3. IGCC IN CHINA: Market Definition and Basis of Need

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Introduction

Development Schedule

The market potential for IGCC in China hinges on the Country's goals of controlling emissions from power generating plants and improving the efficiency of the electricity generating process. Both goals are important to China. Emissions reduction because of China's desire to minimize its contribution to the Global Emissions Budget. Fuel conversion efficiency because of the ethics of minimizing waste is of increasing importance in their planning of infrastructure systems.

These goals impact the following areas in the power industry in China:

1) *New Plant Construction* – New construction will need to increasingly consider the application of the more effective emission control technologies – IGCC will likely become gradually a leading candidate in this area, in particular in the larger power plants in areas with access to coal of suitable composition.

2) *Rehabilitation/Repowering of Plants in Non-Compliance with Emission Standards* – It is unlikely that IGCC will play a role in this area ahead of IGCC application in new plants. However, the repowering approach is desirable and a survey of power plants where there could be a good fit needs to be conducted in the near term (technical feasibility and economic benefit considering existing equipment and plant layout).

3) *Decommissioning of Plants in Gross Non-Compliance with Standards* – This concerns the smaller generating units (under 100 MW) in power plants which cannot be considered for rehabilitation/repowering or conversion to heat-and-power cycles. The accelerated decommissioning of these units is expected for fuel efficiency and environmental reasons. These events will affect the generating capacity requirements in China's power grids and bring about new plant construction, which may or may not involve IGCC.

4) *Based on the above the market potential for IGCC in China* (defined as actual IGCC units operating in power plants) can be seen as a long term rather than a short term development.

Power Groups and Coal Quality

The overall power grid of China can be broken down into the following Power Groups, Provincial Power Companies and Autonomous Regions:

1) North China Power Group	6) Shandong Provincial	11) Sichuan Provincial
2) Central China Power Group	7) Fujian Provincial	12) Yunnan provincial
3) East China Power Group	8) Guandong Provincial	13) Hainan Provincial
4) Northeast Power Group	9) Guanxi Provincial	14) Xinjiang Autonomous
5) Northwest Power Group	10) Guizhou Provincial	15) Xizang Autonomous

The coal mines in the Shanxi Coal Basin (e.g., Datong, Shanxi Province) and the Sichuan Coal Basin; as well as mines in the East China Power Group (e.g., Huaibei), Shandong Provincial, Central China Power Group (e.g., Kailuan) and Northeast Power Group (e.g., Fuxin, Fushun, Jixi and Hegang) produce most of the high rank coal in China. It is in these areas of China that the IGCC market initiation is expected to develop.

Accordingly, to obtain a perspective on the nature of the potential IGCC market in China, it is of interest to examine the energy picture in Asia, the role of China in the region, and the impact of the energy conversion processes practiced in China on the worldwide picture.

Energy Demand Growth in China Relative to Asia And The World

Population Growth

The Asia region (both OECD* Asia and non-OECD Asia) represented 58.7 percent of the total world population in 1990. It is projected that the population for this region will represent 57.8% of the world's population in 2025. Exhibits 1 and 2 show the world population distribution for

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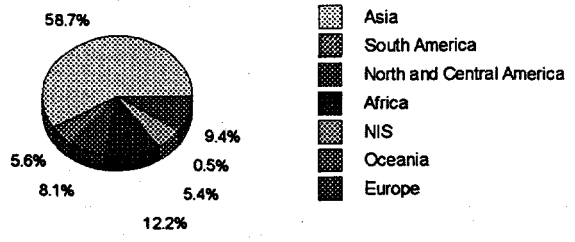
* Organization for Economic Cooperation and Development (OECD): Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. This group of countries represented 17% of the world population in 1994.

Non-OECD Asia: Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia, China, Fiji, French Polynesia, Hong Kong, India, Indonesia, Kiribati, Laos, Malaysia, Macao, Maldives, Mongolia, Myanmar, Nauru, Nepal, New Caledonia, Niue, North Korea, Pakistan, Papua New Guinea, Philippines, Singapore, Solomon Islands, South Korea, Sri Lanka, Taiwan, Thailand, Tonga, Vanuatu, Vietnam, and Western Samoa. This group of countries represented 52% of the world population in 1994.

Exhibit 1

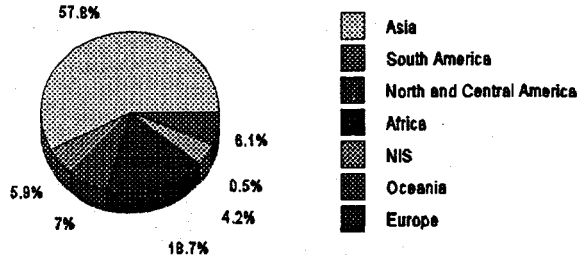
World Population Distribution for 1990



Reference: World Resources, WRI, 1990

Exhibit 2

World Population Distribution Projection for 2025



Reference: World Resources, WRI, 1990

1990 and projections for 2025.

The world population is expected to increase by more than 2 billion people between 1990 and 2010. Exhibit 3 presents the distribution of population for 16 selected Asian countries. China and India lead the list of countries with the biggest population. It is expected that the population in China and India will increase by 23.9 and 40.9 percent respectively by the year 2025. Increased energy availability and consumption for this burgeoning population will lead to corresponding increases in overall standards of living, with corresponding impacts to be addressed as a result of this growth environmental, energy efficiency, etc.

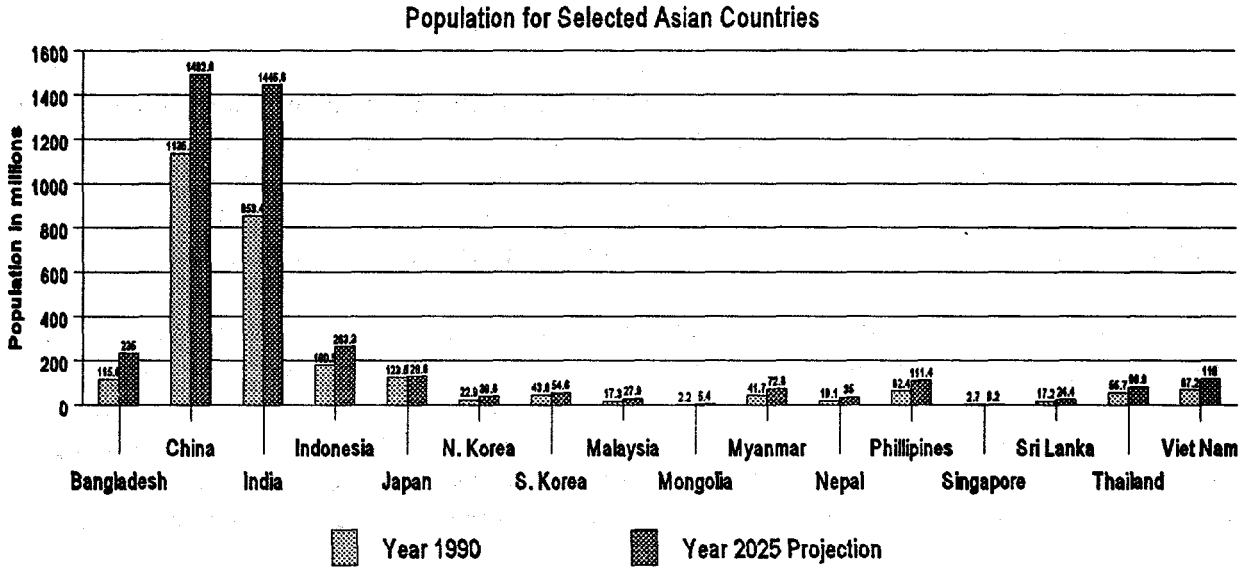
Energy Consumption in Asia

World energy consumption is undergoing continued growth and change in regard to energy sources and means of utilization. World energy consumption is projected to increase from 346 quadrillion Btu (quads) in 1990 to 472 quads in 2010. Recognizing that growth is faster in certain regions versus others, as an average, this represents more than a 1.6 percent increase annually on a world-wide basis.

Energy Consumption by Country

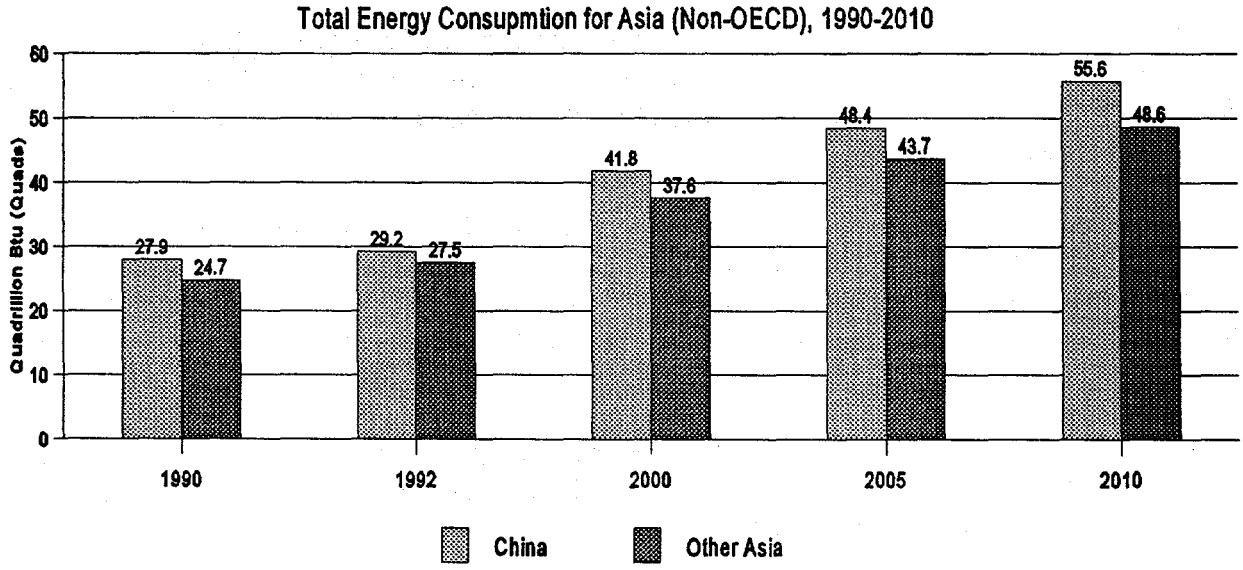
The largest gains in energy consumption are expected in Asian countries with rapid economic growth. Among the larger countries in the region, China and India, as the two largest, have pursued aggressive policies to encourage economic development and are expected to continue these policies through 2010. Based on this assumption, Exhibit 4 shows that China will reach 55.6 quads of total energy consumption by 2010.

Exhibit 3



Reference: World Resources, WRI, 1990

Exhibit 4



Asia (Non-OECD) Includes Countries with 53% of World Population
Reference: International Energy Outlook 1995, U.S. DOE

Energy consumption in the non-OECD region is expected to grow by 1.8 percent annually over the 1990-2025 period. Energy consumption has increased more rapidly in the non-OECD economies relative to those of the OECD since 1970. As a result, non-OECD consumers will account for about 50 percent of the total world energy consumption by 2010.

The industrial and residential energy sectors are still the major energy consumption sectors in the Asian region. Exhibit 5 presents figures showing that China and India were the leaders in 1990 energy consumption in the industry sector category, which amounted to 354 and 67.6 million TOE, respectively. China, South Korea, India, and Indonesia proved to be the largest energy users in the residential/commercial consumption sector in the region during 1990.

Significant growth is expected in the transportation sector, which is relatively underdeveloped at present. In the residential sector, additional growth is expected to result from energy use shifts such as replacement of non-commercial fuels, e.g., plants and animal wastes, by conventional fuels such as propane and other fuels when more advanced heating and cooking equipment is adopted in some of these countries. China and several other countries in the region are expected to continue to have rapid growth in economic activity, accompanied by rapid growth in energy consumption.

Energy Consumption by Fuel

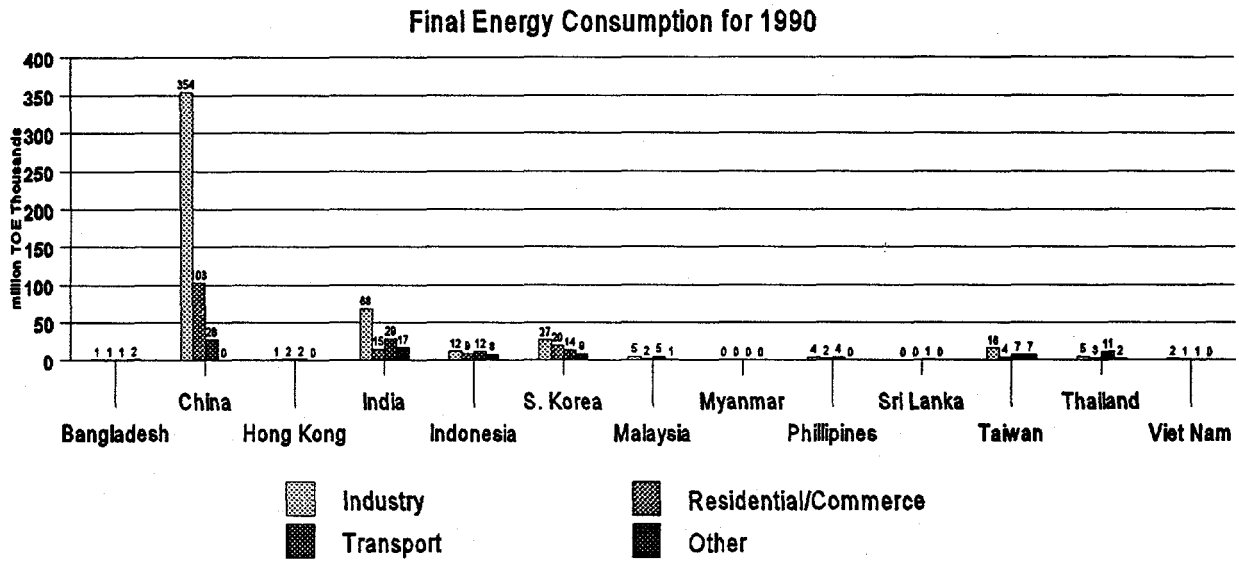
Between 1970 and 1990, energy consumption in the world increased by approximately 140 quads, reflecting an annual growth rate of 2.6 percent. During this period, oil provided the largest share of energy supply, but its share of total energy has been declining. Among the fossil fuels, natural gas consumption rose most rapidly. The share of non-fossil fuel consumption rose substantially, from 6 percent to 13 percent, between 1970 and 1990.

As shown in Exhibit 6, coal and oil contribute the largest share of energy supply in non-OECD Asia. By the year 2010, total energy consumption is expected to be 52.8 quads for coal and 34.6 quads for oil in this region. The projected figures for 2010 represent almost a doubling of the 1990 energy consumption figures.

Coal – Coal remains one of the major world energy sources in terms of primary energy consumption as shown in Exhibit 7. The amount of coal consumed in Asia is expected to increase very significantly over the period 1990-2010. Increased coal use in China alone is expected to account for more than three-fourths of the projected increase. Coal consumption worldwide in 2010 could be as high as 7,379 million tons.

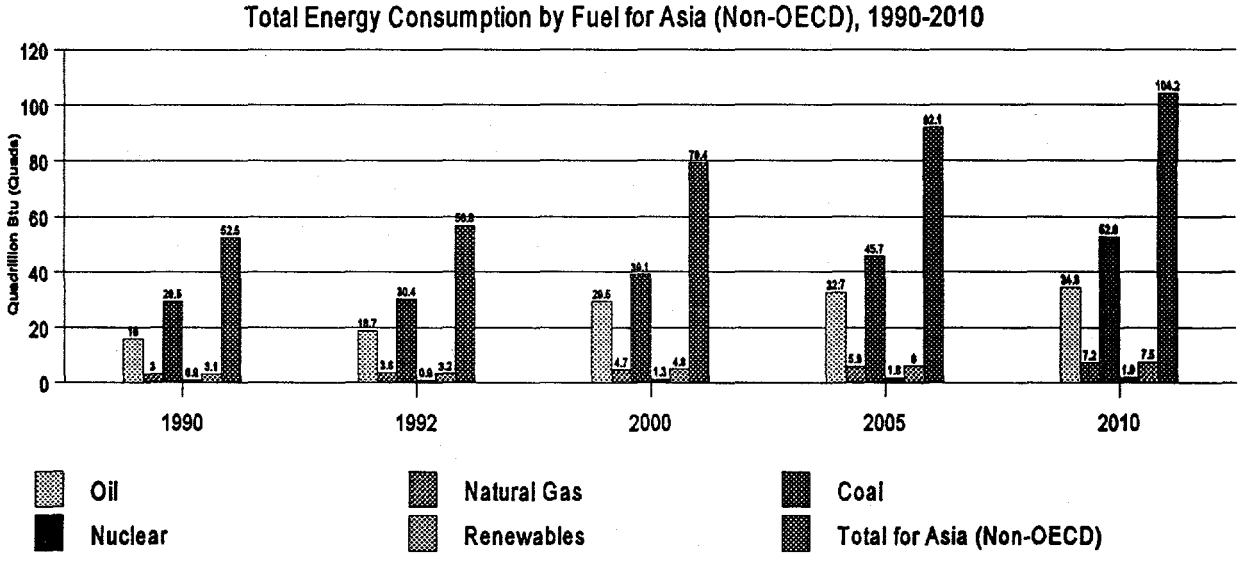
Exhibit 8 demonstrates the distribution of indigenous energy production and energy imports for selected Asian economies. The projected exceptional economic growth in this area will give rise to large coal imports for those economies.

Exhibit 5



Reference: World Resource, WRI, 1990

Exhibit 6



Asia (Non-OECD) Includes Countries with 53% of World Population
Reference: International Energy Outlook 1995, U.S. DOE

Exhibit 7

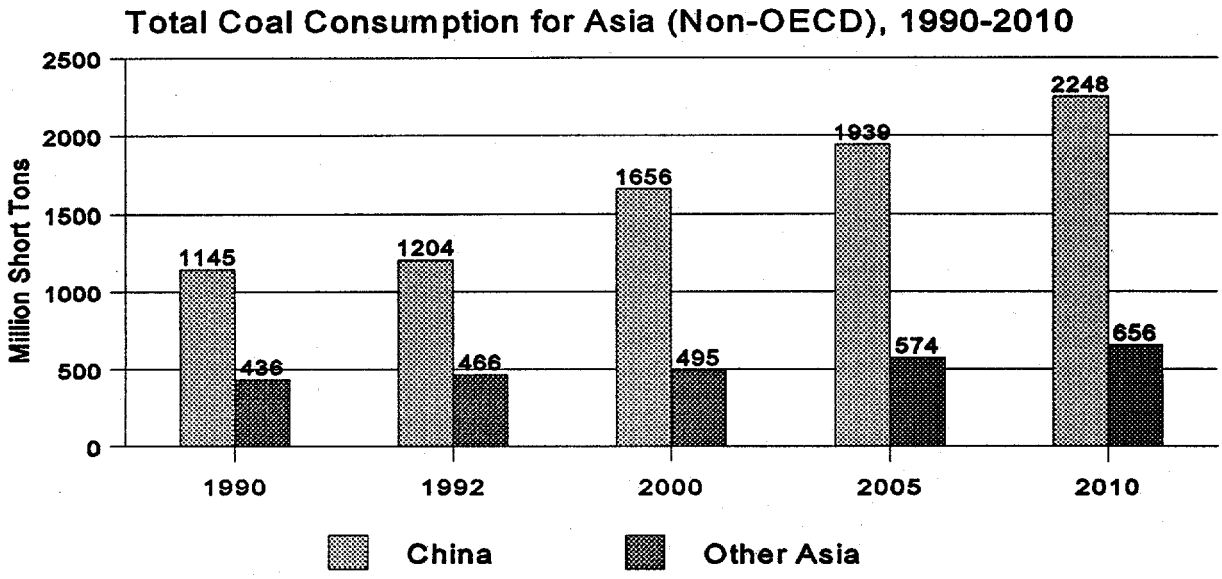


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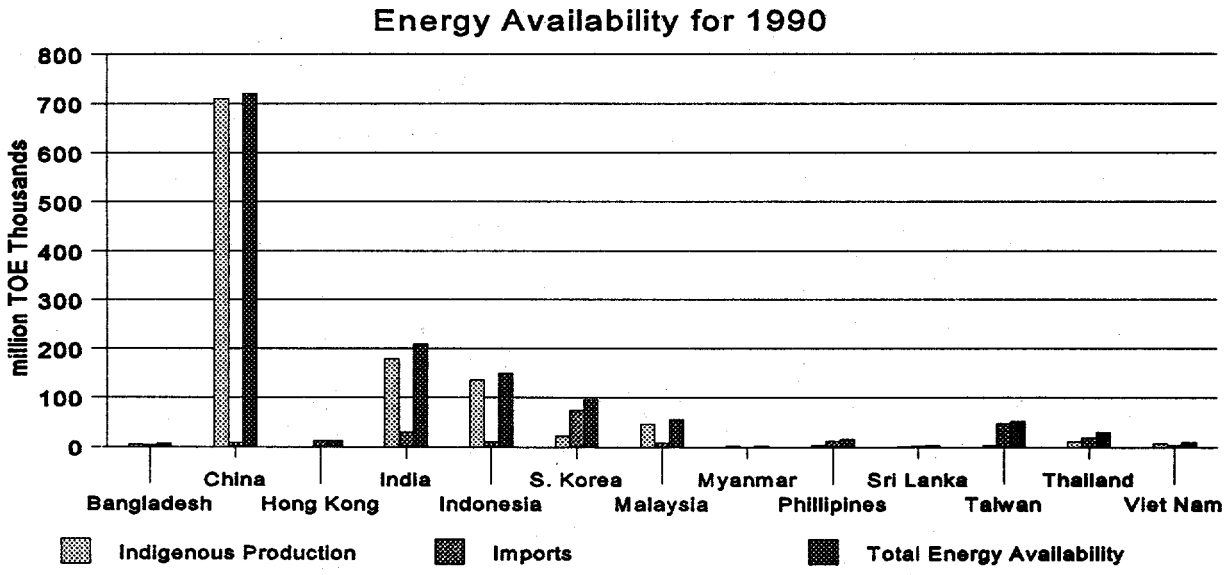
Exhibit 8



Reference: Energy Indicators of Developing Member Economies, ADB, 1992

China accounts for more than 80 percent of the growth in the region. Both India and China are expected to implement large construction programs for new electric power generating plants in the future. China may use imported coal for some regions because doing so may well be more economical than mining and shipping its own coal to the sites of the new generating units. Indonesia and China, Asia's own coal export suppliers, are making considerable advances in the export market, and are thus already well-positioned to benefit from plans for expanded coal consumption in the Asian market.

As a result of fast-paced economic growth in the region, coal consumption is expected to grow most rapidly in non-OECD Asia, which is projected to account for 44 percent of total world coal consumption by 2010, compared to 31 percent in 1990. Consumption in the Asian region is projected to grow by 84 percent from 1,581 to 2,904 million tons between 1990 and 2010. China, alone, is expected to increase its coal consumption by 1,103 million tons, nearly doubling the current level of domestic consumption. Assuming no change in fuel use policies in China, coal should continue to provide close to three-quarters of all energy consumed there in 2010. In Asia overall, coal imports are projected to rise during the next two decades, from 184 million tons in 1990 to 385 million tons in 2010.

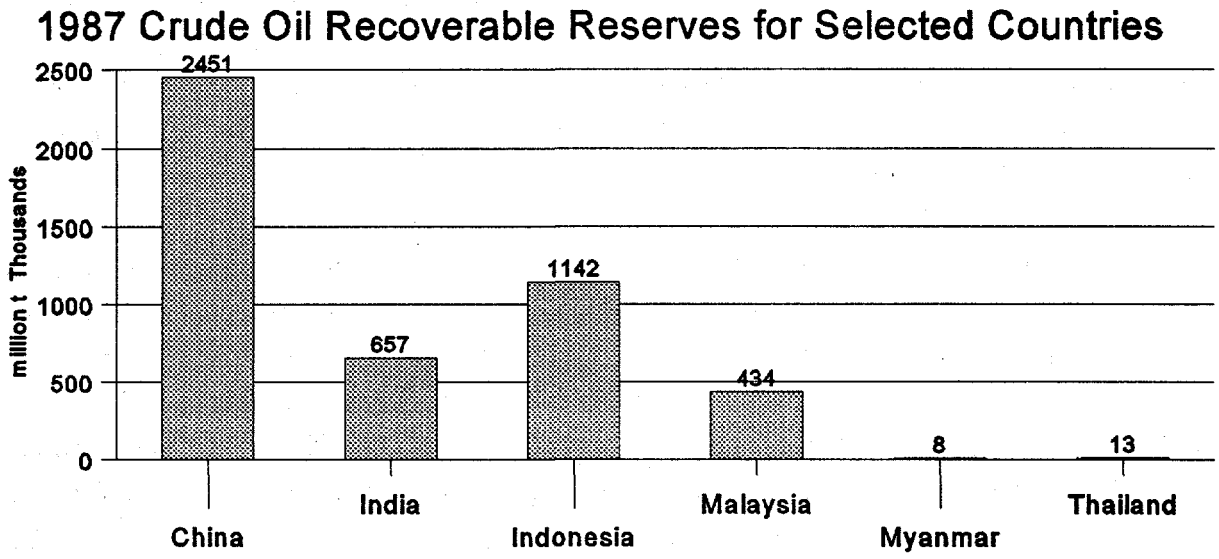
Oil – In brief the projections for oil resources worldwide as of 1991 are as follows:

Place	Billion barrels
Persian Gulf	483-620
North America (including Mexico)	139-281
Russia and Eastern Europe	130-274
Far East (including China)	81-198
South and Central America	75-136
Western Europe	45-78
Australia and New Zealand	4-13

The projected growth in oil consumption for non-OECD Asia is expected to average 3.9 percent per year for the region over the 1990-2010 period. China's oil consumption is expected to grow by 2.8 percent per year, from 2.3 to 4.0 million barrels per day. Exhibit 9 shows a detailed breakdown of recoverable reserves of crude oil in Asia.

Whereas world coal resources of significant scale are probably fairly well known – although revised assessments of new mineable coal deposits do come up periodically – the oil and gas exploration industry is continually and aggressively looking for major new finds. In the 1980's,

Exhibit 9



Source: World Resources, WRI, 1990-91

with a few exceptions, major new finds have proved elusive in new areas, where oil reserves appeared promising but unproven. In the 1990's, the oil exploration industry seems to have shifted gears and appears to be concentrating in incremental production from areas where oil has already been found. In the greater Asia region, these efforts seem to be focused on locations in Russia, Kazakhstan, Indochina, China (onshore) and others.

The transportation sector, the chemical and other industries, and certain power generation and heating/cooling applications using diesel-type fuels will continue to depend on oil for the foreseeable future. Oil demand for these type of users, in particular transportation, is expected to accelerate in the Asia region. This demand together with the expected constraints in the local refining infrastructure will limit the use of oil as a fuel for power generation.

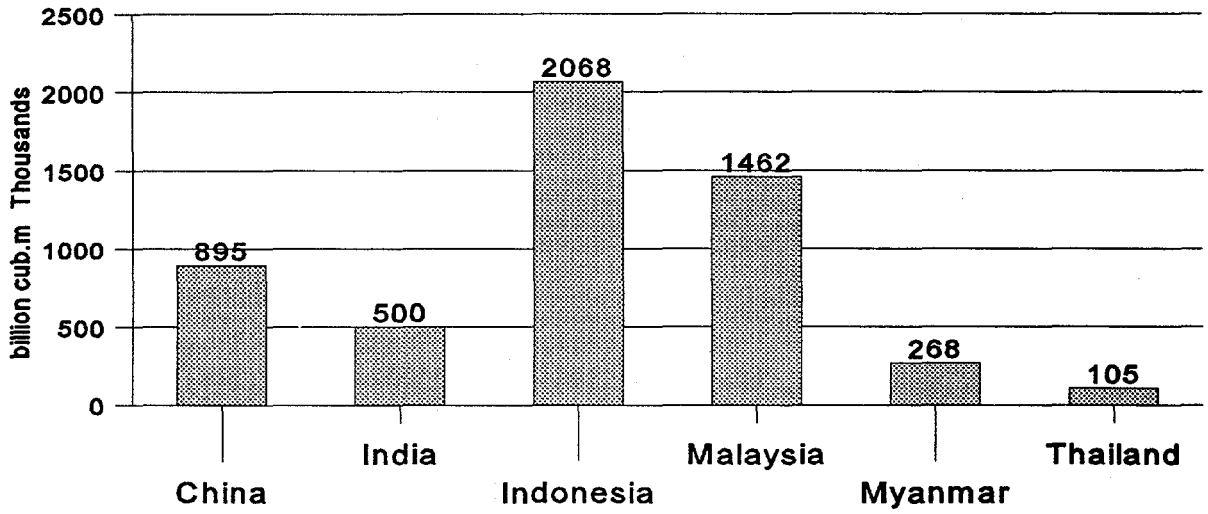
Gas – A number of relatively recent events in the worldwide energy industry are likely to figure prominently in the future of natural gas and its increased use for electricity generation. Technological advances concerning system efficiency in gas-fired power generation and the environmental advantages of natural gas make it an attractive fuel for China and other Asian countries which currently rely heavily on coal.

Exhibit 10 shows a detailed breakdown of known resources of recoverable natural gas in Asia. In this region, natural gas has been gaining increasing importance as a fuel and feedstock to industry.

Developed countries like Japan have been importing gas from local Asian sources and the Persian Gulf for power generation and industrial uses. This gas has been committed through long term

Exhibit 10

1987 Natural Gas Recoverable Reserves



Source: World Resources, WRI, 1990-91

contracts. Less developed countries are planning to accelerate industries such as plastics production and others, which utilize gas as feedstock, as well as to utilize it for power generation blocks to quickly meet electricity shortfalls.

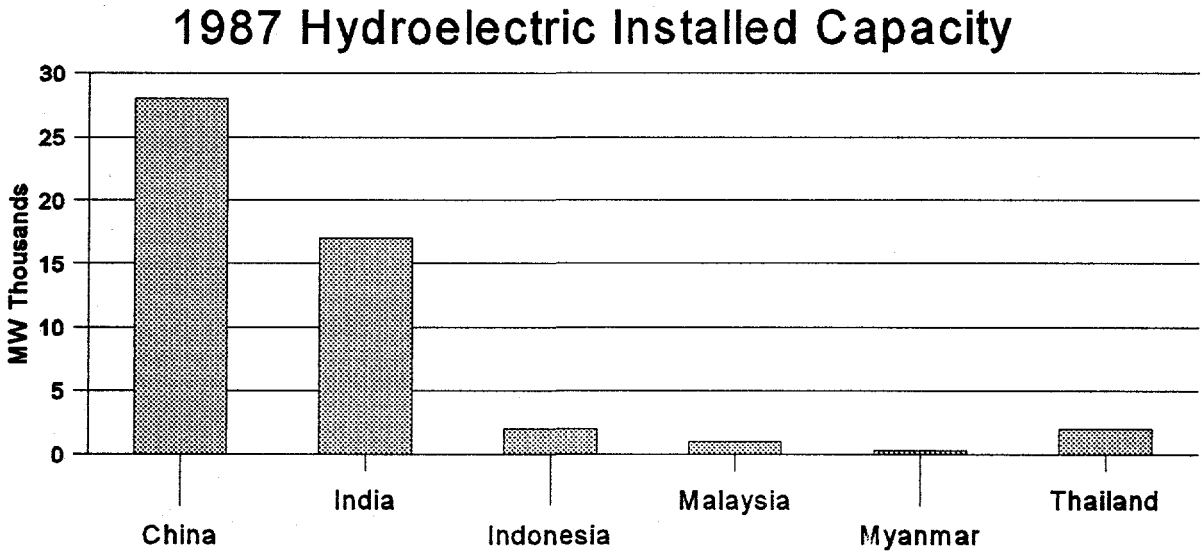
The capital requirements for gas transmission (pipelines) or transportation (liquefied form) are expected to localize the availability of gas for energy and industry users to the large bulk buyers with long term commitments and the users near the gas producers in the region. With a few significant exceptions, such as the proposal for a pipeline traversing South East Asia (feeding from fields in Malaysia, Indonesia and Brunei) – or longer term pipeline concepts bringing gas from Central Asia, Siberia or even North America – gas may not be readily available to significant areas of the Asia region.

Most of the world's liquefied natural gas (LNG) trade has centered in the Asia/Pacific Rim region, which accounts for about three-quarters of all LNG trade. Indonesia, Malaysia, and Australia are the primary exporters, and Japan, South Korea, and Taiwan are the main consumers. These six economies will most likely remain the centerpiece of LNG trade. Although neither country will operate at a level comparable to those mentioned above, both Myanmar and Thailand have the potential for significant growth in natural gas production. China has substantial gas reserves, and its clean-burning qualities make it an attractive alternative to coal where applicable. Significant efforts are also being dedicated by China to exploit natural gas associated with coal beds. This could amount to a large supplemental gas source.

Nuclear – China, South Korea, Taiwan, India, and a few other economies in Asia are currently operating nuclear power plants and have major programs for nuclear expansion. With the exception of South Korea, these programs are small, relative to their in-country energy demands, but are expected to grow in the future. By 2010, additional programs are expected to be operating in the Philippines and North Korea. Nuclear capacity for the region is projected to be between 27.7 and 35.7 gigawatts by 2010.

Renewable Energy – Asia is projected to experience fast-paced growth in consumption of hydroelectricity and other renewable resources. In non-OECD Asia, consumption of these resources is expected to more than double between 1990 and 2010, from 3 to 8 quads. Many countries in the region have relatively large hydroelectric resources. China's consumption of renewable resources in 2010 is expected to be more than three times its 1990 level. Most of the increase in its consumption of renewable energy is attributable to hydroelectricity.

Exhibit 11



Source: World Resources, WRI, 1990-91

It is evident that Asia has significant hydroelectric potential, which however will need to be carefully examined in planning its development. China has large hydroelectric development potential; according to some estimates, more than 350 gigawatts. Exhibit 11 shows a breakdown of Asian hydropower resources.

Other than hydropower, wind and solar energy resources are expected to play a significant role in the supply of energy, particularly to dispersed communities and users which account for a significant fraction of the demand in the region. Windpower development in particular offers much potential for many countries in the region.

Energy Production and Fuels for Power

Exhibit 12 provides the distribution for different fuels as primary energy supply sources for 1990. China and India lead the list of Asian countries with coal as their primary energy supply fuel, with 514.96 and 100.83 million TOE, respectively. South Korea, Indonesia, and Taiwan have oil as the primary energy supply source.

The 1987 electricity production for selected Asian economies by the type of generation is presented by Exhibit 13.

Carbon Dioxide Emissions

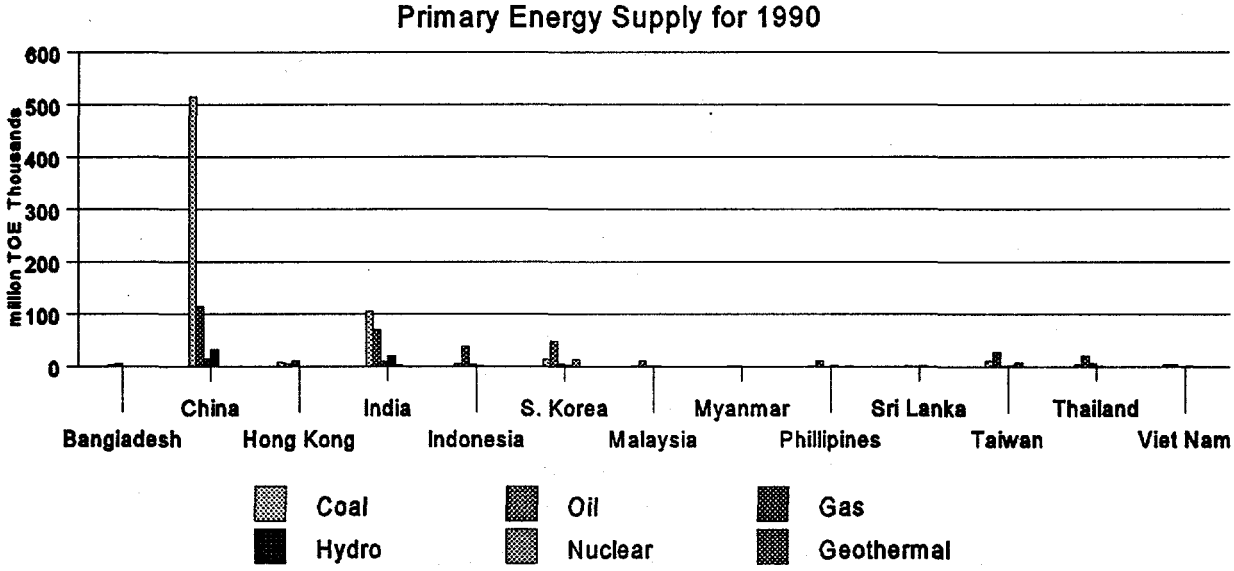
Almost half of all carbon dioxide (CO_2) emissions come from coal use. In 1990, on a world-wide basis, CO_2 emissions from coal use were 2,343 million metric tons. By the year 2010, it is projected that total non-OECD CO_2 emissions from coal use will be approximately 1,352 million metric tons.

Exhibits 14 and 15 show total CO_2 emissions for Asia and total carbon dioxide emissions from coal use. China is estimated to have produced 1,145 million metric tons of CO_2 emissions in 1990. The CO_2 emissions are expected to increase by the year 2010 to about 2,248 million metric tons. However, the application by China of power generation processes such as IGCC which provide improved control of emissions and fuel efficiency will go a long way to improve the overall emissions picture on a worldwide scale..

Conclusions on Market Potential for IGCC in China

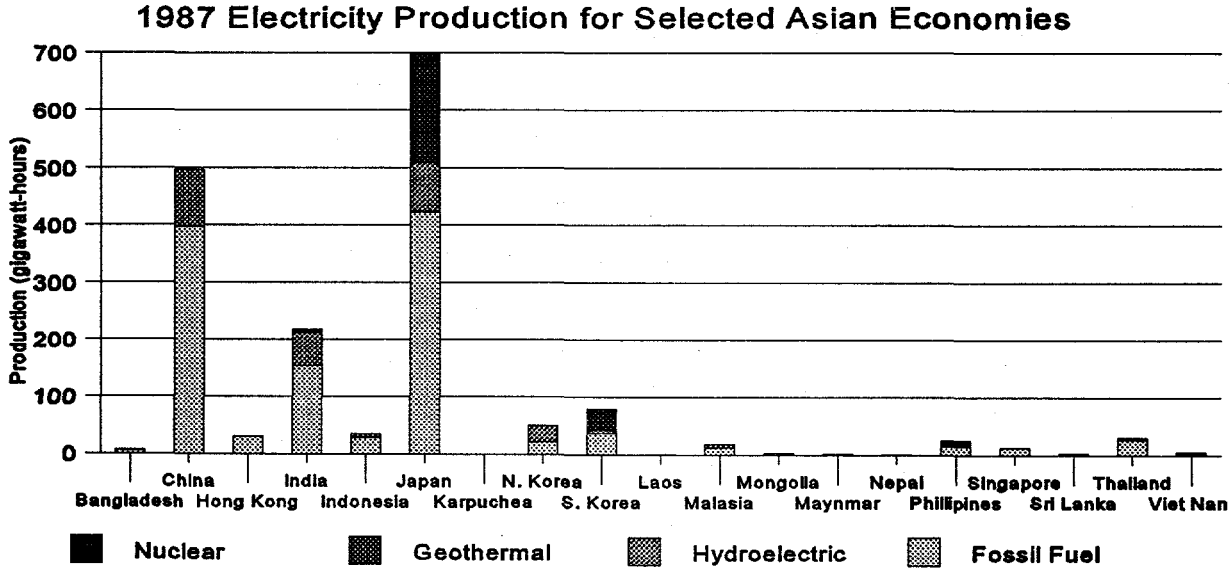
It appears evident that the market potential for IGCC in China is substantial particularly in the longer term (15 to 20 year horizon). However, the realization of this potential will depend on the availability of project financing. China and the US have taken some significant steps in collaborative efforts to initiate IGCC planning for China's power systems. However, because of project financing requirements, it appears necessary to bring into the discussion and planning process multilateral financial organizations such as the Asian Development Bank and the World Bank.

Exhibit 12



Reference: Energy Indicators of Developing Member Economies, ADB, 1992

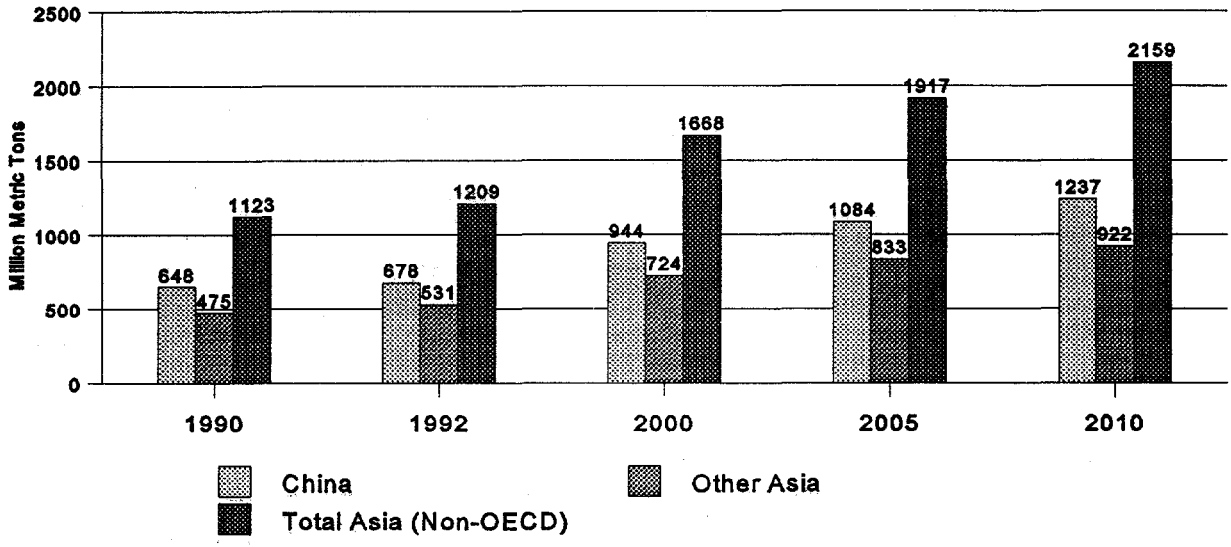
Exhibit 13



Reference: World Resources, WRI, 1990

Exhibit 14

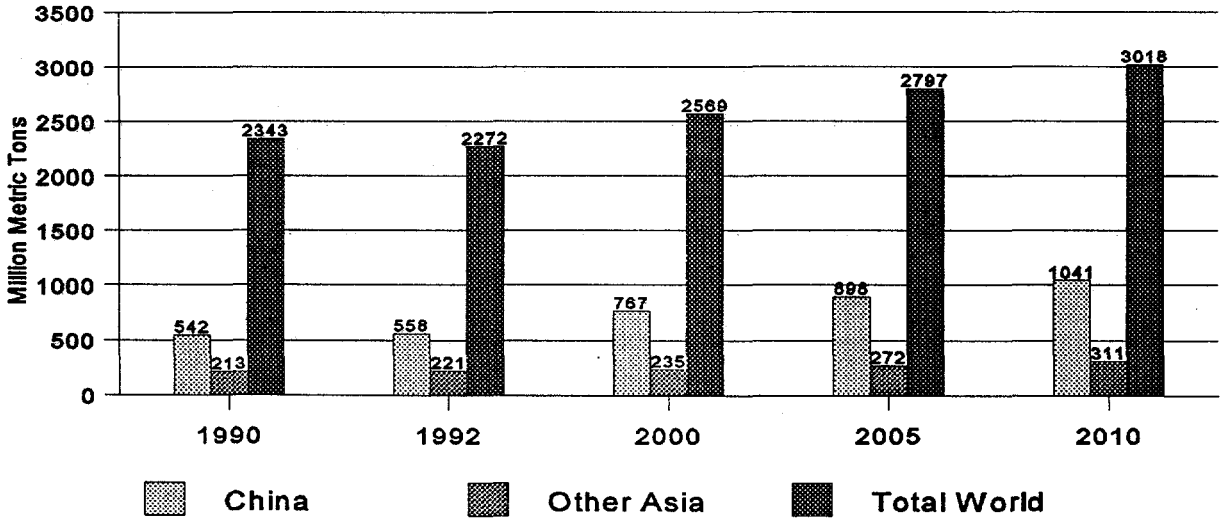
Total Carbon Emissions for Asia (Non-OECD), 1990-2010



Asia (Non-OECD) Includes Countries with 53% of World Population
Reference: International Energy Outlook 1995, U.S. DOE

Exhibit 15

Total Carbon Dioxide Emissions From Coal Use, 1990-2010



Asia (Non-OECD) Includes Countries with 53% of World Population
Reference: International Energy Outlook 1995, U.S. DOE

4. The Potential Impact and Benefits on Global Environment of US IGCC Technology in China

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Potential Impacts of IGCC Adoption in China on the Global Environment Based on the Reduction of Polluting Emissions

The very rapid movement of China to use coal for power production presents a real concern about local and global environmental impacts. If new information on global warming increases the importance of controlling CO_2 emissions, the impact could be even more dramatic. Chinese power plants do not have even the most rudimentary pollution control devices for controlling SO_2 or NO_x which are common in most developed countries. Therefore, whatever China does in the future concerning coal burning power plants will have a global impact.

China's energy consumption, dominated by coal, has resulted in serious air pollution, including urban particulates, acid rain area expansion and large greenhouse gas emissions. In north China particulate concentrations are 4-6 times higher than the level declared by the World Health Organization. In one-fourth of the cities in north China the SO_2 emissions are three times the national standard. China is the third largest greenhouse gas emission country in the world as a result of coal combustion for energy. With the increase of energy consumption, particularly the increase of coal utilization, pollution from energy will further increase in the future. A series of policies and regulations have been promulgated to alleviate this condition including strategies to use clean coal technologies. Of these technologies, IGCC is the least polluting.

According to various energy reports, China is in need of adding 17 GW of new generating capacity per year for at least the next 10 years. The demand for electricity is now outrunning supply by more than 20 percent. China is said to be planning to meet this need by increasing its generation capacity from the current 165 GW to 265 GW in ten years. This is equivalent to adding two hundred, 500 MW IGCC plants. While this is not possible, projections have been made for the projected market share of IGCC plants to the year 2020. The market share could be:

0%	1996 to 2005
2%-3%	2005 to 2010 (1 to 1.5 GW or 2-3, 500 MW IGCC plants)

5%-10%	by 2015
15%-20%	by 2020

If the 15 percent estimate is realized, the market could be more than 3,000 MW of IGCC power plants. In addition, it is known that IGCC is an effective technology for repowering old coal burning power plants by adding a gas turbine and gasifier to the existing plant using the existing equipment and structures. It is also a low cost method for increasing capacity and lengthening the technological and economic life span of old plants, avoiding large investments of building new plants.

Table 1 provides the production of electricity by country and the estimated growth of power production. This table is shown to give some idea of the relative effect China's power production can have on global environment issues.

Table 1. Electric Power Production

	Electric Power Production 10^9 kWh	**Growth, Percent**	**Growth 10^9 kWh/yr**
World Total	11,771.0	3.63	427.8
United States	3,040.9	2.59	78.8
Russia	1,726.0	2.92	50.5
China	**621.6**	**7.54**	**46.8**
India	286.0	9.14	26.1
South Africa	166.7	6.41	10.7
Indonesia	44.3	12.05	5.3
Czech-Slovakia	89.3	2.08	1.9
Bulgaria	41.3	1.73	0.7
Hungary	28.4	1.74	0.5

Since roughly 75 percent of China's power is produced by coal, any improvement in the emissions

of pollutants by technology changes can have a significant impact on the global environment. The use of IGCC, which is currently the cleanest advanced power producing technology, (see Table 3) can reduce the negative impacts of China's emissions further than other competing technologies.

Economic and Social Benefits of IGCC Demonstration and Adoption in China for Power Generation

China needs big power increments and is willing to participate in an IGCC demonstration, although timing and financing are not clear. There are additional benefits that would result from the use of IGCC in China for power production apart from the obvious superior environmental characteristics as compared to other coal burning systems.

Water is scarce in China. IGCC plants use comparatively much less water (30 to 50 percent) than other coal burning technologies. These plants can be constructed in areas with low water resources where conventional plants cannot be operated. Because of lack of transmission capability, this can mean that power can be added to places where insufficient water resources prevented the installation of large power plants. Economic development in rural areas depends on availability of commercial energy.

IGCC plants have high availability, 85 percent as compared to 50 to 70 percent now typical for Chinese power plants. IGCC plants will be dispatched first which will reduce the amount of brownouts and blackouts being experienced on a frequent basis in all sections of the country. Economic growth and public welfare are hampered by the country's frequent blackouts. The main benefit of new power plants in today's China market is stopping the blackouts.

IGCC plants can operate with a wide variety of coals and biomass which could help solve waste disposal problems.

Advanced IGCC plants will be available within ten years that will have efficiencies of up to 50 percent while maintaining unmatched environmental performance, including greater potential CO_2 benefits.

IGCC can be started incrementally in phased construction by installing a natural gas fired gas turbine followed by combined cycle, followed by installation of a gasifier. This can reduce the initial cost and have other financial benefits. One benefit is that developers can get into the market with little initial capital cost. In China, which does not have abundant supplies of natural

gas, this is less of a benefit.

IGCC, which is capable of utilizing relevant new technology, offers good prospects for new and advanced technology industries, such as subcritical/supercritical IGCC using advanced turbine technology with high steam parameters, the IGHAT with high efficiency and low cost by using humid air, and the advanced IGFC-CC by using fuel cell technology.

Identification of Technical and Economic Risks Associated with the Use of IGCC Technology in China

The gasification of coal is not a new technology. Various coals and biomass have been commercially gasified for many years to produce town gas and chemicals. In China, Texaco and IGT have supplied gasifiers for the production of chemicals for fertilizers and other uses. However, gasifiers have not been used for power production in China and no demo plants have been planned for IGCC power plants. The acceptance of IGCC chemical plants by utilities would be a concern in China as it is in the U.S. Additionally, China is inclined to favor entrained bed gasifiers, oxygen blown. Even with cold gas cleanup, this technology would have to be demonstrated in China using Chinese coals before it can be considered for a large power producing plant. A 50 MW IGCC power plant is planned to be installed by 1997 by Shanghai Coke and Chemicals. This would be a very small IGCC plant and may use the existing low pressure U-Gas gasifier.

There are other technical considerations that apply to IGCC plants as well as other technologies. While there are abundant supplies of coal and mining capability in China, the transportation infrastructure is liable to limit its use in areas that need additional electric power. Power is needed in the coastal areas but the coal sources are far from the coast. Mine mouth plants are a consideration but transmission and distribution lines are not as extensive as in developed countries. Therefore the location of a large IGCC power plant becomes an important consideration. Even after locating and installing a large plant the reliable delivery of coal to the plant is questionable and could be a risk which is usually not a concern in other countries.

Texaco has recently signed an agreement to provide nine coal based gasification plants for fertilizer production. There are now fourteen Texaco gasification plants in China and eight of them use coal. The first was licensed in 1978. This experience will assist in proving the applicability of gasifiers using Chinese coals; however these are not IGCC plants. Texaco has over 20 licenses to put gasifiers in China and at least one company is approved to do engineering work.

Commercially, the Texaco gasifier is offered with a quenched gas, producing some power level steam and a clean particulate, alkali, and ammonia free gas. When oxygen blown, the gas has a HHV of 300 Btu/scf, a suitable for combustion in a gas turbine without preheating. This gasifier combined with a Selexol to remove H_2S, and a GE Frame 7F GT in combined cycle can produce a net 300 MW of power. This system demonstrated using some Chinese coal would be commercially guaranteed and is a near-term IGCC option.

From the standpoint of the Chinese, who would be purchasing a large power producing IGCC, once a demo plant has been operated satisfactorily there would be no technical or economic risks that would be of great concern even though IGCC promoters in China have expressed the usual concerns such as commercial availability, technical guarantees, capital costs and COEs, gas turbine life when burning low Btu gas, low sulfur coal use and competition with other technologies. However, the Chinese do not have the ability to finance the new power plant projects and would have to rely on vendors from other countries to provide technology, expertise and funds. Chinese officials have said that they plant to spend $200 billion for power plants by 2010, much of it with foreign financing. These financiers/vendors would be faced with a number of problems which would be considered risky. These include:

- government policies,
- a too rapidly expanding economy,
- guarantee of fuel supply and delivery,
- reliable operation by Chinese personnel,
- timely approvals and permitting by three levels of authorities,
- currency conversion,
- differences in contractual policies,
- unfavorable rate of return,
- financing from provincial or foreign sources,
- much of the added capacity will be built on a build-operate-transfer basis (BOT)
- lower productivity of Chinese labor,

- lack of respect for intellectual property,
- foreign ownership cannot exceed 49 percent.

Finally, the IGCC vendor will have to compete in a very competitive international market which might result in bidding with less of a contingency in order to get the first project. U.S. manufacturers would need to get the price of IGCC down to $800 to $900/kW in order to compete.

The Chinese have formed a Clean Coal Commission and a program called Agenda 21. The focus of this agenda is to implement IGCCs in China in 20 years. A key question is to determine whether an IGCC should be installed in the next 5 to 10 years or wait until later. The Agenda 21 schedule showed a completion date of 1995 for a pre-feasibility study and a solicitation in 1996. This schedule has been changed because of funding problems and the status is not known.

Potential Impacts of IGCC Adoption in China on the Environmental Externalities Associated with Polluting Emissions

While it is extremely difficult to quantify the potential economic impacts of pollutants on the economy of a country some attempts have been made. In a study done for an eastern European country, monetary values corresponding to the costs of damages to the population and to the environment were estimated. These are shown in Table 2. Cost data like this is used in economic analyses to compare and evaluate technology options. Because IGCC emits much less of the pollutants compared to conventional PC plants and fluidized bed coal combustors, these external costs would favor IGCC over the other options.

Table 2. Environmental Costs

Item	External Cost
CO_2	US$ 25/ton
SO_2	US$ 590/ton
NO_x	US$ 300/ton
Dust	US$ 2,590/ton

Table 3 shows the emissions from a supercritical PC boiler and an IGCC. Both use advanced methods for pollution control. It is clear that IGCC emissions are less than PC plant emissions. In China the PC boilers have essentially no pollution controls. The emissions from Chinese PC plants are not known.

Table 3. Comparative Emissions

Item	Supercritical PC (65% CF) lb/10^6 Btu	Oxygen Blown IGCC (Destec) lb/10^6 Btu
SO_2	0.34	0.04
NO_x	0.30	0.08
Dust	0.004	0.004
CO_2	204.3	204.3

A further comparison of emissions from IGCC and conventional PC plants is given in table 4:

Table 4. IGCC vs. PC

Technology	Cost $/kW	Potential reductions (% change)			Efficiency (%)
		SO_2	NO_x	CO_2	
Pulverized coal with emission controls	1,500-1,800	90-95	60	NA	33-35
IGCC (Greenfield)	1,100-1,300	95-99	90	20-40	39-47
IGCC (Repowring)	950-1,200	95-99	90	20-28	39-42

The advantages of using IGCC technology for new power production, as far as impacts of pollutants is concerned, is obvious as the above tables indicate. Until emission regulations are promulgated and enforced in China, the true cost impacts cannot be estimated. If future emission regulations in China for coal fired power plants are less severe than those in other industrialized countries, then the cost of IGCC versus more polluting technologies may not be justified.