and Southeast Asia, American economies will still remain as the major consumer of natural gas in the APEC region, although its share of natural gas consumption in the APEC region will decrease significantly from 79% in 1995 to 67% in 2010.

Historical statistics show that coal and natural gas have been closely competing in APEC economies. For some economies (Chile, China, Taiwan, Mexico, USA), coal consumption has grown faster than that of gas during the past two decades (Figure 1.6). The choice of coal in these economies is due to the availability of coal supply in the domestic and international market as well as its low prices relative to the prices of oil and natural gas. On the other hand, there is a very high growth rate of gas in the economies (Canada, Australia, New Zealand, Indonesia, Malaysia, Thailand) where indigenous gas is readily available. Gas-importing countries like Japan and Korea, where more than 50% of the total gas demand go to the power sector, also have consumed gas at a faster rate than coal. In Vietnam, the very high growth rate of gas is due to the commissioning of a number of gas-fired power plants during the early 1990s. Brunei and Singapore do not consume coal.

Table 1.1: Coal and Gas Consumption by Sub-region (Mtoe)

Coal Consumption	1995	Share to APEC (%)	2010	Share to APEC (%)	Average Growth Rate 1995-2010 (%)
Americas	510	38.4	638	33.0	1.5
East Asia	761	57.3	1164	60.1	2.9
Southeast Asia	18	1.4	74	3.8	9.9
Oceania	40	3.0	60	3.1	2.7
TOTAL	1329	100.0	1936	100.0	2.5
Gas Consumption					
Americas	609	79.1	836	66.9	2.1
East Asia	79	10.3	212	17.0	6.8
Southeast Asia	61	7.9	158	12.7	6.5
Oceania	21	2.7	43	3.4	4.9
TOTAL	770	100.0	1249	100.0	3.3

Source: APERC (1998)

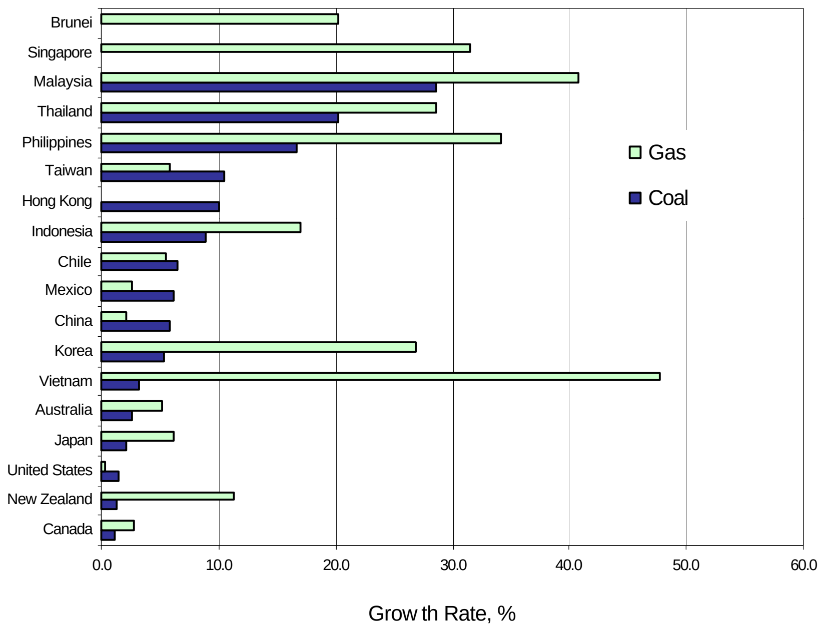


Figure 1.6: Coal and Natural Gas Competition in APEC Economies (1980-1996 growth rates of fuel consumption, %)

Source of data: IEA (1998e), IEA, (1998d)

Note: Available data for gas are:

Korea	- 1990-1996
Philippines	- 1994-1996
Thailand	- 1981-1996
Vietnam	- 1981-1996
Singapore	- 1992-1996
Hong Kong	- 1982-1996 (for coal only)

Figure 1.7 reveals that competition between coal and natural gas in the APEC economies in the future will be stronger. The different growth rates of coal and natural gas among the APEC economies indicate fuel preferences. A very interesting observation to note is that those countries (Australia, China, Japan, Korea, Taiwan) with higher share of coal are also those countries with higher growth

rates of gas during the forecasting period (Figure 1.8). Also, those countries (Canada, Indonesia, Malaysia, Mexico, Thailand) where gas plays a major share in the total primary energy supply, have higher coal growth rates in the future. However, these trends should be interpreted with caution. One factor that explains these trends is the government's energy resource diversification policy. For instance, gas-rich economies like Canada, Indonesia, Malaysia and Mexico are expected to consume more coal in the future because of existing policies to diversify energy sources. Also, in Australia, the decreasing share of coal in the total primary consumption in the future and the higher growth rate of gas compared to coal denote fuel switching in the country's energy mix. In Thailand, the role of coal in the country's primary energy supply is becoming more important considering the limited supply of indigenous gas and imported pipeline gas from existing reserves in Myanmar between 1995-2010. Production of gas in most of the gas fields in Thailand (Bongkot 1-3, Pailin, Namphong and Sirikit) and existing sources in Myanmar (Yadana and Yetagun) is projected to plateau during the period 1999-2011. Further, two of the existing indigenous gas sources in the country (Tantawan and Benchamas) are expected to be depleted by 2006 or 2007. Thus, in the country's power sector, the share of natural gas in the electricity generation mix will peak at 66% between 2001-2002, but it will gradually decrease with the increasing contribution from imported coal. EGAT projects that the share of imported coal will reach 38% (from only 0.15% in 2001) by 2011, slightly exceeding the share of gas-fired power plants at 34%. However, the decision to use imported coal is still under policy consideration at this time because of the strong opposition to coal use. For example, residents in Southern Thailand have been protesting against the plan of putting up three new coal-fired power plants in the region. Thus, natural gas is still expected to play an important role in the country's future energy mix considering the ongoing reforms in the natural gas industry of Thailand. In China, although the government is promoting the use of natural gas in areas with proven gas reserves, the country continues to prefer coal in view of its abundant supply and limited access to alternative sources of energy.

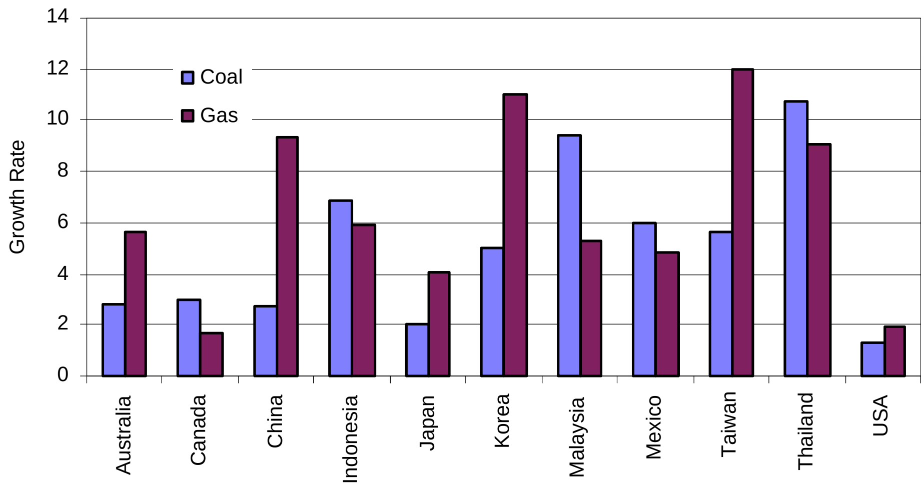


Figure 1.7: Annual Growth Rate of Coal and Gas Consumption (%), 1995-2010
Source of data: APERC (1998)

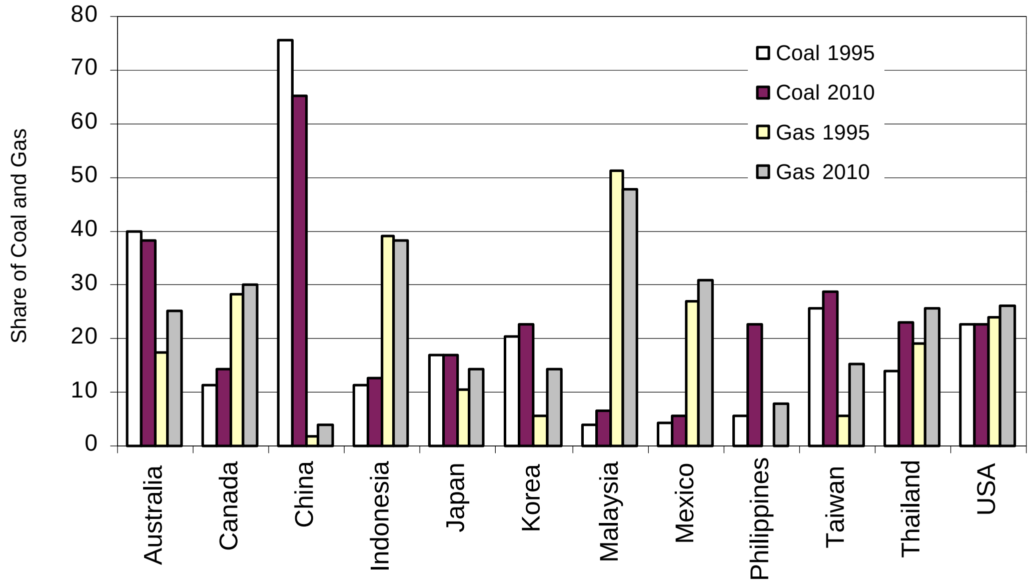


Figure 1.8: Share of Coal and Gas in the TPES (%)
Source of data: APERC (1998)

1.2 Coal and Natural Gas Competition in the Power Sector

The power sector is the major user of coal and natural gas in the APEC region (Figure 1.9 and Figure 1.10). In Japan, Taiwan, Hong Kong, Korea, Thailand, Malaysia, Philippines and Russia, the main use of coal and natural gas is for electricity production. Other APEC economies (Mexico, Chile, Australia and Indonesia) consume coal mainly for power generation and natural gas for industrial purposes. USA and Canada also utilize coal to produce power but majority of their natural gas resources is used in the residential and commercial sector. In New Zealand and Peru, natural gas is predominant in the power sector and coal in the industry sector. China and Vietnam, on the other hand, use most of their coal and natural gas resources in the industry sector.

The power sector will remain the dominant user of coal in the future (Figure 1.11). Gas consumption will also remain highest in the power sector but will be substantial in the industrial, residential and commercial sectors. However, among other end-uses, the power sector will continue to be the fastest growing consumer of coal and natural gas, increasing annually by 3.3% and 4.8%, respectively, for the period 1995 to 2010. Consumption of coal in the transport and residential/commercial sector is expected to decline annually by 14.2% and 1.6%, respectively, while that of gas is forecasted to grow respectively by 3.3% and 2.3% per annum during the same period.

In the power sector, coal is the dominant energy source for electricity generation in the APEC region. Of the total electricity generated in 1996, coal contributed 43% while other fuels (hydro, gas, nuclear and others), between 20% and 2%.

Figure 1.12 shows that in the major coal producing APEC economies (Australia, China and the USA), coal accounts for more than 50% of the power generation mix. Coal contribution to power generation is also substantial in Taipei, Chile, and Indonesia).

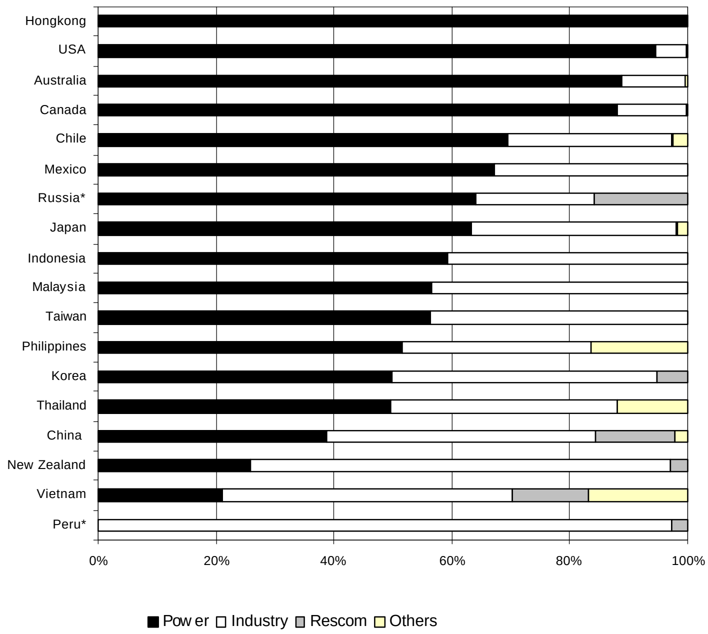


Figure 1.9: Consumption of Coal per End-use, 1996 (In Percent)
Note: Others include transport, Agriculture, others and non-specified
* 1995 figures
Source of data: IEA (1998d), IEA (1998e)

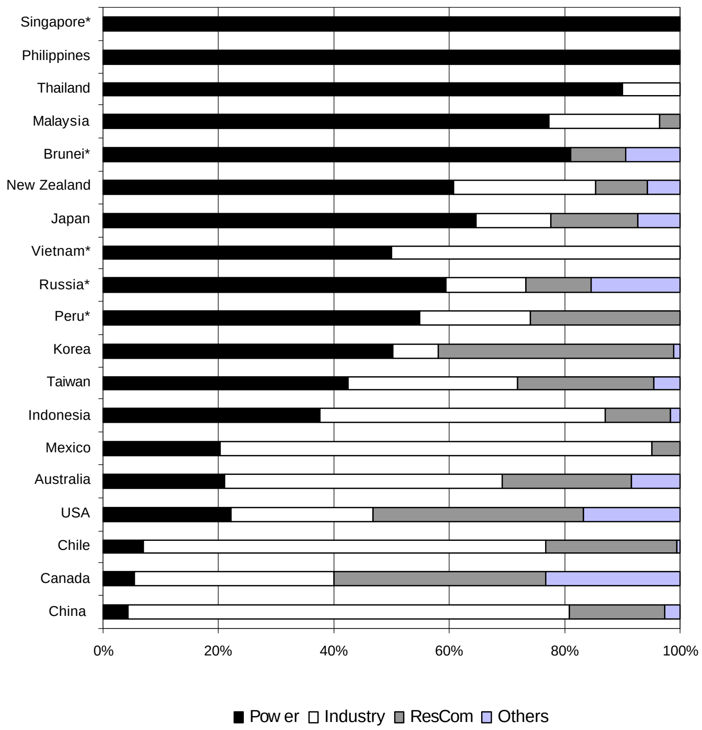


Figure 1.10: Consumption of Natural Gas per End-use, 1996 (In percent)

Note: Others include transport, Agriculture, others and non-specified
* 1995 figures

Source of data: IEA (1998d), IEA (1998e)

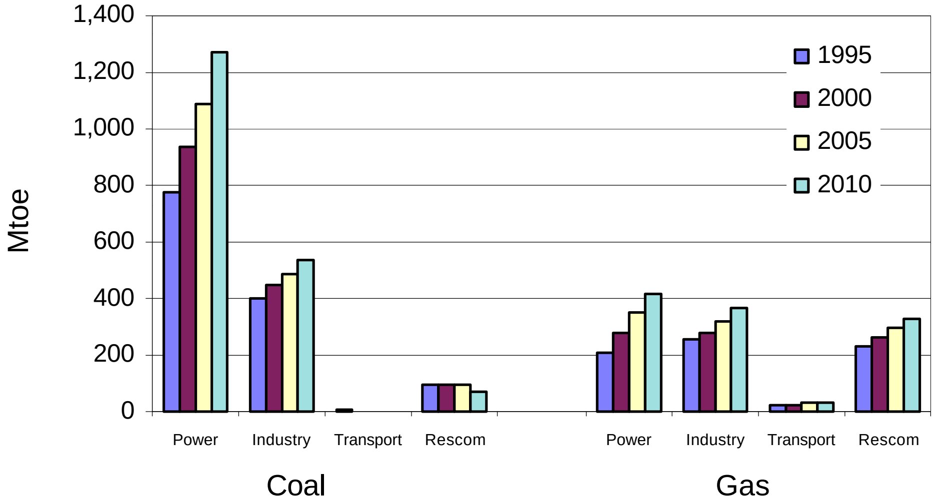


Figure 1.11: Sectoral Consumption of Coal and Gas in the APEC Region
Source of data: APERC (1998)

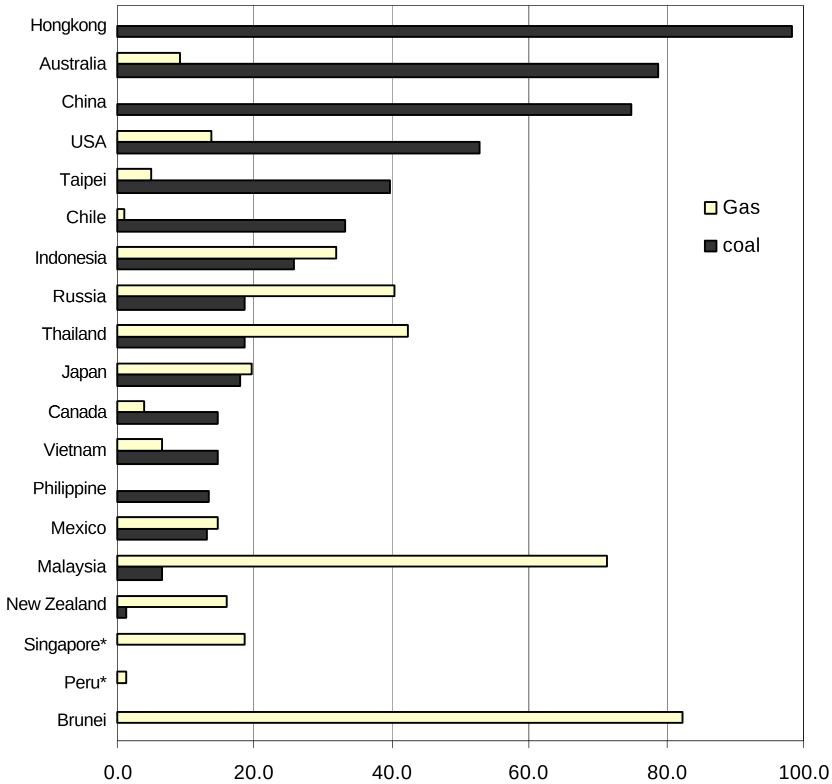


Figure 1.12: Share of Coal and Natural Gas in the Generation Mix, 1996 (%)
* 1995 figures
Source of data: IEA, (1998d), IEA (1998b)

The role of natural gas in the power sector of the APEC economies, on the other hand, is also important (Figure 1.12). The share of natural gas in the electricity generation mix of some gas-producing countries is very high (more than 40% in Russia, Malaysia, Thailand and Brunei); significant in some others (between 10 and 40% in New Zealand, Mexico, Indonesia and the US); while not very significant in the remaining countries. In net energy importing economies (Japan, Singapore and South Korea), the role of natural gas in the power sector is also substantial.

Power generation in the APEC region is expected to increase by 3.1% from 1595 Mtoe in 1995 to 2530 Mtoe in 2010 (Table 1.2). Gas-fired power generation will grow fastest, and its share to total power mix will increase from 13% in 1995 to 17% in 2010. Coal share will increase slightly but will remain the dominant fuel in the power generation mix.

Table 1.2: Power Generation in APEC by Type of Fuel

	1995		2000		2005		2010	
	Mtoe	Share	Mtoe	Share	Mtoe	Share	Mtoe	Share
Coal	775.6	49%	933.5	49%	1088.9	50%	1269.8	50%
Oil	141.6	9%	152.5	8%	170.2	8%	198.7	8%
Gas	207.2	13%	280.8	15%	352.4	16%	420.7	17%
Hydro	90.2	6%	101.9	5%	116.5	5%	131.9	5%
Nuclear	308.1	19%	323	17%	344.1	16%	384.4	15%
NRE	72	5%	104	5%	111.3	5%	124	5%
TOTAL	1594.7	100%	1895.7	100%	2183.4	100%	2529.5	100%

Source: APERC (1998)

Table 1.3 also shows that coal and gas will dominate the generating capacity additions of the APEC region in 1995 to 2010. Increases in coal generating capacity additions will come from East Asian countries (mainly China) while the source of increases in gas capacity will be the Americas.

Table 1.3: Generating Capacity Additions, 1995-2010 (In GW)

	APEC	% Share	Americas	East Asia	Southeast Asia	Oceania
Oil	45	4.8	19	18	8	0
Gas	345	36.5	216	80	42	7
Coal	363	38.4	25	291	38	9
Hydro	135	14.3	6	120	8	1
Nuclear	52	5.5	-8	60	n/a	n/a
NRE	6	.6	-2	2	5	1
Total	946	100.0	256	571	101	18

Source: APERC (1998)

Coal and natural gas are strong rivals even during the past two decades. Historically, in most of the APEC economies, natural gas demand in the power sector has been growing faster than coal, even in the coal-rich countries like Australia, Russia and Canada (Figure 1.13). Statistics show that the annual average rate of natural gas increase for the period 1980-1996 ranges from 3% in Russia to 55% in Indonesia.

Figure 1.14 shows that the strong competition between coal and natural gas in the power sector will continue in the future. It also implies that natural gas is the fuel of choice for power generation in most of the APEC economies (Australia, Canada, Korea, Mexico, Taiwan and the USA). The environmental qualities of natural gas and the availability of highly efficient combined-cycle gas turbine technologies make natural gas an attractive fuel choice.

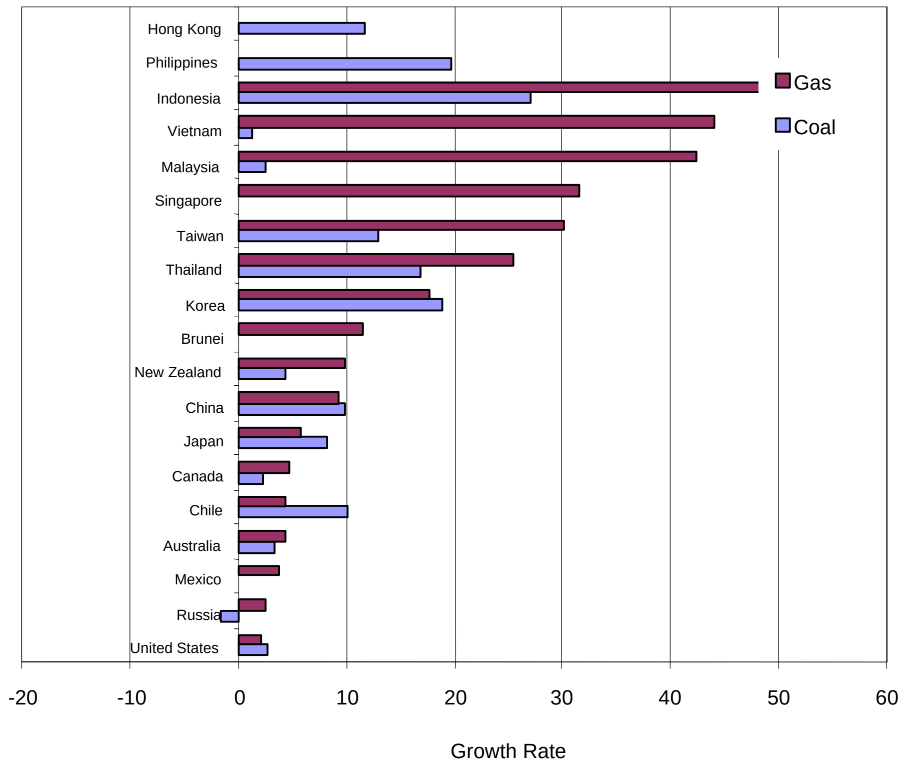


Figure 1.13: Coal and Natural Gas Competition in Power Generation
(1980-1996 growth rates in fuel consumption for power generation, %)
Note: Available data are:
Indonesia - coal (1985-1996), gas (1986-1996)
Malaysia - coal (1990-1996)
Hong Kong - coal (1982-1996)
Russia - coal (1992-1996), gas (1992-1996)
Korea - gas (1990-1996)
Taiwan - gas (1990-1996)
Thailand - gas (1981-1996)
Vietnam - gas (1981-1996)
Source of data: IEA (1998d), IEA (1998e)

Figure 1.15 shows that the economies (Australia, Canada, USA, Taiwan and China) whose share of coal in the total fuel mix is high are those economies that will use more gas in the future. In Australia, for example, the share of gas in the fuel mix is projected to increase to 19% in 2010 from 10% in 1995, while the share of coal will decrease from 84% to 74% during the same period. In Taiwan, the share of gas in the fuel mix will quadruple in 2010 from 5% in 1995. Figure 1.15 also reveals that economies whose share of gas in the power sector is high are those economies that will increase the use coal in the future. In Indonesia, for example, coal share in the fuel generation mix is forecast to grow to 35% in 2010 from 26% in 1995. In Thailand, the contribution of coal in the power sector is also projected to double from 20% in 1995. In both cases, the share of natural gas is maintained at 35-46% up to 2010. Other economies (Korea, Mexico) will increase both the shares of coal and gas but growth in natural gas demand will be more rapid.

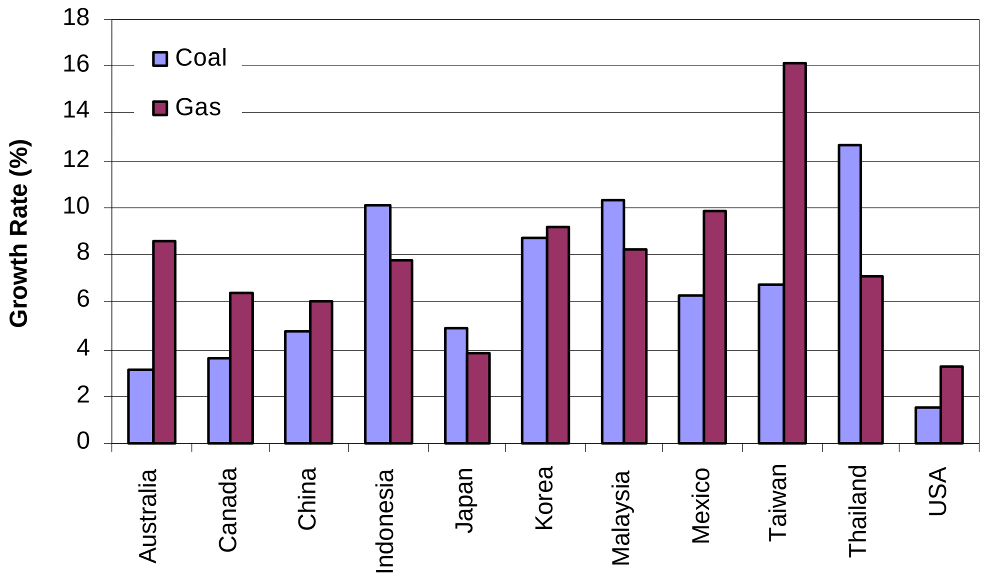


Figure 1.14: Annual Growth rate of Coal and Gas Consumption for power generation (%), 1995-2010
Source of data: APERC (1998)

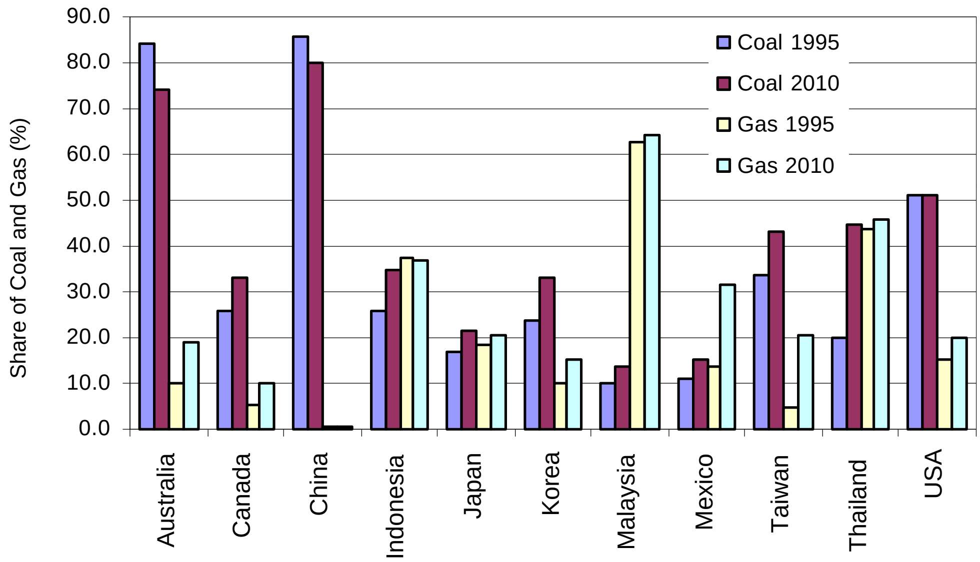


Figure 1.15: Share of Coal and Gas to Total Fuel Mix (%), 1995-2010
Source of data: APERC (1998)

1.3 Conclusion

The APEC region is dependent on oil, coal and natural gas for its primary energy consumption. The shares of coal and natural gas are expected to increase significantly. That of oil will decrease but will remain highest than coal or natural gas shares. This indicates, however, that coal and gas consumption will grow faster than oil. The source of coal growth will be the Southeast Asian economies, while the source of natural gas growth will be the East Asian economies, particularly China. Overall, natural gas is expected to increase faster than that of coal.

The power sector is the major user of coal and natural gas in the region and will remain so up to 2010. Overall, coal contributes more than natural gas in the power generation mix, but the growth of natural gas consumption is projected to surpass that of coal.

Historical data also confirms the close competition between coal and natural gas in the APEC economies.

Moreover, those economies that uses more coal at present are expected to use more gas in the future. However, those economies that consume more gas now will use more coal in the future. The main reason that explains this trend is the government’s policy of fuel diversification.

2. COMPETING SOURCES OF COAL AND NATURAL GAS

The APEC region has sufficient supplies of coal and natural gas, both from within and outside the region. APEC's current reserves of coal and natural gas assure a secure supply for the short and medium-term. Coal production and demand are more or less balanced. In the case of natural gas, there is a projected shortfall in production in the long-term, which could be attributed to undeveloped infrastructures. However, there are international markets which APEC economies can tap for additional supplies of coal and gas. Furthermore, the continuous development of indigenous resources is being pursued and the related infrastructures are being put in place by energy producing as well as consuming economies to keep up with future energy demand.

The development and use of coal and natural gas in the APEC region is mixed ranging from free-market to subsidized conditions. In view of the increasing demand for valuable energy resources and the growing concern for the environment and sustainable development, there is a trend among APEC economies to optimize the development of their resources through changes in policies that are expected to result in a more secure energy supply to fuel their drive towards economic progress.

2.1 Reserves and Production

The APEC region has half of the world's reserves of natural gas and coal (Table 2.1). The economies that are rich in coal are invariably also rich in natural gas. These economies also lead in producing coal and gas, not only for domestic but also for export to other countries within or outside the region. The increasing availability of both fuels affects their upward growth particularly in the power generation sector.

Four of the countries with the largest coal reserves in the world are in APEC. These are the USA, Russia, China, and Australia, accounting for almost 94% of total coal reserves in APEC, and 63% in the world. Two other major coal producing economies—Indonesia and Canada—account for about 6% of coal reserves in APEC. The reserves-to-production (R/P) ratios in major coal producing APEC economies are estimated to be in the range of 100-350 years excluding China's which is placed at 82 years.

Table 2.1: Coal Reserves in APEC as of end 1997, million tons

Economy	Anthracite and bituminous	Sub-bituminous and Lignite	Total Coal Reserves	Share of Reserves in World	R/P Ratio (years)
USA	106,495	134,063	240,558	23.3%	244
Russian Federation	n.a.	n.a.	199,584	19.3%	*
China	62,200	52,300	114,500	11.1%	82
Australia	45,340	45,600	90,940	8.8%	327
Indonesia	962	31,101	32,063	3.1%	*
Canada	4,509	4,114	8,623	0.8%	110
Mexico	860	351	1,211	0.1%	116
Japan	804	17	821	0.1%	191
South Korea	183	-	183	+	41
New Zealand	27	90	117	+	31
Taiwan	99	-	99	+	*
Total APEC	221,479	267,636	688,699	66.8%	
Total World	519,358	512,252	1,031,610		219

Note: + - less than 0.1%, * - over 500 years
Source: BP (1999), EIA (1998)

Similarly, the APEC region as a whole has large natural gas resource base (Table 2.2). Almost half of the world’s total proven gas reserves are found within the APEC region. Russia—the country with the biggest gas reserves—alone accounts for more than 33% of the world's and 75% of APEC's total gas reserves. The United States, Canada, Mexico, Indonesia, and Malaysia also hold large natural gas reserves in the range of 2,000-5,000 billion cubic meters (Bcm). China’s natural gas reserves are slightly above 1,000 BCM. Peru, Thailand, Vietnam, Australia, Brunei, and Papua New Guinea have natural gas reserves in the range of 200-500 Bcm. The other APEC economies have gas reserves less than 100 Bcm. Given current production rates, the R/P ratio of gas in the APEC region is about 44 years. Gas R/P ratio in Latin America, East and Southeast Asia, however, are generally higher than in North America (except Mexico) and Oceania.

The APEC region is a major producer of coal and natural gas. In 1997, almost 70% of coal produced in the world came from the APEC region (Table 2.3). The major APEC producers are China, the USA, Australia, Russian Federation, Canada and Indonesia. The US had led in coal production until 1990, when China has become the top producer.

The APEC region is also a major producer of natural gas accounting for 70% of world natural gas production in 1996. The gas-rich countries are also major gas producers (i.e., Russia, US, Canada, Indonesia, Malaysia, Mexico, China, and Australia). Russia and the US combine for about 70% of natural gas produced in the APEC region.

Increased production of coal and natural gas is expected in the future. Strategies to develop indigenous coal and gas resources are being implemented, and the related infrastructures are being enhanced or put in place. Coal production in the APEC region will continue to increase by 2.2% annually to reach 1,925 Mtoe in 2010, with China, the US, Australia and Indonesia taking the lead. Coal production in North America (US and Canada) is expected to grow by 1.5% per year until 2010. In Australia, coal production, mostly for export, is expected to increase by over 60% to 2010, mostly for export. Coal production in China is likely to increase by 3.5% per year in response to strong domestic demand and market reforms. Meanwhile, coal production in Russia, together with the other republics of the former Soviet Union, is expected to meet domestic demand and to sustain a constant level of exports over the period to 2010.

Table 2.2: Natural Gas Reserves and Production in APEC Region, 1997

Economy/ Sub-region	Total Reserves (Bcm)	% of Reserves to World Total	R/P Ratio (years)	Gas Production (Bcm)
Canada	1,840	1.28%	10.9636	167.83
Mexico	1,808	1.26%	53.8079	33.60
USA	4,711	3.27%	8.73916	539.07
North America	8,359	5.81%	11.29	740.50
Chile	98	0.07%	57.4443	1.71
Peru	199	0.14%	178.156	1.12
Latin America	297	0.21%	105.32	2.82
China	1,160	0.81%	57.6713	20.11
Japan	39	0.03%	17.1203	2.28
Korea				
Taiwan	76	0.05%	88.3721	0.86
Hong Kong				
Russia	48,140	33.44%	85.82	560.90
East Asia	49,415	34.33%	84.59	584.15
Indonesia	2,045	1.42%	27.5484	74.23
Malaysia	2,258	1.57%	58.6204	38.52
Philippines	76	0.05%		
Singapore				1.45 mtoe
Thailand	198	0.14%	12.1264	16.33
Vietnam	170	0.12%	16.484	10.313
Brunei	399	0.28%		
South East Asia	5,146	3.57%	36.9172	139.39
Australia	550	0.38%	18.6188	29.54
New Zealand	68	0.05%	12.0354	5.65
Papua New Guinea	255	0.18%		
Oceania	873	0.61%	24.8082	35.19
APEC	64,090	44.52%	42.67	1,502.05
World	143,947	100%	62.6905	2,296.15

Sources: Oil and Gas Journal (1998 and 1999), BP statistics (1999), IEA (1998e)

To meet production targets, coal-producing economies have prioritized the development of their coal resources. Australia has low-cost mines that were developed in response to the rapidly expanding world market. It will continue to be the major supplier to Asia, meeting almost one-half of the region's total coal import demand in 2020. In Indonesia, new mines are being developed to produce export-quality coal and supply the domestic market. Indonesia and China are expected to meet 25% of Asia's total import needs by 2020. The production of coal will be limited by the existing infrastructure and available investment. For coal producers, particularly China and Indonesia, this would mean increasing mining and distribution capacities, and enhancing production efficiencies.

Table 2.3: APEC's Top Coal Producers, 1997

Economy	Production (Mtoe)	% of World production
China	698	30.1%
USA	579	25.0%
Australia	142	6.1%
Russian Federation	110	4.7%
Canada	43	1.9%
Indonesia	34	1.4%
APEC	1,617	68.6%
World	2,321	100%

Notes: Production includes commercial solid fuels only, i.e., bituminous coal and anthracite (hard coal), and lignite and brown (sub-bituminous) coal
Source: BP (1999)

Table 2.4: Natural Gas Exploration and Development Projects in APEC

	On-going/Planned Gas Projects	Start Date
Australia	Buffalo field (320 (MMcf/d) Barrolka gas field (6.45 Tcf) Expansion of East Spar/Hariet area (162 Bcf remaining reserves) Bonaparte Basin (25.5 MMcf/d) Garanjie Field (30-50 Bcf)	
Canada	Grand Banks-White Rose Sable gas fields (only 6 out of 24 gas fields) Terra Nova (75 MMcf/d)	1998 2001 2001
Chile	Offshore exploration	
China	Yacheng 13-1 gas field Ledong Gas Fields Domgfang 1-1 Rehabilitating and upgrading of Sichuan fields Development of fields in Shaanxi-Gansu-Ningxia and Tarim Basin	
Indonesia	Natuna gas field (46 Tcf) Tangguh (13 Tcf) Rayun I and Bungin I (3D seismic studies on 1998)	 2003
Malaysia/ Thailand	10 Fields from MalaysiaThailand JDA (10 Tcf) -Block A-18 – 2 Tcf (first JDA field to come on line)	 2000
Peru	Camisea natural gas field (11 Tcf)	1996
Russia	Sakhalin* I (540 Bcm) Irkutsk (277 Bcm in C1 and 593 Bcm in C2)	
Thailand	Pailin Field (165 Tcf) Block 11/38 and Block 12/32 (Gulf of Thailand)	End 1998 2001
Vietnam	Twin Dragon field (26.6 MMcf/d) Son Tra Ly gas field (440 Bcf) Malay Basin-Block B (3-5 Tcf)	2000

Sources: EIA (1999b), EIA (1998b)

Based on projections, natural gas production in the APEC region is also expected to increase by 2.3% per annum from 757.8 Mtoe in 1995 to 1071.1 Mtoe in 2010.[1] The growth in gas demand will come from East Asia, specifically China, increasing by 6% from 1995 to 2010. Natural gas production in other regions (Americas, Southeast Asia and Oceania) is also forecasted to grow between 1.9% to 5.2% during the same period.

To meet gas production targets, some economies are strongly promoting the development of indigenous resources (Table 2.4). In Asia, for example, although the financial crisis had delayed ongoing gas projects,[2] many of the Asian APEC economies are going ahead with their plans. For instance, Unocal announced in mid-November that the development on the first phase of the Pailin field in Thailand will continue as scheduled, and production at the rate of 165 million cubic feet per day is expected to begin at the end of 1998. Unocal and Total (of France) also intend to continue development drilling, appraisal work and exploration commitments in concessions in Myanmar, Thailand, and Indonesia. In Malaysia, Esso and Shell will continue with their investment in exploration and field development. Other economies (Russia, Australia, Canada, China, Indonesia, Malaysia) will continue to develop their indigenous resources to meet domestic and international gas demand.

2.2 Supply-Demand Balance

The APEC region enjoys a comfortable balance as far as coal demand-supply relationship is concerned (Figure 2.1). Current figures show that proven coal reserves are more than adequate to meet anticipated demands for coal. Coal reserves are widely distributed and current coal production in the region has been higher than consumption. In addition, the existence of several exporters ensures that supply is stable. However, in year 2010 demand is expected to slightly exceed production which would mean higher imports of coal from outside the region.

The Americas and East Asia are the most important sub-regions in APEC in terms of coal production and consumption (Table 2.5). In 1995, East Asia accounted for about half of coal production and consumption in APEC, followed closely by the Americas. Coal consumption of southeast Asia and Oceania are rather negligible compared to the two mentioned, but Oceania's coal production is very significant.

In 1995, only East Asia, consisting of China, Japan, Korea and Taiwan, consumed more coal than it produced, and the deficit was filled by imports. In 2010, East Asia will remain a net coal importer as its coal production will lag behind coal consumption. In the same year, the Americas, due primarily to the US, will also be a net importer of coal with its coal production lagging behind coal consumption.

The gas demand-supply situation in the APEC region is less comfortable compared with that of coal. The region as a whole has huge natural gas resource base, particularly in Russia, but the lack of domestic and regional pipeline system has prevented exports to the APEC region. Thus, since 1980, the production of gas within the region has lagged behind consumption. The outlook for gas in 2010 is more critical, because there will be a larger gap between production and demand. As such, non-APEC gas-producing countries would play a crucial role in bridging this gap.

The region is composed of net importers and net exporters of gas (Figure 2.2). For some economies (China, Chile, Peru, Philippines, Vietnam, and New Zealand) the demand for gas is just equal to supply, thus trade within these economies has not taken place. In some gas resource-rich economies (Malaysia, Indonesia, Russia, and Brunei), the lack of gas infrastructure and domestic uses of natural gas made the country to consider LNG exports. Other economies with insufficient indigenous gas supplies (USA, Mexico) import between 1% to 13% of its gas supplies from other countries. Resource-strapped economies like Japan, Korea, Singapore and Taiwan are completely import dependent.

Projected gas demand in the APEC region is expected to outpace projected gas production. Gas demand is projected to increase at a faster rate of 3.3% per annum from 770 Mtoe in 1995 to 1,249 Mtoe in 2010 (Figure 2.1). Gas supply, on the other hand, is projected to grow at a slower rate of 2.3% per year, from 758 Mtoe in 1995 to 1,071 Mtoe in 2010. Thus, by 2010 most of the economies Malaysia, Indonesia, Russia, and Brunei), the lack of gas infrastructure and domestic uses of natural gas made the country to consider LNG exports. Other economies with insufficient indigenous gas importer. The net imports of gas in the region are expected to increase by 14 times the import in 1995

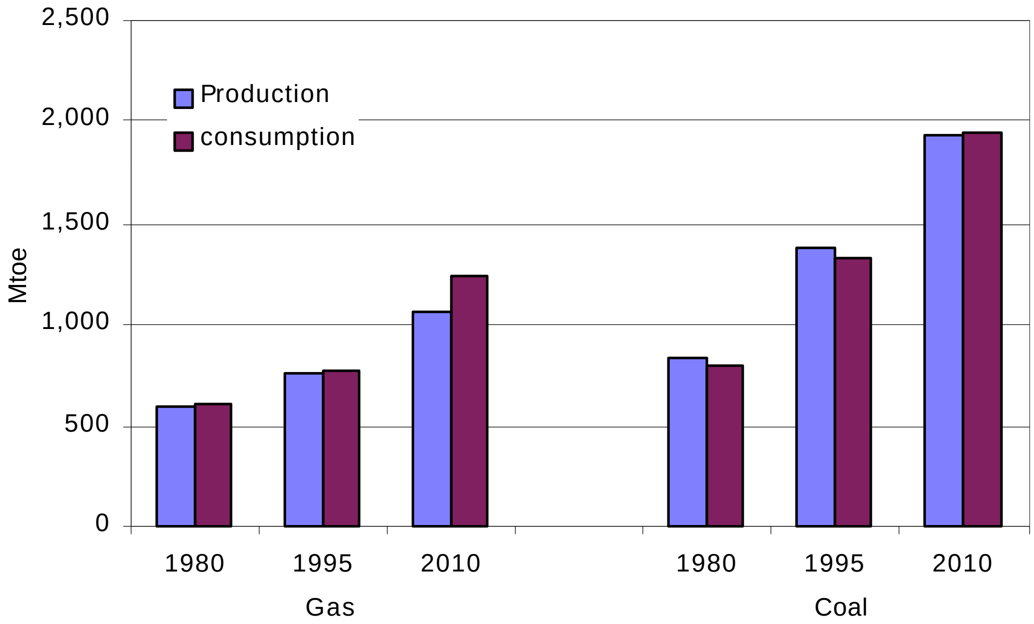


Figure 2.1: Coal and Natural Gas Production vs. Consumption
Source: APERC (1998)

Table 2.5: Coal Production and Consumption by Sub-region

	1995		2010		Annual
	Mtoe	% share in APEC	Mtoe	% share in APEC	Growth Rate (1995-2010
Consumption					
Americas	486	38%	615	33%	1.8%
East Asia	739	58%	1,135	60%	3.6%
Southeast Asia	15	1%	74	4%	25.9%
Oceania	38	3%	58	3%	3.1%
Production					
Americas	518	39%	685	36%	2.8%
East Asia	653	49%	951	49%	3%
Southeast Asia	31	2%	89	5%	12.8%
Oceania	131	10%	200	10%	3.5%

Source: APERC (1998)

(Table 2.6). Theoretically, the shortfall of natural gas supply in the region could be filled-up by imports from the Middle East and other non-APEC member economies.

On a sub-regional basis, the growth in gas production will lag behind consumption except for Oceania (Table 2.6). The gap between supply and demand will be large in East Asia (excluding Russia). The growth in East Asian production will come from China[3] whose share is projected to increase to 94% from 15 Mtoe in 1980 to 39.7 Mtoe in 2010. The growth in consumption, on the other hand, will also be highest in China where it is expected to increase annually by almost 10% from 15 Mtoe in 1995 to 57.3 Mtoe in 2010. The share of Korea and Taiwan in the region’s total consumption is projected to grow to 19% and 9%, respectively, while Japan’s share will slow-down from 66% in 1995 to 45% in

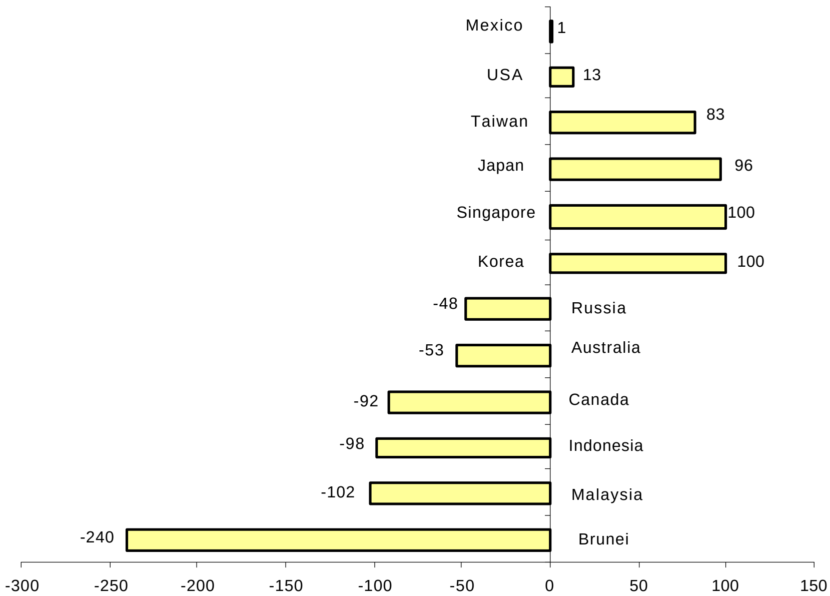


Figure 2.2: Net Natural Gas Imports, 1996 (% of gas production)
Source: IEA (1998d, 1998e)

2010. By 2005, China will become a net importer as projected demand increases will be more rapid than its future production.

In Southeast Asia, growth in gas consumption and production during the past decade has been at a remarkable pace marking 13.1% and 10.2% annual average growth rate from 1980 to 1995, respectively. It was also during this period that the region had substantial LNG exports. The Asian economic downturn, however, has slackened the growth in demand and delayed development of indigenous gas projects. Projections of gas demand in Thailand, for example, had been cut by 20% that led to the postponement of many gas projects. As a result, gas consumption in Southeast Asia for the period 1995 to 2010 will be moderate marking an annual growth rate of 6.5%. Production, on the other hand, will also experience a modest growth of 2.9% per year during the same period which will result to a decline in the region's net exports.

The projected gas consumption in Oceania is expected to grow at a slower rate of 4.9% from 21 Mtoe in 1995 to 43 Mtoe in 2010. Relative to demand, gas supply is forecasted to be higher resulting to substantial exports in the region. In fact, Oceania will remain a major net exporter in the APEC region by 2010. Growth in gas consumption in the American economies is expected to be faster than the projected increases in the production. As a result, the region will depend on gas imports to meet the projected increases in gas demand. Net imports are expected to increase by almost five times from 8 Mtoe 1995 to 38 Mtoe in 2010.

2.3 Trade and Infrastructure

APEC economies play an active role in the trade of coal and natural gas in international markets, both as buyers and sellers of these resources. To keep their competitive edge, coal and gas suppliers have prioritized their upstream development programs including the necessary infrastructures to bring these energy commodities to the international market.

In view of the availability of coal and natural gas both in the domestic and international markets, the

Table 2.6: Natural Gas Production and Consumption by Sub-region, Mtoe

	1995	2010	Annual Growth Rate (%) (1995-2010)
Consumption			
Americas	609	836	2.1
East Asia	79	212	6.8
Southeast Asia	61	158	6.5
Oceania	21	43	4.9
Production			
Americas	601	799	1.9
East Asia	18	42	6.0
Southeast Asia	110	168	2.9
Oceania	29	62	5.2
Net Imports			
Americas	8	38	10.8
East Asia	61	170	6
Southeast Asia	-48	-10	-9.8
Oceania	-8	-19	5.8
APEC	12.6	177.4	19.3

Source: APERC (1998)

use of these resources has been significant even in resource-poor or energy importing economies of APEC. In particular, the availability of both resources in the international market have given power producers (government and private developers) more alternatives to consider in planning or setting up new power plants. The advantage of coal over natural gas in the power sector is that it is more readily available through established international markets and infrastructure. On the other hand, more gas pipelines are being built or planned thus increasing the availability of gas.

2.3.1. Coal Trade

APEC is a major player in the global trade of coal. It has the top importers and exporters of coal in the world. In 1995, APEC was a net exporter of coal. However, it is expected that APEC will become a net coal importer in 2010.

The main buyers of coal in APEC and the top three importers of coal in the world are Japan, Korea and Chinese Taipei, accounting for about 39%, 9% and 6% of traded coal in the world. It is projected that by 2010 Japan will import about 40% more than its 1995 coal imports, while Korea and Chinese Taipei would double their coal importation.

On the other hand, the top coal exporter in the world and APEC is Australia, which accounted for about 28% of traded coal in 1997. Second is the US accounting for about 19% of global traded coal, fourth is Indonesia (6.8%), while Canada and China accounted for 5.3% and 5.1%, respectively. Australia, Indonesia and China are the major coal suppliers in Asia/Pacific because of proximity, while the USA and Canada are major exporters of coal mainly in the Atlantic (Europe) market. Australia exports to Europe when transport costs and coal availability is favorable.[4]

There are two major international markets for coal: the Pacific and Atlantic (European) coal markets. The US plays a major role as a marginal supplier in the steam coal market. High excess capacity allows the US to swing into and out of the market. South Africa is in a good position to respond to additional demand in Asia. However, it operates to full rail and port capacity, and could not similarly meet the tonnages which the US can readily meet and transport from its large supply base. Australia has low-cost mines which were developed in response to the rapidly expanding world market. It will continue to be the major exporter to Asia, meeting almost one-half of the region's total coal import demand in 2020. In Indonesia, new mines are being developed to produce export-quality coal and supply the domestic market. Indonesia and China are expected to meet 25% of Asia's total import needs by 2020.

While international coal trade has existed for a long time, the volume involved in coal trade is relatively small compared to coal production or consumption. Australian and Indonesian coal exports, which correspond to about 70% of local coal production, accounted for only 6.5% and about 1% of the 1995 coal production in APEC, respectively. China, the number one producer of coal in the world, exported 3% of its coal production in 1995 corresponding to only 1.45% of global coal production. The United States exported 10% of its 1995 coal production which is equivalent to only 3.6% of global coal production.

Coal trade is expected to grow moderately since importing countries need increasing quantities of coal (among other energy commodities) to meet the needs of their growing economies. However, a number of issues will determine the rate of growth in coal imports and the market conditions under which that trade will be conducted. These include international and national policy responses to levels of greenhouse gas emissions, prospects in Asia and financial confidence in the viability of independent power producers.[5] Growth in coal demand in Japan, Korea and Taiwan in recent years has contributed to a substantial rise in Asian coal imports, and would continue to be so in the next 20 years. China, which is both exporting and importing coal, is expected to provide preference to domestic consumption because (1) consumers are required to get permission to import coal, and (2) coal imports add to a power project's potential for running into foreign exchange problems, making it hard to get initial financing from lenders. Australia is expected to be the major exporter to Asia, meeting almost one-half of the region's total coal import demand in 2020.

Meanwhile, there is a potential oversupply in traded coal because producers have anticipated positive forecasts of growth in coal demand, especially in the Asian region. Plans for new coal mining projects and the removal of port constraints in most major coal regions indicate that demand will continue to be well met over the next five years.

2.3.2. Natural Gas Trade

The international trade of natural gas also occurs in regionalized markets, namely: North America, Asia Pacific and Latin America. The North American gas market is largely sufficient in natural gas, but gas is traded extensively within the region. The United States, despite its large indigenous natural gas resource, is the largest importer of pipeline gas among the APEC economies (Table 2.7). Canada, the largest exporter of pipeline gas, and Mexico are the main sources of natural gas of the US. At the same time, the US also imports LNG from Algeria. The Asian market comprises most of the world trade in LNG—which accounts for a major share of gas consumption in Asia. Japan is the largest importer of LNG accounting for more than 60% of world LNG consumption and 79% of the region’s LNG consumption (Table 2.8). Indonesia, on the other hand, is the largest LNG exporter, followed by Malaysia and Australia. In Latin America, cross-border trade between Argentina, Bolivia, Peru and Chile will be realized soon with the completion of gas pipeline projects linking these countries.

Trade is expected to increase further over the next 10 to 15 years, particularly in Asia, where demand will be largely driven by the power generation sector. Various LNG demand forecasts for Asia indicate that the demand could reach to about 160 million tons per year by the year 2015 from the current demand of 62 million tons[6]). Japan will remain the world’s largest LNG importer over the forecast period, with trade totalling nearly 80 billion cubic meters per year by 2010, increasing by 36% from 1995. South Korea's LNG imports will increase to 29.5 billion cubic meters per year while Taiwan is expected to increase three-fold rising to 14 billion cubic meters per year during the same period. Japan, South Korea and Taiwan will represent 80 % of the LNG increase and the rest by new buyers such as China, India and the Philippines.

At present, around three-fourths of gas is traded through pipeline, primarily within North America and Europe. According to a Banque Paribus report, the pipelines' share is expected to drop below 70% as more gas is extracted from distant regions, making shipping necessary.[7]

Table 2.7: Natural Gas Pipeline imports in the APEC region, 1996 (million cu meters)

Importing Economies	Exporting Countries/Economies					Total
	Canada	Kazakhstan	Malaysia	Mexico	USA	
Canada					1,218	1,218
Mexico					871	871
Russia		1,247				1,247
Singapore			1,585			1,585
USA	81,645			393		82,038
TOTAL	81,645	1,247	1,585	393	2,089	86,959

Source: IEA (1998e)

Table 2.8: LNG Imports in the APEC Region, 1996 (in million cu meters)

Importing Countries	Exporting Countries/Economies							Total
	Australia	Algeria	Brunei	Indonesia	Malaysia	UAE	USA	
Japan	10,037		7,949	25,631	13,272	6,314	1,770	64,973
Korea	73		921	8,179	3,359			12,532
Taipei				2,220	1,602			3,822
USA		1,000						1,000
TOTAL	10,110	1,000	8,870	36,030	18,233	6,314	1,770	82,327

Source: IEA (1998e)

2.3.3. Infrastructure

To be more competitive in the international trade of coal and gas, suppliers have prioritized their upstream development programs and necessary infrastructures to bring these energy commodities to the international market.

The major coal-producing economies of APEC have prioritized the development of their infrastructure for the transport of coal for the domestic and the international markets. Australia, the USA and Canada have sufficient infrastructure facilities for coal transport. In Australia, coal is transported to ports by railways. There are six coal ports in Australia and nine coal loading terminals. In the USA, the rail system is extensive but only major carriers serve most coal mines. Barging is also used but limited to domestic consumers. Meanwhile, existing port have carrying capacities exceeding export requirements.[8] Canada has railways and ports to transport coal for domestic and export markets.

In China, coal mines are far from domestic markets. Coal is transported by rail, (40% of rail freight), water (15% of water-borne freight) and road. The country's present transport infrastructure is estimated to carry only about 60% of coal demand. As such, measures were taken to improve these facilities. Overall coal carrying capacity is expected to reach 830-850 million tons by 2000, an increase of 160 million tons over the capacity reached in the Eight Five-Year Plan. At the end of the ninth plan, the coal carrying capacity of the "Three Western Regions" will reach 350-370 million tons, an increase of 140 million tons over the eighth plan. Meanwhile, major ports for all commodities will be enhanced. By 2000, the combined loading capacity of all ports in the north will reach 190 million tons.

Indonesia's current mining operations are close to the coast or navigable waterways, thus minimizing costs from mine to port or barge loading facilities. However, there are undeveloped mines in non-strategic areas and future exploitation would entail additional transportation costs and large investments in associated infrastructure.

Meanwhile, domestic gas infrastructures are already in place with further additions underway. The APEC region has a total of 525,859 km of domestic gas transmission pipelines, and 1.8 million km of distribution pipelines, majority of which are in the US and Canada (Table 2.9). The domestic natural gas infrastructure in Asia and Oceania, on the other hand, is far less developed and, at present, inadequate to bring gas to the market. Most of pipelines—initially built, owned and operated by the government—were built between a single source of supply and a single source of demand.[9] For instance, Australia's state gas markets are characterized by a single supplier from a single basin through a single transmission pipelines or a single production source to a single distributor. The lack of domestic infrastructure in Asian economies was due mainly to the high capital investment required in constructing transmission and distribution facilities.

In well-developed infrastructures such as in Canada and the US, most plans for new infrastructure aim at increasing system capacity through pipeline looping, compression additions, or both.[10] The development of domestic gas infrastructure in the APEC region, therefore, will be focused mainly in the Asian (Australia, Indonesia, Thailand, Philippines, Vietnam) and Latin American (Mexico) economies (Table 2.10). About 452 miles of ongoing gas infrastructure projects in the region will be completed between 1999 to 2007, and most of this will be built in Mexico.

In the North American region, pipeline infrastructures have grown rapidly to support the trade between the USA, Mexico and Canada. That for the Asian region, on the other hand, is less developed than in North America. At present, there are only two international trade pipelines that exist in Asia: Malaysia-Singapore and Thailand-Myanmar pipelines. In Latin America, the completion of the Gas Andes pipeline in 1997 has provided gas supplies in Chile from Argentina. To meet the expected demand, other economies are exerting more efforts to develop more transmission infrastructures to facilitate the entry of gas into the market (Table 2.11). The most notable of these pipeline projects are the trans-ASEAN and the Northeast Asian gas grids which is further elaborated in the succeeding section.

Table 2.9: Domestic Natural Gas Pipelines in the Asian Region

Economy	Transmission Lines (km)	Distribution Lines (km)
Australia*	10,475	59,206
Canada *	23,000 (main) and 47,000 (regional)	178,000
Japan*	742	189,700
New Zealand	2,550	6,680
USA*	453,462	1,380,676
Brunei	920	
China	6,200	
Indonesia	1,703	
Malaysia	377	
Thailand	350	
Total	525,859	1,814,262

Note: Pipelines in Brunei, China, Indonesia, Malaysia and Thailand include transmission and distribution lines.
* As of 1994
Sources: IEA (1994), Carson (1998)

International trade also requires adequate LNG facilities to ease the import and export of gas. At present, the APEC region has a total LNG liquefaction capacity of 2,580 billion cubic feet, of which

98% is in Asia (Table 2.12). New facilities in the region are also being constructed. Planned extensions to existing capacity involve almost one trillion cubic feet of additional LNG capacity.

Table 2.10: Domestic Natural Gas Infrastructure Projects in APEC

Economy	Infrastructure projects	Length (miles)	Cost ($ billion)	Completion date
Australia	Interstate gas grid (plan)	6,831	4.07	
Indonesia	Prabumulih to Cilegon	0.5	0.3	2000
	Asemera to Prabumulih	0.09		
	East Java to West Java Interconnector	0.4		
	Extension of the East Java grid	0.18	0.11	
	South Sulawesi to Ujung Pandang	0.27	0.084	
	Natuna Field to Natuna Island			
	Connect Cirebon and Surabaya,	0.225		2000
	East Kalimantan and Surabaya, and		0.99	between
	West Natuna and Central Java (plan)			2001-2010
Mexico	Tabasco-Yucatan Palmillas-Toluca	450	0.276	1999
Philippines	Malampaya field to Manila (plan)	0.5		2001
Thailand	Erawan Field to Ratchaburi			2007
Vietnam	Lan Tay and Lan Do fields	0.37		1999
	Bach Ho field Long Hai (plan)	0.228	0.3-0.4	

Sources: EIA (1999b), IEA (1998b), IEA (1996), APEC/CEERD-AIT Survey (1998/1999)

2.3.4. Trans-ASEAN Gas Grid

An ambitious endeavor in energy cooperation in ASEAN, the Trans-ASEAN Gas pipeline grid is an 8,000-km long undersea link that would connect the region's net exporters like Brunei, Malaysia and Indonesia, to the region's gas importers like the Philippines, Thailand, and Singapore.[11] The realization of the Trans-ASEAN Gas Transmission System (TAGTS),[12] and its timing are based on two major assumptions:[13]

- The producing countries, which cannot export or decide not to export their gas surplus in a particular year, can use this for domestic needs or export in a later year; and
- Natuna is a key issue for the future ASEAN import/export situation and the potential linkages will be significantly affected by the occurrence and timing of the Natuna development. Other major sources are Kalimantan (Kutai Basin) and the Brunei and Sabah fields.

Five sections have been proposed. Economic analyses of these sections were undertaken (Table 2.13), and alternative options studied (Table 2.14). The most economically attractive options are shown in Table 2.15. A number of recommendations from ASEAN policy makers and energy players have also been generated for the realization of the proposed ASEAN gas grid (Box 3.1).

Table 2.11: On-going and Planned International Gas Pipelines Projects

On-going/Planned Gas Projects	Length (miles)	Cost ($ million)	Start-up date
Australia			
PNG's Kitubu and Pandora-Cape York-Gladstone	1,500	1,400	2001
Canada			
Alliance Pipeline (from W. Canada to Chicago)	1,900	2,500	1999
From W. Canada-Illinois-Wisconsin Express Project	150-200	220-280	2001
ANR link (Illinois, Joliet) w/ Alliance pipeline -		125	plan
Expansion of ANR existing system through Supply Link (Chicago to Defiance, Ohio)- plan			1999 (plan)
Independence Pipeline (Defiance to Leidy, Pennsylvania)		630	
Manitoba via Wiscosin w/ Joliet, Illinois	775	1,200	plan
Trans Voyaguer (Saskatchewan-Manitoba)	388		plan
There are several other projects proposed for expanding transport facilities.			
Chile			
Gas Atacama pipeline	583	750	1999
Nor Andino alliance		400	
Tierra del Fuego, Argentina to Punta Arenas	70	6.5	1999
China			
Lake Baikal, Siberia or Irkutsk to Beijing, China	1,863.4	7,000	
Kazakhtan to east coast China	3,726.71		
Central Asia to China	4,720.5		
Indonesia/ Singapore/ Thailand/ Brunei			
West Natuna to Malaysia	0.130		
Natuna to Thailand	1000		2007
West Natuna to Singapore	397	300-400	2001
Connect Arun and Natuna (via Malaysia waters), East Kalimantan and Brunei, and Natuna and Brunei, and , Brunei and Bontang	2,000	2,100	2010-2020
Malaysia			
Trans-Thailand-Malaysia pipeline			
Mexico			
Tabasco-Central America (Guatemala, Honduras, El Salvador, Nicaragua and Costa Rica)	450	500	plan
Peru			
Andes to Lima (via Pisco on the Southern Coast of Peru)		2,000	2001
Plan to link Bolivia/Brazil/Peru			
Russia			
Yamal-Europe	2,500	40,000	2010
Rusia-Turkey (via Black sea)		3,000	2000
Kovytka, Irkutsk to China (under feasibility study)			
Thailand			
Yadana field (Myanmar) to Ratchaburi	0.416	1,000	1998
USA			
Three separate gas pipeline projects (from Canada to Midwestern area of US and into the Northern New England)			1999

Source: EIA (1999b)

Table 2.12: Existing, Ongoing and Planned LNG Liquefaction Plants

	Plant Operator	Trains	Capacity (Bcf)	Start-up
EXISTING			2,580.4	
Australia:				
Northwest Shelf	NWS joint venture	3	365.2	1989-1992
Brunei:				
Lumut	Brunei LNG	5	316.6	1972
Indonesia:				
Arun Phase I	PT Arun NGL	3	219.2	1978
Arun Phase II	PT Arun NGL	2	146.1	1984
Arun Phase III	PT Badak NGL			
Bontang A/B	PT Badak NGL	2	73	1986
Bontang C/D	PT Badak NGL	2	156	1977
Bontang E	PT Badak NGL	1	112	1989
Bontang F	PT Badak NGL	1	112	1993
Bontang G (start up due 1998)	PT Badak NGL	1	131.5	1998
Malaysia:				
Bintulu MLNG I	MLNG 1	3	394.5	1983
Bintulu MLNG 2	MLNG 2	3	379	1995
USA				
Kenai	Philips	1	63.3	1969
UNDER CONSTRUCTION			131.5	
Indonesia:				
Bontang H	PT Badak NGL	1	131.5	Originally 2000, but facing delays
PLANNED			915.56	
Australia:				
Bayu Undan (Darwin II)	BHP/Philips	1	146	Originally 2003, but facing delays
Gorgon LNG	Chevron, Mobil, Shell, and Texaco	2	418.8	Originally 2003, but facing delays
China*				
Guangdong LNG Fujian LNG Shanghai LNG				2002-2005 *under study
Indonesia:				
Bontang I				Unknown
Irian Jaya (Tangguh)	Arco/Pertamina	2	292.2	Originally 2003, but facing delays
Malaysia:				
Bintulu MLNG 3	MLNG 3	2	331.16	2001
Russia:				
Sakhalin II	Sakhalin Energy		292.2	Originally 2005, but facing delays
Canada:				
Pac-rim LNG				Originally 2000, but facing delays

Source: Petroleum Economist (1998), Hydrocarbon Asia (1998)

Box 2.1: Recommendations on the ASEAN Gas Grid

Creating the necessary market foundation

- Introduction of future gas pricing policies based on market value of gas

Supply network:

- further investment in exploration and exploitation of the potential resources;
- implementation of LNG importation projects as a complement to pipeline projects;
- creation of proposed trans-ASEAN network on a staged basis;
- consider the importance of the Natuna gas field in the development and utilization of natural gas

Removing potential barriers:

- initiation of regular forums involving all ASEAN countries, aiming at developing a common basis and cooperation framework in the field of energy and gas policy, pricing policy and legal and institutional aspect.
- promotion of technological and know-how transfer, improve conditions for exploration of potential reserve, constant monitoring of supply and resources;
- conduct further feasibility studies including possible financing schemes for specific infrastructure projects arising from the conclusions of the Master Plan study;
- continuously review and follow-up potential forecast of gas demand by sector and by country/region.

Areas for agreements and cooperation:

- Definition of important rules and arrangements of the transnational pipeline projects through cooperation in network, bilateral or multi-lateral agreements on items such as:
    - scheduling of LNG exports and imports and of possible gas pipeline links;
    - transit rights, application of GATT rules and/or other treaties;
    - regime and regulation of gas transit;
    - tariffication of transmission principles'
    - pricing issues;
    - setting up of pipeline consortium
    - financing of the pipelines;
    - sovereign guarantees, if required;
    - security of supply, force majeur, etc.;
    - disputes settlements.

Source: AEEMTRC (1996)

2.3.5. Northeast Asian Gas Grid

The Northeast Asian gas grid, on the other hand, is planned to free and make available the natural gas resource from Russia to the Northeast Asian market.[14] There are four potentially gas-producing regions in Russia: Sakhalin and the Sakha Republic, in the Russian Far East, and the Irkutsk and Krasnoyarsk regions in Eastern Siberia, all have a combined proven reserves of almost 90 trillion cubic feet. These identified but undeveloped gas reserves are adequate to supply the Northeast Asian market.

Table 2.16 summarizes several pipeline route alternatives for the different projects which are under consideration. Feasibility studies have been undertaken on this project focused mainly on the reserves, markets and the selection of pipeline routes.

The realization of the Northeast Asian pipeline, however, faces obstacles including:[15]

- Lack of institutional arrangements needed either to mobilize local capital or to recruit outside investment to create needed infrastructure in North Korea and the Russian Far East;
- Lack of governmental plans and policies in China and Japan that will support the pipeline projects;
- China's electrical power planning still provides no explicit role for gas-fired generation; and
- Lack of an internal gas transmission and distribution network in Japan;

Table 2.13: Basic Configurations of the Trans-ASEAN Gas Transmission System

Option	Gas Flowrate (billion cubic meters per year)	Year	Investment Costs (Million US$)	Operating Costs (Million US$)	DCFRR (%/year)	Netback Value (At 20%/year) (US$/MMBtu) (3)	Average Wellhead Costs (US$/MMBtu)
SECTION 1 ALTERNATIVE 1 (Samarinda-Beaufort-Batangas 8 BCMY)	8	2020	2255.0	29.2	31.0	1.9	0.5
SECTION 1 ALTERNATIVE 2 (Samarinda-Beaufort-Batangas 15 BCMY)	10 from Samarinda 5 from Beaufort	2020	2946.5	56.9	40.0	2.5	0.5
SECTION 2 (Samarinda-Surabaya)	10 from 2010 15 from 2015	2010	1763.9	32.3	43.0	2.6	0.5
SECTION 3 (Surabaya-Jakarta)	8 from 2010 10 from 2015	2010	639.0	8.2			
SECTION 4 (Natuna-Batam-Asamera-Jakarta)	6 to Singapore 7 to Asamera 15 to Jakarta	2020	4066.0	93.8	31.0	2.8	2.0
SECTION 5 (Natuna-Kerteh-Bangkok)	10 to Kerteh 15 to Bangkok	2020	3155.0	46.7	34.0	2.9	2.0

Notes:
(1) Value of gas delivered to the Bongkot fields.
(2) Transmission costs from Natuna to the Bongkot fields.
(3) For LNG options, it is the FOB value of gas at the outlet at the liquefaction plants.
(4) Investment and Operating Costs refers to regasification only.

Source: AEEMTRC (1996)

Table 2.14: Alternative Options of the Trans-ASEAN Gas Transmission System

Option	Gas Flowrate (billion cubic meters per year)	Year	Investment Costs (Million US$)	Operating Costs (Million US$)	DCFRR (%/year)	Netback Value (At 20%/year) (US$/MMBtu)	Average Wellhead Costs (US$/MMBtu)
ALTERNATIVE 1.A (SECTION 1) (Camago-Batangas) Beaufort-Camago-Batangas)	5 from Camagao 2.5 from Canago +2.5 from Sabah	1st phase: 2000 2nd phase: 2010	1474.9	7.0	34.0	2.5	0.5 from Kalimantan 1.75 from Philippines
ALTERNATIVE 1.B (SECTION 1) (Samarinda-Beaufort-Batangas slow build up)	5.0 from 2010 9.0 from 2015 15.0 from 2020	2010	2946.5	56.9	21.0	0.8	0.5
ALTERNATIVE 2.A (SECTION 2) (Samarinda-Surabaya)	10.0 from 2006 15.0 from 2015	2006	1763.9	32.3	41.0	2.5	0.5
ALTERNATIVE 3.A (SECTION 3) Surabaya –Jakarta)	8.0 from 2006 10.0 from 2015	2006	639.0	8.2	65.0		
ALTERNATIVE 4.A (SECTION 4) (Asamera-Batam)	6.0	2000	538.0	4.4	33.0	3.1	0.5
ALTERNATIVE 4.B (SECTION 4) (Natuna-Batam-Asamera-Jakarta)	6.0 to Singapore 7.0 to Asamera 15.0 to Jakarta	2020	3887.4	80.3	----	2.8	2.0
ALTERNATIVE 5 (SECTION 5) (Natuna-Bongkot Fields)	9.0	2010	1091.0	11.0	----	2.9 (1)	2.0
Philippines LNG from Middle East (4)	4.0	2020	500.0	22.5 (5)	----	2.3	----
Thailand LNG from Middle East (4)	2.0 8.0	1st phase: 2001 2nd phase: 2005	410.0 290.0	18.5 31.1	----	2.0	----
Badak LNG to Japan (4)	4.6	2012	440.0	20.0	----	2.6	----
Badak LNG to Surabaya (4)	4.6	2012	440.0	20.0	----	2.8	----

Notes: (1) For Bongkot, value of gas delivered to the Bongkot fields. (2) Transmission costs from Natuna to the Bongkot fields. (3) For LNG options, it is the FOB value of gas at the outlet at the liquefaction plants. (4) Investment and Operating Costs refers to regasification only.
Operating Costs refer to regasification only.

Source: AEEMTRC (1996)

Table 2.15: Attractive Options According to Economic Analysis

	Estimated Investment Cost (US$)	Estimated Transmission Cost (US$/MMBtu)
Asamera-Batam/Singapore (Section 4 Alternative 4A)	3.9 billion	0.57
Natuna-Bongkot fields (Section 5 Alternative 5A)	1.1 billion	0.48
Natuna-Kerth-Bangkok (Section 5)	3.2 billion	0.53
Samarinda-Beaufort-Batangas (Section Alternative 1B)	2.9 billion	0.82

Source: AEEMTRC (1996)

- Energy demand in Japan is very unlikely to grow as rapidly as in the past because of the current recession, long-term population decline, and the slow economic growth accompanying financial reconstruction.

The deregulation and reforms in the natural gas industries in Japan and China are important to the development of the Northeast Asian gas grid. Deregulation measures in Japan were taken up in 1995 and 1996 that allowed a gas utility to sell gas beyond its service area and that promoted third party access. However, the Institute of Energy Economics, Japan (IEEJ) argues that for gas utility deregulation measures to significantly affect increased demand for natural gas, wholesale gas supply to reduce the gas cost for small and medium-sized city gas companies should be promoted. Additionally, the development of a system of gas trunk pipelines to enable direct and economical supply to large users is needed.

Table 2.16: Northeast Asian Grid Pipeline Projects

	Alternatives	Comments
Sakhalin project	a 500-mile pipeline to an LNG terminal on southern Sakhalin a subsea pipeline extension to Japan a pipeline crossing from northern Sakhalin to the Russian mainland, via Khabarovsk and Vladivostok on its way to North and South Korea, and perhaps to Japan in the vicinity of Kitakyushu or Shimonoseki.	The current marketing is complicated and prolonged by the absence of any domestic pipelines capable of receiving Russian gas on its arrival either in Hokkaido or western Japan.
Irkutsk project	A 56-inch trunk line would extend 4,100 km from Irkusk pas Ulaanbaatas via Mongolia and northern China to Beijing, into South Korea either by a subsea route or via North Korea, and on to Japan.	A memorandum was signed on Dec 25, 1997 between the Russia, China, Japan, Korea and Mongolia to prepare a project feasibility study by 1998.
Sakha project (Yakutia)	Yakutsk and southward along Russia’s eastern margin past Vladivostok, via North Korea to markets in South Korea and Japan. Yakutsk bypassing Korean peninsula to a subsea pipeline crossing into Hokkaido. Irkutsk to Vladivostok along the Trans-Siberian Railroad, then crossing both North and South Korea to Japan.	Feasibility studies have been undertaken since 1970s.

Source: Tusing (1998)

2.4 Implications of Resource Availability on Energy Security and Fuel Choice for Power Generation

While the prospects for the long term supply for coal in APEC is positive, that for natural gas is not very comfortable. The market however contributes to the stability of the international supply of coal and natural gas. Moreover, in the Asian region the development of the natural gas pipeline grid will contribute to the stability of gas supplies.

The international coal market is stable and could be relied upon by coal importing economies to deliver the required coal supply. Furthermore, investments in coal production in other countries can ensure a secure supply of coal, as what Japan has done. The main element that could interrupt coal supplies is the issue of labor unrest in the coal mining industries of the producing economies. Strikes and work stoppages by coal miners are potential problems for coal importers. In 1996, Russian coal production fell drastically in 1996 due in most part to labor unrest and strikes in the coal industry. In December 1996, 200,000 miners staged a strike that effectively closed half of Russia's coal mines. The primary reason for the strikes was the inability to pay wages because consumers failed to pay up to 80% of their bills in 1996. The biggest financial problems were felt by the higher cost underground mines, with open-pit mines faring better. The bulk of non-payment came from electric power producers. Non-payments were partially compensated for by subsidies from the Russian government (EIA, 1998). The US has also experienced disruptions in coal transport because of problems in the railway system. These fears, among others, have resulted in a cautious development of import coal facilities.

On the other hand, several strategies have been implemented by a number of APEC economies to ensure a secure supply of natural gas. For example, APEC economies endowed with rich oil and gas resources are strongly promoting the development of indigenous oil and gas resources. The main reason is to ensure the availability of oil and gas supply in the future. Some APEC economies also enter into joint venture contracts or concessions with other non-APEC member economies around the world so as to secure gas supplies in the future. Thailand, for example, have joint development projects with Myanmar and Malaysia, China with Sudan, Venezuela, Iraq, Kuwait and Kazakhstan, and Japan with several Asian countries and with the Middle East[16] countries. Other economies that are import dependent also have set up necessary strategies in gas trade. Japan, Korea and Taiwan, for example, enter into long-term contracts in order to secure gas supplies in the future.

In addition to gas supply sources, the development of gas infrastructure has been growing in the APEC region especially in the Asia-Pacific. Several international and domestic projects are planned for construction so as to facilitate the entry of gas to the market. The plan to interconnect the isolated gas system within and outside the APEC region (the Northeast Asian and Southeast Asian grids) to move natural gas from gas-surplus countries to gas-short economies is also a means to secure gas availability and stability. Furthermore, the short distances between gas producing countries (Indonesia, Malaysia and Brunei) and those importing member countries (Thailand, Singapore and Philippines) would make pipeline trading more attractive than via LNG.[17]

The development of trade groupings in the Latin American market will also contribute to the security of supply in Latin America. At present, international gas trade takes place only between Bolivia and Argentina and the US and Mexico. The intra-regional trade groupings such as Mercosur and the Andean Pacts in the Latin American market, however, results to the development and construction of international gas pipelines in the Latin American countries. The planned pipelines will connect inter gas pipeline connecting Paraguay, Uruguay and Peru to be developed over the next 15 years. Brazil and Chile’s gas pipelines are planned to be built through private financing.

Meanwhile, the availability of a stable supply of energy sources results in competition of coal and natural gas in the power sector. Coal has long been established as a major fuel for power generation in many APEC economies because of its availability, either through local production or importation. On the other hand, natural gas is increasingly being used by APEC economies due to its more advantageous use in terms of efficiency and environmental impacts, among others, and its increasing availability.

The use of coal and natural gas for power generation is very significant even for economies with limited reserves (Figures 2.3 and 2.4) with coal having the greater share for power generation compared to gas. In 1995, the share of coal in power generation in coal producing economies ranged from 26% in Indonesia to 86% in China depending on the availability of other energy resources, while that for net coal importing economies ranged from 2% in Malaysia to 34% in Chinese Taipei. On the other hand, the use of natural gas among gas-producing economies ranged from 5% in Canada to 90% in Brunei, while that for gas importing economies ranged from 2% in Chile to 21% in Singapore. Furthermore, the major players (importers and exporters) in either sector are invariably the same economies, excluding the United States which is a net gas importer. It can be argued that coal has long been established as a major fuel for power generation because of its availability in the market.

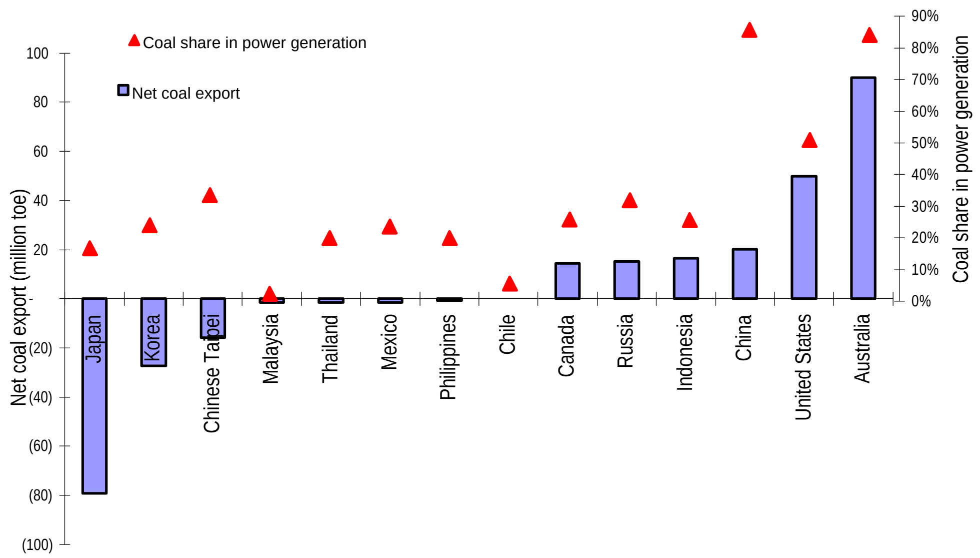


Figure 2.3: Coal Availability versus Use in Power Generation
Source: APERC (1998), IEA (1997)

Among coal-rich economies, Australia and China are highly dependent on coal for power generation because coal is more available in their countries, while other resources are not. In particular, China is hard-pressed to develop its coal resources to fulfill its growing energy demand and reduce its dependence on imported energy. The United States has a large demand for power with more than half of its power generation supplied by coal. It is fortunate that it has several supply options ranging from local production to importation of energy from neighboring countries. Canada, Russia and Indonesia also use coal for power generation but to a lesser extent compared to the aforementioned economies. This can be attributed to the energy resources which are available in these economies. Canada is abundant in hydropower, while Russia and Indonesia are abundant in petroleum sources.

Meanwhile, among major coal-importing economies—Japan, Chinese Taipei and Korea—power generation is balanced among coal, petroleum and nuclear-based power plants, which could be attributed to the policies on these economies to rely on more stable and available energy supplies. Among minor coal-importing economies, the Philippines and Thailand coal use for power generation is also high at about 20% of their generation mix. They have significant coal resources but the quality is low. Hence, they have to import better-quality coals in response to public complaints particularly from communities which host the coal power plants.

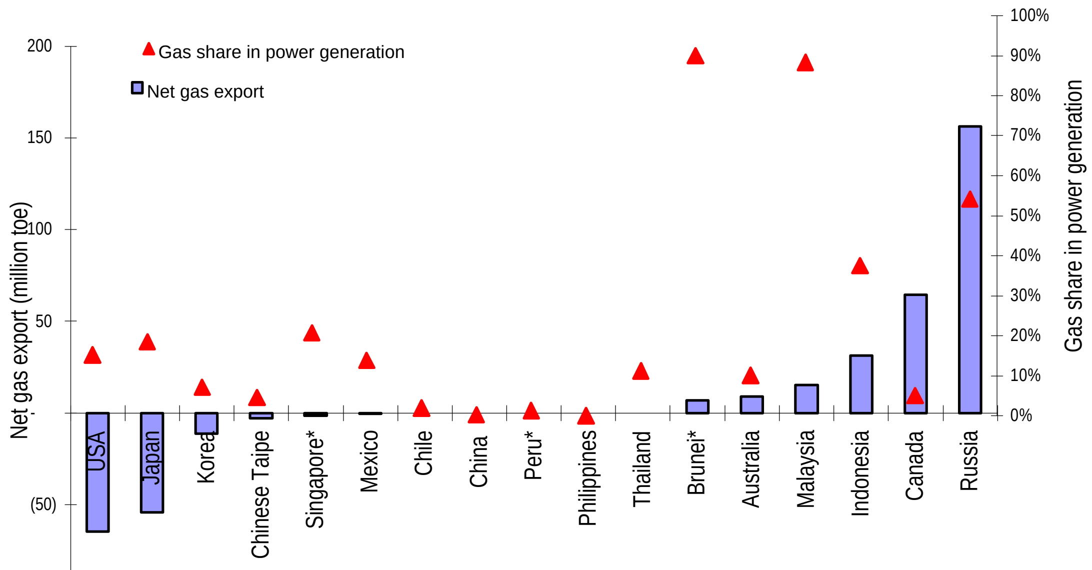


Figure 2.4: Gas Availability versus Use in Power Generation
Source: APERC (1998), IEA (1998b)

The use of natural gas for power generation is on the rise in competition with coal. Among the major gas producers, gas is the primary fuel for power generation in Brunei, Malaysia, Russia and Indonesia (over 40% of their power generation mix). This can be attributed to their rich petroleum reserves which have been developed at an early stage. However, Canada and Australia, which are rich in hydropower and coal, respectively, have a low dependency (5% and 10%) on gas for power generation. Meanwhile, the three gas-importing economies—Japan, Korea and Chinese Taipei—depend on gas for about 20% or less of their power generation mix. Again, this seems a reasonable level for importing economies to reduce their dependence on volatile supply markets. The United States, on the other hand, sources 15% of its generation mix from natural gas because of its availability from Canada.

The competition between coal and natural gas for power generation will intensify in the future as more reserves are tapped and the related infrastructures are put in place. Therefore, the availability of coal and natural gas supplies is a major consideration in the selection of fuel for power generation.

2.5 Policy Issues

In APEC, there are existing and emerging policies that govern the development and use of coal and natural gas. These policies take into consideration the availability of resources, the changes in economic and investment climates at the country and global levels, and developmental and environmental aspects leading to economic progress. These policies have favored the increased use of coal and natural gas, and in particular effect competition between coal and natural gas for power generation.

The important policies are discussed in more detail below and summarized in Table 2.17.

Exploration, Development and Production

Most of the economies with rich or even limited coal or gas reserves have adopted policies to develop and diversify their own resources, invariably to decrease their dependence on imported oil and/or increase their revenues through exports.

Resource-rich economies such as the USA, Canada and Australia have developed their resources with limited government control, and strong participation of the private sector and foreign investors. Other economies which have limited oil and natural gas resources, like China, have developed their resources but with government control in full or in part to protect their local coal or gas industries. However, the trend is toward freer market conditions, in a bid to attract foreign and local investment.

The development of indigenous resources such as coal and natural gas, however, is tempered with concerns for the environment. Many economies have laws which protect the environment. Even China which is in great need of energy had to close down a number of small-scale coal mines and limit the use of coal to reduce the negative impacts on the environment.

In the USA, there is no control that affects prices or quantities. However, a number of regulations do exist on the development and use of coal, such as the 1977 Surface Mining Control and Reclamation Act and the 1990 Clean Air Act Amendments. The latter imposed limits on electric utilities SO2 emissions in two phases (1995-1999, and starting 1 January 2000).

In Canada, the northern part has not been well explored or developed due to aboriginal land claims and economic factors. Additionally, environmental consideration is also one of the obstacles to further development of its gas reserves.[18]

Investment

Resource-rich economies such as the USA, Australia and Canada have developed their local resources through private and foreign investments in free market conditions. In general, the developers of new coal and gas discoveries particularly in Asia are also the developers in the established coal and gas fields, and thus have the experience and the money to invest in new ventures.

In Australia, foreign investors can own up to 100% of mining businesses at all stages of development. However, the Australian coal industry is regulated by the governments of New South Wales and Queensland. In New South Wales, review proposals have been released covering the development approval process and the licencing regime, which has been responsible for delays in projects. In Queensland, a review of environmental management regulation is underway. A number of measures were also required to protect coal resources for future development, including assessment of resources, preparation of a strategic development plan, planning classification of key sites, and development of multiple land use classification for conservation areas. In 1997, export controls were removed. Before April 1996, granting of approval for coal export did not require prices, but remained subject to the Commonwealth Environment Protection Act and the Australia Heritage Commission Act of 1974.

Meanwhile economies in Asia which do not have enough capital to develop their own resources are opening up to foreign investors by way of creating favorable market conditions for private sector participation, and rationalizing or reorganizing existing energy industries. At present, Japan, Russia and Vietnam are reorganizing their local coal industries for this purpose.

Policies of some APEC economies to support further upstream gas development have been less attractive for foreign investment due to economic, legal, political and environmental uncertainties. Foreign investors in Russia, for example, are reluctant to invest in the exploration and development of natural gas resources due to number of issues: (1) inadequate legal assurance to foreign investors[19]; (2) Russian tax system (supply side) is also very complex[20]; (3) legal issues surrounding the Caspian Sea's resources[21]; (4) lack of infrastructure; and (5) severe political and economic and social pains associated with the transition from communism to capitalism, making for a difficult operating environment even for skilled international gas companies.

In China political and legal uncertainties are the main barriers to foreign upstream gas investment.

In Mexico, the government has not given high priority to the development and use of its natural gas reserves. A major constraint has been the lack of investment in pipeline infrastructure for transporting gas over long distances (most production is in offshore and southern onshore regions while population is concentrated inland and in the north). Additionally, the Mexican government does not allow completely foreign companies to exploit its hydrocarbon resources. Foreign participation in oil and gas exploration and production is still prescribed by the Mexican constitution (which allows only Pemex to engage in these activities). However, there has been a speculation that the government will allow foreign firms to produce gas in the northern part of Mexico.

Russia has implemented several measures for a streamlined coal industry. Presidential Decree (Measures to Enhance the Coal Industry) was issued in February 1996 which: (i) ordered the closure of 14 of Russia's 234 deep mines (including 37 mines which had already ceased production), and (ii) converted Rosugol—the government coal company which controls most coal pits in Russia—to a joint-stock company restructuring plan, involving mine closures and the rehabilitation of existing plan and equipment, began in 1993 and was supposed to have resulted to the privatization of Rosugol and the ending of subsidies. A Presidential Decree was issued in 1997 which put Rosugol in liquidation, a process which is scheduled for completion in mid-1998, and reorganized the structure within the Ministry of Fuel and Energy to support the continuing rationalization and privatization of the industry.

Another strategy is the development of resources not only within the country but also outside. For instance, gas- and coal-short or non-producing countries (Japan, Korea, Taiwan) invest in resource-rich countries to secure gas and coal supply for the future. For instance, Japan has invested in Australian coal industry, although its investment is comparatively small. Australia has also invested in Indonesian coal, which is more of a global business strategy than as an energy security objective. Thailand's largest coal mining group, Banpu, has also invested in Indonesian coal mines to ensure a stable supply of coal for Thai consumption.

Trade

Resource-poor economies have to supplement their energy supply with imports. Furthermore, they diversify their energy mix and the source of imported energy to minimize their dependence on one particular resource or country. In addition, some economies have invested in the development of resources in other countries to ensure a stable energy supply.

The most serious emerging issue that could impact on coal and natural gas is the potential for a binding international agreement to reduce emissions of carbon and other greenhouse gases. If the Kyoto Protocol is ratified, it would mean reduced coal consumption, particularly in the United States, and increased consumption for natural gas.[22]

The APEC region will become a net importer of gas by 2010. APERC projects that net imports of natural gas by 2010, are expected to be more than 14 times the level of 1995. Less than 2 percent of natural gas supply came from outside the APEC region in 1995, but by 2010 the region will import 14% of its gas requirement. The region's growing dependence on external sources of gas has important implications for the regions gas security. As the economies in the region import larger and larger quantities of energy from outside sources, their vulnerability to supply disruptions, and potential economic losses would rise (APERC, 1998).

Infrastructure

The development of Northeast Asian and ASEAN gas pipeline provides an opportunity for regional resource cooperation among the APEC economies. However, although many of the economies favor the development of the trans-national pipelines system, the potential constraints are numerous:

- competing demands for capital
- infrastructural constraints
- differing political systems
- incompatible ideologies
- imbalance of military and economic power
- political conflicts
- differing pricing systems
- incomplete legal regimes

On the technical side, as the number of gas grid interconnections among the APEC economies increase, additional issues need to be addressed such as transit issues, pipeline compatibility, and pipeline capacities.

Demand and utilization

To minimize dependence on oil, economies with limited resources of oil and natural gas have diversified their energy mix. For instance, China and the Philippines have intensified the development of their rich coal resources, among others, for domestic consumption, especially for power generation. Japan, Chinese Taipei and Korea have increased their importation of coal and natural gas for power generation. Even oil-rich Indonesia has a national energy diversification plan to reduce dependence on oil and gas for energy. Since 1976, coal is considered as the main alternative source of energy in Indonesia for electricity generation, and the cement and other industries that require large amounts of energy and whose locations are favorable for coal supply.

The promotion of energy efficient technologies and energy conservation which incorporate coal and natural gas is also part of the programs of many economies.

Table 2.17: Existing Energy Policies in APEC

Existing Policies	APEC Economies
Exploration, Development and Production	
Intensify the development of indigenous energy resources	
Coal	Australia, China, Indonesia, Japan, Philippines
Open new mines and improve the efficiency of existing mines	China
Encourage the development of small-scale coal mines	Philippines, China has closed a number of small coal mines
Provide subsidy and other incentives to local producers	Japan, China
Natural gas	Brunei, Indonesia, Malaysia, Philippines, Thailand, China
Promote the diversification of energy types and sources	
Coal	Indonesia, Philippines, Japan
Natural gas	USA, Indonesia, Malaysia, Philippines, Singapore, Thailand, Taipei, Brunei, Mexico
Promote environment concerns in energy development	USA, Canada, New Zealand, Japan, Brunei, Malaysia, Indonesia, Philippines, Thailand, Chinese Taipei, Australia
Encourage energy investments overseas	
Coal	Japan, Korea, Chinese Taipei
Natural gas	Chinese Taipei, China, Japan, Malaysia, Korea
Investment	
Encourage private sector participation and foreign investment in resource development.	
Coal	Australia, China, Indonesia, Philippines
Natural gas	Indonesia, Philippines, Malaysia, China, Thailand, Taipei, Chile, Mexico
Improved contractual arrangements between the government and private gas investors	USA, Indonesia, China
Improved investment policies	Thailand, China, Philippines, Indonesia, Taiwan
Relaxation of foreign gas investment reviews	Canada, Australia
Elimination of ownership restrictions in the upstream oil and gas industry	Canada
Rationalization, privatization or reorganization of the energy sector	Japan, Russia, China, Vietnam, Thailand
Infrastructure	
Improvement of transport infrastructure	
Coal	China
Natural gas	
Promote a sound development of gas utilities through gradual release of restrictions	Chinese Taipei
Develop/Increase gas infrastructure	Thailand, Indonesia, Philippines, China, Malaysia

Table 2.17: Existing Energy Policies in APEC (continued)

Existing Policies	APEC Economies
Trade	
Easing up or removal of trade restrictions (including procedures and regulations)	
Coal	Australia
Natural gas	Canada, Australia
Unbundling of gas trading and retailing	New Zealand, Australia, Japan
Facilitate spot market for trading gas and gas pipeline capacity	New Zealand
Promote open access to gas transmission	New Zealand, Australia
Diversification of energy sources	
Coal	Chinese Taipei, Philippines
Natural gas	
LNG supply sources	Taiwan, Japan
Encouragement of private sector and foreign investor participation	Indonesia, Philippines, USA, Australia
Increase exports to maximize government revenues	
Coal	Australia, China, Indonesia, USA, Canada
Natural gas (LNG)	Indonesia, Brunei, Malaysia
Promote energy cooperation	Most APEC economies
Demand and Utilization	
Diversification of energy types and sources/fuel switching	
Coal	Chinese Taipei, Philippines
Natural gas	USA, Canada, Japan, Indonesia, Malaysia, Philippines, Singapore, Thailand, Taipei
Promotion of energy efficient technologies and energy conservation	USA, Canada, Australia, New Zealand, Japan, Brunei, Indonesia, Malaysia, Philippines, Thailand
Improved end-use gas technology	Australia, Japan
Preferential treatment given to energy users	
Coal	Philippines
Enhance the market for domestic coal	Philippines
Acceleration of mines site power plant construction	China
Natural gas	
Promote/Increase use of natural gas	USA, New Zealand, Japan, Indonesia, Mexico, Australia, Korea, Malaysia, China, Taiwan

Source: APEC/CEERD-AIT Survey (1998/1999), EIA (1999b), IEA (1996a, 1997b, 1996d, 1997c, 1998c)

2.6 Conclusions

The APEC region is assured of natural gas and coal supplies considering that it holds more than half of coal and natural gas reserves in the world. The region's production of natural gas and coal has been increasing and plans are underway for increased production. However, while coal enjoys a comfortable supply-demand balance, that for natural gas is less so due to its limited reserves and less developed infrastructures. Coal and gas imports from APEC and non-APEC countries satisfy the needs of the major energy-consuming economies. However, there is a need to improve the related infrastructures to bring these resources to the domestic and international markets. The availability of these resources, both from within and outside the region, has played a major role in energy security and in the selection of fuel for power generation. Finally, policies conducive to the development and consumption of these resources have been put in place by many governments of APEC to fuel their drive towards economic development.

Endnotes

[1] APERC (1998)

[2] The uncertainties brought about by the financial and economic crisis had dampened the ongoing oil and gas exploration activities. In Indonesia, for example, the worst hit by the crisis that has been complicated by domestic politics, a number of operators have invoked the force majeure provisions in their contracts and are seeking a suspension of drilling commitments for a year (Asia Gas Report, June 1998). Similarly, in the Philippines which is less affected by the crisis, oil and gas developers have asked the government for an adjustment in their work programs.

[3] China is the major gas producer in the East Asian region while Japan, Korea and Taiwan are major importers with negligible indigenous gas production.

[4] IEA (1998a)

[5] IEA (1998a)

[6] Hydrocarbon Asia (1998)

[7] Hydrocarbon Asia (1998)

[8] IEA (1998a)

[9] IEA (1996b)

[10] IEA (1994)

[11] The final study (The Master Plan on Natural Gas Development & Utilization in ASEAN) concerning the ASEAN pipeline grid has been completed and endorsed at the 14th ASEAN Ministers on Energy Meeting on July 1, 1996. The objective of the study is to evaluate the technical feasibility and he economic viability of developing new markets for the huge natural gas resource of ASEAN Member economies through a single large transportation and distribution system. The final report is composed of seven components covering an analysis of the potential gas demand and supply, institutional arrangements, existing and potential gas trading arrangements technical analysis, pricing policies and possible gasline linkages.

[12] The gas producing economies, have already expanded within itself a pipeline network that will enhance or form the backbone for the infrastructure of the TAGTS.

[13] AEEMTRC (1998)

[14] Japan, South Korea, China and Taiwan have the markets, the capital and the technology to develop the energy resources and Russia have enormous untapped natural gas deposits.

[15] Tusing (1998)

[16] The Middle East, has the potential of becoming a leading supplier of natural gas in Asia as it holds 33.2% of the total world's natural gas reserves.

[17] AEEMTRC (1996)

[18] Mobil, a gas developer in Sable Island, for example, has expressed strong concerns that any delays for environmental or other reasons could jeopardize the economics of the project, which they hope to have up and running by November 1999.

[19] Some provisions in the Oil and Gas Law that foreign companies find objectionable are: 1) the requirement to have parliamentary approval for fields in areas defined as "strategic" and for production sharing agreements not awarded by tender; 2) the Russian government's rights to modify conditions of a production sharing agreement if "major economic changes" occur during the term of the agreement, 3) a provision that subsequent individual laws will determine which fields can be developed under production sharing agreement, and 4) the lack of recourse available to foreign investors to resolve disputes in an international tribunal (IEA, 1996)

[20] Russian taxes are subject to frequent change, and are based upon revenues than profits, leading to high rates of taxation. In fact, most of the oil and gas companies in Russia have complained that they are taxed heavily by the Russian government.

[21] Russia has changed its position several times on dividing territorial limits on oil and gas development among its littoral states.

[22] EIA (1999)

3. Coal and Natural Gas Prices

One of the main forces driving the competition between coal and natural gas is the relative price between the two fuels, both in the international and domestic markets. The prices of coal in the international market converge and have been stable and declining in real terms. Domestic coal prices are still determined by policy in many developing APEC economies, but have tended to follow international prices with the removal of trade barriers. Moreover, they tend to be lower than domestic natural gas prices in coal-rich countries. Thus, coal remains an attractive fuel even with its negative environmental impacts. On the other hand, the international markets for natural gas are fragmented, and gas prices have been indexed to crude oil prices. Domestic natural gas prices, except in a few countries with competitive natural gas markets, are heavily regulated by governments. They tend to be lower than domestic coal prices in gas-rich countries. In general, however, the high cost of transporting natural gas makes it an expensive fuel option. Yet, the environmental qualities attributed to natural gas make it an increasingly preferred fuel.

3.1 Prices of Coal in the International Market

It has to be said at the onset that this study refers only to the prices of steam (thermal) coal, or the coal used for power generation. Although, coking (metallurgical) coal is also sometimes used for power generation (e.g. in Japan), the discussion on prices will be limited to steam coal.

In terms of flow of supply, coal is traded in two markets: Atlantic (European) market and Pacific (Asian) market. The APEC economies are major players in the Pacific market, as well as Atlantic market. Australia, U.S., Canada, Russia, and China exports to both markets, while Japan, South Korea, and Taipei, China are the major importers in the Pacific market. Indonesia is also a large coal producer and a major coal exporter.

Despite this distinction, coal prices in the two markets converge, through South Africa, a major coal producer and exporter in both markets. Coal prices are mainly determined through bilateral negotiations. Long term contracts with annual price review characterize contract arrangements in the Pacific market, while term or spot contracts are the norm in the Atlantic market. In Asia, international coal prices evolve in relation to the benchmark prices, which are year-long prices agreed between Australian coal companies (the major exporters) and Japanese utilities (the major importers). In addition, Asian coal prices are also influenced by the ENEL (Italian tenderer for steam coal) price, which is determined by the US and South Africa. This, in turn, links the Atlantic and Pacific prices, thus making an increasing trend of the Asian buyers to purchase coal in the spot market and looking at the spot prices as the reference price for term contracts.

The share of thermal coal purchased through the spot market is very significant: 15% for Taiwan and 6% for Japan. The Asian thermal spot market has provided ad hoc supply to users and offers an opportunity to test new coal brands, or to introduce a new product at discounted prices. Low spot prices over the past few years have led coal consumers to increase their planned use of the thermal coal spot market.

Overall, the price setting mechanism for steam coal can be summarized in the following way:[1]

- While buyers in both the Atlantic (European) and Pacific (Asian) markets operate in the spot and term markets, the proportion of spot sales is higher in Europe than in Asia. Price is formed in the more flexible European market and transmitted, via South African sales, to the Asia-Pacific market.
- Price in the European market is established through competitive bids, with an upper limit imposed by the price at which US coal will enter the market. The US export price will generally have to be competitive with the US domestic price in order to free supply for export. In the absence of a sufficient US export coal, the price may rise in the short term but is otherwise set at the margin by the price in the US domestic market, which has tended to fall over recent years.
- Since the bulk of sales are from producers other than the US, costs of production in other key major exporting countries will have an impact on long term price but competition to maintain market share will tend to limit the impact of this factor and keep price growth flat.

Indeed, international coal prices have declined in nominal and real terms and have been stable in the last 20 years because of productivity improvements in coal mines and increasing competition among suppliers. For example, as shown in Figure 3.1, the values of steam coal imports by Japan have stabilized from US$60-70 per tonne in the early 1980s to around US$40-50 per tonne in 1990s. This trend is expected to continue in the future.

Several other factors explain the decline and stability of international coal prices and limit the tendency for future price rise.[2] The United States, whose coal exports account for less than 10% of domestic production but close to 20% of world trade, puts a limit on coal price by acting as a marginal supplier. Coal reserves are widely distributed and the existence of several major exporters (U.S., Australia, Canada, Russia, China, South Africa) assures stable supply, and therefore, prices. The volume involved in international coal trade is a small proportion of global production and consumption; thus, the potential for exporters in increasing coal trade is high, limiting the tendency for prices to rise. Moreover, new exporters (e.g Indonesia, India) can enter the market and also prevent future coal price rise.

3.2 Prices of Natural Gas in the International Market

There are three distinct markets for internationally-traded natural gas: North America, Europe, and Asia-Pacific. The North American and European markets are mainly involved in the trade of gas by pipelines, while the Asia-Pacific market accounts for about 80% of gas trade in the form of liquefied natural gas (LNG). Natural gas trade by pipelines is developing in Latin America with the exploitation of natural gas resources in the region in response to growing energy demand.

The APEC member economies participate in the North American and Asia-Pacific market, and soon in the Latin American market. U.S. is the main importer in North America, while Canada and Mexico,

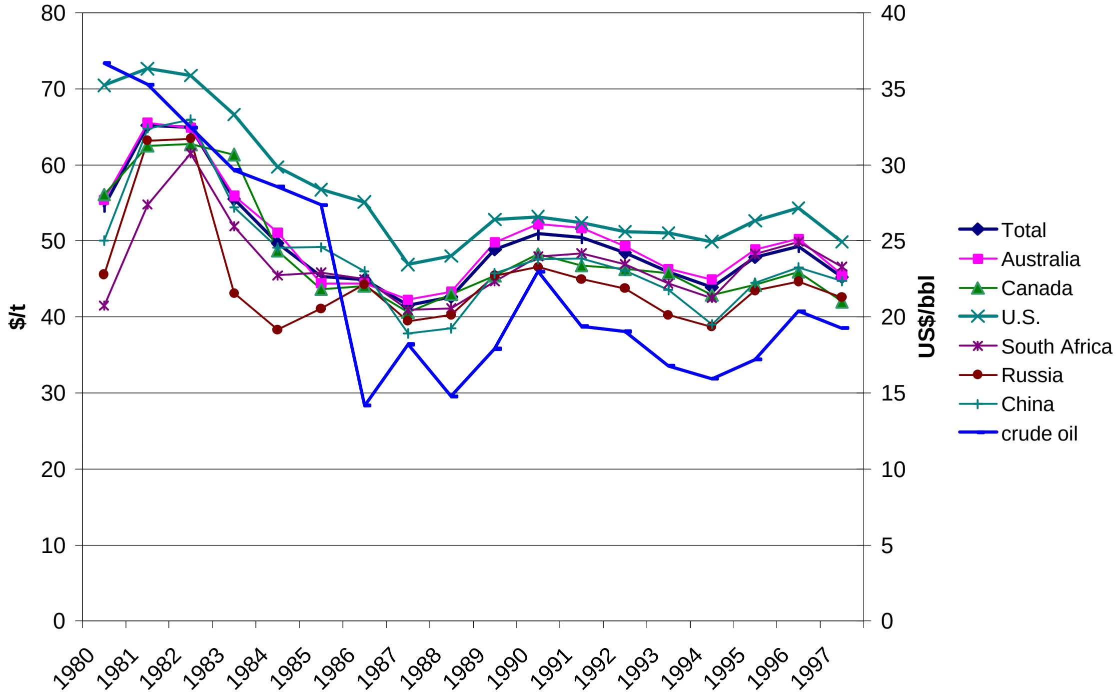


Figure 3. 1: Japanese Steam Coal Import Unit Values
Source: IEA (1998a)

together with Algeria and United Arab Emirates, are the main exporters. On the other hand, in Asia-Pacific, Japan, South Korea, and Taiwan are the major importers, while Australia, Brunei, Indonesia, and Malaysia are the major exporters. Japan, in addition, also imports from the Middle East and North America (Alaska). In Latin America, Chile and Brazil will be the main markets for natural gas trade, while Argentina will be the main origin for gas imports by pipeline. Already, two gas pipeline projects are being developed in Argentina to supply to power plants in Chile.[3]
Unlike those of coal, natural gas prices in these markets do not converge. As shown in Figure 3.2, the prices of imported LNG in the Asia-Pacific market are higher by a factor of almost two than piped gas in North America. The difference, obviously, is accounted for by higher cost of transporting and processing LNG.

Gas prices for LNG in the Asian market are determined through formula prices. These formula prices normally index LNG prices to the international crude oil price plus other parameters. The recent decline in crude oil prices, however, has depressed LNG prices to a level that is too low to encourage the development of new LNG projects.[4] To improve the pricing mechanism for LNG, it was recommended that a premium over the oil prices formula should be assess by deeming a crude price, that is, agreeing on a fixed price for crude that is unaffected by market fluctuations.[5] But the Asian financial crisis, which had dampened energy demand in the region, has further dimmed the prospects for LNG prices to improve in the near term.

The persistent reliance on a crude-oil-based formula is partly due to the lack of a real spot LNG market.[6] LNG projects are capital intensive and involved long-term contracts. This characteristic of the industry has prevented the easy entry of new players, and therefore, has thwarted the opportunities for spot transactions. But limited surplus capacity has led to some spot LNG transactions. They now represent about 2% of the world LNG trade. On the other hand, an increase in the number of players in the LNG trade (for example, China, India, and Thailand are potential markets for LNG) could contribute to a growing LNG market and more flexible trade. A second factor that might result in a

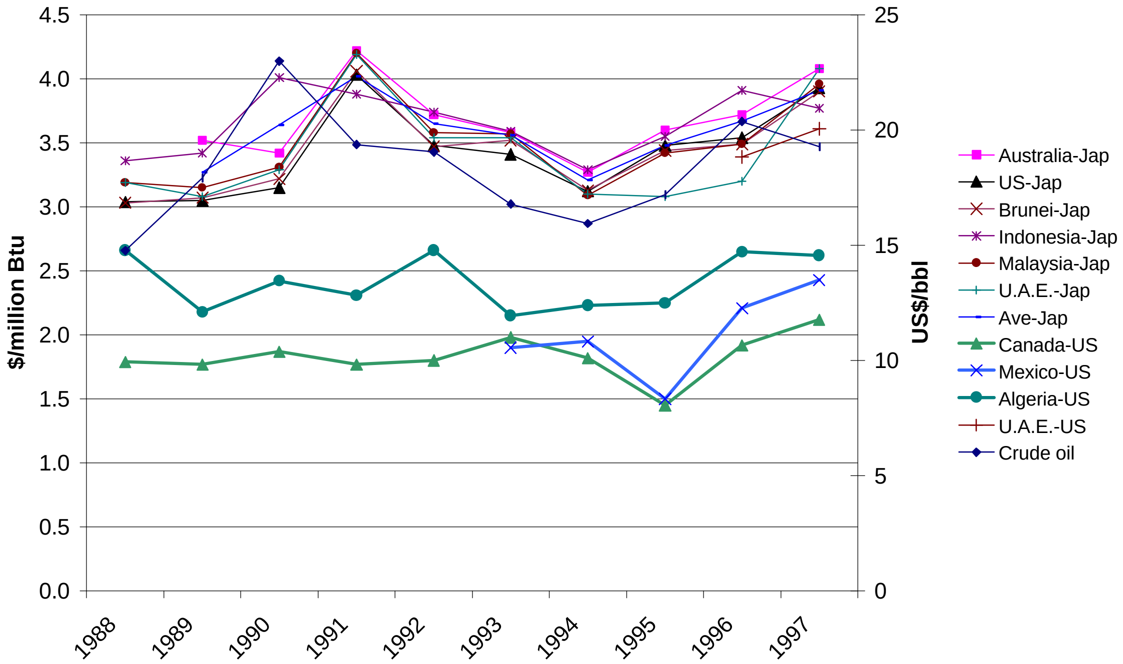


Figure 3. 2: LNG and Natural Gas Import Prices to US and Japan
Source: IEA (1998e)

Gas prices for LNG in the Asian market are determined through formula prices. These formula prices normally index LNG prices to the international crude oil price plus other parameters. The recent decline in crude oil prices, however, has depressed LNG prices to a level that is too low to encourage the development of new LNG projects.[7] To improve the pricing mechanism for LNG, it was recommended that a premium over the oil prices formula should be assess by deeming a crude price, that is, agreeing on a fixed price for crude that is unaffected by market fluctuations.[8] But the Asian spot market is the Korean seasonality problem.[9] Gas demand in South Korea has a strong winter peak, but LNG contracts require even deliveries throughout the year. This could be handled by increasing storage capacity, but this is expensive and the growth of the Korean market threatens to exceed storage capacity. Korean gas consumers can trade with Japanese and Taiwanese buyers, but they have not organized to take advantage of this kind of trade arrangement.
Nevertheless, several factors could lead to a change in LNG prices:[10]

- a change in oil prices;
- a change in the approach to pricing LNG contracts;
- a change in the environmental “premium” assigned to natural gas; and
- an alteration in the current “balance” between supply and demand.

3.3 Domestic Prices of Coal and Natural Gas

Coal

While there is a single trend on coal pricing in the international market, coal pricing in the domestic market varies according to the policy of the individual APEC economies, and domestic coal prices tends to be heavily subsidised. There is a similar trend, however, of introducing market-based pricing. China, for example, the largest producer and consumer of coal, operated a dual pricing system for coal until 1994.[11] "Allocated coal" produced from state, provincial and country mines were priced artificially low. On the other hand, "free market coal" was produced primarily by small township mines and sold at negotiated prices if transport was available. Otherwise, coal produced by these mines was sold to state mining bureaus. This dual pricing system, however, led to the inefficient and uneconomic allocation of coal, not to mention the heavy losses incurred by the state coal mines.

In January 1994, the dual pricing system was abolished, and measures were introduced to make the coal industry more profitable. Subsidies to the coal industry were gradually reduced. The long existence of dual pricing system, however, "has created a pattern of disinvestment in coal production, preparation and infrastructure which will take time to correct." In fact, infrastructure constraints have forced township producers to sell to local state authorities, causing only a small proportion of coal produced to be sold at market prices.

Coal in small domestic markets (for example, the Philippines) had been also subsidized and protected from competition from internationally traded coal by large tariff barriers and import quotas. This policy has changed with domestic coal prices being aligned to international coal prices and the gradual removal of trade barriers.

In developed APEC member economies (i.e. Australia, Canada, the US) domestic coal prices are market-based and determined by negotiations between buyers and sellers.

Natural gas

The natural gas markets in the U.S. and Canada are competitive, and therefore, natural gas prices are determined by the interplay of supply and demand. The North American natural gas market is characterized by a high degree of competition, particularly at the wholesale level, and transparency. Local distribution companies (LDCs) can choose their supplier and can connect directly to gas producers through third party access. Gas consumers, on the other hand, are increasingly having the flexibility to choose their suppliers. In this market, gas prices vary from one place to another reflecting the differences in the wellhead prices, transportation costs and topographical conditions[12]. Transportation costs, however, are still subject to government regulations on a traditional cost-of-service basis so as to prevent the exercise of monopoly powers.[13]

On the other hand, the domestic natural gas markets in the other APEC economies are either monopolistic or in the transition from being monopolistic to competitive, thus prices are usually regulated by the government. Among APEC member economies in Asia, domestic natural gas prices are regulated by the government (Table 3.1). Moreover, domestic gas prices are generally highest for residential consumers and lowest for the power sector, with those for industrial consumers lying in between. One exception is Indonesia, in which gas prices to industry are subsidized to promote certain activities (for example, fertilizers and petrochemicals). On the other hand, gas prices in gas importing countries (Japan, South Korea, and Chinese Taipei) are higher to account for the cost of liquefaction and transportation. Gas prices in Japan, however, are significantly above those in the rest of Asia because of the high cost of land in Japan and the structure of the gas industry in the country.[14] Yet, part of the reason natural gas prices in gas-producing Asian countries are low is the effort of these governments to subsidize natural gas prices to promote equity and selected industries.

Government intervention in gas pricing to make natural gas affordable to small consumers and to promote selected industries (e.g. fertilizers and petrochemicals) has resulted in gas prices that are below the costs of production and transportation. This policy, however, has negative consequences.[15] First, it encourages excessive consumption of natural gas, and therefore, runs counter to any policy on energy conservation. Second, because costs are not adequately recovered, financing future investments in exploration and development and infrastructures to meet growing demand becomes more difficult. Third, it leads to a less than optimal use of national economic resources, as government funds are diverted to building additional supply capacity to meet artificially stimulated demand.

Lastly, higher energy demand growth than might otherwise have occurred also has negative environmental impact.

The lack of competition in the natural gas industries in Asia is primarily a reflection of their relative infancy.[16] The transition to competition has, however, become an issue along with the growth of the natural gas industries in the region. There is now a movement toward market-based pricing in the Asian gas market. Some other APEC economies (South Korea, Russia, Mexico, Peru and Taiwan) are already in the process of restructuring their natural gas industry through privatization, unbundling, and deregulation to make it more market-oriented. In additional, the governments of Brunei, Indonesia, Taiwan, South Korea and Thailand are encouraging private sector participation in gas exploration and development as well as gas transport. This would bring eventually more participants in the market and increase competition. The expansion of the transmission and distribution networks, including cross-border interconnections, is also increasing the opportunities for consumer choice and therefore, competition.

3.4 Relative Coal and Natural Gas Prices

One of the most important determinants of the degree of competition between coal and natural gas, both in the international and domestic energy markets, is the relative price between the two fuels. Since the mid-1980s the nominal prices of coal in the international market have stayed within the US$62.8-83.7 per toe range, indicating long-term stability and declining prices in real terms. The international prices of natural gas, on the other hand, in particular LNG, hovered around a wider range, US$125.6-167.5 per toe, and were two times higher on the average (see Figure 3.3).

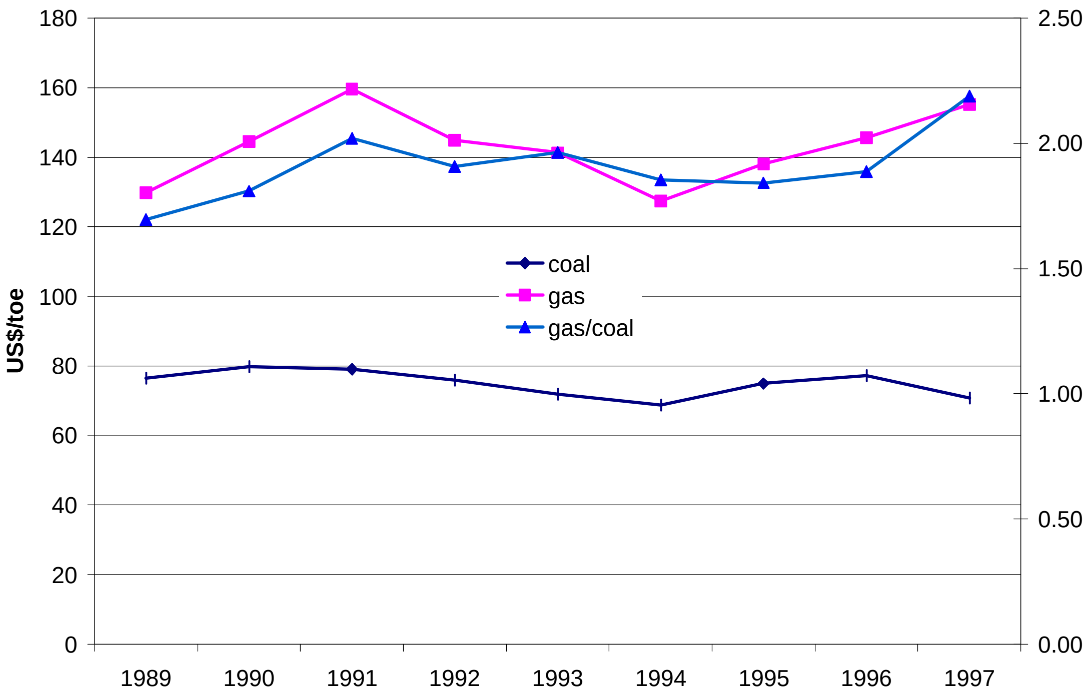


Figure 3. 3: Relative Prices Between Coal and Natural Gas
Source of basic data: IEA (1998a and 1998e)

The difference between coal and natural gas prices in the international market is explained by the higher cost of transporting LNG. In addition, the greater volatility of natural gas prices is explained by their indexation to crude oil prices.

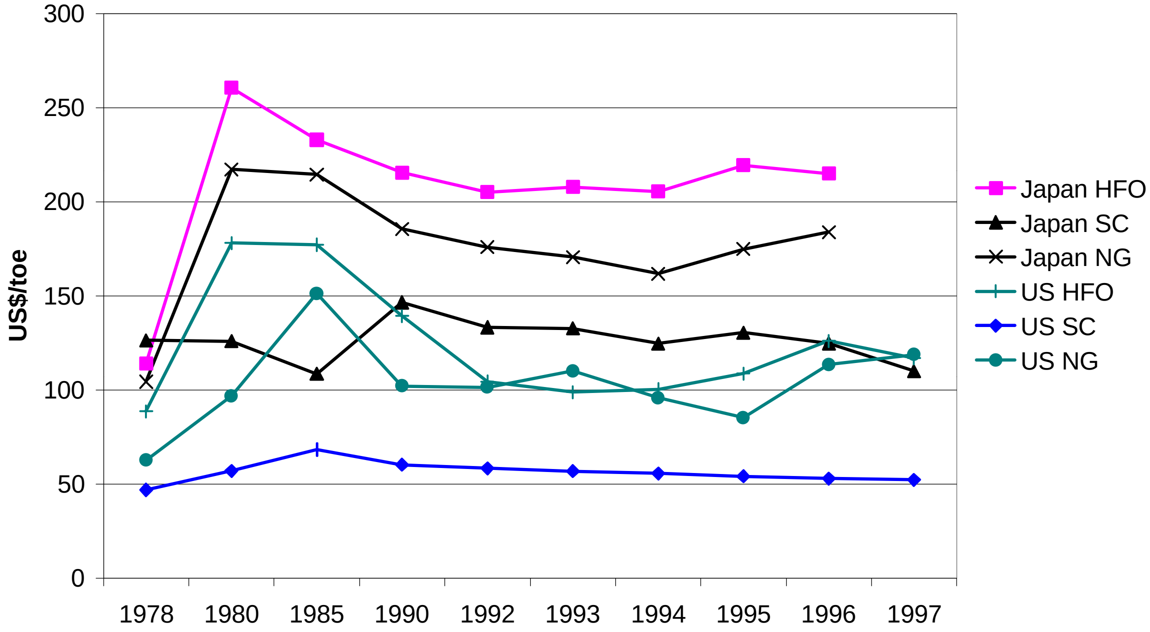
Table 3. 1: Summary of gas pricing arrangements in selected Asian countries

	Brunei	Indonesia	South Korea	Malaysia	Chinese Taipei	Thailand
General policy on gas pricing	Prices regulated by the government	Prices regulated by the government for essential industry and smaller consumers. Prices determined by negotiation for large private sector users.	Government regulates the price of gas to ensure that it remains an economically attractive fuel.	Commercial and residential prices are determined by Gas Malaysia, subject to government approval. Prices determined by negotiation for the power and industry sectors.	Prices regulated by the government.	Prices based on price paid by PTT to producers plus the cost of transmission. Subject to ministerial approval.
Industry		US$1-1.5/MMBtu	US$6/MMBtu (1995)	US$4.3/MMBtu (1994)	US$7.82/MMBtu (1997)	
Power	US$0.3/MMBtu (1994)	US$2.4-3/MMBtu (single tariff for each supply region)	US$4.6/MMBtu (1994)	US$3.4/MMBtu (1994)	US$6.57/MMBtu (1997)	US$2.8/MMBtu (1993)
Commercial	US$0.3/MMBtu (1994)	US$1.3-1.7/MMBtu (varies with consumption)	US$7.1/MMBtu (1995)	US$6.4/MMBtu (1994)	US$5.4/MMBtu (1995)	
Residential	US$0.2/MMBtu (1994)	US$1.3-1.7/MMBtu	US$9/MMBtu (1995)	US$6.8/MMBtu (1994)	US$7.86/MMBtu (1997)	
Degree of unbundling	n.a.	some[i]	none	n.a.	none	Prices includes cost of transportation
Tax	no tax on gas sales	no tax on gas sales	10% VAT, customs tariff of 1% and an excise tax on LNG imports of 10%	no tax on gas sales	customs tariff of 5%, excise tax of 0.11 NTD/cm and VAT of 5%	VAT of 7%
Comments	Gas prices have remained constant since 1991. Government has stated that it wishes to revise energy prices to increase awareness of true energy costs and discourage energy wastage.	Government's main objective is to promote economic growth and equity. Currently there is a debate within the government about price subsidies to gas consumers such as the fertilizer industry.	Government is considering revisions to natural gas pricing arrangements to assist in demand side policy objectives.	The 6th Malaysia Plan (1991-1995) states that energy prices should reflect the true or economic cost of supply and be able to raise sufficient revenues for the sector's development.	CPC plans to progressively cut gas prices as the level of consumption increases.	In setting gas prices to consumers the government links the price to the cost of alternative fuels.

Source: IEA (1996b); Chinese Petroleum Corporation (AIT Survey)

[i] Private sector pipelines are able to negotiate a fee from the consumer for transporting gas.

On the other hand, relative fuel prices in domestic energy markets depend on energy resource endowments. Coal prices remain lower than natural gas prices in net energy importing countries (e.g. Japan, Chinese Taipei) as well as in countries with large coal reserves (e.g. Australia, US) (see Figure 3.4 and Table 3.2). On the other hand, natural gas prices tend to be lower than coal prices in countries with larger natural gas reserves (e.g. Canada, Chile, and Mexico).



Note: HFO-heavy fuel oil; SC-steam coal; NG –natural gas

Figure 3. 4: Competing Fuels for Power Generation

Source: IEA (1998b)

Table 3.2: Domestic Coal and Natural Gas Prices for Electricity Generation (including taxes, in US$/toe)

Country	Coal	Natural gas
Australia	43.36 (1991)	
Brunei		11.9 (1994)
Canada	74.7 (1992)	62.9 (1992)
Chile	100.83 (1997)	79.81 (1997)
Indonesia		95.23-119.04
Japan	124.9 (1996)	184.1 (1996)
Malaysia		134.91 (1994)
Mexico	126.9 (1997)	67.6 (1997)
South Korea		220.86 (1994)
Taipei	185.9 (1994)	298 (1994)
Thailand		118.88 (1993)
United States	52.4 (1997)	118.9 (1997)

Sources: IEA (1998b, 1996b); APEC/CEERD-AIT Survey (1998/1999)

Expectations about the future levels of coal and natural gas prices also influence fuel choice. A report published by OECD in 1998 indicates the expectations of some APEC economies included in the study about future coal and natural gas prices (see Figure 3.5). As shown, Canada and South Korea expect coal prices at power plant level to remain constant in real terms in the next 50 years. Japan and China, however, assume slightly increasing coal prices over the same period. Russia expects real domestic coal prices to jump from less than US$2 per GJ in 1996 to more than US$4 per GJ in 2045. In stark contrast with these countries, the US sees slightly declining coal prices in real terms over the same period.

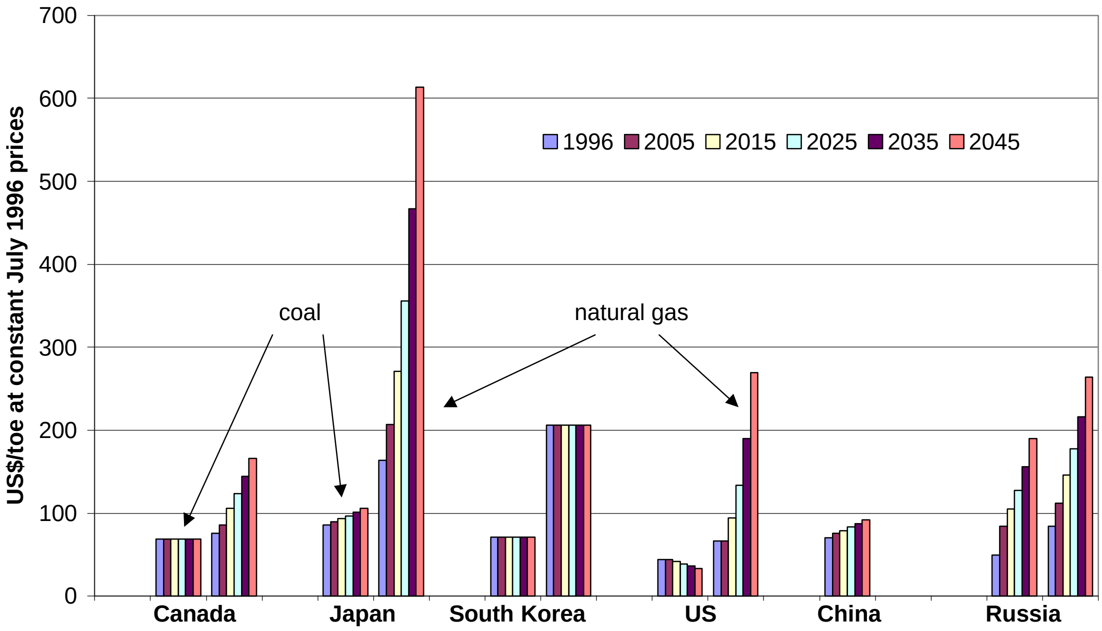


Figure 3. 5: Projected Coal and Natural Gas Prices
Source of basic data: IEA (1998g)

On the other hand, except for South Korea, these countries expect natural gas prices to rise in varying degrees in real terms during the same 50-year period. Japan expects natural gas prices to triple in less than 50 years. The US and Russia assume a moderate increase in natural gas prices, while Canada sees a more gradual rise in natural gas prices. South Korea maintains a constant real natural gas prices assumption for the future.

The consequences of these price assumptions are sharply increasing relative prices of natural gas to coal in Japan and the US, moderately increasing relative prices in Canada, slightly increasing relative prices in Russia, and constant relative prices in South Korea. Thus, it can be said that competition between coal and natural gas will be strongest, among these countries, in Japan and the US. Interestingly, Japan’s case represents relative prices and competition of the two fuels in the international market, while that of the US represents relative prices and competition in the domestic markets.

Overall, stable and low international prices of coal, both historically and as expected in the future, makes it a mainstay fuel in the overall energy and power generation mix of many APEC economies (see Figures 1.6 and 1.7 in Chapter 1). In addition, in countries in which the share of coal is not as substantial as gas at present, expectations of stable coal prices will be a major factor for increasing the share of coal (e.g. Malaysia, Mexico, Philippines). As a result, coal consumption in these countries is expected to grow significantly.

On the other hand, the higher prices of natural gas have not been a stumbling block for increasing its consumption. Because of its environmental qualities, natural gas use is increasing faster than coal in many of the APEC economies, particularly those that already have large exposure to coal (Australia, Canada, China, US).

At the same time, however, the higher prices of natural gas (as a result of the high transportation cost) is the limiting factor for its rapid penetration in domestic energy markets. This is particularly true in the case of APEC economies that are importing LNG (except Taiwan, whose gas share in power generation was only 5% in 1995) and that are potential markets for LNG (China and Thailand). In Japan, for example, natural gas share in the power generation mix is expected to increase from 19% in 1995 to 21% in 2010, equivalent to a 3.8% annual growth in consumption (see Figures 1.13 and 1.14 in Chapter 1). In contrast, coal share would increase from 17% to 22%, equivalent to a 4.8% annual increase in consumption. A similar trend is observed for South Korea, even though annual gas consumption for power generation will be increasing slightly (9.1% vs. 8.8%, respectively). In China, gas share in power generation will remain minimal despite higher growth rate for natural gas consumption. The limited supply of indigenous natural gas in Thailand will force it to turn to imported coal as against LNG.

3.5 Policy Issues

The stability and convergence of coal prices in the international market has influenced domestic coal pricing policy. Coupled with the gradual removal of trade barriers, domestic coal pricing has become more competitive and more market- oriented. In other words, domestic coal prices in many, if not most, of the APEC economies are deemed to be free or are being freed from government regulation.

On the other hand, the spectrum of domestic natural gas pricing regimes extends from being purely monopolistic, where prices are directly controlled by the government, to competitive, where prices are set by the market (see Figure 3.6). As indicate in Figure 3.6, most Asia-Pacific economies have regulated natural gas prices at the wholesale and retail levels, while natural gas prices in North America are regulated only at the retail level. In addition, strong government intervention in gas price setting in Asian economies has caused price differentials between consumer groups. This was already shown in Table 6.1. The only exception is New Zealand, in which natural gas prices are not regulated either in the wholesale nor retail levels.

The evolution of natural gas prices from being monopolistic, and subject to strong government intervention, to being competitive, and determined by the market, has important implication in coal and natural gas competition, particularly in domestic energy markets where natural gas is indigenous (e.g. Australia, Canada, Indonesia, Malaysia, Mexico, Thailand, Russia, and the US). Domestic natural gas prices would become more competitive with deregulation in natural gas markets. A clear example in this regard is the experience of the US. Following the deregulation of the gas industry in 1980s, many new companies were attracted into the wholesale market. The ensuing competition placed downward pressures on natural gas prices, benefiting industry participants and gas consumers. Large gas consumers such as electric utilities and industries saw gas prices decline by 26-31% between 1988 and 1995.[17] This was one of the reasons why natural gas became an attractive fuel option for IPPs, which spread following the opening up of the electricity generation sector in the 1980s.

3.6 Conclusion

The prices of coal and natural gas in the international market are mainly dependent on the structure of the trade markets for the two fuels. International coal prices are lower than natural gas prices because

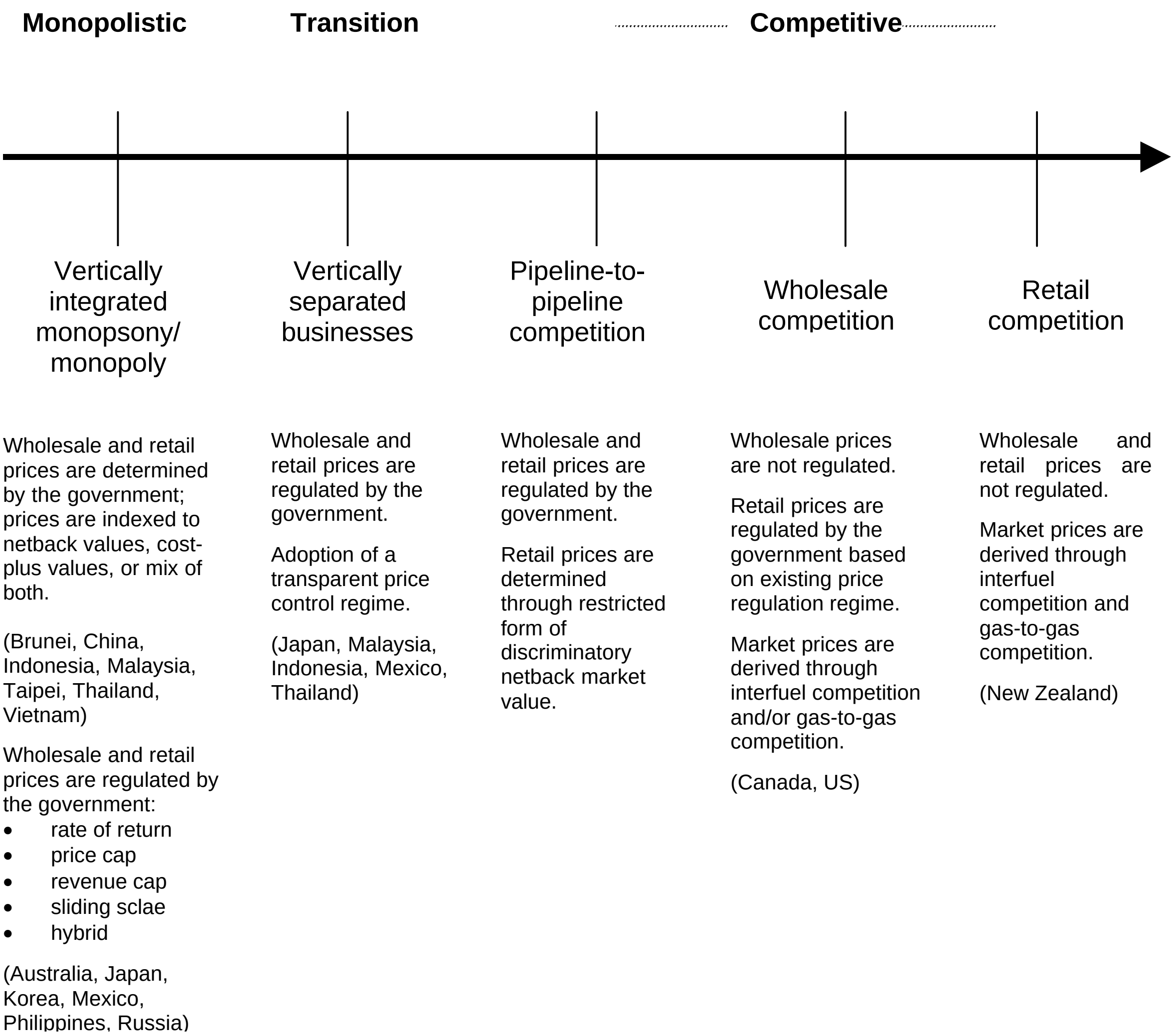


Figure 3. 6: Evolution of Natural Gas Pricing Policy

of the competitive structure of the international coal market. The markets for natural gas are fragmented, and natural gas prices tend to be linked to fuel oil prices. Domestic coal and natural gas prices are largely determined by policy except in a few APEC economies where prices are dictated by the market. With trade deregulation, however, domestic coal prices are following international prices. Moreover, deregulation in domestic natural gas markets will also tend to free natural gas prices.

Relative prices between coal and natural gas is one of the main forces driving the competition between the two fuels. International coal prices have been stable and declining in real terms, continuing to make it an attractive fuel choice among the APEC economies. Natural gas, however, despite its higher prices than coal, is making in roads in the overall energy mix and power generation fuel mix because of its environmental qualities. At the same time, however, the high cost of transporting natural gas is limiting its penetration in domestic energy markets.

Endnotes

[1] IEA (1997f)
[2] Ibid.
[3] These are as follows:

- the 925 km gas pipeline Gasoducto Atacama project from Campo Duran, Jujuy, Argentina to Mejillones, Chile to supply two 355 MW power plant; and
- the 880 km gas pipeline Gasoducto Norgas project from Tartagal, Salta, Argentina to Tocopilla, Chile to supply three 230 MW combined cycle power plants.

A third project involves the construction of 408 km transmission lines to carry electricity produced from three combined cycle gas-fired plants in Salta, Argentina to Escondida substation in Chile's northern grid.

[4] Intarapravich (1996)
[5] Ibid.
[6] Fesharaki (1998)
[7] Intarapravich (1996)
[8] Ibid.
[9] Shepherd (1999)
[10] IEA (1996b)
[11] IEA (1997f)
[12] In North America, weather is the primary reason behind the spot price movements due to the residential and commercial demand's sensitivity to winter heating and power generation demand to summer cooling (IEA, 1998f).
[13] FERC assumes that the competition in the transport grid is not yet feasible.
[14] IEA (1996b), p. 83.
[15] Ibid., p. 93.
[16] Ibid., p. 53.
[17] Andrej (1998)

4. ENVIRONMENTAL CONCERNS

From an environmental perspective (considering pollutant emissions such as SO_2, NOx, and particulate matters (PM); and greenhouse gases), natural gas offers far greater benefit than coal. Among the many factors that influence the competitiveness between these two fuels, environment holds an important place. The key environmental factors to affect the competitiveness between coal and natural gas are of three types. First, the environmental regulations in the APEC economies are becoming more stringent, and act as a driving force to shift fuel choice towards cleaner fuels. Second, the emerging climate change issues, particularly after the Kyoto Protocol (which established GHGs emission reduction targets), will profoundly affect coal consumption pattern in the Annex-1 APEC countries, and also in those non-Annex-1 APEC countries which release large amount of GHGs (such as China). Finally, the availability of advanced technological options (pre-combustion, combustion and post combustion technologies) to reduce environmental impacts will have a significant impact by improving the competitiveness of coal. All these factors have important implications on the fuel choice in APEC economies. The implications would either be a shift from coal to natural gas or minimizing the adverse environmental impacts of coal through suitable measures, such as using low sulphur coal or adopting clean coal technologies. It is foreseen however that there will be increased demand for natural gas, and at the same time coal will continue to be an important energy source.

4.1 Environmental Situation

The APEC group includes economies ranging from heavily coal dependent (such as China: coal 73%, natural gas 2%) to those that are natural gas dependent (such as Brunei: coal 0%, natural gas 63%). Depending upon the share of coal in their fuel mix, APEC countries are faced with associated environmental problems. Coal, being a fossil fuel that releases large amount of pollutants per unit of energy delivered, is often a culprit of such environmental problems. And natural gas, a cleaner fuel, emerges as an attractive alternative in many cases.

The APEC economies suffer from three major types environmental problems associated with coal combustion: local air pollution problems such as SO_2, NOx and PM emissions (particularly in the vicinity of coal power plants); regional problems such as acid rain and acid deposition in lakes and forests; and finally, emission of greenhouse gases.

SO_2, NO_X and Particulate matters (PM) emissions

The deterioration of air qualities resulting from emission of SO_2, NOx and PM are widespread across the coal consuming APEC countries, particularly worse in developing APEC economies such as China and Thailand. Coal (in some cases, having sulphur content as high as 4%) constitutes an important fuel source for power generation in majority of developing economies. These countries (such as China, Russia, Vietnam), however, lack sufficient pollution control measures and also operate somewhat inefficient and aging plants. The emissions of particulate and SO_2 from large amounts of coal combustion have caused harmful effects in several parts of the APEC countries, for example in Beijing and Chongqing (P.R. China), and Mae Moh (Thailand). The APEC developed economies (such as USA, Japan, Korea, Canada, and Australia), however, have less problems of air pollution. The countries have improved their environmental situation relying on environmental regulations and stringent standards on one hand, and promotion of fuel switching and pollution control measures on other.

Aside from air pollution, problems of acid rain are also visible in many parts of the APEC economies. The provinces of Guangxi, Gueizhou, and Sichuan in the southwestern part of China constitute the third largest area of acid rain in the World[1]. Acid rain has affected many lakes and forests in Canada as well. A cross border effect of emissions is observed in Japan, where SO_2 emissions from the coastline of China are believed to have caused acid rain.

Coal is a dominating source of SO_2 emission in most of the APEC countries. In China, for example, 90% of total SO_2 emission results from coal combustion alone. The coal consumed in the APEC economies are of various qualities, some coal containing sulphur as high as 4%, such as in south western part of China. The lignite used in Thailand’s power plants has average sulphur content of 2%. APEC economies are expected to see rise in their SO_2 emission as their coal consumption rise. Developed economies -- having stabilized their SO_2 emission – however will see further decrease in their total SO_2 emission, even with increase in their coal consumption. Limiting SO_2 emission will continue to be a major goal in many APEC economies’ environmental policies. The APEC countries are already seen formulating various strategies of limiting SO_2 emissions, such as switching into low sulphur coal, installation of control technologies (usually FGDs), and adopting advanced type of clean coal technologies. Also, cleaner fuels such as natural gas is being increasingly promoted as an attractive option in APEC economies.

Installations of pollution control technologies are not sufficient in APEC economies. Most coal-fired power plants in APEC economies are installed with particulate emission control devices, because they are efficient and are lower in cost. Whereas, only 23% of the total coal fired power generation capacity within APEC is equipped with SO_2 control measures[2]. Majority of APEC economies have thus relied on low sulphur coal and high stack dispersion method to reduce SO_2 emissions. The most common SO_2 control technology applied is flue gas desulphrisation (FGD) based on wet limestone process. Such facilities have been installed in Canada, China, Hong Kong, Japan, Korea, Chinese Taipei, Thailand and the US.

With increase in environmental awareness, the APEC economies are beginning to concentrate on reducing adverse environmental impacts of coal use. Among others, an option of switching into natural gas has become attractive for many economies.

CO_2 emission

Where SO_2, NOx, and PM emissions from coal combustion pose threat to the local air quality in APEC countries, emissions of CO_2 bring the threat of global climate change. APEC economies’ CO_2 emissions constitute a significant share, about 60% to the total global emission. This is because four highest CO_2 emitting countries in the world, namely the US, China, Russia, and Japan, are in APEC. Total emission volume of these four countries accounted nearly 80% of the total APEC emissions in 1995. The United States emits the highest amount of CO_2 in the world and also has second largest per capita emission. China ranks as the second highest CO_2 emitter in the world, but, its per capita emission is lower than the world average. Notably, Brunei emits relatively a small amount of CO_2 among the APEC economies, but has the highest per capita CO_2 emission (see Table 4.1).

Table 4.1: CO_2 Emissions from Fuel Combustion in Selected APEC Economies (Million ton)

	Total CO_2 emission (1995)	Share of Coal in Total	Per Capita Emission (ton)
World	*22149.60*	*8617.20*	*3.92*
USA	5228.50	1855.04	19.88
Japan	1150.90	311.22	9.17
China	3006.77	2550.00	2.51
Australia	286.00	148.36	15.84
Canada	470.00	99.92	15.90
Russia	1547.89	426.63	10.44
Brunei	7.83	-	27.49
Singapore	58.71	0.13	19.66
Others (APEC)	1536.25	-	-
APEC Total	13292.85	-	-

Source of Data: IEA (1997a).

Fossil fuels are major sources of CO_2 emissions in the APEC economies. Coal, being the most carbon intensive among all fossil fuels, is responsible for a significant share of CO_2 emissions in many APEC economies. In China, where domestic coal is used extensively, 85% of CO_2 emission results from coal combustion alone. Coal contributes more than 50% of CO_2 emissions in Australia and about 25% in Japan, Russia, and Korea. Even with this large CO_2 emission potential, coal will continue to be an important fuel in most of the APEC economies. The APERC study estimates that coal consumption in the APEC economies will rise by about 42% by 2010, if the present trend continues[3]. Given the current concerns of the climate change issues, particularly after the Kyoto Protocol, coal utilization in many APEC economies will be subjected to international pressures. Compared to coal, natural gas contains about half of carbon per unit of energy and produces negligible SO_2 and NOx. This means, wherever situations permit natural gas is likely to the fuel choice in these APEC economies.

In short, local environmental problems (i.e. emission of SO_2, NOx and PM) would occupy an important place in the developing economies' policy issues, whereas, CO_2 emissions would be of major concern in the developed APEC economies, pressed by their commitment to the Kyoto Protocol. Both situations would reduce coal's prospect with respect to natural gas.

4.2 Environmental Policy and Regulation

Environmental regulation for local pollutants in the APEC economies has evolved in two directions: increasing stringency of environmental standards and adoption of market based instruments (MBI). Coal consuming APEC economies set long term and short term goals for controlling ambient concentration of pollutants such as particulate matter, SO_2 and NO_x, that are consistent with World Health Organization guidelines. Ambient air quality standards (AAQS) in these economies were the main instrument in regulating atmospheric emissions in the power sector. With increasing problems on air pollution, air quality standards were revised in several economies to meet international requirements on air quality. But with environmental quality could not be satisfied with the AAQS, the APEC economies, though not all, have adopted stack emission standards to control emissions in the power sector. Many APEC economies, having experience in using MBIs to protect environment (usually in water use), are now considering introducing MBIs in the power sector.

Table 4.2: Instruments Applied in APEC Economies to Control Pollution in the Power Sector

Countries	Command and control			Market Based Instruments
	Ambient Std	Point Source	Fuel Standard	
Australia	SO_2	PM, NOx		SO_2 tradable quota
Canada		PM, SO_2, NO_X		
Chile	PM,SO_2, NO_X	None		
China		PM, SO_2, NO_X		SO_2 charge & tradable quota
Chinese Taipei		PM, SO_2, NO_X	Yes	NOx tradable quota
Hong Kong		PM, SO_2, NO_X	Yes	
Indonesia		PM, SO_2, NO_X	Yes	
Japan		PM, SO_2, NO_X	Yes	SO_2 charge
Korea		PM, SO_2, NO_X	Yes	
Malaysia	SO_2, NO_X	PM		
Mexico		PM, SO_2, NO_X		
New Zealand	PM,SO_2, NO_X	None	Yes	
Philippines		PM, SO_2, NO_X	Yes	
Thailand	SO_2	PM, NOx		
USA		PM, SO_2, NO_X		SO_2 tradable quota
Vietnam		PM, SO_2, NO_X		

Note: Ambient standards mentioned here represent only those standards, on which the economies rely instead of point source standards. And, fuel standards include specification, limitation of sulphur content imposed on coal use or import.
Source of Data: APEC (1997a); and APEC (1998) and APEC/CEERD-AIT Survey (1998/1999).

The developed APEC economies such as Korea and the US, having emission standards already in place, are seen tightening the standards further. The US has introduced additional market based instruments to reduce SO_2 emissions. The developing APEC economies, faced with deteriorating environmental qualities from rapid industrialization, began to respond with stricter environmental regulations only recently. Coal combustion, a major cause for deterioration of air qualities (especially, in the vicinity of power plants), has been a target of these environmental regulations and standards. Countries such as Thailand, Indonesia, and the Philippines issued emission standards for coal power plants for the first time during the first half of 1990s. The emissions standards in other APEC economies are progressively being tightened. As next century approaches, many countries (such as the US, Korea, Indonesia) will see these emission standard becoming almost twice more stringent (see BOX-1).

The differences in the standards between the countries are large. One reason is the difference in fuel types that are used in these economies. Some economies allow flexibility for the local or regional governments to set up their own emission standards based on national guidelines. The local standards are normally stringent than the national standards. The environmental awareness within the local communities has played a key role in setting more stringent local standards. Also, there is a greater emphasis on reducing SO_2 than NOx in most of the economies. Moreover, in some APEC economies, environmental regulations impose stringent standards only to the new plants to be built but are lax on the existing plants (such as in Thailand and Philippines) to allow utilities enough time to adapt.

The volume of SO_2 emissions largely depends upon the sulphur content of the fuel used in combustion. Some of the APEC economies have thus taken initiatives to control sulphur at the fuel-input levels, by issuing fuel quality standards to restrict high sulphur content fuels. An emission standard of 1600 mg/m^3 can be achieved, for example, by using coal containing sulphur less than 0.8%. Chinese Taipei limits sulphur content of imported coal to 0.62%. Similarly, Philippines restricts sulphur content of coal to 1%.

Majority of the APEC economies rely on command and control type of regulatory measures to limit air pollution in the power sector. Only a few countries have begun experimenting with market based

BOX 1 : Evolution of Emission Standards in Selected APEC countries

- **China:** Environmental regulations and emission standards were issued in 1996 to control SO_2 and NOx emissions from coal fired plants.
- **Indonesia:** Emission standards have been set for existing plants and will be made more stringent after the year 2000, almost twice as much.
- **Mexico:** Two different sets of emission standards were promulgated in 1994, one is to be applied for the period of 1994-1997, and another set, which is more stringent emission standard, will have been effective from 1998 onwards.
- **Philippines:** Restriction was imposed from 1994 on SO_2 emission in existing power plants. New power plants coming on stream from 1994, have to follow more stringent standards. More stringent standard will have been in place since 1998.
- **South Korea:** Emission standards were revised in 1995 and are to be made more stringent from 1999 onwards.
- **Taiwan:** Emission standards for coal fired plants were made progressively stringent in 1989 and 1990 and, new regulations came into effect from 1993.
- **Thailand:** Emission standards were imposed after the Mae Moh incidence in 1992. All new power plants now have to limit their emissions within the standards. The stack emission standards are expected to be announced soon.
- **US:** The U.S. is imposing restrictions to emissions of SO_2 and NOx from power plants through two-phase programs: Phase I covers the period 1995 to 2000, and Phase II begins from 2000 onwards. The emission standards for Phase II are stringent by about twice compared to those in the Phase I.

Source of Data: APEC (1997a) and APEC/CEERD-AIT Survey (1998/1999).

Table 4.3: Emission Standards[a] for New Coal Fired Power Stations in the APEC Economies

Countries	SPM (mg/m^3)	SO_2 (mg/m^3)	NO_X as NO_2 (mg/m^3)
Australia (guidelines)	100	Ambient only	860
Canada (guideline)	130	700	460
Chile	Ambient only	Ambient only	Ambient only
China[b]	200-600	1200-2100	650-1000
Hong Kong[c]	50	200	670
Indonesia	250	1500	1700
from 2000	125	750	850
Japan	100	K-value method	410
R.O. Korea	100	1430	720
from 1999	50	770	720
Malaysia	400	Ambient only	Ambient only
Mexico	475	7610	840
from 1998	380	6440	785
New Zealand	Ambient only	Ambient only	Ambient only
Philippines	160-220	1090	1090
from 1998	160-220	760	1090
Chinese Taipei	29	1430	720
Countries	SPM (mg/m^3)	SO_2 (mg/m^3)	NO_X as NO_2 (mg/m^3)
Thailand	400	Ambient only	940
United States	40[d]	1480	560-620

a. Adjusted to gas volumes based on dry flue gas at standard temperature (0^oC) and pressure (101.3 kPa) and 6% O_2.
b. New plants built or examined and approved for construction after December 31, 1996.
c. New plants.
d. PM 10.
Source: APEC (1997a).

instruments. Market based instruments have been applied successfully in the US. The US program of allowances for limiting emission of SO_2 was introduced in 1995. This program allocates certain allowances of emissions to utilities every year; each allowance consists of emission permit of one short ton of SO_2. These allowances are then allowed to be traded or can be banked. Canada, Australia, and China are among the countries to introduce market based instruments in some parts of the countries. China expects to apply levy on SO_2 emissions in some provinces and cities in the near future. Having environmental regulation and standards already in place by the end of this century, the APEC economies can gradually introduce market based instruments to deal with environmental problems in the power sector.

Some APEC economies have adapted policies to set up a target of reducing total SO_2 emissions to certain level. Such capping or top down approach can have an effect far below to the level of choosing fuel type. China, for example, has set a control target of reducing its SO_2 emissions to 1990 level by 2000. This means China will have to switch into low sulphur coal or other cleaner fuel and also increase application of SO_2 emission control technologies. The target set by the US is even rigorous, its goal is to reduce annual SO_2 emissions by 10 million tons below 1980 level. In terms of total SO_2 emission volume reduction, Japan has shown remarkable success, its total SO_2 emission in 1987 was half that in 1975.

4.3 Global Climate Change Commitment

Several APEC economies are among the Annex-1 countries of the Climate Change Conventions that have long term commitments to reduce greenhouse gas emissions. Among the 21 member countries of APEC, six countries (Australia, Canada, Japan, New Zealand, Russia, USA) have obligations to reduce their GHGs emission to a stated level ranging from +8% to –7% of 1990 level (see Table 4.4). Whereas other developing countries, though not committed yet, are required to formulate and implement climate change mitigation and adaptation programs. Some developing Asian APEC economies have expressed a long-term reduction interest in the emission of climate change gases. Korea, for example, has no obligation to reduce CO_2 emissions, but has a plan to voluntarily regulate GHGs emissions from 2000-17 and to observe reduction obligation beginning in 2018.

Table 4.4: GHGs Emissions Reduction Commitment by Annex-1 APEC Countries

Annex-1 APEC countries	Reduction commitment (% of base year)
Australia	108
Canada	94
Japan	94
New Zealand	100
Russia	100
United States	93

The Annex-1 countries must achieve the established targets within the period 2008 to 2012. Achieving the GHGs reduction targets as committed in the Kyoto protocol will be a challenge for many APEC countries, particularly, for the Annex-1 countries. Australia, for example, derives 94% of the country's primary energy supply from fossil fuel, of which 40% belongs to coal.

Many APEC countries (such as USA, Australia) thus have developed greenhouse gas reduction strategies to meet climate change challenges. Australia's GHGs strategies stress on reducing the green house intensity of energy supply (see National Greenhouse Strategy, 1998), which favor natural gas to coal. The US strategy focus on cooperating with private sectors, and market based instruments such as emission trading.

The Kyoto Protocol also includes a number of provisions, which have potential to encourage the APEC economies to engage in cooperative efforts to meet climate change challenges. The protocol allows reducing the cost of compliance through provisions like, international emission trading, Joint Implementation projects, and the Clean Development Mechanism (CDM). Emission trading and joint implementation projects are allowed among the Annex-1 countries. And under the CDM mechanism, Annex-1 countries can take emission credits for the projects that reduce emissions in non-Annex-1 countries.

4.4 Implication of Environmental Issues on Fuel Choice

a. Emission standards

The evolution of emission standards in the APEC economies will affect the competition between natural gas and coal considerably. The tightening of emission standards means the utilities have to comply by choosing options such as switching into low sulphur coal, adopting clean coal technologies (combustion and post combustion technologies), or switching into cleaner fuel such as natural gas. Natural gas then becomes the obvious fuel choice for the economies, particularly those which have gas resources. Also, natural gas will be attractive for the economies that are net energy importing countries and have access to the international supply of natural gas.

As observed in the countries such as in the US, Japan and China, the utilities respond to stringent environmental regulations by switching into low sulphur coal first. This is because low sulphur coal is relatively a cheaper option. This is followed by use of pollution control technologies, as observed in Japan, where 80% coal fired plants have been installed with FGD.

Some APEC economies, which have introduced emission standards for the first time, put limit only to the new power plants that are to be constructed, whereas the older plants are allowed to continue emitting as before. Such policies would affect only the new power plants which are to be built i.e. they may opt for cleaner fuel (such as natural gas) or consider installing control technologies to comply with the regulations whereas the old existing plants will consume coal in traditional way.

Since the option of having low sulphur coal is relatively cheaper than installing pollution control technologies, the tendency among the APEC economies would be to shift towards low sulphur coal first. This will be so particularly in those economies, which have low sulphur content indigenous coal (such as Australia, US, China), or those, which depend on import (such as Korea, Japan). Installation of control technologies will also rise in the APEC economies, if the standards are made further stringent, then complying will not be possible through low sulphur coal alone (such as in Japan, Korea). Also control technologies will be options for those countries, which intend to utilize domestic low quality coal (such as Thailand, China). Switching into natural gas are attractive option as well, though it will require overcoming constrain of infrastructure and access to the market for some economies.

b. Local and regional governments measures

In addition to the impacts made by the national regulations and standards, some countries will also experience impacts due to strong measures taken by their local governments. Such measures may include imposition of restriction to further expand coal use in certain critical regions or, accelerate installing of clean coal technologies.

For example, the provincial government of Guangdong announced in May 1995 that there would be no new coal plants in delta area of Pearl River, because of SO_2 pollution in the region. Similarly, there will be no more coal plant to be added in Mae Moh in Thailand. The operating plants in both of these regions are being installed with desulphurization equipment. Also in Japan, local governments have been successful in negotiating with utilities to set more stringent local standards compared to the national standard, thus driving utilities to use low sulphur coal and install control technologies.

c. Control targets

Some economies have, along with emission standards, also set up a control target for limiting national emissions to certain level within a specified year, for instance, to limit emission to 1990 level by year 2000. Such targets or capping are bound to have impacts to the coal use practices in these countries.

For example, China has set up a control target that total SO_2 emission from all fossil fuel plants will remain at constant 1990 level. This implies that China will have to take various measure to limit SO_2 emission, such as switching to low sulphur coal, increased used of control technologies, etc. Similarly, the US has set a goal of reducing annual SO_2 emissions by 10 million tons below 1980 level.

d. Climate change

The emerging climate change issues will make strong influence on fuel choice and energy consumption pattern in the APEC economies. The APEC economies are seeking various options to mitigate their greenhouse gas emissions, which include a shift to less carbon content fuels such as natural gas, improvement of power plant efficiency and shift to more efficient clean coal technologies.

The power sector, an important sector for mitigating GHGs, has a variety of options available for reducing carbon emissions. An attractive carbon reduction option available is the use of less carbon intensive technologies (mainly natural gas fired plants). Others include use of carbon free technologies (i.e. wind, solar, biomass, geothermal, nuclear, hydro, etc.), improving operating efficiencies of existing plants, and investing in demand side technologies that reduce electricity consumption.

At present the Kyoto Protocol has not been ratified by any APEC economies yet. As soon as the protocol is enacted, one possible implication would be setting up a carbon price in some economies (most likely in Annex-1 countries). Depending upon the carbon price, coal plants will loose its competitiveness. If the carbon price is set high, coal plants will not be economical any more. In such situation, the power suppliers will find building natural gas plant more attractive. Also, another possible effect will be early retirement of coal plants (most of the coal plants are fairly old in many economies), and replacement by natural gas plants. And, if economically feasible, existing coal plants could be modified into natural gas fired plants.

Being a low carbon content fuel, natural gas is favorable among all fossil fuels. Australia and Korea, for example, will see increased use of natural gas in response to Kyoto protocol. However, the critical question for many economies would be whether natural gas would be readily available.

Kyoto Protocol may not necessarily result in a shift from coal to natural gas in some of the economies, as developing economies have potentials of exploiting efficiency improvements in energy use first. China, for example, emphasizes on exploiting the large potential of improving efficiency in boilers. On the other hand, many countries place other energy sources (rather than natural gas) in priority, for example, Japan and China are considering nuclear, and Canada and China are promoting hydropower (for example, Three Gorges Dam) as options to mitigate climate change.

JI, CDM, etc.

The international provisions included in the Kyoto Protocol, such as emission trading, joint implementation, CDM may also influence coal and natural gas role in the power sector. The CDM, for example, allows Annex-1 countries to take emission credit from projects that reduce emissions in non-Annex-1 countries. This offers the developing economies investment and technologies from developed countries such as USA, Japan, which have developed advanced clean coal and gas technologies. It is possible that many of the projects that will be undertaken under CDM will involve fuel switching in power generation, which may likely be in favor of natural gas. Some demonstration pilot projects on clean coal technologies are already in operation in various Asian countries under AIJ (Activities Implemented Jointly) program. On other hand, the transfer of advanced technologies will affect the way fuel is consumed due to the higher efficiency of these technologies. Moreover, by acquiring emission credits through emission trading, JI, and CDM, the Annex-1 countries have option of either reducing emission in their own country (for example, through switching from coal to natural gas) or buying cheaper emission credits to compensate their emissions. This will require a detail economic analysis of both options.

e. Other Issues

Private and public utilities

Many of the APEC economies are going through the process of deregulation in power sector. Such economies, having now both IPPs and public utilities in operation, may witness their national environmental policies affecting these two utilities (IPPs and public utilities) differently while making fuel choice. For example, publicly owned utilities such as Taipower in Chinese Taipei and KEPCO in Korea and regional power utilities such as those of Japan are often more directly influenced by environmental policies than independent power producers that operate within a more competitive environment[4].

Financial institutions

Beyond the in-country environmental policies, the policies adopted by international lending and financial institutions will also affect the utilities particularly in the developing APEC economies, while making choice in fuel and technologies. International agencies such as World Bank, ADB, OECF now emphasize on environmental protection as an important factor while sanctioning loan. This will require government utilities or private power producers to be more concerned about environmental aspects (such as using cleaner fuel and control technologies) while seeking loans from such institutions.

Advanced technologies

Where there are technologies now available for absorbing SO_2 and NOx emissions, there are no technologies available yet to remove CO_2 emissions from fossil fuel combustion, though research in this direction are also being conducted. A breakthrough in development of such technologies, though not expected to happen in the near future, would considerably affect the prospect of competition between natural gas and coal.

4.5 Policy issues

The APEC economies are at different stages of development, and so are their environmental concerns. Majorities of the APEC economies' environmental policies are based on command and control regulations at present, and most have not yet introduced market based instruments (MBI), thus giving no incentives to reduce emissions or switching into cleaner fuels such as natural gas. Some APEC economies (such as in Chile, Thailand, Malaysia and New Zealand) still rely on ambient air quality standards (instead of point source emission standards), which are not adequate for effective environmental protection. Some economies continue to subsidize coal (for example China), not only giving unfair advantage to coal, but also resulting in inefficient use of coal. Also, existing policies in many economies do not take into account the environmental cost of coal consumption, which thus ignores natural gas environmental competitiveness. Addressing these issues when formulating environmental policies will have implications on the competition between natural gas and coal in the APEC economies.

The environmental policies in the APEC economies will revolve around three major issues: strengthening of environmental regulations, gradual introduction of MBIs, and promoting environmental technologies.

Though not all, some of the APEC economies will see strengthening of their environmental regulations further with formulation of the point source emission standards that are more stringent. However, relying only on command and control approaches has some drawbacks. Such policies, for example, cannot achieve cost effective emission abatements. The economies will also need to explore gradual introduction of market based instruments (MBIs). Outright replacement of command and control with MBI will probably not be appropriate, since most of the economies have little or no experience in market based instruments yet. Since environmental regulations are already in place in many APEC economies, the challenge will then be to gradually introduce these market-based instruments.

Market based instruments, such as taxes and tradable permits, use efficiency of the market to achieve cost effective abatement for environmental protection. Success of market based instruments in dealing with SO_2 emission from coal consumption have already been demonstrated in the US, through sulphur dioxide trading program began in 1995. The program was effective to cut SO_2 emissions by almost 50%, at a significantly lower cost than other alternatives.

Where MBI for SO_2 and NOx are suitable for domestic implementation, MBIs for CO_2 emissions can include several countries within the APEC economies. Several types of market based instruments have been envisaged in Kyoto protocol (such as Joint Implementation, Emission Trading and Clean Development Mechanism), which promote cost effective reduction of GHGs. The APEC economies will explore these instruments further and see possibility of implementing them for their benefit.

China has gained some experiences from successful implementation of market-based instruments, particularly in water pollution control. China was able to reduce water pollutant discharge by about 50% within 1987 to 1993. China has also introduced sulphur tax in two provinces (Guandong and Guizhou) and in some cities. Having such experiences, China may expand effective MBIs (similar to the US) to control emission of sulphur dioxide from coal combustion further.

The policies based on command and control are more likely to result in a shift in fuel choice towards natural gas, because, the developers will have to comply with the regulations first and will face less flexibility. On the other hand, policies based on MBIs will provide flexibility for power producer to choose from a range of options which are economically most beneficial. The result would not necessarily be a shift from coal to natural gas, because other options (such as buying emission quota) can be more economical. The policies that the APEC economies choose will have significant impact to the coal and natural gas competition. A policy of introducing sulphur tax, for example, would increase electricity price generated by coal-fired power plants significantly depending upon the quality of coal used. The utilities may then react by installing desulphurization facilities or by switching into lower sulphur coal or natural gas. Similarly, if carbon tax is imposed to reduce GHGs emission, it can significantly tilt fuel choice in favor of natural gas. At present, carbon tax is yet to be considered in any of the APEC economies. Some economies, being at lower level of developing stage, widely hold a view that carbon tax can slow down their economic development process. Such developing economies favor carbon tax as long as they are levied on rich countries but not on the poor countries. It may, however, be possible that the APEC economies begin experimenting with such taxes, at least in pilot phases in some regions or part of the country.

There remain other issues. For example, some economies cannot be flexible in choosing natural gas or coal. The policies of the economies that are endowed with large coal deposits will focus on promoting efficiency in coal consumption and environmental protection. Market based approaches to environmental protection are worth exploring in such economies.

Another issue is of reducing GHG emission. The APEC economies hold a possibility to emerge as a separate group, within which GHGs emission can be traded. Such grouping, as some argues, will be more efficient than allocating cap of emission to individual nations. This will allow the nations within the group to reduce emission where it is economically most beneficial.

Also policies, which promote adaptation and dissemination of environmentally sound technologies are important, especially in coal use. Environmental technologies would become important in those economies, which intend to utilize indigenous coal, especially more in the countries having lower coal quality (such as in Thailand and China). Also more stringency in the emission standards would necessitate increasing the adoption of environmental technologies in the APEC economies, because option of low sulphur coal alone will not be sufficient for compliance. Since high costs associated with the technologies have been barrier for adaptation of environmental technologies, the policy issues in the APEC countries may consider providing financial incentives to the technology users on one hand and introducing pollution charges (externality costs) to the polluters on the other (see Chapter 5 for further discussion on technology issues).

4.6 Conclusion

The competition between coal and natural gas in the APEC economies are to be affected by evolving environmental regulations, climate change challenges and increased availability of environmental technologies in the economies. Natural gas, a cleaner fuel, is becoming an attractive fuel in many economies with the rise of environmental awareness and emerging climate change issues in the economies. Particularly, the evolution of stringent emission standards in the APEC economies, and implications of the Kyoto Protocol will affect the competition between these two fuels significantly, making natural gas attractive to some extent. However, factors such as high capital requirement, inflexibility of transporting, will continue to limit the use of natural gas. On the other hand, recent advances in coal technologies have increased environmental competitiveness of coal significantly. Coal and natural gas will continue to compete with each other in foreseeable future in many APEC economies, and natural gas is expected to be a fuel choice whenever it is available readily and is economical.

Endnotes

[1] Zhang, M.C. (1993).
[2] APEC (1997a).
[3] Asia Pacific Energy Research Center (APERC) (1998).
[4] Fesharaki, F. et al. (1998).

5. TECHNOLOGY CHOICES

Technological development has intensified the competition between coal and natural gas in electricity production. While both clean coal and natural gas technologies can meet strict environmental limitations for new generating sources, they have different costs and technical performance. The fundamental question becomes which technology offers the lowest cost power output to its ratepayers. Investment costs, O&M costs are the basic components of generation costs. The projected annual costs of generating electricity vary differently depending on the assumptions for various factors such as discount rate, load factor, economic lifetime and fuel prices. On the other hand, the efficiency of power plant also varies from technology to technology. Therefore, the APEC economies have various technology choices mainly due to their generation costs and different performance.

5.1 Clean Coal and Natural Gas Technologies

Some key natural gas and clean coal technologies which have been technically and economically demonstrated, or are commercially available are shown in Table 5.1.

The main constraint of coal use is the impact on the environment. Without emission control, 80% of the ash, 90% of the sulphur in coal and 90% of the NOx are emitted during combustion[1]. The emission can be reduced by emission control technologies. Pre-combustion cleaning technologies can remove substantial fractions of ash and sulphur from coal prior to its combustion or process use, thus reducing the production of ash and SOx in the combustion stage. Some advanced coal-based power generation technologies are comparable to conventional coal-fired plants in terms of thermal efficiencies and achieve a higher level of environmental performance.

Natural gas has less environmental emissions than coal. Without pre-combustion cleaning technologies, about 0.4-1.8 g/kWh NOx (around 35% of conventional coal-fired technology), 0.01-0.1 g/kWh particulate (around 0.3% of conventional coal-fired technology) and negligible SOx are emitted from natural gas-based power generation technologies. With more stringent environmental concern, some emission control might be needed to reduce NOx or particulate emission.

Table 5. 1: Key Clean Coal and Natural Gas Technologies

Fuel	Category	Technologies
Coal	Pre-combustion & Conversion	– Physical Cleaning – Chem/Bio Cleaning – Low Rank Upgrading – Coal/water Mixtures – Gasification – Indirect Liquefaction – Direct Liquefaction

	Combustion	– Subcritical PF
		– Supercritical PF
		– Ultra Supercritical PF
		– Fluidized Bed Combustion (FBC)
		  – Atmospheric Fluidized Bed Combustion (bubbling & circulating) -(AFBC)
		  – Pressurized Fluidized Bed Combustion (bubbling & circulating) - (PFBC)
		– Integrated Gasification Combined Cycle (IGCC)

Natural gas	Combustion	– Natural gas fired steam – Gas Turbine – Combine Cycle – Advanced Gas Turbine – Fuel Cell
Emission Control	Particulate emission control	– Electrostatic Precipitator (ESP) – Bag Filter (BF) – Venturi Scrubber (VS) – Mechanical/inertial collectors (cyclones/lulticyclones)
	SO2 emission control	– Flue Gas Desulphurisation (spray dry scrubbing) - FGD(SDS) – Flue Gas Desulphurisation (other wet scrubbers, i.e. not limestone) - FGD(OWS) – Flue Gas Desulphurisation (regenerable processes) - FGD(R) – Flue Gas Desulphurisation (wet limestone/gypsum system) - FGD(WL/G) – Flue Gas Desulphurisation (wet limestone/no gypsum system) - FGD(WL/no G) – Sorbent Injection – Combined SO2/NOx removal processes
	NOx emission control	– Selective Catalytic Reduction (SCR) – Selective non-catalytic reduction (SNCR) – Low NOx Burners (LNB) – Low NOx Concentric Firing System (LNCFS) – Two Stage Combustion (TSC) – Over Fire Air (OFA) – Flue Gas Recirculation (FGR)

Source: IEA (1997e); APEC (1997a); The GREENTIE Directory

5.1.1 Clean Coal Technologies

Clean coal technologies form the foundation for a new generation of coal-fired power plants. These technologies enable coal utilization to be extremely clean, greatly reducing concerns about many pollutants and dramatically reducing the emission of greenhouse gases.

Clean coal technologies can be installed at any of the three functional stages in the coal chain, or in a fourth manner that departs from the traditional method of coal burning. These are pre-combustion, combustion, post-combustion and conversion technologies. The coal can be cleaned by pre-combustion technologies before it burns. The pollutants inside the combustor or boiler can also be removed by combustion technologies while coal burns. Post combustion technologies on the other hand, can reduce the amount of particulate, sulfur oxides and nitrogen oxides in the equipment leading to the stack. Lastly, conversion technologies bypass the combustion altogether, changing coal into a clean natural gas or liquid that can be used as a fuel. It allows pollutants in the coal to be removed economically and effectively prior to combustion.

Pre-Combustion and Conversion Technologies

Pre-combustion cleaning technologies have two major categories: physical cleaning and chemical cleaning. The conventional physical cleaning assists with the removal of 10-30% of total sulphur from raw coal. It can only remove the pyritic sulphur, but cannot remove the organic sulphur in coal. On the other hand, advanced coal cleaning technologies, based on the use of chemicals and capable of removing both pyritic and organic sulphur, have the potential to reduce the sulphur content of coal by up to 90%, but are currently not economic. The conventional cleaning methods are estimated to cost about US$0.3/GJ, whereas deep physical and chemical cleaning methods cost, respectively, around US$2.0/GJ and US$2.5-3.5 /GJ[2]. The technical and economic status of some pre-combustion and conversion technologies are shown in Table 5.2.

Conversion technologies include direct/indirect liquefaction and gasification. The direct coal liquefaction technologies can produce about 4.6 barrels of liquids from a ton of ash-free coal. Direct liquefaction technology efficiency ranges from 55% to 60%. The efficiency of indirect coal liquefaction technology ranges from 40% to 47%, but could be improved to 60% with more advanced technology. The efficiency of coal liquefaction technology can reach up to 60% with advanced two-stage technology currently under development. The efficiency of coal gasification ranges from 75% to 80%.

SOx emission can be reduced by more than 95% by liquefaction technologies. Coal gasification technology can reduce SOx emission on 90% to 99%. Direct liquefaction technology can also reduce 97% of NOx emission, while indirect liquefaction technology has relatively low NOx emission reduction of 70%.

Table 5. 2: Technical and Economic Status of Coal Upgrading Technologies

Technology	Status	Conversion Efficiency %	Capital Cost (US$/kW)	Emissions Reduction (%)	
				SOx	NOx
Physical Cleaning	Commercial/ Demonstrated	90	1-3	30	n.a.
Chem/Bio Cleaning	R&D	85-90	5-10	90-95	n.a.
Low Rank Upgrading	R&D	80	1-5	30-95	n.a.
Coal/water Mixtures	Demonstrated	n.a.	n.a.	50-75	n.a.
Gasification	Commercial/ Demonstrated	75-80	n.a.	90-99	n.a.
Indirect Liquefaction	R&D	60	n.a.	95	70
Direct Liquefaction	R&D	55-60	n.a.	99	97

Note: Conversion efficiencies measure the ratio between heating value of the fuel in process output and input stream

Source: IEA (1997e)

Combustion Technologies

Summary data on the technical and economic potential of key coal combustion technologies is presented in Table 5.3.

Table 5. 3: Technical and Economic Status of Coal Combustion Technologies

Parameter	Subcritical PF	Supercritical PF	AFBC	PFBC	IGCC
Maturity of Technology	Completely proven	Substantially proven	Proven at small scale (<200 mw) only	Only five commercial units built, limited experience	Only one commercial unit
Range of Unit Size Available	All commercial size available	All commercial sizes available	Small units only at present	Currently limited to two sizes	Currently limited to large gas turbine units
Fuel flexibility	Burns a wide range of coals, but less good than FBC at extremes of moisture/ash	Burns a wide range of coals, but less good than FBC at extremes of moisture/ash	Will burn practically anything that can be burned	Should burn same range as AFBC, but not proven	Should use wide range of coals, but not proven
Thermal Efficiency	36-38% Limited by steam conditions	40-46% High, further increase depends on materials development	34-40% Relatively low, but supercritical steam conditions will raise	42-45% Inherently less good than IGCC. Topping / 2^{nd} generation will raise	43-48% High, further increases as gas turbines improve
Operational Flexibility	Performance limited at low load	Performance limited at low load	Wide load range and response	Potentially similar to pf but needs proof	Limited experience, needs demonstration*
Environmental Performance	Low efficiency and FGD solids a problem	Better than subcritical because of higher efficiency	Low efficiency and large volume of solids	Good, but solids residues a potential problem	Excellent, inert slag, sulfur recovered in elemental form
Availability	Proven to be excellent	Proven to be good	Limited experience at utility scale	Limited experience	Limited experience, results modest so far
Build time	On-site erection required	On-site erection required	On-site erection required, but no FGD required	Long so far, but substantial opportunity for modularisation	Long so far, but opportunity for shop fabrication of major items
Current specific capital cost	US$900-1300 /kW Cheapest	US$950-1600 /kW Medium	US$1000-1600/kW Potentially cheaper than PF+FGD	US$1100-1500/kW Expensive	US$1200-1600/kW Most expensive

Note: Thermal efficiency is the net efficiency based on the lower heating value of the fuel
Source: IEA (1996c); IEA (1997e)

The conventional coal power plant uses subcritical pulverized fuel combustion (PF). Over most of the world, subcritical PF is the predominant coal technology. It is a well proven technology with over 40 years of operational experience. Super critical pulverized fired plant is a substantially proven technology which was used in few countries. Ultra-supercritical PF technology is still under development. The advanced clean coal technologies that are being developed include Atmospheric Fluidized Bed Combustion (AFBC); Pressurized Fluidized Bed Combustion (PFBC); and Integrated Gasification Combined Cycle (IGCC) technologies. The coal combustion technologies differ in terms of efficiency, costs and emission reduction.

The conventional coal technology has of thermal efficiency of 36-38% (net, lower heating value basis). The advanced clean coal technologies can achieve higher efficiency than the conventional technologies. Among the advanced coal technologies, IGCC is the most efficient, achieving 43-48% efficiency (net, LHV). The efficiency for AFBC is relatively low, ranging from 34% to 40%. Supercritical PF and PFBC can also achieve high efficiency, ranging from 40% to 46%. (Refer to Table 5.3). Most of advanced clean coal technologies are capable of higher efficiencies with values of up to 50% achievable with further development.

In terms of costs, among the coal technologies, the subcritical PF is the cheapest technology (US$900-1300/kW) and IGCC is the most expensive one (US$1000-1800/kW). The capital costs of AFBC and PFBC are in the middle (around US$1000-1600/kW), but AFBC has the potential to be less expensive than conventional coal technology with FGD emission control. The cost of supercritical PF technologies range widely from US$950/kW to US$1600/kW.

Without emission control, 80% of the ash, 90% of the sulphur in coal and 90% of the NOx are emitted during combustion[3] for conventional technology. Advanced clean coal technologies can reduce by more than 90% of SOx and 60% of NOx emitted during combustion. Among these technologies, IGCC is the most effective technology which can reduce both of SO2 and NOx emissions by 98%.

Post-combustion technologies

Table 5.4 shows the technical and economic status of emission control technologies. SO2 emissions from coal combustion can be reduced by flue gas desulphurisation (FGD) and sorbent injection technologies by 55% to 97%. The SO2 emission reduction technology has a capital cost of US$ 88-380/kW.

Low NOx burner, selective catalytic reduction (SCR), and reburning are NOx reduction technologies which can reduce 40% to 90% of NOx emission. The capital cost of NOx emission reduction technologies is around US$10-130/kW.

Electrostatic precipitators (ESP) are used for dust control in most power stations, which the emission reduction efficiency can be above 95%. Bag filters (BF) which can achieve better emissions control than ESP have only found application in few countries.

Table 5.4: Technical and Economic Status of Air Emission Control Technologies for Pulverised Coal-fired Power Plants

Technology	Status	Conversion Efficiency %	Capital Cost (US$/kW)	Emissions Reduction (%)	
				SOx	NOx
Advanced Flue Gas Desulfurisation (FGD)	Commercial/ Demonstrated	37-39	200-350	90-97	
Sorbent Injection	Commercial/ Demonstrated	37-39	88-100	55-75	
Spray Drying	Commercial/ Demonstrated	37-39	120-380	70-90	
Combined SOx/NOx	Demonstrated/ R&D	37-39	280-360	70-95	70-90
SCR	Commercial/ Demonstrated	n.a	50-80		>80
Reburning	Demonstrated	38-40	15-50	0-2	60
Low NOx Burner	Commercial/ Demonstrated	38-40	10-30		45-60
Post-combustion NOx	Commercial/ Demonstrated	37-38	100-130		40-90

Note: Net plant thermal-electric conversion efficiencies based upon the lower heating value of the fuel and sub-critical steam cycle. Capital costs add to power plant investment.
Source: IEA (1997e); APEC (1997a)

5.1.2 Natural Gas Technologies

The conventional technologies for natural gas-fueled power plant include gas turbine, gas-fired steam units, and combined cycle. The advanced type of natural gas technologies include intercooled steam injected gas turbine (ISIGT) and fuel cells power plant.

Summary data on the technical and economic potential of these key natural gas technologies are presented in Table 5.5.

Gas-fired, gas turbine and combined cycle technologies are commercially available, and the gas-fired technology is currently being superseded by more efficient technologies (i.e. combined cycles). ISIGT and fuel cells are in demonstration stage and are undergoing continuous development.

Table 5. 5: Technical and Economic Status of Natural gas Technologies

Technology	Status	Conversion Efficiency %	Capital Cost (US$/kW)	Emission (g/kWh)		
				CO_2	NOx	CO
Gas-fired steam	Commercial	30-37	790	500	0.8	0.07
Gas Combined Cycle	Commercial	43-58	480-600	425	0.4-1.3	0.07-0.12
Gas combustion turbine	Commercial	30-42	250-600	525	0.4-1.8	0.15
Fuel Cells	Demonstrated/ R&D	40-60	580-2100	290-520	0.11	0.07
Intercooled Steam Injected Gas Turbine (ISIGT)	Demonstrated/ R&D	42-47	900-1100	100	0.04	0.2

Source: The GREENTIE Directory

Among the conventional technologies, the combined cycle is most efficient, achieving 43-58% efficiency, and might be up to 60% in the near future. The efficiency for gas turbine technology is typically from 30 to 37%, but it can be as high as 42% for new gas turbine models. The advanced types of gas technologies are expected to have technical potential of 47 to 60% efficiency.

In terms of costs, among the gas technologies, gas turbine is the cheapest technology (US$250-600/kW) and fuel cell is the most expensive one (US$580-2100/kW). The capital costs of combined cycle technologies are in the middle (around US$480-600/kW).

Natural gas normally has little or no sulphur. Therefore flue gas desulphurisation systems are not needed. However, as with coal-fired plants, nitrogen oxides are produced during the combustion process. Low NOx burners can partially reduce the production of NOx in gas turbine combustors can also be used to reduce NOx production, but this reduces thermal efficiency and so is less common in new machines. In areas where strict NOx emission regulations are in effect, additional measures are normally needed. Post-combustion systems, mainly selective catalytic reduction, can be used.

5.1.3 Comparison of Clean Coal and Natural Gas Technologies

The comparison of clean coal and natural gas technologies is shown in Table 5.6. Coal and natural gas based power technologies have been the dominant choices for new utility capacity. While both alternatives can meet all the very strict environmental limitations for new sources, they do have very different costs and performance. The fundamental question becomes which technology choice offers the lowest cost power source to its ratepayers.

Coal is cheaper than natural gas. This offers a significant fuel price advantage for coal-based technologies. In the future, the price outlook for coal and natural gas are mainly influenced by reserves and production costs. Coal reserves are abundant. Natural gas reserves are more limited and are costly to develop. The coal prices might not be expected to rise significantly, while natural gas prices could rise significantly in the future.

In terms of efficiency, natural gas technologies have higher efficiency than coal technologies. But natural gas technologies' efficiency is very sensitive to unit operations and can decline to energy efficiencies similar to conventional units if plant is operated at 50% loads[4]. Advanced clean coal technologies have the potential to further improve efficiency, for example, the efficiency of IGCC can be rised up to 60%.

Gas-based technologies also have a capital cost and non-fuel operating cost advantage over coal technologies. It costs more to run a coal plant because it is a more complex technology requiring more employees, more costly equipment to maintain and purchase of more material supplies such as limestone to remove sulfur dioxide.

Natural gas technologies have less pollutant emission than coal technologies due to its lower particulate and sulfur content. Therefore, gas technology’s pollution control costs are less than that of coal technologies. Advanced clean coal technologies have the potential to further improve environmental performance through both reduced emission rate and improved energy efficiency.

“Peaking” power capacity is used less often and its choice is dominated by capital cost considerations. Natural gas technologies’ capital cost advantage makes it the dominant choice for utilities to meet peaking load requirement. On the other hand, “baseload” power capacity is needed to operate most of the time to meet the large electricity demand. The baseload technology selection is mainly depended on variable operating cost since fixed capital costs become less significant when spread over a larger generation baseline. Therefore, the lower cost baseload generating plants are mainly dominated by coal-based technologies.

Table 5. 6: Comparison of Clean Coal and Natural Gas Technologies

Factors	Comparison of Clean Coal and Natural Gas Technologies
Investment Cost	– Natural gas based technologies have lower capital cost than coal.
O&M cost	– It costs more to run a coal plant because it is a more complex technology requiring more employees, more costly equipment to maintain and purchase of more commodities such as limestone to remove sulfur dioxide.
Fuel price	– Natural gas has higher price than coal.
Efficiency	– Natural gas technologies have higher efficiency than coal. – The natural gas technologies’ efficiency is very sensitive to unit operations and can decline to energy efficiencies similar to conventional units if plant is operated at 50% loads. – Advanced clean coal technologies have the potential to further improve efficiency.
Environmental compliance and costs	– Gas technology’s pollution control costs are less than for coal technologies due to its lower particulate and sulfur content. – Advanced clean coal technologies have the potential to further improve environmental performance through both reduced emission rate and improved energy efficiency.
Capacity Factor	– Coal-based technologies have a significant advantage in system economic dispatching over natural gas based units which allow them to operate at higher capacity factor and spread their fixed costs over more generation. – Coal unit has lower variable cost than natural gas and is dispatched before gas-fired units.

Source: http://www.ceednet.org; IEA (1996c)

5.2 Status of Clean Coal and Natural Gas Technologies in APEC Economies

The various clean coal and natural gas technologies have their individual strengths and weaknesses and also in different states of development. Technological development has intensified the competition of coal and natural gas in electricity production. Both coal and natural gas based power technologies have been the dominant choices for new utility capacity in the APEC economies.

5.2.1 Clean Coal Technologies

Pre-combustion Technologies

Coal preparation is not widely practiced in the coal producing APEC economies. Practically all the coal beneficiated in preparation plants are anthracite or bituminous coal. Subbituminous coal and lignite beneficiation is currently not economic, but new technological developments and high value products may enhance prospects for beneficiation in the future. The benefits of increased coal cleaning extend throughout the coal chain, from reducing coal transport costs to more effective coal use, less pollution, and less waste disposal.

In China, only about 300 Mt per year of coal is washed. The Ministry of Coal plans to expand coal cleaning capacity to 500 Mt per year by 2000, accounting for about one-third of projected production in the year. A joint demonstration project called Green Aid Plan (GAP) has also been going on in order to disseminate Japanese coal preparation technology in some high sulfur coal region of P.R.C.

Upgrading, conversion to other forms of fuel and gasification are all methods under consideration to improve the quality and utilization of Indonesia’s lower rank coal.

Combustion Technologies

The power generation capacity of coal-fired power plant and existing clean coal technologies in APEC economies are shown in Table 5.7 and 5.8. The clean coal technologies under construction or planned in APEC economies are shown in Table 5.9.

Table 5. 7: Power Generation Capacity of Coal-Fired Power Plant in APEC Economies (MW)

Country	Advanced technologies*	Total
Australia	0	26000
Canada	170	18400
Chile	0	1500
P.R.China	27	147300
Hong Kong	0	6300
Indonesia	0	2900
Japan	5710	19800
Korea	0	7300
Malaysia	0	600
Mexico	0	2600
New Zealand	0	1000
Philippines	400	1500
Chinese Taipei	0	5900
Thailand	0.03	2600
US	4700	320900

* Technologies include AFBC, CFBC, PFBC, IGCC and Ultra-supercritical combustion
Source: APEC (1997a)

Most coal-fired generating plants in the APEC economies are based on pulverized-coal combustion. Majority of the coal-fired boilers is of the subcritical single reheat type. Supercritical boilers are already commercially available and have been in service in Japan, the United States and Russia[5]. Fluidized bed combustion technologies have been adopted in USA, Canada, Japan, China and Philippines. Major development of IGCC is currently underway in the USA which has 770 MW capacity of IGCC. By 1997, five USC plants totaling 6000 MW were built in Japan and the U.S.

Most coal-fired generating plants in the APEC economies are based on pulverized-coal combustion. Majority of the coal-fired boilers is of the subcritical single reheat type. Supercritical boilers are

Table 5. 8: Existing Clean Coal Power Generation Capacity in APEC economies (MW)

Country	AFBC	CFBC	PFBC	IGCC	USC	Total
CANADA	0	170	0	0	0	170
JAPAN	350	0	160	0	5200	5710
PHILIPPINES	100	300	0	0	0	400
USA	700	2520	0	770	710	4700
CHINA	0	27	0	0	0	27
THAILAND	0	0.03	0	0	0	0.03
Total	1150	3017	160	770	5910	11007

Source: APEC (1997a); EGAT (1999); IEA (1998a)

Table 5. 9: Power Generation Capacity of Clean Coal Technologies under construction or planned in APEC economies (MW)

Country	Technology	Capacity (MW)	Commission Year
CHINA	CFB	100	
CHINA	CFB	50	1998 FOR IPP
INDONESIA	CFB	110	2000
INDONESIA	CFB	100	1999
KOREA	CFB	200	1999, ABB
MALAYSIA	CFB	100	
PHILIPPINE	CFB	100	2003
THAILAND	CFB	330	
CANADA	CFB	800	2005-2010
CHILE	CFB	67	
USA	CFB	500	2000
Sub-total		2457	
CHINA	IGCC		
USA	IGCC	40	1999
USA	IGCC	240	1999
USA	IGCC	170	2001
USA	IGCC	385x2	2000
JAPAN	IGCC	550	2001
Sub-total		1770	
Japan	PFBC	360	2000, new.
Japan	PFBC	250	2000, new.
Japan	PFBC	250	2005, new.
USA	PFBC	350	2002, new
China	PFBC	150	2000 Repower
Taipei	PFBC	350	New
Sub-total		1710	
Japan	USC	1000	1998
Japan	USC	1050x2	2000/2001
Japan	USC	700	2003
Sub-total		2800	

Source: IEA (1998a); OECF (1995); Fesharaki, F. (1998); Soud, Hermine N. (1997)

already commercially available and have been in service in Japan, the United States and Russia[6]. Fluidized bed combustion technologies have been adopted in USA, Canada, Japan, China and

Philippines. Major development of IGCC is currently underway in the USA which has 770 MW capacity of IGCC. By 1997, five USC plants totaling 6000 MW were built in Japan and the U.S.

Countries such as Chile, Korea, Indonesia, Malaysia and Thailand are going to adopt fluidized bed combustion. Similarly, several PFBC are under construction or planned in USA, Japan, China and Chinese Taipei. Also, several IGCC are under construction or proposed in Japan, the U.S. and China.

Post-combustion technologies

In all APEC economies, atmospheric emissions regulations are increasingly becoming stringent. Only a few economies rely exclusively on ambient air quality goals to control emission from coal-fired plants; stack emissions standards are additionally specified through legislation or license conditions.

All APEC economies use a mix of measures to control emissions of particulates, SO2 and NOx. Whereas adequate stack height continues to be employed as a method of reducing impacts of flue gas emissions on the environment, it is no longer solely relied on for control of all emissions.

Coal-consuming APEC economies consider the control of sulfur dioxide emissions as top priority, followed by particulates, nitrogen oxides, and carbon dioxide. The priority given to carbon dioxide emissions reflects the immediate concern of member economies related to reducing pollution that can have a direct effect on human health.

<u>SO2 Emission Control</u>

The SO2 emissions control at coal-fired power plants in APEC economies is shown in Table 5.10. In APEC economies, sulphur dioxide control is largely achieved through use of low sulfur coals and adequate chimney heights. SO2 control technology accounts for only 23% of the total coal-fired power generation capacity in APEC economies. Flue gas desulfurisation based on the wet limestone process which accounts for 19% of the total APEC coal-fired capacity is the most common SO2 control technology employed. Some countries have installed wet limestone based flue gas desulfurisation facilities such as Canada, PRC, Hong Kong, Japan, Republic of Korea, Chinese Taipei, Thailand and U.S. Sorbent injection is also practiced in some plants for SO2 control. There are also some experiences of using other flue gas desulfurisation technologies such as spray drying, regenerable systems and combined SO2/NOx removal.

<u>Particulate matter Emission Control</u>

All APEC economies have achieved particulate emission control, and 99% of total coal-fired power generation capacity are equiped with particulate control technologies (refer to Table 5.11).

ESPs is the most common technology applied in APEC economies, which accounts for more than 85% of coal-fired power generation capacity. Bag filters, which account for less than 6% of coal-fired power plant applications within APEC are used in Australia, Republic of the Philippines and the U.S. And they may increase their share, especially in the U.S., if the air toxic provisions of the Clean Air Act are enforced. Wet scrubbers are employed in some power plants at about 5% of the total coal-fired power generation capacity within APEC, mainly in the PRC at older units less than 200 MW[5].

<u>NOx Emission Control</u>

Nitrogen oxide control is practiced at about 39% of total coal-fired power generation capacity within APEC. The remaining capacity relies on tall stacks for nitrogen oxide control (refer to Table 5.12).

Table 5.10: SO_2 emissions controls[a] at coal-fired power plants in APEC economies (GW)

	FGD (WL/G)	FGD (WL/no G)	FGD (SDS)	Sorbent Injection	Other[b]	No Control	Total
Australia	0	0	0	0	0	26	26
Canada	1.4	0	0	0.8	0	16.2	18.4
Chile	0	0	0	0	0	1.5	1.5
P.R.China	0.7	0	0.4	0.3	1.3	144.6	147.3
Hong Kong	0.7	0	0	0	0	5.6	6.3
Indonesia	0	0	0	0	0	2.9	2.9
Japan	18.2	0	0	0.4	0	1.2	19.8
Korea	2	0	0	0	0	5.3	7.3
Malaysia	0	0	0	0	0	0.6	0.6
Mexico	0	0	0	0	0	2.6	2.6
New Zealand	0	0	0	0	0	1	1
Philippines	0	0	0	0.1	0	1.4	1.5
Chinese Taipei	5.5	0	0	0	0	0.4	5.9
Thailand	0	2.4	0	0	0	0.2	2.6
US	19.6	55.1	7.6	4.4	10.3	223.9	320.9
Total	48.1	57.5	8	6	11.6	433.4	564.6

a. Other than sulfur content of fuel; includes facilities planned or under construction
b. Includes other dry and wet flue gas desulfurisation processes, regenerable processes, combined SO_2/NOx removal, and IGCC
Source: APEC (1997a)

Table 5.11: Particulate emissions control at coal-fired power plants in APEC economies (GW)

	ESP	BF	VS	Other	No Control	Total
Australia	17.1	8.6	0	0	0.3	26
Canada	17.1	0	0	0.7	0	18.4
Chile	1.3	0	0	0	0.2	1.5
P.R.China	109.5	0	24.6	13.2	0	147.3
Hong Kong	6.3	0	0	0	0	6.3
Indonesia	2.9	0	0	0	0	2.9
Japan	19.4	0	0	0.4	0	19.8
Korea	7.3	0	0	0	0	7.3
Malaysia	0.6	0	0	0	0	0.6
Mexico	2.6	0	0	0	0	2.6
New Zealand	1	0	0	0	0	1
Philippines	1.4	0.1	0	0	0	1.5
Chinese Taipei	5.9	0	0	0	0	5.9
Thailand	2.6	0	0	0	0	2.6
US	188.1	23.7	1.9	6	1.2	320.9
Total	483.7	32.4	26.5	20.3	1.7	564.6

Source: APEC (1997a)

Low NOx burners which account for 29% of the coal-fired capacity are the most widely used technology for controlling NOx emissions. Australia, Canada, Hong Kong, Indonesia, Japan, Republic of Korea, Malaysia, Chinese Taipei and the U.S. have installed low NOx burners in their power plants. Over-fire air is also used in the U.S. and China which accounts for about 9% of the total coal-based capacity. Only Japan and the U.S. have the experience of flue gas treatment for NOx control.

Table 5.12: Combustion-based NOx emission control at coal-fired power plants in APEC economies (GW)

	LNB[a]	LNB with TSC or OFA or FGR or TSC/FGR	OFA	Technologies other than Pulverised Combustion[b]	Other[c]	No Control	Total
Australia	1.1	6.6	0	0	0	18.3	26
Canada	6.6	0	0	0.2	0	11.6	18.4
Chile	0	0	0	0	0	1.5	1.5
P.R.China	0	0	11.3	0	0	136	147.3
Hong Kong	5.6	0	0	0	0.7	0	6.3
Indonesia	0.8	0	0	0	0	2.1	2.9
Japan	0	18	0	0.4	1.2	0.2	19.8
Korea	0	5.7	0	0	0	1.6	7.3
Malaysia	0.6	0	0	0	0	0	0.6
Mexico	0	0	0	0	0	2.6	2.6
New Zealand	0	0	0	0	0	1	1
Philippines	0	0	0	0.1	0	1.4	1.5
Chinese Taipei	0	5.9	0	0	0	0	5.9
Thailand	0	0	0	0	0	2.6	2.6
US	86.9	26.9	39.1	4	3.7	160.3	320.9
Total	101.6	63.1	50.4	4.7	5.6	339.2	564.6

a. Includes reduced/modified NOx burners and LNCFS
b. Includes AFBC, CFBC, PFBC and IGCC
c. Includes TSC, alone or in combinaiton with OFA or FGR, combined SO2/NOx removal, FGR alone and reburning.
Source: APEC (1997a)

5.2.2 Natural Gas Technologies

The power generation capacity of natural gas technologies and planned advanced natural gas technologies are shown in Table 5.13 and 5.14.

At present, most gas-fired technologies are used in U.S. and Japan which account for about 70% and 17% respectively of total gas combustion capacity within APEC. There are gas technologies in Philippine and Vietnam, but they are not using natural gas as fuel at present. In the future, natural gas might be alternative fuel for these gas technologies. The shift to natural gas for power generation is underway in the Philippines and Vietnam and some 3,500 MW are expected to come on line by year 2003. In Chinese Taipei, Tai power also plans to boost the use of natural gas in existing plants. Some advanced gas technologies will be used in some countries in the future. The United States and Korea will adopt advanced gas turbine and fuel cell will be used in the U.S.

5.3 Efficiency Improvement

The improvement of power plant efficiency will reduce the need for capacity expansion and the quantity of fuel consumed which have the effect on cost of technology and environmental impacts directly. Different countries in APEC economies have various considerations for improving the power plant efficiency.

Table 5.13: Power Generation Capacity of Gas-fired Technologies in APEC Economies (MW)

Country	Year	Single fuel	Multi fuel	Total
Australia	1995	3860	800	4650
Canada	1995	2590	1960	4490
Hong Kong	1997	n.a	n.a	1563
Indonesia	1994	n.a	n.a	2697
Japan	1995	20820	23260	43490
Korea	1994	n.a	n.a	6434
Malaysia	1997	n.a	n.a	4225
Mexico	1997	1660	5980	1219
New Zealand	1995	n.a	n.a	1790
Philippines	1997	0	0	0
	2002	n.a	n.a	1200
Singapore	1997	n.a	n.a	850
Chinese Taipei	1997	n.a	n.a	3438
	2010	n.a	n.a	11425
US	1997	n.a	n.a	177736
Vietnam	1995	0	0	0
	2003	n.a	n.a	2291

Source: IEA (1998b); APEC/CEERD-AIT Survey (1998/1999); ADB (1997); http://www.eia.doe.gov

Table 5.14: Power Generation Capacity of Natural Gas Technologies under construction or planned in APEC economies (MW)

Country	Technology	Capacity (MW)	Commission Year
USA	Advanced Gas Turbine (ACCGT)	350	2005-2010
Korea	Advanced Gas Turbine	2000	
USA	Fuel Cell	10	2005-2010

Source: Modern power system (1995-1997); Petroleum Economist (1998)

5.3.1 General Measures for Efficiency Improvement

The main measures for improving the power plant efficiency are summarized in Table 5.15.

Table 5.15: General Measures for Efficiency Improvement

General measures to improve the power plant efficiency
➢ Increase in the unit scale ➢ Increase in steam pressure and temperature ➢ Improvement of the fuel quality ➢ Continuous operation of units ➢ Adoption of Co-generation technology ➢ Adoption of advanced clean coal technologies for coal-fired power plant ➢ Switching low efficient plant (e.g coal) to high efficient plant (e.g natural gas) ➢ Repowering the existing plant with advanced technologies ➢ Retrofitting the existing power plant ➢ Retirement of old and low efficient power plant

Source: OECF (1995); IEA (1997e)

For a new power plant, the advanced technologies which have high efficiency as discussed in Chapter 5.1 can be used for pursuing the high efficiency of power plant. The efficiency for gas turbine technology is typically 30% to 35%, but it can be as high as 42% for new gas turbine models. By the turn of century, combined cycle conversion efficiency, based upon the lower heating value of the fuel, is expected to approach 60%, with less NOx emissions without post-combustion cleanup. Efficiencies approaching 50% are also possible for clean coal technologies.

Co-generation is one way to improve the overall conversion efficiency of power projects. From an energy-policy perspective, the appeal of co-generation is its ability to improve fuel efficiency. Co-generation systems achieve overall fuel efficiencies 10% to 30% higher than if power and heat were provided by separate conventional energy conversion systems[7].

The repowering which integrate the new technology into an existing power plant site can increase the available capacity at the site, improve efficiency and lower the plant's air emissions profile. A repowered plant can produce more power than the original plant (sometimes twice as much or more), as well as extend the plant's lifetime by 20 or 30 years[8]. The use of IGCC to repower existing coal plants has become a popular application. Savings compared to a new plant can vary from US$100/kW to US$300/kW and in some cases significantly shorten the permitting time due to existing permits[9].

Retrofitting can be regarded as an ultimate form of fossil-power plant maintenance, intended to restore or better the original performance, while coping with changing environmental requirements and prolonging plant life. The potential market for power plant retrofitting is very large, since many current plants are reaching the end of their design lives.

Since gas-based technologies have higher efficiency and less emission than other fossil fuel-based technologies, switching into gas technologies or introducing more gas technologies is also one of measures to improve the power plant efficiency. Retiring old and low efficient power plant, increase scale of unit, improving fuel quality or continuos operation are also the options for efficiency improvement.

5.3.2 The Status of Efficiency Improvement in APEC Economies

The improvement of power plant efficiency will reduce the need for capacity expansion, the quantity of fuel consumed and environmental impacts. Different countries have various considerations for improving the power plant efficiency. APEC economies are pursuing the application of high efficiency plant wherever economically feasible in their plans for new plant or for upgrading, retrofitting or repowering existing facilities. Table 5.16 shows the status of power plant efficiency improvement in APEC economies.

Table 5.16: The status of efficiency improvement in APEC economies

Measures	Aus.	Can.	P.R.C	Ind.	Jap.	Kor.	Mal.	Phil.	Taipei	US	H.K.
Retirement											
Increase scale of unit											
Improve fuel quality											
continuous operation											
Retrofitting											
Repowering			*		*						
Cogeneration											
Clean coal technologies											
More gas technologies											

* To be adopted in the future

Source: OECF (1995); APEC/CEERD-AIT Survey (1998/1999); APEC (1997a); EGAT (1999); IEA (1998a); http://www.icompub.co.uk/cgi-bin

Some economies are adopting cogeneration to improve efficiency such as Australia, Malaysia, China and Chinese Taipei. In Malaysia, open cycle gas turbine generating plants are converted into combined cycle plants. Also in Korea, the country's first major repowering project, is expected to boost the efficiency of the 460 MW Inchon power plant. China and Japan are also planning to repower conventional coal-fired plant by using PFBC technology. IGCC technology has also been used for repowering US coal plant. In Hong Kong, a total of 4000 MW capacity of conventional coal power plant will be renewed in 1999. Since gas-based technologies have higher efficiency and less emission than other fossil fuel-based technologies, some economies switch into gas technologies for new power plant such as Australia, Canada, China, Malaysia and Chinese Taipei. Other measures such as retiring old power plants, increasing scale of unit, improving fuel quality are also used to improve the power plant efficiency in some APEC economies.

5.4 Factors Affecting Technologies Choice in APEC Economies

There are several factors affecting technology choice between coal and natural gas. The main factors are environmental compliance, thermal efficiency and costs. These factors are explored below.

5.4.1 Environmental Compliance

Gas-fired technologies which emit lower particulate and SOx have environmental advantage over coal-fired technologies. The disadvantage of coal-fired technologies is the impact on the environment. The introduction of appropriate clean coal technologies can achieve both goals of expanded coal use and decreased environmental impacts.

With increasing stringency in environmental control and with the commitment to reduce greenhouse gas emissions for some economies, gas-based technologies become a choice for those APEC economies with access to stable supply of natural gas. On the other hand, environmental compliance for coal-fired power generating plants is made possible in a cost-effective manner with development and advances in coal technologies, which are encouraged in those APEC economies with abundant resources and lower coal prices.

5.4.2 Thermal Efficiency

The application of high efficiency power plant will reduce the need for capacity expansion, the quantity of fuel consumed and environmental impacts. Table 5.17 and 5.18 show the thermal efficiency of coal and gas-fired power plants. The thermal efficiency of coal-fired power plants in APEC economies is above 38% except for one coal power plant in Canada which has relatively lower efficiency of 33%. Among the existing coal-fired power plants, plants in Japan and Korea have higher efficiency than others. The efficiency of gas-fired power plant ranges from 45% up to 60%. The gas-fired power plant in Russia has higher efficiency than other existing gas-fired power plants. In all countries, gas-fired power plants have higher efficiency than coal-fired power plants.

5.4.3 Costs

Cost is one of import factors affecting technology choice. In this study, the following cost components and factors were analyzed for coal and gas-fired power plants in APEC economies: investment costs, operating and maintenance (O&M) costs, fuel costs and generation costs. A common economic lifetime of 40 years, commissioning date (first of January 2005) and 75% load factor have been adopted for estimating average levelised costs of generating electricity. The results of projected: investment cost, O&M cost, generation cost and fuel price assumption for both natural gas and coal-

Table 5.17: Thermal Efficiency of Coal-fired Power Plant

Country	Plant	Site	Plant type/Emission control equipment	Thermal Efficiency [LHV] %
Canada	CA-C1 [A]	New	PF/FGD, SCR	38.6
	CA-C2 [A]	New	CFB/FGD, deNOx	33
Japan	JP-C [A]	New	PF/FGD, deNOx, dust	42**
Korea	KR-C [A]	New	PF(SC)/FGD, SCR	41
US	US-C1 [A]	New	PF/FGD, LNB, ESP	40
	US-C2 [B]	New	IGCC/LNB, ESP	49
China	CN-C [A]	New	PF(SC)/FGD, ESP	39
Russia	RU-C [A]	New	PF/FGD	38
Hong Kong	HEC	Existing	Average	39*
	CLPC	Existing	Average	36*
Chinese Taipei	Average	Existing	Coal-fired	34*
Vietnam	Average	Existing	Coal-fired	23-25*

* It is not clear the efficiency is either LHV or HHV ;
** HHV
A: Power plants commercially available;
B: Power plants expected to be commercially available by 2005-2010
Source: IEA (1998g); APEC/CEERD-AIT Survey (1998/1999)

Table 5.18: Thermal Efficiency of Gas-fired Power Plant

Country	Plant	Site	Plant type/Emission control equipment	Thermal Efficiency [LHV] %
Canada	CA-G [A]	New	CCGT	45
Japan	JP-G [A]	New	CCGT, LNG/deNOx	48**
Korea	KR-G [A]	New	CCGT, LNG	53.1
US	US-G1 [A]	New	CCGT/SCR	50
	US-G2 [B]	New	ACCGT/SCR	60
	US-FC [B]	New	Fuel cell/LNB, ESP	58
Russia	RU-G [A]	New	CCGT	56
Singapore	Average	Existing	Combined cycle	45*
Hong Kong	Average	Existing	Combined cycle	50*
Chinese Taipei	Average	Existing	Gas turbine	36*
	Average	Existing	Combined cycle	41*
Malaysia	Average	Existing	Average	24.1*
Vietnam	Average	Existing	Gas turbine	33-35*

* It is not clear the efficiency is either LHV or HHV
** Peak at 5^0C
A: Power plants commercially available
B: Power plants expected to be commercially available by 2005-2010
Source: IEA (1998g); APEC/CEERD-AIT Survey (1998/1999)

fired power plants are shown as follows:

Investment Cost

The investment costs of natural gas and coal-fired power plants are shown in Table 5.19 and 5.20. Investment costs include pre-construction, overnight construction, major refurbishment, and decommissioning costs. The projected base construction costs for coal power plants range from less than US$800/kW in China to more than US$2500/kW in Japan. Construction costs for gas-fired power plants range from US$420/kW to US$1640/kW, which are much lower than those of coal-fired power plants. Japan has the highest investment cost for both coal and gas-fired power plants. The lowest investment cost for coal-fired power plant is in China. The United States has the lowest investment cost for gas-fired power plant. The investment costs of most of gas-fired power plants are higher than coal-fired power plants except for one fuel cell power plant in the U.S.

Table 5.19: Coal-fired Power Plant Investment Costs to the Date of Commissioning (US$/1.7.1996/kW)

Country	Plant	Plant type/Emission control equipment	Net Capacity (MW)	Base Construction Cost	Total Investment Cost	
					5% discount rate	10% discount rate
Canada	CA-C1 [A]	PF/FGD, SCR	4x750	837	1133	1164
	CA-C2 [A]	CFB/FGD, deNOx	4x200	1360	1804	1872
Japan	JP-C [A]	PF/FGD, deNOx, dust	[4] 1x930	2561	2739	2930
Korea	KR-C [A]	PF(SC)/FGD, SCR	[2] 1x500	1174	1300	1438
US	US-C1 [A]	PF/FGD, LNB, ESP	1x300	1009	1277	1348
	US-C2 [B]	IGCC/LNB, ESP	1x380	1154	1445	1532
China	CN-C [A]	PF(SC)/FGD, ESP	2x600	772	966	1114
Russia	RU-C [A]	PF/FGD	4x300	1291	1439	1601
Malaysia	MS-C [A]	Coal-fired	200	1664	n.a	n.a
Thailand	TH-C	Coal-fired	average	1175	n.a	n.a
Indonesia		Coal-fired	600	1020	n.a	n.a
Philippine		Coal-fired	average	1300	n.a	n.a
Taipei		Coal-fired	average	37825*	n.a	n.a

Capacity: [number of units on the site, if more than 1] number of units included in cost estimated x unit capacity
* The unit is NT/kW
A: Power plants commercially available
B: Power plants expected

Coal combustion systems
PF: Pulverised coal combustion
CFB: Circulating fluidised bed
IGCC: Integrated gasification combined cycle

Pollution control systems
FGD: Flue gas desulphurisation
LNB: Low NOx burners
SCR: Selective catalytic reduction
deNOx: Unspecified NOx control system
ESP: Electrostatic precipitator

Source: IEA (1998g); **OECF (1995); APEC/**CEERD-AIT Survey (1998/1999)

Table 5.20: Gas-fired Power Plant Investment Costs to the Date of Commissioning (US$/1.7.1996/kW)

Country	Plant	Plant type/Emission control equipment	Net Capacity (MW)	Base Construction Cost	Total Investment Cost	
					5% discount rate	10% discount rate
Canada	CA-G [A]	CCGT	2x750	536	820	884
Japan	JP-G [A]	CCGT, LNG/deNOx	[4] 2x350	1640	1703	1771
Korea	KR-G [A]	CCGT, LNG	[2] 1x450	583	661	671
US	US-G1 [A]	CCGT/SCR	1x250	422	502	509
	US-G2 [B]	ACCGT/SCR	1x350	419	452	453
	US-FC [B]	Fuel cell/LNB, ESP	1x10	1408	1618	1710
Russia	RU-G [A]	CCGT	4x360	721	782	847
Malaysia	MS-G	GT	270	559	n.a	n.a
Thailand		GT	average	511	n.a	n.a
		Combined cycle	average	619	n.a	n.a
Indonesia		GT	120	574	n.a	n.a
		Combined cycle	500	678	n.a	n.a
Philippine		GT	average	467	n.a	n.a
		Combined cycle	average	850	n.a	n.a

Capacity: [number of units on the site, if more than 1] number of units included in cost estimated x unit capacity
A: Power plants commercially available
B: Power plants expected to be commercially available by 2005-2010

Pollution control systems
FGD: Flue gas desulphurisation
LNB: Low NOx burners
SCR: Selective catalytic reduction
deNOx: Unspecified NOx control system
ESP: Electrostatic precipitator

Gas combustion systems
CCGT: Combined cycle gas turbine
ACCGT: Advanced CCGT
GT: Gas turbine

Source: IEA (1998g); **OECF (1995); APEC/**CEERD-AIT Survey (1998/1999)

Environmental compliance is one factor affecting the investment of technology. Gas-fired technologies have less emission control costs than coal-fired technologies due to its lower particulate and sulfur content. For example, some capital costs for emission control in Chinese Taipei's coal-fired power plants is shown in Table 5.21.

Table 5.21: Capital Costs for Emission Control Technologies

Emission control technology	ESP	FGD	SCR
Capital cost (US$/kW)	17	110	61

Source: APEC/CEERD-AIT Survey (1998/1999)

Projected O&M Costs

Table 5.22 shows the projected O&M costs in 2005. Costs related to treatment, storage, conditioning, and disposal of fuel residues, e.g. disposal of coal ash, gypsum and waste are included in O&M costs. Gas-fired power plants are less expensive than coal-fired power plants in all countries. Projected O&M costs for coal-fired power plants range from US$26/kW to US$81/kW capacity per year. Japan has the highest projected O&M cost for both gas and coal-fired power plants. The lowest investment costs for both gas and coal-fired power plants are estimated in Canada. In all countries, the O&M costs of coal-fired power plants are expensive than gas-fired power plants.

Table 5.22: Projected O&M Costs in 2005 (US$ of 1.7.1996/kW net capacity per year)

Country	Coal		Natural gas	
	Plant	O&M costs	Plant	O&M costs
Canada	CA-C1[A]	26.01	CA-G [A]	13.04
	CA-C2 [A]	50.55		
Japan	JP-C [A]	81.33	JP-G [A]	51.11
Korea	KR-C [A]	53.13	KR-G [A]	21.8
US	US-C1 [A]	33.5	US-G1 [A]	18.09
	US-C2 [B]	32.84	US-G1 [B]	17.42
			US-FC [B]	27.48
China	CN-C [A]	36.05		
Russia	RU-C [A]	32.99	RU-G [A]	20.09
Taipei	Average	0.088*	Gas turbine	0.1227*
			Combined cycle	0.2078*

* The unit is NT/kWh
A: Power plants commercially available
B: Power plants expected to be commercially available by 2005-2010
Source: IEA (1998g); APEC/CEERD-AIT Survey (1998/1999)

Projected Fuel Prices

The coal and gas prices are given at the power plant, which are used for calculating levelised generation costs. Coal prices in Canada and Korea are assumed constant. Japan, China and Russia assume increasing coal prices while the United States assumes decreasing coal prices. Most countries project an increase in natural gas prices such as Canada, Japan, US and Russia except Korea assume constant natural gas prices. Natural gas prices are higher than coal prices in all countries. The projected fuel prices are shown in Table 5.23 and 5.24.

Table 5.23: Projected Coal Prices at the Power Plant (US$ of 1.7.1996/Gjoule)

Country	Plant	1996	2005	2015	2025	2035	2045
Canada	CA-C1 [A] /C2 [A]	1.64	1.64	1.64	1.64	1.64	1.64
Japan	JP-C [A]	2.05	2.13	2.22	2.31	2.42	2.52
Korea	KR-C [A]	1.69	1.69	1.69	1.69	1.69	1.69
US	US-C1 [A] /C2 [B]	1.06	1.06	0.99	0.92	0.86	0.8
China	CN-C [A]	1.67	1.8	1.89	1.99	2.09	2.2
Russia	RU-C [A]	1.18	2.01	2.5	3.05	3.72	4.53
Taipei		0.5497*	n.a	n.a	n.a	n.a	n.a

* The unit is NT/kWh
Source: IEA (1998g); APEC/CEERD-AIT Survey (1998/1999)

Table 5.24: Projected Natural gas Prices at the Power Plant (US$ of 1.7.1996/Gjoule)

Country	Plant	1996	2005	2015	2025	2035	2045
Canada	CA-G [A]	1.81	2.05	2.53	2.94	3.44	3.96
Japan	JP-G [A]	3.9	4.95	6.48	8.5	11.15	14.65
Korea	KR-G [A]	4.93	4.93	4.93	4.93	4.93	4.93
US	US-G1 [A] /G2 [B]	1.58	1.58	2.25	3.19	4.53	6.44
Russia	RU-G [A]	2.01	2.68	3.48	4.24	5.17	6.30
Taipei	Gas turbine	1.746*	n.a	n.a	n.a	n.a	n.a

* The unit is NT/kWh
Source: IEA (1998g); **OECF (1995); APEC/**CEERD-AIT Survey (1998/1999)

Projected Generation Costs

As discussed above, the investment cost and O&M cost of coal-fired power plants are higher than gas-fired power plant. But coal has cheaper prices than natural gas. The fundamental question becomes which technology offers the lowest cost power output to its ratepayers. The levelised lifetime generation cost based on discounting all costs and revenues expressed in constant money terms provide a way for fairly comparing the relative costs among different electricity generation options.

The levelised generation costs are sensitive to the economic and technical assumptions adopted in the calculation. Discount rate, load factor, lifetime of technology, fuel price, and other factors can affect generation cost of technology. Discount rate is one factor affecting the levelised generation cost. Increasing discount rate can increase the levelised generation cost. Some capital sensitive technologies are more competitive at low discount rates while low capital technologies increase their competitiveness at high discount rates. Another factor is load factor. The levelised generation costs decrease when the load factor is increased. The capital intensive technologies are more sensitive to load factor variation than low capital intensive technologies. Economic lifetime is also a factor affecting the levelised generation cost. Generally, the lifetime levelised generation cost decreases as increasing the economic lifetime of a power plant. The generation cost is also sensitive to fuel prices. The assumption of natural gas prices are more critical than coal prices since natural gas prices are more violent than coal prices. If natural gas prices are projected to rise faster, clean coal technologies will become more competitive compared to natural gas.

Table 5.25 shows the projected generation costs for coal and gas-fired power plants. In terms of generation cost, coal-fired technologies are cheaper than natural gas-fired technologies in Japan and Korea where gas-fired power plants are fueled with LNG. In Canada and US, gas-fired power plants are more expensive than coal-fired power plants at 5% discount rate for some of the plants considered, but cheaper at 10% discount rate for all plants. In Russia, gas-fired power plants are cheaper than coal-fired power plants at both 5 and 10% discount rate. The coal/natural gas generation costs ratio is shown in Figure 5.1.

Table 5.25: Projected Generation Costs Calculated with Generic Assumptions (USmill of 1.7.1996/kWh)

Country	Coal			Natural gas		
	Plant	5% discount rate	10% discount rate	Plant	5% discount rate	10% discount rate
Canada	CA-C1 [A]	29.21	37.03	CA-G [A]	30.03	33.04
	CA-C2 [A]	41.45	54.19			
Japan	JP-C [A]	55.81	76.14	JP-G [A]	79.1	84.4
Korea	KR-C [A]	34.4	44.96	KR-G [A]	42.52	46.98
US	US-C1 [A]	25.05	34.71	US-G1 [A]	27.14	27.37
	US-C2[B]	24.79	35.7	US-G2 [A]	23.27	23.6
				US-FC[B]	35.59	44.75
China	CN-C [A]	31.82	39.96			
Russia	RU-C [A]	46.32	55.34	RU-G [A]	35.41	38.99

Source: IEA (1998g); OECF (1995)

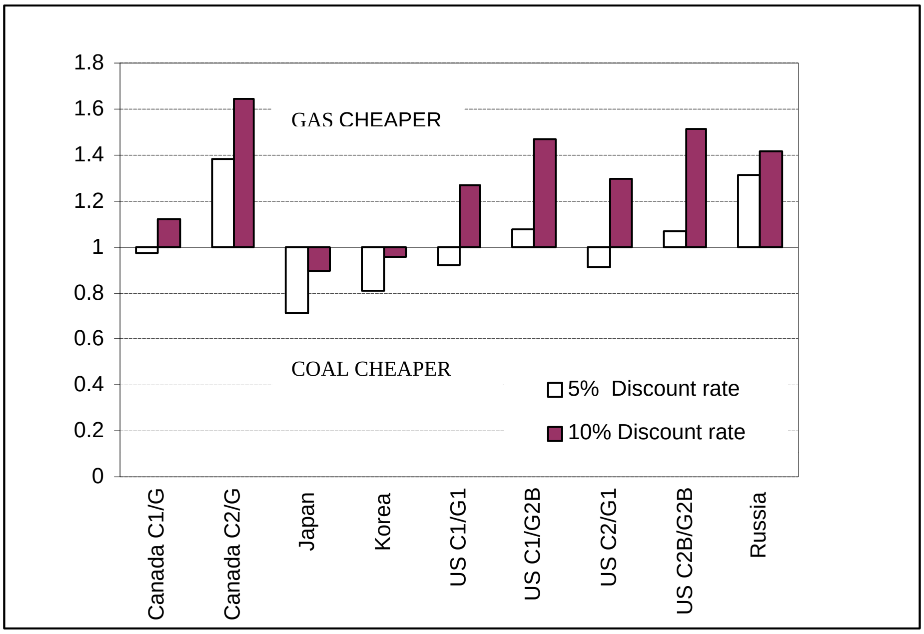


Figure 5.1: Coal/Natural Gas Generation Cost Ratios

The choice between coal and natural gas also depends on the type of plant required. Generally, power plant for peak load operation is dominated by capital cost consideration since it is used only for short time. Gas-fired power plants having capital cost advantage over coal-fired power plants should be used for peak load. On the other hand, power plant for base load operation is required to operate most of time. Therefore, the choice is dominated by variable operating cost. Coal-fired power plants have lower variable costs than gas-fired power plants. Normally, coal-fired power plants are dispatched for base load operation before gas-fired power plants.

5.5 Conclusion

The various clean coal and natural gas technologies all have their individual strengths and weaknesses and all also in different states of development. Technological development has intensified the competition of coal and natural gas in electricity production. Both coal and natural gas based power technologies have been the dominant choices for new utility capacity in the APEC economies. Environmental performance, costs, and efficiency are the key factors affecting the technology choice between coal and natural gas.

With increasing stringency in environmental control and with the commitment to reduce greenhouse gas emissions for some economies, gas-based technologies become a choice for those APEC economies with access to stable supply of natural gas. On the other hand, environmental compliance for coal-fired power generating plants is made possible in a cost-effective manner with development and advances in coal technologies, which are encouraged in those APEC economies with abundant resources and lower coal prices.

In addition to environmental performance, the cost of the technology is another important factor affecting technology choice in APEC economies. Investment costs and O&M costs of coal-based technologies are higher than that of gas-based technologies, but coal prices are lower than natural gas prices. Generation costs which consider all costs and fuel prices vary depending on the countries. Generally, those economies with abundant natural gas resource and cheaper natural gas prices are expected to have lower electricity generation cost for gas-based technologies than coal-based technologies. Also, those economies, which are not producing coal and natural gas, are expected to have lower electricity generation cost for coal-based technologies than gas-based technologies due to expensive imported natural gas prices.

The other main factor is power plant efficiency. Gas-fired technologies have higher efficiency than coal-fired technologies. But the efficiency of clean coal technologies also can be improved up to 50%. The improvement of power plant efficiency will reduce the need for capacity expansion, the quantity of fuel consumed, which affects the cost of technology and environmental impacts directly. Different countries have various considerations for improving the power plant efficiency. Adopting cogeneration, clean coal technologies, repowering the existing power plants and switching into more efficient technologies (such as gas technologies) are the most common measures practiced in APEC economies.

Endnotes

[1] APEC (1997a)
[2] IEA (1997e)
[3] APEC (1997a)
[4] EIA (1994)
[5] APEC (1997a)
[6] APEC (1997a)
[7] IEA (1997e)
[8] IEA (1997e)
[9] Modern Power Systems (1995)

6. THE IMPACTS OF ELECTRICITY SECTOR PRIVATIZATION AND RESTRUCTURING

Independent or private power producers (IPPs) have increased their contribution to electricity generation worldwide, including among the APEC member economies. The development of private power has taken and is taking place in the context of structural changes happening in the electricity sector. The APEC economies are at different stages, or follow various modes, and proceed at different paces as far as these structural changes are concerned. In any case, these structural changes tend to shift the risks associated with power generation away from the public sector onto private investors. Because of this IPPs are conservative in their fuel and technology choice. IPPs choice of fuel and technology is mainly influenced by the economics of electricity generation as well as the prevailing policies related to the environment, pricing, and the development of the local resource base. In addition, privatization and restructuring create other challenges and opportunities that would influence the fuel choice of IPPs as well as generation utilities.

6.1 Privatization and Restructuring and the Role of IPPs

The electricity sectors in the APEC economies are at different stages of privatization and restructuring (Figure 6.1). A few of these economies are in the most advanced stage of having privatized all electricity sector functions (generation, transmission, and distribution) and at the same time introduced wholesale and retail competition in the supply of electricity. The economies that have introduced retail competition include Australia[1], Chile, Singapore[2], and Peru. New Zealand has also introduced limited retail competition, but generation and transmission remain in the hands of state-owned corporations, although it is certain that these will be privatized in the future.[3] Some of the states in the United States have introduced retail competition, but the transition to this stage is still being debated at the federal level. In all states, however, wholesale competition has been made a reality by the federal government by mandating third party (open) access to transmission networks. In the Alberta province of Canada, wholesale competition is also already a reality with operation of a power pool since 1996, the first in North America. The Alberta Department of Energy has also prepared the necessary legislation to enable electricity consumers to choose their suppliers beginning 1999.

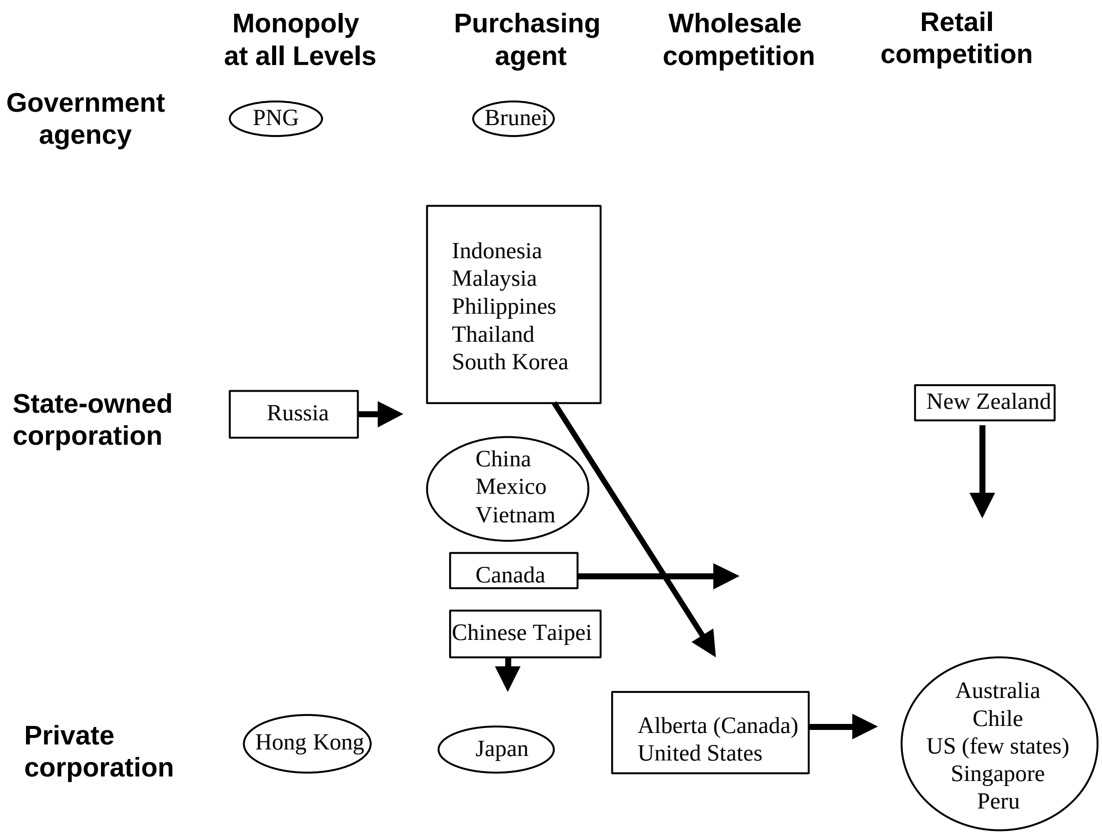


Figure 6. 1: Status of Restructuring and Privatization in APEC Economies
Note: The classifications of the electricity industry structure and type of ownership are based on Sally Hunt and Graham Shuttleworth, 1996. *Competition and Choice in Electricity*, John Wiley and Sons, Chichester.

Majority of the APEC economies has introduced competition in generation by allowing non-utility generation, but the electricity sectors in these economies remain in the hands of state-owned utilities. The only exception is Japan, which is served by private vertically- integrated utilities. Most of these economies are in the transition to privatizing their electric utilities and introducing competition in wholesale electricity supply. These include Indonesia, Malaysia, Philippines, Thailand, and South Korea. The other provinces in Canada, particularly Ontario, which are served by a mix of publicly- and privately-owned utilities, would soon be seen following the moves of Alberta. Taiwan has scheduled the privatization of its electric monopoly, but there is no indication that it will introduce wholesale competition in the foreseeable future. China, Mexico, and Vietnam will remain in the hands of electric monopolies for some time, but are big markets for private power developers.

Papua New Guinea, Russia, and Hong Kong are the only three countries that have not introduced competition in generation. However, it is only a matter of time when independent power producers will be invited to take part in power generation in these economies.

The entry of IPPs in generation has become almost a necessity in the transition of electricity sectors from being dominated by a vertically-integrated monopoly to one characterized by competition. It is only in a few cases in which competition was introduced by emphasizing privatization of existing generation assets (e.g. Australia, Chile, New Zealand, Singapore) and even in these instances, the entry of IPPs becomes inevitable.[4] In most cases, particularly in developing countries with strong electricity demand and limited financial resources, IPPs serve to fill the electricity-supply demand gap and ease the financial burden of state-owned electric utilities. The entry of IPPs in these instances paves the way for further reforms and contributes to increasing the competitiveness of the electricity sector.

The Public Utilities Regulatory Policy Act of the U.S. in 1978 gave birth to the IPP industry. (In fact, most IPPs are U.S.-based companies.) It was in recognition of the idea that generation need not be undertaken by a large monopoly for reason of economies of scale and can be separated from transmission and distribution. The idea was born largely because of the development of small generation technologies, particularly the gas turbine combined cycle (GTCC). Since then, IPPs have spread worldwide in their search for new markets outside the U.S. Private power generation has become a global industry with the number of generation companies coming from outside the U.S., including local IPPs, increasing in number.

Most IPPs are in the large U.S. market (Figure 6.2). In 1997, non-utility capacity in the U.S. totaled 74,021 MW, of which coal-fired capacity accounted for 11,236 MW (15%) and gas-fired capacity, for 31,476 MW (42.5%). Moreover, non-utilities have planned to add 10,203 MW between 1998 and 2001, of which coal-fired plants total 409 MW and gas-fired plants 6,118 MW. The ageing of power plants in the U.S. market are reviving the mature U.S. market. Planned retirements between 1998 and 2001 amount to 12,851 MW. Non-utility capacity represents less than one-tenth of utility capacity, which reached 754,925 MW in 1997. However, non-utility generation has grown from only 5% of the total in 1986 to 11% in 1996.

There are also several IPPs in Canada, though their contribution is relatively minimal. As of 1994, IPPs owned about 1% of installed capacity and produced 1.3% of total generation, which was sold entirely to utilities. All in all the North American market hosts nearly 70% of the IPPs worldwide.

In recent years, however, IPP projects have been mostly located and growing fastest in Asia-Pacific and Latin America, which host 17% and 0.6%, respectively, of the IPPs worldwide. Table 6.1 indicates that about half of the IPP projects globally in 1996 and 1997 were in Asia-Pacific. Latin America, on the other hand, showed strong growth in IPP activities during this two-year period.

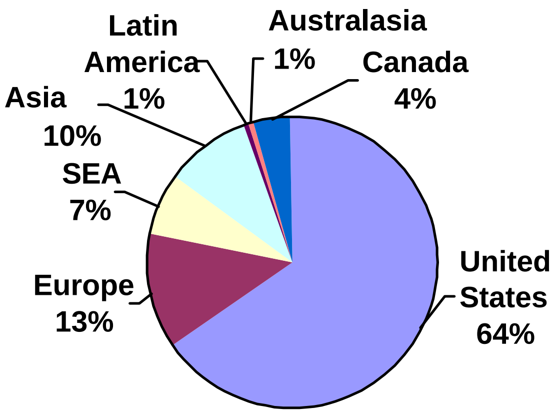


Figure 6. 2: Geographical Distribution of IPPs
Source: Hughes and Parag (1997)

A survey of equipment manufacturers in 1996 also showed the Asian and Latin American market standing out. Asia, including Southeast Asia, Central Asia and Russia, accounted for 40% of equipment orders by megawatts in 1996, equivalent to 10,559 MW.[5] Latin America, with 6,840 MW, accounted for 26%. Equipment orders in Europe, the Middle East and Africa together totalled 6,036 MW for a 23% share. The United States and Canada accounted for only 10%, or 2,743 MW, of all orders in 1996

Table 6.1: IPP Project Finance in 1996 and 1997

	Number of projects		Total cost (US$ million)		Capacity (MW)	
	1996	1997	1996	1997	1996	1997
Asia-Pacific	26	29	9,703	15,430	8,962	13,944
North America	6	8	802	407	953	406
Europe	11	6	7,316	2,695	4,622	3,223
Africa/Middle East	-	2	-	1,682	-	1,536
Latin America	8	14	2,623	2,260	2,356	3,142
Total	51	57	20,443	20,791	16,893	20,715

Sources: Burr (1998); Anderson and Burr (1997)

Industry analysts and observers note, however, that the North American market will rebound with the deregulation of the electricity markets in this region. The ageing generating capacity in the US will also open up opportunities for future IPP growth in this mature market.

In Asia-Pacific, China, the Philippines, Australia, Malaysia, and Indonesia host the most number of projects (Table 6.2).

Table 6.2: Status of IPPs in Asia-Pacific

Countries	Number in operation (GW)	Number under construction or development (GW)	Number planned or under consideration (GW)
Australia	9 (3.3)	2 (0.2)	15 (4.6)
China	26 (6.6)	14 (10)	61 (75)
Indonesia	5 (0.78)	9 (10)	31 (23.7)
Japan		3 (0.018)	(5.7)[2]
Malaysia	9 (4.3)		6 (5.3)
New Zealand	3 (0.2)		6 (0.847)[1]
Philippines	33 (5.2)[4]	4 (1.2)	18 (4.1)
South Korea			(6.25)[3]
Taipei, China[8]	1(0.6)	8 (8.55)	
Thailand[6]		7 (5.8)	(12.5)[5]
Vietnam		6 (2.315)[9]	(>7.2)[7]

Notes:
1 two are planned with a capacity of 0.385 GW and four are under consideration, 0.462 GW
2 planned by 2004, 2.6 GW in phase 1 and 3.1 GW in phase 2
3 the current policy limits IPPs to add up to 6.250 GW of capacity by 2010
4 including rehabilitated projects and operated and maintained or leased to private sector
5 up to 2011
6 excluding small power producers, cross-border projects, and generation subsidiaries that are implemented by the private sector
7 all the 7.2 GW capacity are combined cycle and excludes hydro projects that are likely to be offered for BOT financing
8 three of the ongoing projects are due for commercial operation in 1999; three of the nine projects, including the one already operating, will be running on gas, another three on coal, two on orimulsion, and one on oil
9 two of these projects, with a combined capacity of 495 MW, are expected to come on stream in 1999; both are oil based; three of the four remaining projects, with a combined capacity of 912 MW, will run on natural gas
Source: APEC/CEERD-AIT Survey (1998/1999); CEERD Database; Carson (1998)

As mentioned early on, the growth of the IPPs is traced to the changing ownership and overall industry structure of the electricity sector. But there are other forces that have influenced this growth, including:[6]

- unmet electricity demand;
- changes in multilateral banks lending policies;
- globalization of capital market access; and
- steady advance of technology.

Unmet electricity demand. This is shown by the low per capita electricity consumption and low electrification rates among the developing member-economies of APEC. Chile, Malaysia, and Thailand, for example, had per capita electricity consumption below 2,000 kWh in 1996. The situation is worse in Indonesia, Philippines, and Vietnam, which had per capita electricity consumption of less than 500 kWh. China and Peru, consuming 637 kWh and 525 kWh, respectively, per person in 1996, are somewhere in between. This is way beyond that in the U.S. and Canada, which is in the range of 11,000 – 15,000 kWh per person. Japan, Singapore, South Korea, Taiwan and Australia are in the 6,000 – 8,000 kWh range.

The electrification rates in some of these countries are also low, contributing to the low per capita electricity consumption and indicating not only the need for increased generating capacity, but more importantly for expanded electricity infrastructures (transmission and distribution networks and decentralized energy systems). For example, the proportion of households that have access to electricity in Indonesia, Papua New Guinea, and Vietnam in 1994 is below 50%.

Yet the opportunities for independent power in these countries is high not simply because of low per capita electricity consumption and low electrification rates, but more so because of high demand growth arising from high economic growth. For example, APERC projects that Southeast Asia will start to recover from the crisis after 2000 and would register an annual average economic growth of 4.3% between 2001 and 2010.[7] China, which remains isolated from the crisis, would grow between 4.4% and 4.6% annually in the same period. Chile and Mexico are expected to continue to grow 4-6% in the next ten years. In most of these countries, unmet electricity demand is associated with the inability of the entrenched government utilities to sustain needed investments in generating capacity and power infrastructures. Even countries with high per capita electricity consumption and high electrification rates present good opportunities for independent power investment because of expected increase in electricity demand, also arising from economic growth. For example, Australia, Canada, and New Zealand, APERC projects, would grow in the range of 2.5% and 4% in 2000-2010.

Changes in multilateral banks lending policies. In many developing countries, including members of APEC, multilateral banks (the World Bank and ADB) are usually the architects of electricity sector reforms. In some cases, they encourage policy-makers to institute reforms by financing technical assistance studies that are mainly aimed at informing and convincing high and middle level officials of the benefits of reforms. More often than not, these technical assistance studies are coupled with institutional strengthening activities designed to inculcate the necessary competence among middle level officials and their staff, including attached government agencies, to properly execute recommended reforms. In recent years, however, multilateral banks have taken a proactive stance to somehow "force" governments to institute reforms.

The World Bank, for instance, which allocates nearly 15% of its development funds to the power sector, issued a policy paper in 1993 that states the bank is not prepared to lend to countries unless they are prepared to undertake a program of reforms. The key elements of those reforms are the introduction of more competitive pressures and more market oriented systems, open regulatory structures, pricing that covers costs, and the elimination of elaborate systems of cross subsidies. In the Asian Development (ADB), the main focus of their energy activities is in reforming government policies, determining correct pricing of power and in assisting in implementing institutional improvements.

Another way by which multilateral banks have encouraged the growth of IPPs is by introducing private sector financing in their portfolio. This means multilateral banks finance private power projects by contributing equity or extending loans—a departure from their traditional role of lending to development and public infrastructure projects sponsored by the government. The World Bank does this through the International Finance Corporation (IFC), which can extend loans and invest equity capital to private sector projects without government guarantee. The ADB has a stake in an affiliate institution called the Asian Finance and Investment Corporation (AFIC), which functions similarly as IFC. In 1983, ADB began making equity investments to private sector companies. Since then, it has expanded its private sector operations by establishing a Private Sector Department that make equity contributions and provide direct loans to private entities, including IPPs.

Globalization of capital markets. The rise of global capital markets has facilitated the financing of private power projects. *Independent Energy* reported in its annual rankings of financial institutions, which invest and lend to and arrange deals for private power projects, that revenue bond issues in 1996 tripled those in 1995, increasing from US$5 billion to nearly US$15 billion.[8] Increased access to international capital markets is one reason for this increased bond activity. Another is the attractiveness of bonds because of their longer- term maturity, some up to 20 years. A third reason is that capital markets provide a vast, additional source of financing for an industry with huge financing requirements.

Steady advance of technology. The development of small generation technologies, in contrast to large power plants of government-owned utilities, has facilitated investment in private power. This technological breakthrough has reduced the financing requirements and risks associated with large power stations. Advanced generation technologies are also attractive not only because of their size, but moreso because of their high efficiency (GTCC has surpassed the 50% mark and has reached the 60% threshold), short construction schedules, low capital cost, and that they use natural gas, which has less environmental emissions. On the other hand, the continual improvement of boiler technologies is increasing the opportunities for IPPs to tap markets with indigenous supply of coal, or where coal is the most competitive option, and, at the same time, comply with increasing national and international environmental standards.

6.2 Fuel and Technology Choice of IPPs

IPPs have contributed to the changing fuel mix in power generation in APEC economies. Most IPP projects are using either coal or natural gas, which are the preferred fuels in many of the APEC economies (see Chapter 1). In the U.S., for instance, gas-fired plants account for more than 42% of non-utility capacity, while coal-fired plants, for 15%. Moreover, 60% of the planned non-utility capacity additions between 1998 and 2001, which represent at least half of the planned utility capacity additions during this period, will be using natural gas. Natural gas is also becoming popular among U.S. electric utilities. Gas-fired plants account for less than 20% of existing utility capacity, but for close to 90% of planned utility capacity additions between 1998 and 2007. IPPs in Australia and South Korea also prefer natural gas. In Australia, where coal contributes around 80% to total power generation, seven of the eight new power stations proposed during 1997 will be using natural gas. In South Korea, in which coal accounts for 35% of total power generation, three of the four IPP projects due to come on stream between 2001 and 2004 will burn LNG. Another block of 3,650 MW planned for 2005-2010 will be designed for LNG.

In China, the largest market for IPPs in Asia[9], coal remains as the most competitive fuel choice. Coal accounts for about 88% of total fuel consumption for power generation, and coal consumption for power generation is still growing between 9% and 10% per annum. The 2 x 350 MW Laibin B, which is the first BOT by Chinese standard and expected to come on-stream in October 1999, will be using coal. The 2 x 700 MW Zhuhai, which qualifies as a BOT by international standard and expected to be commissioned in 1999-2000, is a US$1.2 billion power project using coal. Shandong Zhonghua Power Co., the largest IPP to date and which reached financial closing in 1998, is building four coal-fired power plants with a combined capacity of 3,000 MW at a total cost of US$2.2 billion.

In some countries, in which neither coal nor natural gas is the dominant fuel, IPPs are also choosing coal and natural gas. In Mexico, for example, which is the largest producer of oil in Latin America, the first two major IPP projects, the 484 MW Merida III and the 700 MW Samalayuca II, will be using gas-fired combined cycle technology. In addition, a number of gas field development projects are underway to supply to these two and future IPP projects. In New Zealand, in which hydropower contributes more than 70% of electricity produced, future IPP projects will be using natural gas. In the Philippines, which is predominantly oil-based, IPPs are choosing between coal and small hydro projects, and a few projects will tap indigenous natural gas supply.

Coal and natural gas combined account for at least 60% of total power generation in Australia, Brunei, China, Hong Kong, China, Indonesia, Malaysia, Russia, Singapore, Thailand, the United States, and Vietnam (see Figures 1.12 and 1.13 Chapter 1). These figures also show that there are as many APEC economies in which the share of natural gas (in the power generation mix) is greater than coal as those in which the share of coal is greater than natural gas, indicating the close competition between the two fuels. However, natural gas consumption for power generation is growing faster than that of coal, as well as total power generation, in more APEC economies (see Figure 1.14 Chapter 1), including those in which coal share in power generation is higher (that is, Australia, Canada, and Chinese Taipei). In China, South Korea, and the U.S., which uses much more coal, growth in natural gas consumption is rivalling that of coal. These trends indicate increasing preference for natural gas.

The choice of fuel dictates the choice of technology. With increasing preference for natural gas, gas turbines have been filling in the demand for new capacity worldwide. Steam turbines, however, remains popular in Asia, even though the region has consistently topped the market for gas turbine capacity additions (Figures 6.3 and 6.4).

Based on a survey of 10 major global power equipment suppliers conducted by *Independent Energy* in 1996, gas turbine is the preferred technology for new generation capacity worldwide.[10] The survey showed that out of 395 units ordered in 1996, 264 (or 67%) were gas turbines (Table 6.3). In terms of capacity, this represents 51% (or 18,170 MW) of the 35,807 MW total capacity ordered.

Nevertheless, an earlier survey also by *Independent Energy* shows that steam turbines seem to be the favorite in Asia.[11] The survey covered the period from January 1994 to May 1996 and 14 global power equipment companies that reported 107 GW in orders for steam turbines, gas turbines, heat-recovery steam generators, combustion boilers, and combustion engines. Steam turbines accounted for 50% of the total capacity orders, indicating preference for solid fuels. The 1996 survey tends to confirm this as China, the largest market for IPPs in Asia and where coal is the dominant fuel, got most orders for 21 units with a combined rating of 4,190 MW.

A survey of independent power projects that reached financial closing in 1997[12] also shows that coal-fired technologies still dominate the Asian as well as the Pacific power markets for new generation capacity. In China, for instance, of the four major projects listed in the survey, including Laibin B, three with a combined capacity of 4,120 MW are using coal. The other 400 MW project is running on gas. Australia had four projects with a total capacity of 5,239 MW fuelled by coal.

The picture in Asia, however, varies from country to country. In Thailand, for example, coal is competing closely with gas. Of the seven ongoing IPP projects expected to become operational between 1999 and 2003, four with a total capacity of 2,394.3 MW will be using gas, and the other three projects will run on coal, but with a higher combined capacity of 3,441 MW.

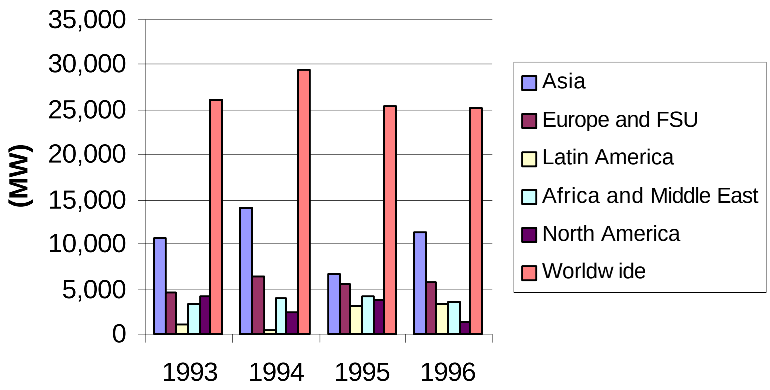


Figure 6. 3: Gas Turbine Capacity Additions by Region
Source: Schuler (1997)

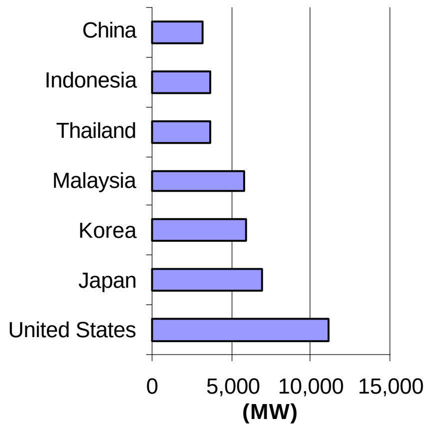


Figure 6. 4: Gas Turbine Capacity Additions by Country, 1993-1996
Source: Schuler (1997)

Table 6.3: Global Power Equipment Orders in 1996

Technology	Number of units	Capacity (MW)
Diesel	42	788
Gas turbine	264	18,170
HRSG	36	4,421
Steam turbine	53	12,428
Total	395	35,807

Source: Anderson (1997)

In the Philippines, of the more than 20 IPP greenfield projects commissioned since 1991, only one (the 700 MW Pagbilao plant by Hopewell) is coal-fired. Most are oil-based, and the rest are using either hydro or geothermal. Future projects, however, will fit coal and hydro. Already, another coal project by Hopewell with a capacity of 1,000 MW is scheduled to come on-stream in mid-1999. In addition, four smaller coal-fired projects with a total capacity of 525 MW are being considered as against several small and large hydro projects. Only three natural gas projects are in the pipeline, with a total capacity of 2,700 MW.

In Vietnam, all of the gas-fired combined cycle planned after 2005 through 2020 (with a total capacity of 7,200 MW) are candidate for BOT implementation. Moreover, most of the planned hydro projects (totaling 8,700 MW) will be offered for private development. These projects account for 53% of the planned capacity additions between 1998 and 2020.

The choice of fuel and technology by IPPs is driven by:

- the availability of fuel;
- relative fuel prices;
- attractiveness of the corresponding generation technology, in terms of:
  - cost
  - efficiency
  - construction/installation lead times
  - environment compliance;
- environment considerations; and
- costs of generation.

The choice of fuel is influenced first of all by the local resource base. For example, the existing generation capacity in all of Latin America, New Zealand, and Canada are predominantly hydropower. Power plants in the U.S., Australia, and China are using mainly coal. Indigenous and imported coal, however, is also a least cost option in Indonesia, Malaysia, the Philippines, and Thailand. Coal-fired private power projects are being developed in these countries. Natural gas is the main fuel for power generation in Brunei, Indonesia, Malaysia, Thailand, and Vietnam. And because natural gas is also available in significant quantities in Australia, Canada, China, Latin America, New Zealand, and the US, IPPs in these countries are also using natural gas. Thus, for example, capacity additions under implementation and planned in Latin America will tap the rich gas resource of the entire region through indigenous development and cross-border cooperation. In Peru and Mexico, domestic gas fields are being developed to supply to IPP projects. IPPs in Chile will be supplied by natural gas from neighboring Argentina. Several IPP projects in New Zealand that are under consideration will use geothermal and natural gas. More than half of the non-utility generation in the U.S. comes from natural gas-fired power plants and majority of the planned additions will also use natural gas. Few gas projects are also being developed in China and Australia. Russia has a good balance of coal and natural gas in its generation mix.

Relative fuel prices are also a major factor in the fuel choice of IPPs as well as utilities undergoing privatization and restructuring. Both are concerned about increasing competitiveness and therefore, minimizing costs. Chapter 3 already discussed the implications of fuel prices on coal and natural gas competition. In general, coal remains a very attractive option because of its stable and declining prices in real terms. However, non-price factors are driving the increasing preference for natural gas.

Gas-fired power plants are often the particularly attractive option for IPPs because of:[13]

- their relatively low capital construction cost;
- the use of a well-established technology;

- their shorter construction lead times;
- their relatively high fuel conversion efficiency; and
- their lower environmental impacts. (See also Chapter 5.)

Privatization and deregulation of energy markets worldwide are compelling utilities and independent power producers to be more competitive. In this type of environment, there is a strong preference for equipment that has high conversion efficiency and that can be installed in months rather than in years. Gas turbine technologies feature both.

Complying with national and international environmental regulations is also one major factor influencing the choice of fuel and technology. Governments are putting in place more stringent environmental emission standards and regulations as a result of increasing environmental awareness and partly in response to pressures from the international community. Private power developers seeking additional financing have also to comply with environmental requirements of multilateral and bilateral financial institutions and international commercial banks, which are increasingly developing their own environmental compliance process.

Gas-fired generation technologies have become attractive also because of the less environmental emissions associated with natural gas burning than coal and oil, and therefore facilitates compliance to national and international environmental regulations.

However, improvements in coal-firing technology, along with the successful commercialization of fluidized bed combustion, have resulted in clean and efficient coal-fired power plants. Clean coal technologies are the most attractive option where low-cost coal is available (e.g. China, Australia, and Indonesia), or when the supply of gas is limited (Philippines and Thailand).

The immediate factor driving the choice of fuel for power plant is the cost of generation. This is a function not only of the cost of fuel and technology, but also of the economic and technical assumptions used in calculating generation costs. Gas-fired technologies, in most cases, are the least cost option. In particular:[14]

- gas-fired power plants increase their competitiveness when using high discount rates;
- the levelized generation cost of gas-fired power plants is not very sensitive to load factor variation; and
- for gas-fired power plants, capital costs represent only a small part of total levelized costs and, therefore, increasing the economic lifetime has little influence on levelized generation costs.

Choosing gas-fired generation technologies, however, is very sensitive to natural gas prices assumption as fuel accounts for more than 60% of total gas generation costs. Clean coal technologies become an attractive option at higher levels of natural gas prices.

6.3 Policy Issues

The ongoing privatization and restructuring in the electricity sectors of APEC economies has increased the role of IPPs. The success of these twin policies, however, hinges on the resolution of a number of policy and technical issues that become more complicated as competition evolves from the generation to retail level (see Table 6.4).

In addition, there are policy issues that directly impact on the growth of IPPs:

- vulnerability of long-term take-or-pay power purchase contracts;

- limited domestic financing of IPP projects (more because of underdeveloped domestic capital markets);
- heavy reliance on government guarantees (or improper allocation of risks); and
- cautious approach to privatization and restructuring.

Table 6.4: General Policy and Technical Issues Related to Privatization and Restructuring

The mode of privatization
Implications on ownership and companies structure
social policy obligations of traditional utilities
the sharing of benefits between investors and consumers
strategies for the recovery of stranded costs
Instruments for the recovery of fixed costs
method for determining the selling price from a power pool
Procurement of ancillary services (e.g. spinning reserves, reactive power)
demand-side bidding
hedging contracts
method for determining transmission tariffs

IPPs have increased the utilization of natural gas and are forcing coal to become more competitive. The above-mentioned issues have implications on coal and natural gas competition insofar as they tend to retard the growth of IPPs. The discussion of the issues is, of course, beyond the scope of this report.

Yet, privatization and restructuring cause at least three issues that can directly affect the fuel and technology choice of IPPs, in general, and the competition between coal and natural gas, in particular:

- **The move towards privatization and restructuring in the electricity sector can create uncertainty in terms of the development of new generation technologies.** In a highly regulated environment, in which state-owned utilities are the main contractor for generation technologies, the risks of developing new technologies are shared between the equipment manufacturer and the regulated utility. In a liberalized market, the utility, or the IPP, for that matter, seeks to minimize risks and pass it on to the manufacturer.

  In addition, the Asian financial crisis and the economic slowdown in many parts of the world have created an over-capacity for manufacturing generation equipment. In other words, demand for new capacity is lagging behind supply and capacity. This, too, can dampen development of new technologies.[15]

  The implication could be greater on the steady advance of boiler and steam technologies, and therefore, will have an impact on choosing coal.

- **Privatization and restructuring of the electricity industry is affecting coal and natural gas competition not only in terms of fuel choice but also in terms of its implications on the fuel supply industries**. In general, the move towards greater efficiency in the electricity sector will tend to effect a similar movement in the fuel sectors. Operating in more competitive environment, power producers will want to minimize costs and reduce risks (as they are going to assume more risks in a restructured industry). Fuel cost is the largest long- term component of generation costs, and power producers will want to minimize it. Generators will also want to be assured of reliable fuel supply and therefore, they will put a premium on availability and stability of fuel supply. In a truly competitive environment, they will want to share market and price risks with their fuel suppliers. All these tendencies will force fuel suppliers to be efficient as well. In the end, privatization and restructuring in the electricity sector will cause similar changes in the fuel supply industry.

- **A third issue associated with restructuring, which can tilt the competition in favor of natural gas, is the increasing convergence between the natural gas industry and power generation.** This convergence is driven by the following trends:
  - many oil and gas companies are entering the power generation business;
  - power suppliers forge “long-term relationship” (in contrast to long-term fuel supply contracts) with fuel suppliers (e.g. U.S.), to be assured of reliable fuel supply at competitive prices; and
  - private power projects are being developed in tandem with gas field development (e.g. Latin America, Southeast Asia).

  The convergence between electricity and natural gas is also driven the rise of merchant power plants. Merchant plants sell to competitive power markets, in contrast to the traditional IPP projects that sell electricity to a utility through long-term power purchase agreements (PPAs). The move towards greater competition in the electricity markets of APEC economies will see the growth of merchant power plants, which maybe existing projects whose long-term contracts have expired or new projects that sell part or all of electricity produced to the competitive market. Already, merchant power projects are in operation or under development in the United States and Australia and soon will rise in Chile, Peru, Singapore, and New Zealand. All these economies have introduced wholesale and limited retail competition.

  Merchant power producers put high priority on reliable fuel supply. As against committing to a long-term fuel supply contract with fuel suppliers, merchant power sponsors prefer establishing long-term relationship with fuel suppliers who are willing to share price risks and take an equity position in the project. This situation is now more likely to happen than ever with the number of gas producers entering the business of power generation increasing. In addition, to minimize risks new merchant projects will tend to be running on natural gas because the plants can be built on a small scale.

  Lastly, although there are inherent differences between gas and electricity as energy commodities, the two industries have many similarities both from structural and regulatory point of view that also facilitate this convergence.

6.4 Conclusion

The ongoing privatization and electricity sector restructuring in APEC economies have increased the role of IPPs in power generation. IPPs, in turn, are contributing to the changing patterns in fuel consumption for power generation. IPPs give high priority to minimizing risks, especially in a highly competitive environment, such as the evolution towards wholesale and retail competition in the electricity sectors among the APEC economies. In this type of environment, gas-fired generation technologies tend to have an edge in terms of efficiency, construction lead times, capital cost, and environmental impacts. However, advanced boiler and steam technologies that mitigate the environmental impacts associated with coal burning are attractive, especially when low-cost coal is available and during high price expectations for natural gas.

Moreover, privatization and electricity sector restructuring create uncertainties in technology developments, challenges among coal and natural gas suppliers, and new opportunities for IPPs to become more competitive—all of these intensifies the competition between coal and natural gas as the preferred fuels for power generation.

Endnotes

[1] The National Electricity Market (NEM) will initially include the states of Victoria, New South Wales (NSW), South Australia, Queensland, and the Australian Capital Territory (ACT), with the possibility of an expansion into Tasmania following its grid interconnection. Western Australia and the Northern Territory will not participate in the market due to geographical and cost factors. All consumers become contestable (can choose their supplier) by July 1999 in ACT; January 2001 in NSW, Queensland, and Victoria; and January 2003 in South Australia.

[2] A "pool and settlement system" was introduced in April 1998, and in principle allows electricity consumers whose demand exceeds 5 MW to choose their supplier. At the moment, however, this is not yet happening because there is only one supplier, Power Supply, a subsidiary of Singapore Power.

[3] The three SOEs arising from the recent split of the Electricity Corporation of New Zealand (ECNZ) will enter the wholesale market in April 1999. They will account for 60% of total generation. Contact Energy, another state-owned generation company, will be sold.

[4] Also, by definition, privatized generation assets are considered IPPs.

[5] Anderson (1997)

[6] Simon (1996)

[7] APERC (1998)

[8] Burr (1997)

[9] There are four forms of IPPs in China: an equity joint-venture, a co-op joint venture, a wholly foreign-owned entity, and through investment in joint stock company. Most IPPs in China are co-op joint ventures as the structure allows more flexibility in recovering investment. (Carson, 1998)

[10] Anderson (1997)

[11] Burr (1996)

[12] Burr (1998)

[13] Apogee Research (1997)

[14] IEA (1998g)

[15] However, opportunities for servicing and retrofitting existing equipment are growing. For example, Babcock and Wilcox (B&W), a leading US based manufacturer of boilers, foresees that service and after sales market will account for 75% of their business in the next few years (*Asian Power*, October 1998). In order to capture a larger share of the service market, GE has formed an integrated organization called GE Energy Services that provides one-stop shop for service customers around the world (*Asian Power*, November 1998).

7. CONCLUSION

The competition between coal and natural gas is a complex process that involves the interplay of several parameters. The study examined 5 main factors that can potentially affect these competition: competing sources of coal and gas, environmental policy, prices, technology choices, and the structural reforms and privatization in the power sector. The study found that the competition since the past decade is a result of the interaction among these factors inextricably intertwined with the historical development of the energy sector (upstream and downstream).

As a background in understanding fuel competition, one has to understand the energy industry structure and the level of government intervention in the energy sector. The energy industries in most APEC economies are publicly-owned though few others are private sector dominated but regulated by the government. The tendency with the former is that policies related to energy resource development have strong influence in the fuel choice in the economy and the power sector. With the latter, though various parameters can come into play, strong influence would come from economic, technical, and other factors.

The availability of coal and natural gas as indigenous resource determines the relative importance of these fuels in the total energy mix. Economies with high reserves of coal tend to have higher shares of coal in power generation (China); economies with high reserves of gas use more gas (Brunei, Malaysia); those with substantial reserves of both coal and natural gas tend to use both (USA). Energy exporting economies (Australia, Indonesia, Russia) however tend to deviate from these trends due to the priorities of energy resources for exports. Economies without or less endowed with coal and natural gas, but with access to these fuels in the international market (Japan, Korea, Chinese Taipei) tend to have a balanced utilization of these fuels, but some prefer coal than gas (Hong Kong, Philippines). Therefore, policies related to resource development for domestic utilization (economies with energy resource endowment), exports (net exporting economies), and trade liberalization (net importing economies) influence the relative importance of different fuels.

The increase in the consumption of either coal or natural gas as well as the increase in the installed capacity of either coal-fired or gas-fired technologies in power generation in APEC economies were supported by those economies with local resource base of these fuels and some net energy importing economies with access to these fuels in the international market. Unlike coal which has been a mainstay fuel in power generation, gas discoveries and development in most APEC economies (except in North America) have been recent. The momentum gained in gas consumption would likely be sustained in the medium and long term since national and regional gas infrastructures (Northeast Asian and ASEAN gas grid projects) are currently being planned or developed. The North American natural gas market trades mainly piped gas while the Pacific market trades LNG (exports to East Asia). Intra-regional trade of gas (within Southeast Asia, Australia and South America) is also piped gas.

The above heavy trends are partly explained by fuel economics. Coal is cheaper than natural gas in the international market (North American and Pacific markets). However, domestic prices of these fuels deviate from the international trend. Economies with huge reserves of coal tend to have coal cheaper than natural gas, and those economies with big reserves of gas tend to have gas cheaper than coal. Domestic pricing policies can also affect the competition between these two fuels. Price expectations in several of these economies are however stable and low for coal while highly volatile and increasing for natural gas.

While the economics of coal and natural gas as fuels can go either way, the economics of electricity generation can be moving in similar manner but in opposite directions. For some APEC economies with certain price expectations, discount rate and technical assumptions, the levelized cost of electricity from coal is lower than from natural gas while for some others electricity generated from natural gas is lower than from coal. There are furthermore other cost components that must be considered for which natural gas-fired technologies have a cost advantage over coal-fired technologies. These are capital costs, non fuel O&M and fuel efficiency.

One of the reasons why most governments support the development of natural gas resource as well as for some economies to continue to use imported but expensive natural gas, is the environment. Moreover, with the reliance of most APEC economies on the command and control approach in environmental regulation, the rigidity of this approach favors an increase in natural gas utilization. Furthermore, the development of more efficient and cost-competitive gas-fired technologies makes natural gas an attractive fuel.

The attractiveness of natural gas on environmental grounds did not diminish that of coal. The development of clean coal as well as advanced technologies that comply with stringent environmental standards retains coal as the fuel choice of those economies traditionally dependent on coal and those with huge coal reserves. Though the capital costs of these technologies are relatively higher, lower coal prices can offset this resulting in still lower levelized cost of electricity.

The global warming concern especially for those member economies with international commitments under the Kyoto Protocol is not being resolved with these technological developments related to coal. The development of flexible and clean development mechanisms and global emissions trading could however maintain the level of coal use in APEC economies that are highly dependent on coal.

In addition to the above factors, structural reforms and privatization in the power sector indirectly contribute to the above competition. Though the APEC economies that introduce reforms are at different stages and have proceeded at different paces, common among them is the presence of independent power producers (IPPs). In the region, IPPs tend to select fuel based on the availability of the resource in the economy. Thus, economies with huge reserves of coal IPPs invest in coal-fired technologies while in gas-rich economies natural-gas fired technologies. Other factors that influence the fuel choice of IPPs include relative fuel prices, attractiveness of the technology, environmental considerations and the costs of generation. However, IPPs tend to prefer natural gas when it is available since natural gas-fired technologies have relatively low capital construction cost, a well-established gas technology, short construction time, higher conversion efficiency and lower environmental impact.

Appendix-1

List of the Government and Private Offices Who Responded the Survey

Countries	Whole set*	Coal	Gas	Power	Environment	Remarks
Australia	Resource and Energy Group				Environment Australia	
Canada						Natural Resources Canada sent a letter informing the office that they were not able to respond quickly to the survey due to time constraint. They are still interested to answer the survey, however, the final draft is already finished.
Chile	National Energy Commission					
China						Energy Research Institute sent a letter containing the lists of internet addresses that could answer the questions in the survey.
Hong Kong		China Light and Power Company	China Light and Power Company	Energy Efficiency Office Electrical & Mechanical Services Dept. China Light and Power Company	Planning and Environment and Lands Bureau	The Census and Statistics Department of Hong Kong also provided information regarding the country's overall energy structure.
Indonesia			Perusahaan Gas Negara			
Japan						Japan Coal Energy Center sent documents related to coal (see appendix 2).
Malaysia				Malaysia Energy Center Sarawak Electricity Supply Corp		
Mexico			PEMEX-gas Sectretario de Energia	Sectretario de Energia		Secretario de Energia also provided other documents related to the study.
New Zealand						We received documents from the Ministry of Commerce containing information on the cuntry's energy outlook and the environment.

List of the Government and Private Offices Who Responded the Survey (continued)

Countries	Whole set*	Coal	Gas	Power	Environment	Remarks
Papua New Guinea			Department of Petroleum & Energy	Department of Petroleum & Energy		The response includes part I of the survey.
Philippines	Philippine Department of Energy				Environmental Management Bureau	
Singapore				Ministry of Trade & Industry (MTI)		MTI also sent a response on Part I of the survey.
South Korea					Energy and Environment and Research Dept.	
Chinese Taipei	Energy Commission, Ministry of Economic Affairs		Chinese Petroleum Corporation		Taiwan's Environmental Protection Administration	
Thailand						The National Energy Policy Office of Thailand sent a letter containing homepage addresses.
USA*				Econo-Power International Co.		US Department of Energy provided several documents related to the survey.
Vietnam				Institute of Energy		

*Whole set includes overall energy policy and structure (Part I), coal (Part II), gas (Part III), power (Part IV) and environment (Part V) questionnaires

Appendix-2

List of the Books and Other Information Received from the Respondents

Australia
1. Safeguarding the Future: Australia's Response to climate Change
2. Climate Change: Australia's Second National Report under the UN Framework,1997
3. Urban Pollution in Australia, 1997
4. National Greenhouse Strategy, 1998

Chile
1. Balance Nacional de Energia 1977-1996(Energy Balance)
2. Journal: Energia
3. Electric Sector in Chile, 1997

Japan
1. Clean Coal: Global Opportunities for Small Business, 1998
2. Sustainable Development with Clean Coal, 1997

Malaysia
1. Statistics of Electricity Supply Industry in Malaysia, 1998
2. Electricity Supply Industry in Malaysia,1997

Mexico
1. Activities Report 1997-1998
2. Energy Sector Statistical Compendium, 1980-1997
3. National Energy Balance
4. Natural Gas Market Prospectives
5. Electricity Sector Prospective
6. Federal Electricity Commission Annual Report 1997
7. Pemex Activities Report, 1997-1998
8. CRE, Energy Regulatory Commission Annual Report, 1997
9. CRE,Guide to obtain Electricity Generation, Importation and Exportation Permits
10. FIEDE, Energy Savings Trust Activities Report 1997
11. Mexico and Climate Change
12. internet addresses
13. Diskettes containing the reports on DSM programs

Papua New Guinea
1. Gas-Based Power Generation Study, 1991

Philippines
1. DENR Administrative Order/Memorandum Circular
2. Draft Philippine Energy Plan, 1999-20083
3. Various information related to coal, oil and gas and power

USA
1. Energy Policies of IEA Countries
2. National Air Pollutant Emission Trends, 1990-1996
3. Climate Action Report
4. Inventory of US Greenhouse Gas
5. CD ROM containing energy statistics and others
6. Internet addresses

Taiwan

1. A letter from EPA, China containing China's policies and strategies

Appendix-3

Number of Questionnaires Distributed

Country	Whole set*	Coal	Gas	Power	Environment	TOTAL
Australia	1	6	1	10	1	19
Brunei	1		1	1	1	4
Canada	1	5	4	14	1	25
Chile	1	3		4		8
China	1	5	1	6	1	14
Hong Kong	1	1		6	1	9
Indonesia	1	3	7	3		14
Japan	1	5	3	2		11
Malaysia	1		3	4	1	9
Mexico	1		2	2		5
New Zealand	1		1	1	1	4
Papua NG	1					1
Peru	1			1		2
Philippines	1	1	1	1	1	5
Russia	1	1	10	6		18
Singapore	1			2	1	4
South Korea	1	1		1	1	4
Chinese Taipei	1		1	1	1	4
Thailand	1	1	3	3		8
USA	1	10	6	41	1	59
Vietnam	1		1		1	3
TOTAL	21	42	45	109	13	230

*Whole set includes the questionnaires on energy policy and structure, coal, gas, power and environment and copies of this were sent to the government offices only. Separate questionnaires for coal, gas, power and environment were given to both public and private companies.

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