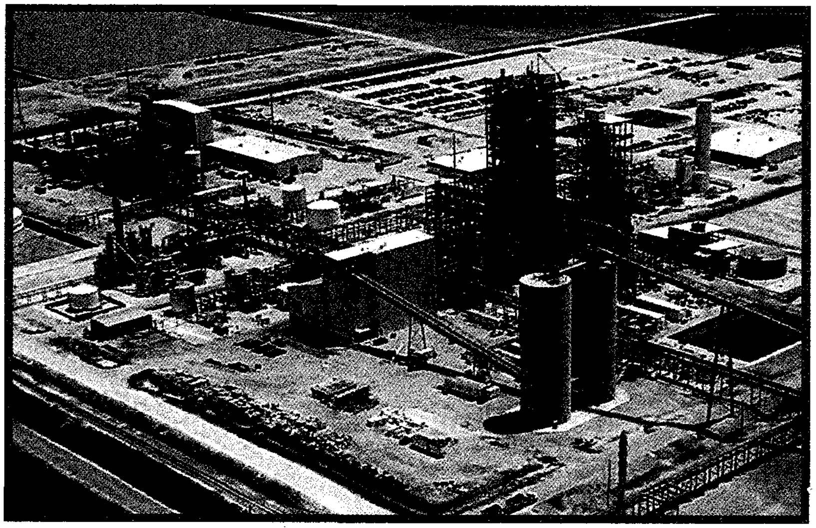
CONF-970121 -Vol. 1

Fifth Annual Clean Coal Technology Conference

PROCEEDINGS

Powering the Next Millennium



Hyatt Regency Westshore
January 7-10, 1997, Tampa, Florida

MASTER

THE CENTER FOR ENERGY & ECONOMIC DEVELOPMENT

National Mining Association
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Fifth Annual Clean Coal Technology Conference

Proceedings

January 7-10, 1997
Tampa, Florida

MASTER

Powering the Next Millennium

The Fifth Annual Clean Coal Technology Conference will focus on presenting strategies and approaches that will enable clean coal technologies to resolve the competing, interrelated demands for power, economic viability, and environmental constraints associated with the use of coal in the post-2000 era. The program will address the dynamic changes that will result from utility competition and industry restructuring, and to the evolution of markets abroad. Current projections for electricity highlight the preferential role that electric power will have in accomplishing the long-range goals of most nations. Increased demands can be met by utilizing coal in technologies that achieve environmental goals while keeping the cost-per-unit of energy competitive. Results from projects in the DOE Clean Coal Technology Demonstration Program confirm that technology is the pathway to achieving these goals.

The industry/government partnership, cemented over the past 10 years, is focussed on moving the clean coal technologies into the domestic and international marketplaces. The Fifth Annual Clean Coal Technology Conference will provide a forum to discuss these benchmark issues and the essential role and need for these technologies in the post-2000 era.

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Opening Plenary Session

Powering the Next Millennium: Challenges in Meeting the Goal

Welcome Address

CLEAN COAL TECHNOLOGY CONFERENCE
WELCOME REMARKS/POLK PLANT

Chuck Black
Vice President, Energy Supply
Tampa, Florida

Good morning. On behalf of Tampa Electric and TECO Energy, I'd like to welcome all of you to Tampa.

We are proud and delighted that the U.S. Department of Energy has chosen our city for its Fifth Annual Clean Coal Technology Conference.

It's quite fitting that the theme of this conference is "Powering the Next Millennium" and that the Department of Energy chose Tampa as the site for this year's Clean Coal Technology Conference.

We are proud to have the DOE as our partner in our Polk Power Station as we move forward to put innovative technologies to work.

The Polk Power Station, which you'll have a chance to tour as part of this conference, is an example of the public and private sectors working together to provide for the long-term energy needs of our customers <u>and</u> to balance that with our need for a clean environment.

We thank the community and the Department of Energy for their partnership and support in this first-of-its-kind venture.

We especially want to thank Secretary of Energy Hazel O'Leary, not only for her Department' s support but also for her participation in the Clean Coal Technology Conference. Here this week, we are all looking forward to her remarks.

I would like to tell you a little about your host utility, Tampa Electric Company, since you'll be seeing at least two of our facilities during this conference.

At Tampa Electric, we serve a sizable portion of the dynamic West Central Florida region, the largest metro market in Florida and second-largest in the Southeast.

Our retail service area encompasses Hillsborough County, plus portions of Pasco, Polk and Pinellas counties.

All together, we cover nearly 2,000 square miles, serving more than 450,000 residential Customers and more than 55,000 commercial and industrial Customers, for a total population of about one million.

We've been providing energy services to West Central Florida since 1899.

Today, as we look forward to celebrating 100 years of serving our community, we're a $3-billion company, with almost 3,000 employees.

I hope you enjoy your stay in Tampa and its many attractions.

As I mentioned, you'll have a chance to tour the new Polk Power Station, but we have another plant that also serves as an attraction in this area.

It's our largest generating facility, Big Bend Station, in South Hillsborough County.

The endangered West Indian manatee has made Big Bend's discharge canal its winter home for the past several years, and 10 years ago, we took steps to protect these gentle giants by creating a manatee sanctuary.

Since that time, nearly three-quarters of a million people from all 50 states and around the world have come to Tampa Electric's Big Bend Manatee Viewing Center to see these marine mammals up close.

I hope you have an opportunity to visit the Manatee Viewing Center while you're here for the conference – it's open daily to the public from 10 a.m. to 5 p.m. and there's no admission charge.

Of course, this conference is the main attraction while you're with us in Florida, and I know we can expect an excellent program over the next several days.

Thank you, and now, I'd like to introduce Jerry Anderson, the president and chief operating officer of TECO Energy, who is our keynote speaker for this morning.

--END--

Keynote Address

KEYNOTE ADDRESS
Vision and Challenge to Ensure that CCTs Contribute in the Next Millennium

Jerry Anderson
President and Chief Operating Officer
TECO Energy

5TH ANNUAL CLEAN COAL TECHNOLOGY CONFERENCE
TAMPA, FLORIDA
JANUARY 8, 1997

Thank you, Chuck, and good morning everyone.

On behalf of our sponsors, and your host utility, I'd like to welcome you all to Tampa and the Fifth Annual Clean Coal Technology Conference.

Tampa Electric is extremely proud to serve as host for this prestigious international conference on "clean-coal technologies that will power the next millennium."

The focus of this conference is the presentation of innovative strategies for the 21st Century that will meet the demands for electric power, economic viability and environmental awareness – all connected with the use of coal.

It promises to be an exciting and informative conference.

Now, let me tell you a little about your host city. Tampa is the business and financial hub of West Central Florida and one of the fastest-growing urban areas in the country.

The Tampa-St. Petersburg metro area is the largest in Florida, with more than two million people.

In fact, it's the second largest in the Southeast behind only Atlanta, and 19th in size in the country.

Many high-tech and high-quality companies agree this is a prime location for business, and have established substantial operations here.

Companies such as Time, Salomon Brothers, Citibank, Disney, Capital One and Beneficial.

There's also a business and construction boom going on in downtown Tampa, particularly along our waterfront.

Our Florida Aquarium celebrates its second anniversary next month, having drawn well over a million visitors since its opening in 1995.

A few blocks away, hockey fans and concert-goers are flocking to the Ice Palace, our new 21,000-seat downtown arena.

Another one of our community's major assets, particularly as a business resource, is the University of South Florida.

A major public university that's leading our state into the 21st Century, USF has also been on the cutting edge of research, innovation and developing new technologies.

Citing just one example, the university's College of Engineering has been actively engaged in the Nineties with Florida's key utilities, including Tampa Electric Company, in researching solar power and electric vehicles.

And, Tampa Electric has worked closely with USF in researching and demonstrating advanced electric technologies at our Electric Technology Resource Center, located on the university's main campus in Tampa.

I hope you have a chance while you're here to see some of the places I've mentioned and more of our beautiful Tampa Bay area, and why we're proud to call it home.

Tampa Electric Company has served the energy needs of this growing and dynamic Tampa Bay market since 1899.

Today, the utility has more than half-a-million customers and close to 3,000 employees.

Tampa Electric's parent company, TECO Energy, is also headquartered here in Tampa. It is one of Florida's largest utility holding companies.

TECO Energy's stock is publicly traded on the New York Stock Exchange and is owned by more than 33,000 shareholders.

Besides Tampa Electric, TECO Energy's family of energy-related companies are involved in water transportation, coal mining, natural gas production, home automation and energy management, engineering and energy services, and wholesale power generation. We have facilities and offices in several states, and in Central America.

Our family of diversified companies experienced rapid growth in 1996.

Last month, we acquired a Tampa-based engineering and energy services company, which provides a wide range of services to commercial customers throughout Florida and in California.

And, in November, TECO Energy agreed to merge with Lykes Energy, the Tampa-based parent of Peoples Gas System, Florida's largest natural gas distribution company.

We expect to complete the merger by the middle of this year. And when we do, we will add Peoples' 1,100 employees, 200,000-plus customers and $300-million in revenues to our diversified business base.

Now, to the subject of this conference, how clean-coal technologies will power the next millennium.

During the conference, you'll have the opportunity to see first-hand how Tampa Electric and the Department of Energy are meeting that 21st Century challenge at the Polk Power Station.

This 250-megawatt, power generating facility, located about 40 minutes east of Tampa in southwestern Polk County, demonstrates the value of public-private partnerships – like ours between the DOE and Tampa Electric.

We are extremely pleased and appreciative to have the DOE as partners in this project, and for bringing this fifth annual clean-coal conference to Tampa.

The DOE has played a key role in the success of the project by co-funding its innovative technology – providing $140 million through its Clean Coal Technology Program to demonstrate this first-of-its-kind technology application.

DOE's partnership and commitment is enabling us to apply these advanced power generation technologies commercially for the first time.

And, we look forward to hearing the DOE perspective on the Polk project and the future of clean-coal technologies from DOE Secretary Hazel O'Leary on Friday, when she helps us formally dedicate the Polk Power Station.

The Polk project also is the product of another successful public-private partnership that broke new ground in the selection of a site for this new power plant.

In fact, it's the first U.S. power plant ever located through community input.

Seven years ago, we gave the people in this community a real voice in where we would build our next power plant.

We relied upon the recommendations of a citizens power plant siting task force to determine the best location for this facility.

Meeting and working in the sunshine, an independent coalition of educators, business and community leaders and environmentalists evaluated 35 potential power plant sites in six West Central Florida counties. They did that over a year's time, before recommending three inland Polk County locations.

Tampa Electric followed the task force's recommendation even though the site that group selected did not meet traditional economic evaluations.

The site we selected DID, however, have the least impact on the environment and the surrounding community.

I expect it is also the lowest overall cost because of the relative ease and speed of its permitting process.

For this innovative work, the Siting Task Force and Tampa Electric garnered a number of environmental awards, including the 1991 Florida Audubon Society Corporate Award, the 1993 Timer Powers Conflict Resolution Award from the state of Florida and the 1993 Ecological Society of America corporate award.

We also received praise from government leaders, utility regulators and the news media for putting this critical choice in the hands of the public.

The Polk Power Station operating today is one of the cleanest, most efficient and economical coal-fired plants in the U.S.

The plant went on line this fall on schedule and on budget, just two years after tthe start of construction.

At Tampa Electric, we are very proud of having been able to bring this $500-million project into our utility rate base with NO increase in prices to our customers.

Last year, the Florida Public Service Commission approved an innovative proposal, which will freeze Tampa Electric's base rates through 1999.

And, the plant actually reduces the average cost of electricity because of its high thermal efficiency and use of low-cost coal.

For Tampa Electric, the Polk Power Station means a clean, economic and efficient source of power – 10-12 percent more efficient than conventional, coal-fired units, and the first unit on Tampa Electric's system to dispatch.

At the same time, we've taken several steps to protect, preserve, and in fact, enhance, the area's environment.

The Polk project was the first utility power plant ever built on old phosphate mining land.

We started our environmental efforts by reclaiming the property, planting some 200 acres of trees and creating 600 acres of lakes.

We've minimized the plant's impact on its immediate surroundings by establishing a protected 1,500-acre recreational preserve, which includes wetlands, uplands and five fishing lakes that will be managed by the Florida Game and Fresh Water Fish Commission.

This expansive natural habitat also provides space for nesting bird islands and osprey platforms.

So, at the Polk Power Station, we're balancing the need for a healthy, diverse environment, with the need for a reliable, efficient energy supply.

The plant's clean-coal technology meets the latter need by fully integrating two leading technologies: combined-cycle turbine, which is the most efficient commercially available method of producing electricity, and coal gasification, which converts coal into a clean-burning synthetic gas.

This project differs from other integrated-gasification, combined-cycle, or IGCC, plants, because it will be completely integrated – from coal gas production to turbine generator operation.

For example, Tampa Electric owns and operates the 150-ton-per-hour air separation unit.

Pure oxygen is required for the operation of the coal gasifier to produce the synthetic gas, which is burned in the combustion turbine.

The high-pressure nitrogen product from the unit is piped to the combustion turbine, generating additional electricity, lowering the combustion temperature and thereby reducing the formation of nitrogen oxides.

By integrating the plant, we'll enhance the high-efficiency of the facility's combined-cycle with the low cost of coal for its fuel.

This plant represents the most advanced electric technology from the power generation side. Now, I'd like to share with you how Tampa Electric is applying advanced electric technologies at the point of end use.

It's happening today at our utility's Electric Technology Resource Center.

The ETRC, located adjacent to the main entrance of the University of South Florida, is Florida's first full-service demonstration facility for electric technologies.

The ETRC is an interactive demonstration facility that allows Tampa Electric's business customers – restaurants, retailers, manufacturers – to come in and try out the newest technologies before they invest and change their methods of operation.

The ETRC features three demonstration areas: One for advanced electric technology, one for commercial foodservice and a lighting display center.

Since it opened just over a year ago, the ETRC has held over 1,000 seminars and events for manufacturers, vendors and business customers; welcomed more than 4,000 visitors; and partnered with more than 100 electric technology equipment makers.

There will be a tour of the ETRC for conference delegates this afternoon, and I hope you'll take the opportunity to visit this showplace for exciting new electric technologies.

Tampa Electric expects that these technologies will increase our customers' competitiveness, improve their productivity and strengthen our area's economy.

And, that's especially important for electric utilities as the industry changes into a more competitive marketplace.

All of us with an interest in coal as a source of energy, should also recognize that this changing political and business environment could affect utilities' use of coal in the 21st Century.

Certainly, any legislative or regulatory change in the way utilities do business has the potential for a major impact on the coal industry.

In the United States, coal will remain the major primary fuel source for the foreseeable future.

What is not clear is the share of new source electric generation that will be coal fired.

Part of this uncertainty is caused by changing environmental regulation.

These environmental concerns are successfully being addressed by the clean-coal program through projects such as our Polk IGCC plant.

However, global competitive pressures are forcing changes in the electric utility business. You will be hearing about those changes at this conference.

In general, I believe increased competition should result in greater utilization of existing coal-fired plants because of their low incremental cost.

The probable near-term effect on the coal industry is positive, with an increase in demand. It is more difficult to estimate the long-term effect.

Changes in the regulatory environment will make it more difficult for utilities to make large, long-term capital commitments.

This uncertainty about the future is the negative that faces the coal industry and the advancement of clean-coal technologies for the longer term.

The initial investment in a clean-coal gasification plant is three times the investment in a natural gas or light oil-fired plant.

Even though that higher initial cost is more than paid off over the life of the plant, it is still a difficult investment decision.

Let me quickly add that I believe we have found the successful formula here in Florida.

As you have heard, we serve a growing community that is environmentally aware.

We have no easy inexpensive sources of energy here, and we simply must provide affordable energy that makes our businesses competitive in a world market.

The coupling of our nation's abundant coal resources with the technology you will see here has allowed us to meet all of these challenges.

Yes, it took thought and care and planning. But with the help of many of you and with the support of the Department of Energy, we have achieved our goal:

- A new source of electric energy, competitively priced – clean, reliable and ready to fuel our future growth.

I know you will benefit from the insights you gain at this conference.

I hope you like what you see here in Florida, and that you enjoy your stay in Tampa.

– END –

Plenary Session:
Introduction of the Session

INTERNATIONAL MARKETS FOR CCTs

Mr. John P. Ferriter, Deputy Executive Director
International Energy Agency
Paris, France

INTRODUCTION

The Role of the IEA

Let me start with a few remarks about the International Energy Agency.

The IEA was created in 1974, in response to the first oil shock to ensure its Members' collective energy security. At that time, the essence of energy security was seen as an uninterrupted oil supply.

Attention focused on developing emergency preparedness measures to respond to a major disruption in the international flow of crude oil, and on promoting long-term cooperation and research and development activities among Members to reduce their dependence on imported oil.

While these activities continue today as fundamental elements of the Agency's work, events of the last several years, in particular the end of the Cold War, have dramatically altered the world political and economic scene, and thus changed the basic environment in which world energy markets function:

- The economic restructuring under way in former communist countries, coupled with the expected continuation of strong incremental energy demand in non-OECD Asia and elsewhere in the developing world, will have significant effects upon both the supply and demand sides of international energy markets - these are now becoming truly "global".

- The resulting world energy balance is shifting, with the OECD now accounting for only half of global energy consumption.

- Energy markets generally have evolved, with deregulation and liberalisation resulting in their being driven more by market forces than through government intervention, although government involvement is clearly still required in certain instances.

- Environmental effects associated with the energy sector, from production through to consumption, have become increasingly vexing and compel innovative approaches to energy policy.

Importance of Coal

The response by energy policy makers to these challenges must draw on coal for a major contribution.

- Coal is one of the world's most important and abundant fossil fuels; its share of many countries' energy mix and the wide distribution of reserves around the world enhance diversity, and thus increase energy security.

- There is major scope for improving the efficiency with which coal is used and for mitigating the pollution and other emissions that its production and use can cause.

- Coal is low-cost compared with oil or gas, perhaps between a quarter and one-half the price for the same primary energy content. Many countries have economically viable domestic resources of coal to support economic development.

What is the IEA doing in the area of Clean Coal Technology?

The IEA Secretariat conducts a wide range of policy research, at the direction of its Members, on energy technology, energy-environment, and energy diversification issues. Much of this is concerned with advising governments on the market conditions required for optimising decisions on economic and energy-environment issues.

Important work of relevance to clean coal technology is also conducted by groups of our Member Countries, which come together to carry out work in areas of particular interest to them. These are known as Implementing Agreements. The oldest of these, IEA Coal Research - The Clean Coal Centre, publishes a wide range of studies, from basic coal science through exploration and production, to coal beneficiation, transport and use. The environmental dimension of each part of the coal chain is ever more important in the decision making process, and is therefore increasingly represented in IEA Coal Research publications.

Other Implementing Agreements on coal include:

- The Coal Combustion Sciences Agreement which is concerned with the basic science of coal combustion, including the development and application of analytical techniques for the analysis of coal combustion processes.

- The Fossil Fuel Multiphase-Flow Sciences Agreement, which coordinates the exchange of information and complementary research tasks in a wide range of research programmes to improve understanding of the behaviour and properties of multiphase phenonema associated with obtaining energy from coal, oil and gas.

- The Fluidised Bed Conversion Programme, which is sharing information about, and collaboratively researching, the physical and chemical processes which occur during fluidised bed conversion, in atmospheric and pressurised fluidised combustion beds, both bubbling and circulating.

Some recent highlights of our work show the approach we are taking in support of the clean coal technologies.

In early December, I led an IEA team at a conference on energy efficiency in Beijing, which we organised with the State Planning Commission. A major part of the conference was devoted to coal development, and coal utilisation in China. Papers presented by the IEA side sought to promote the clean and efficient production and use of coal.

Similarly, in October last year, we organised a joint workshop with the World Bank on the financing of clean coal technologies. The seminar brought together policy makers, financial institutions, equipment manufacturers, and research organisations.

In 1995, the US Department of Energy and other bodies sponsored an IEA Conference on *The Strategic Value of Fossil Fuels: Challenges and Responses*.

We will shortly publish a major study on electricity in Asia, the *Asian Electricity Study*, which examines the electricity sectors in Indonesia, the Philippines, and Thailand. A chapter of the report is devoted to issues of power plant finance.

We have also published a number of reports covering coal issues generally. These include a report on the *Energy Policies of the Russian Federation* (1995), the *Energy Policies of South Africa* (1996), both with coal chapters. Each year we publish *Coal Information*, a major compilation of coal statistics with extensive commentary on coal production, demand and trade. The Coal Information series also provides current information on coal-fired power stations under construction and in planning throughout the world, including those using advanced power generation technology.

As a final example from many activities related to your conference, we have formal recognition at the on-going negotiations on climate change. We are at present developing advice for consideration at the Conference of the Parties (known as COP-3) to be held at the end of this year, and which could have a major bearing on the future of coal.

Role of the IEA Coal Industry Advisory Board

The IEA has a specialist industry source of advice on coal - the Coal Industry Advisory Board. The CIAB currently has 45 Members, representing coal industry interests from 16 countries. Members are corporate leaders from coal production, transport and utilisation companies.

Membership is not limited to OECD Member Countries. In 1995, the CIAB gained two new Members from South Africa, from Eskom and Ingwe. This year I hope we might make progress in gaining Members from China, the world's largest producer of coal and a key player in international coal trade.

The CIAB is vitally concerned with promoting the use of clean coal technologies. The Board has produced a series of three reports published by the IEA* on clean coal technologies, examining industry attitudes to the take-up of both gasification/combined cycle, and advanced steam cycle technologies.

The CIAB studies confirm that there is a wide range of state-of-the-art coal-fired technologies suitable for different conditions in both developed and developing countries. These range from large scale supercritical steam-cycle power generation, through smaller scale fluidised bed plants for power generation and industrial heat, to IGCC technology which is under demonstration for very clean power generation.

Progress in installing such technologies is still slower than had been hoped and expected. Nevertheless, supercritical steam cycle plants are successfully established in Japan, Germany, and Denmark, and there is no shortage of industrial scale and demonstration plants for many of the other technologies.

The CIAB has been studying reasons for this slower progress and is now examining what may be done to accelerate the adoption of advanced coal-fired technology in different regions. The IEA expects to publish a new report from the CIAB, looking at the regional factors influencing the take-up of clean coal technologies, during 1997.

Context for discussing Clean Coal Technologies

The IEA's *World Energy Outlook* (1996) shows the secure future for coal.

We take two cases, which we call the Capacity Constraints case and the Energy Savings case. In the Capacity Constraints case trends in past behaviour are assumed to continue to dominate future energy consumption patterns. In the energy savings case energy consumers choose to use available energy efficient technology to an extent greater than has been seen in the past.

Three major conclusions can be drawn from the projections:

- First, world primary energy demand is expected to continue to grown steadily, as it has grown over the last two decades.

- Second, fossil based fuels will account for almost 90% of total primary energy demand in 2010.

- Third, a structural shift in the shares of different regions in world energy demand is likely to occur - the OECD share of world energy demand will fall in favour of the rest of the world, where the share of world primary energy demand is expected to rise from 28% now, to almost 40% in 2010.

In general terms, the outlook for coal in the world energy scene is for strong competition with gas, weakening demand for some coal uses, but continuing demand for baseload power generation.

Demand for solid fuels - principally coal - is expected to rise steadily in the outlook period to 2010 (at an average annual rate of 1.7% - 2.2%). Overall, the share of solid fuels in the primary fuel mix is likely to remain stable, but there will be significant changes in the pattern of world solid fuels consumption:

- Countries such as China and India, are very coal intensive. Growth in coal demand in the non-OECD countries could be as high as 3.8% per annum, and use in power generation could be as high as 6% per annum.

- In the OECD countries, coal is expected to be increasingly a fuel for power generation. In 1993, the OECD was the largest fuel consuming region. By 2010, however, the OECD could account for only just over one-third of world solid fuel consumption. The Rest of the World could consume more than on-half of world solid fuel.

The messages from our projections for your conference are:

- Coal has, and will retain, a central role in meeting the world's future energy needs.

- The growth area of coal use is in power generation.

- In OECD countries, coal's share in the electricity output mix will be maintained, but coal demand for other uses will fall.

- In the Rest of the World, coal will lose share in final energy consumption, but use in power generation will grow at over 6 percent per annum. The region where attention needs to be focused is Asia.

Technology Choices

Which Coal Technologies will be Chosen?

These messages are good news for coal producers, and seemingly so for coal technology developers and manufacturers. I mentioned earlier that the CIAB has expressed concern about the slower-than-expected take-up of the clean coal technologies. Let me review the evidence for this.

In the OECD countries, tighter emission standards are encouraging interest in clean coal technologies. But there is little prospect for growth in coal use in these countries taken as a whole.

Where growth prospects are greatest, in the Asia-Pacific region, Independent Power Producers are the key to power generation investment in the Asian region. The choices they make on technology will be decisive in determining if clean coal technologies are used.

The CIAB has conducted a survey of Independent Power Producers (IPPs) in several regions, as part of the regional study I mentioned earlier. Sixteen companies involved in independent power generating project development and/or construction were surveyed. Several of the surveyed companies also represented technology supply or engineering/construction firms.

The survey found that at present, IPPs will choose mainly sub-critical pulverised-coal technology (that is, conventional coal-fired power generation technology), and in some cases Atmospheric Fluidised Bed (AFBC) technology. This technology can be clean and economic. Sulphur dioxide, NOx and particulates can be reduced to acceptable levels, and provide low-cost electricity. At present, environmental standards, especially in developing economies, do not require environmental performance beyond the range of conventional plant with add-on pollution control.

Local and regional environmental problems from sulphur dioxide, NOx and particulates can be addressed by available technology, and there is a generally accepted policy framework for governments to adopt to ensure that emissions are controlled in an economically efficient manner.

As an aside, Flue Gas Desulphurisation at the power station would generally be regarded as the technology of choice for reducing sulphur dioxide emissions. This is not always the case. In China, for example, coal use is 70% in direct applications, and only 30% in power generation. During the IEA's recent conference on energy efficiency in China, which I mentioned earlier, coal preparation was described as the highest priority in clean coal technology for China because it would reduce emissions from direct use of coal.

However, on a global level, CO_2 emissions from power generation are becoming increasingly the focus of attention for energy policy makers. The higher levels of conversion efficiency which can be achieved by advanced steam cycle and gasification/combined cycle technologies, are desirable on global environmental grounds.

When asked what their expectations were for 2005, the IPPs responded that they would expect more supercritical steam cycle plants, and Pressurised Fluidised Bed Combustion (PFBC) in specialist uses, but Integrated Gasification Combined Cycle (IGCC) technology would not be in widespread use for coal before 2010.

The factors influencing these views were given as:

- Reliability, technology cost and financing constraints are the most important factors influencing the choice of technology.

- Government regulation, maintainability, technology risk and lender attitudes came a close second.

- Environment was not seen as a major determining factor. But environmental considerations would be important if contained in the category of government regulation, listed as important.

- Need for skilled operators came low on the list of factors, as IPPs felt it is not difficult to find and train them.

What are the problem areas?

The survey revealed that the advanced steam cycle technologies are considered to be commercially proven, but to be more costly and riskier, especially when built in non-OECD countries.

There are more than 350 supercritical units operating world-wide. Their early technical problems have been overcome and improvements incorporated in areas such as metallurgy, equipment design and water treatment. The reliability of these plants is now considered as good as for sub-critical plants. Nonetheless, the IPPs surveyed were cautious in selecting this form of clean coal technology.

IGCC was considered to be too costly to compete without some form of support.

Accelerating the Take-up of Clean Coal Technologies

What can be done?

In looking at what might be done to accelerate the use of the advanced clean coal power generation technologies, three points are clear:

- The regions where rapid growth in coal-fired power generation is occurring, are viewed by developers as having a different investment environment from the OECD countries. In short, there are more risks involved and, possibly, conventional risks are higher.

- Policies to encourage the take-up of advanced clean coal technologies need to be narrowly targeted, since the problems are different for the different parts of the world and for different technologies. Policies may need to be designed to suit particular regions and particular technologies.

- Governments should not be left to cope with the task. It is in the long-term interests of the coal industry to be actively involved.

General Prescription

There is a general prescription for encouraging the take-up of clean coal technologies in power generation:

- Electricity costs from plants *with* pollution control cannot be expected to drop dramatically, or drop below those *without* pollution control, unless completely new technologies are developed. These may be possible, but they are not on the horizon today.

- Consequently, clean coal technologies will be chosen when environmental regulations require them.

- Environmental regulations will be applied when environmental costs to society are recognised.

IEA Coal Research published a report in 1995, *Air Pollution Control Costs for Coal-fired Power Stations*, which quantified the cost of air pollution control costs for coal-fired power stations. They found that for new installations, the costs of sulphur dioxide and NOx control account for about 15% to 20% of the cost of electricity, depending on emission limits, the technology chosen and other technical and economic factors. Particulate control adds 3% to 4% to the cost of electricity.

It is unavoidable that as more stringent emissions controls are imposed, the cost of electricity also rises. For currently available technologies, the price rises steeply as different technologies are used to attain the next higher level of performance.

We know from the experience with control of sulphur dioxide, NOx, and particulates, that once Governments decide on minimum standards of performance, the market will choose the most cost-effective way of meeting the standards. It is important to a cost-effective outcome that Governments do not attempt to impose the particular type of technology which should be used.

At the moment, there is no generally agreed standard which might encourage higher levels of conversion efficiency in plants. Economics determines the level of efficiency considered appropriate in a particular circumstance. As I have already commented, at present power developers in the high growth Asian economies are satisfied with the level of performance that can be attained by conventional sub-critical plant. They can meet all environmental requirements with this type of technology, with add-on pollution control such as Flue Gas Desulphurisation, if necessary.

In the absence of private economic incentive to use clean coal technology, then more advanced technologies will not be chosen until Governments choose to place a higher value on environmental performance, including carbon dioxide. Of course, developers might then turn away from coal if competing fuels, particularly gas, are more economic under a stricter environmental regime.

In the past, Governments have seen their role as supporting the take-up of new technologies in many fields, through direct financial support such as support for research and development, demonstration plants, and capital subsidies. There can be little doubt that programmes along these lines have advanced the technology and economics of clean coal power generation.

But enthusiasm for such measures is waning, under pressure of budget constraints.

Where clean coal technologies are commercially competitive, the situation is fairly straight forward. Governments have a role to develop sound environmental regulations, and to strive for undistorted energy markets where fuel prices reflect costs, including environmental costs.

For the technologies which are close to commercial or not yet generally accepted as proven, the situation is more complex, possibly calling for a range of policy measures.

Generally speaking, measures usually discussed all involve a degree of market intervention. We should be certain we understand the market before interventionist measures are implemented. At least three areas of the market need to be looked at:

- Is there genuine competition between electricity producers? Producers should be obliged by market conditions or regulation to look at the relative economics of the different technologies, and not be guided, say, to give preference to one form of technology over another because it is manufactured in the same country.

- Similarly, is there genuine competition between technology suppliers?

- Have external costs of power generation been taken into account?

Once we have a sound understanding of these points, we can look at measures governments might take to promote clean coal technologies.

A variety of measures have been proposed to complement the more traditional direct financial assistance measures. In listing these measures, I am not suggesting that the IEA necessarily gives its endorsement. Measures which have been proposed include, for example,

- Promotional measures to break down perception barriers concerning the use of coal, and to disseminate information on available, commercially proven, advanced clean coal technologies.

- Certainly, coal has a poor image and countries with major national interests in coal production have a particular responsibility here.

- The CIAB takes the view that there is insufficient understanding of the current reliability and economics of supercritical power generation technology, and has sought to address this by undertaking an analysis (still underway) of costs and other issues relevant in comparing sub-critical, supercritical and ultra-supercritical pulverised coal plants in non-OECD countries.

- Sharing the risk: This might take the form of Governments providing assurances against reduce technology risks. These measures would not be designed to direct a developer to a particular technology, but rather to ensure the developer's choice was not prejudiced.

- Developing "innovative" financing packages for new developments. This suggestion is based on the assumption that the risk-averse nature of lenders will influence technology choices.

- Activities Implemented Jointly (AIJ). AIJ has been proposed as a means by which countries might achieve reductions in global emissions of carbon dioxide, by projects and activities conducted outside their borders. The result could be a greater reduction in emissions, at lower cost, than the country might achieve within its own borders.

- In a comparison made by the CIAB, based on hypothetical 600 MW pulverised coal plants, the annual mass of carbon dioxide emissions for conventional, supercritical and ultra-supercritical plants are 5.2 million short tons, 4.8 million short tons, and 4.4 million short tons, respectively.

- This represents a reduction in emissions of 8% for supercritical, and 15% for ultra-supercritical plants, compared with conventional plant. There is scope for huge reductions in carbon dioxide emissions from Asia, through the use of these technologies.

These proposals are generally at the conceptual stage, and your conference would be making a major contribution if it could develop some ideas, either to further develop those I have listed, or as additional suggestions for promoting clean coal technologies.

The measures I have described should not necessarily replace all the more direct forms of encouragement I mentioned. Research and development, promotion of technology development and deployment, and technology cooperation are all proper roles for government in relation to coal technology. The decline in expenditure in these areas is to be regretted.

Nonetheless, industry has an important role in ensuring the future of coal. The coal industry needs to look to its own long-term interest, and companies along the length of the coal chain - from production to utilisation - should see that their interests are bound up in the future of the clean coal technologies.

At the end of this year, at the third Conference of the Parties on climate change, to be held in Japan, there is a very real prospect that legally binding targets on Greenhouse Gas emissions will be agreed. Such a proposal was put forward by the US Government at the second conference, held last year. If this is the outcome, then clean coal technologies will play a vital role in helping coal-fired power generation meet the new standards expected, in those countries which are party to any agreement emerging.

It would be short-sighted to think that any agreement at COP-3 would not eventually impact on those countries not immediately involved in the climate negotiations. It would also be short-sighted to imagine that failure to agree at COP-3 will signal an end to the debate on energy-climate issues.

Today we might usefully focus on how the clean coal technologies can provide a constructive, and economic, response to maintain coal's prominent position in the world energy scene.

Thank you.

* *Industry Attitudes to Combined Cycle Clean Coal Technologies* **(IEA OECD, 1994)**
Industry Attitudes to Steam Cycle Clean Coal Technologies **(IEA OECD, 1995)**
Factors Affecting the Take-Up of Clean Coal Technologies **(IEA OECD, 1996)**

Draft Outline of Clean Coal Conference Remarks
by
Kenneth Gordon

Senior Vice President, National Economic Research Associates

Tampa, Florida
January 8, 1997

Title: The Role of Clean Coal Technologies in the Evolving Domestic Electricity Market

I. Introduction

-substantial changes taking place in the electricity industry: worldwide phenomenon

-FERC and the state commissions, especially in a few states, driving the change

-fundamental changes are taking place, go beyond simple policy preferences
 -technological change, especially as it affects optimal generation scale
 -lowered transaction costs, ability to organize more "complex" markets
 -experience in other industries, electric experience abroad as an indicator
 -ability of markets to handle formerly vertically integrated arrangements
 - "what is the firm" is a changing concept: not unlike other industries

II. What Will the Future Electric Industry Look Like?

-Early regulatory determinations of structure:
 -the separation of retailing functions and generation activities from transportation
 -transportation = transmission and distribution; continuing regulation via PBR

-Other aspects of structural evolution less clear: the inherent uncertainty of markets

-The point of relying on markets is that we don't know the best outcomes in advance

-Forecasts today of five or ten years in the future are almost certainly off the mark

-with that caveat/disclaimer, turn to what is happeing and may unfold

III. The Industry as it has been Until Recently

- vertical integration, franchise monopoly or the equivalent: this is ending

- thoroughgoing regulation at state and federal levels; monopoly the norm: ending also

- (exception- has been movement toward a competitive wholesale market)

- Traditional regulation (briefly), resource planning, impact of environmental constraints
  - application of specific technologies (include. clean coal) in this framework

- The rise of integrated resource planning (IRP); state and federal policy
  - evaluation of successes and failures
  - regulatory freedom to pursue specific goals: a "benefit" of monopoly
  - the pursuit of economic rents; rent capture for the policymaker
  - Ability to set prices and price structures administratively; w/o reference to cost
  - Extended ability to apply specific technologies in an IRP setting
    - clean coal

- The Critical Shift:

- The substitutution of markets for central planning; inconsistency with traditional practice

- Reduced control by firms and regulators. Shift of power to customers

IV. The critical factors: price, and cost

- link to wholesale
- excess capacity
- alternatives for large customers
- the economic development imperative
- environmental concerns, an uncertain factor

V. The movement to allow customer choice in the states
- California
- the northeast; esp. Massachusetts, R.I. and N.H.
- others such as Texas, Wisc.
- only a few states not at least studying the problem

VI. The federal government
-EPAct
-FERC
  Order 888, 889
- Congress ??
- the end of PURPA and PUHCA? rationales and inconsistency with competition
- antitrust issues ??

VII. Elements of the process , rationales , implications and new requirements

THE END GAME

1. Choice; for all customers

-not simply cost shifting or passing the buck

2. All customers share benefits
   - idealized goal, or realizable end point?
   - link to today's rate structure: an opportunity or a limitation?
   - market driven, cost driven prices and price structures

3. Preparing for the future: more cost based rate structures today
   - must also allow flexibility and opportunities for rebundling services (competitively)
   - must allow for subsequent repricing of bundled services (competitively)

4. Functional separation of electric companies into generation, transmission & distribution
   - monopoly sector: regulate
   - competitive sector: rely on competition and perhaps traditional anti-trust

5. Independent System Operator
   - broad responsibility for regional transmission reliability
   - independent (?) from electric companies (traditional?, future?)
   - equal access and non-discriminatory terms and conditions for all users

6. Short term pool or power exchange
   - a basis for markets to develop around
   - link to or identical to the ISO??
   - why should there be two entities at this level?
   - issue: allowing markets to evolve their own institutional structures

7. Universal Service
   - low income, etc., issues

8. Environmental
   - traditional regulatory involvement (PUCs) versus independent environmental regulation

   - the end of IRP? Essential distinctions

9. Full competition in generation and retail marketing

10. PBR and price cap regulation: The end of rate of return

THE TRANSITION PROCESS

11. Stranded costs and policies
    - historic and sunk costs
    - utility, IPP "uneconomic" costs
    - future "uneconomic" costs

12. New foundations for old policies
- separation of electricity policy goals from other goals: a new coordination
- environmental goals
- social and low income goals
- tie to clean coal and similar technology- specific goals
- explicit mechanisms and goals

VIII. Conclusion

- breaking free from traditional thinking
- redefining approaches to our goals
- remebering: it is the ultimate, not the instrumental goals that really count

Environmental Issues Affecting Clean Coal Technology Deployment

Michael J. Miller
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I. INTRODUCTION

I appreciate the opportunity to "set the stage" at this important conference on the topic of environmental issues affecting deployment of Clean Coal Technologies (CCTs). As you all know, environment was the driving force behind the DOE CCT program. At the time the program was initiated, the primary environmental issue for which CCTs were being demonstrated was acid rain compliance. Since then, the environmental drivers in the US affecting electric generation have become even more complex, competition/restructuring/deregulation/re-regulation (whatever nomenclature you want to use) has also been added to the mix, and natural gas availability (and its competitive price) has had a major effect on coal markets. On the international front, the role of environment is somewhat different in its impact on the selection of power generation technologies. This difference is particularly noticeable in the developing economies where coal is increasingly the fuel of choice.

In this overview presentation today, I will outline what I consider to be the key environmental issues affecting CCT deployment both in the US and internationally. Since the international issues are difficult to characterize given different environmental drivers in various countries and regions, the primary focus of my remarks will be on US deployment. However, I will attempt to make some general remarks, particularly regarding the environmental issues in developing vs. developed countries and how these issues may affect CCT deployment.

Further, how environment affects deployment depends on which particular type of clean coal technology one is addressing. I do not intend to mention many specific technologies other than to use them for the purposes of example. I will generally categorize CCTs into 4 groups since environment is likely to affect deployment for each category somewhat differently. These four categories are:

- Precombustion technologies such as coal cleaning
- Combustion technologies such as low NOx burners
- Postcombustion technologies such as FGD systems and postcombustion NOx control
- New generation technologies such as gasification and fluidized bed combustion

II. KEY ENVIRONMENTAL ISSUES

I will mention 8 environmental issues that I feel will, over the next 5 to 10 years affect deployment of Clean Coal Technologies. Not all are as important as the others in terms of their affect on CCT deployment; therefore, I will focus my attention primarily on issues related to air emissions and mention only in passing issues related to waste (by-products is the term I will use) and water.

1. NOx and SO_2 Controls

Let me start with NOx and SO_2 controls. There are 3 regulatory initiatives affecting NOx and SO_2 reductions from electric utility boilers (and other large combustion sources as well) in the US. These include the ambient standards for ozone, ambient standards for fine particulates and the acid rain provisions of the 1990 Clean Air Act Amendments.

Acid Rain

The passage of the 1990 Clean Air Act Amendments focused heavily on reductions of SO_2 and NOx to reduce the precursors of acid rain (Title IV). The USEPA is still in the process of implementing this program. Phase I of the program is complete. EPA just recently announced NOx limits for the Group II boilers (cyclones, cell and wet bottom boilers) and the Phase II boilers (the other tangential- and wall-fired boilers not covered in Phase I). These new, proposed limits are quite stringent and, if implemented will likely entail retrofit of technologies that were demonstrated during the DOE Clean Coal Technology program, as well as others independently demonstrated by utilities, often in collaboration with EPRI.

For example, boilers with cell burners will likely have to meet an emission limit of 0.68 # NOx/ MBtu under the latest EPA proposed standard. The DOE CCT program demonstrated a low NOx burner for this class of boilers and assessed the levels of NOx reduction this technology could achieve. While it is still unclear if this will be the final limit, the technology demonstrated under the CCT program will likely be used to meet this proposed limit with some caution for accelerated corrosion. The market here is 36 boilers with a capacity of 24 GW.

As the other parts of the Phase II program are implemented, it is likely that other CCTs will be employed as well. For example, EPA's proposed NOx limits for the Phase II tangentially-fired boilers is 0.40 # NOx/MBtu which will be a challenge to meet in all cases. Approximately 300 boilers are affected and it is likely that technologies comparable to the most sophisticated of the set of LNBs evaluated under a Round 2 project (LNCFS-3) will be applied.

Most utilities complied with the SO_2 requirements in Phase I through fuel switching rather than use of FGD systems. Phase II will require additional SO_2 reductions such that the 10 million ton goal required of the Clean Air Act will be met. It is likely that FGD will play a somewhat larger role than in Phase I--how much larger will depend on other regulatory pushes to be discussed later. To the extent that FGD will be used, it is likely that systems demonstrated under the CCT program, such as the high velocity, single reactor vessel Pure Air scrubber or jet bubbling reactor (CT-121) will be deployed. Depending on the date by which a utility must comply, given any allowances it has banked, it may use even newer emerging technologies that enhance the processes demonstrated under the CCT program.

Internationally, there may now be less of an emphasis on ultra-high SO_2 and NOx reductions. In the developed countries of Europe, retrofits for NOx and SO_2 have already been accomplished using the best systems available in the late 1980s. In developing countries, environmental standards are usually dictated by lending institutions or newly formed environmental regulatory agencies. Typically, NOx emissions are met through use of low NOx combustion systems while utilities and new project developers look for the lowest cost SO_2 controls possible. These can be wet scrubbers, but often are spray dryers, alone or in combination with cleaned or naturally occurring low-sulfur coal. Of course, coal cleaning is a CCT, especially advanced technologies such as Care Free™ coal.

Attainment of Ozone Standards (Title I)

Title I of the Clean Air Act also established deadlines for compliance with the ambient air quality standards for ozone. This problem is most acute in the eastern US. The primary contributors to ozone formation are NOx and volatile organic compounds (VOCs). Electric utilities contribute about 1/3 of the NOx emissions with the remainder from mobile sources and other combustion sources. The USEPA has just proposed a new (and more stringent) ozone ambient air quality standard which adds more complexity to this situation. A process is now underway (referred to as the Ozone Transport Assessment Group or OTAG) to determine the degree to which NOx must be reduced and from what sources to meet the current ozone ambient standard.

While OTAG plans to issue its final report in the Spring, it is anticipated that further stationary source NOx reductions may be required beyond what is necessary for Title IV compliance. Depending on the outcome of the OTAG process, EPA's own actions, and the final ozone ambient standard, it is possible that postcombustion NOx systems (selective and non-selective catalytic reduction --SCR/SNCR) will be required on some coal-fired boilers. SCR was also part of the CCT program which developed important information regarding its applicability and limitations, in particular, when burning high to medium to high sulfur coals. Simultaneously, EPRI and several of its member utilities demonstrated the applicability and limits of SNCR to a number of new sources, such as cyclone boilers and wet bottom units.

Fine Particulate Standard

The USEPA also recently proposed a revised particulate ambient air quality standard with the focus on fine particulates (<2.5 microns in diameter). While the exact composition of fine particulates is still not clear, the focus for controls is likely to be NOx and SO_2. Again, depending on the outcome of this debate, further combustion and postcombustion NOx controls and additional FGD may be required beyond that of the Title IV acid rain provisions of the Act.

Because of the relationship between these 3 regulatory inititatives and the fact they could be imposed in a piecemeal fashion, EPA has proposed a Clean Air Power Initiative (CAPI) which would combine these into one rulemaking effort. Without going into the details, the general proposal is for a 50% reduction in SO_2 beyond Title IV Clean Air Act Amendment requirements plus OTAG-wide NOx overage emissions limits of 0.15 to 0.20 #/MBtu with allowances and trading.

2. Air Toxics (Hazardous Air Pollutants)

This issue was also addressed as part of the 1990 Clean Air Act Amendments (Title III). Without going into all the details behind this issue, let me just say that EPA has issued a draft report and concluded that the risks associated with air toxics are low but it is not clear whether regulation of existing sources will be required. The focus for potential controls of coal-fired boilers appears to be on mercury emissions. If this is the case, no current technology exists to control mercury from coal-fired boilers to any great degree other than FGD systems, and then only if the mercury is primarily in its oxidized form. Tests on advanced generation technology (e.g., IGCC) showed emissions of most toxics, including mercury, to be similar to conventional coal plants with FGD systems and particulate controls.

Thus, air toxics would not appear to be a significant driver of CCT deployment in the US. Internationally, air toxics has not emerged as a major issue except in a few developed countries.

3. Global Climate/Greenhouse Gases

Global climate is probably the most important environmental issue affecting the future deployment of CCTs, particularly those involving new, more efficient cycles. It now appears that some mandatory programs with specific deadlines may be agreed to for the developed countries at the next Conference of the Parties this year in Japan. If there is any hope of stabilizing the increase in CO_2 emissions, electric generation technologies which produce less CO_2 per unit of electricity output or ton of coal burned will be a must. CCTs such as IGCC or advanced PFBC cycles are two examples. Further, improvements in combustion efficiency of pulverized coal plants can also help reduce CO_2 emissions increases. Obviously, natural gas has a distinct advantage here as will be pointed out by several speakers at this conference.

The growing economies in the developing world are expanding their electric generation capacity rapidly (e.g., 2000 MW/month in Asia). To date, most of this generation demand is being met by conventional pulverized coal plants, not even those with with the highest efficiency cycles such as supercritical boilers. Obviously, natural gas is, and will also continue to play a role in future generation world-wide where it is available. However, given the remaining reserves of coal worldwide and its cost advantages, coal is likely to be used extensively as most projections have shown.

Depending on the outcome of the greenhouse gas debate, the future of CCTs could either be very gloomy or quite promising. The gloomy forecast is that CO_2 restrictions are so onerous that coal cannot compete if these restrictions are to be met. On the other hand, high efficiency, generation-based CCTs could emerge as the key ingredient in meeting much more modest goals. In my opinion, this issue is probably the most critical for the generation-based CCTs in terms of future deployment.

4. Solid By-Products and Water

When we discuss environmental issues affecting CCT deployment, we tend to focus on air issues. Admittedly, these typically are the biggest economic drivers for siting new coal-based generation and retrofitting existing coal plants. However, technologies which use less water, discharge fewer solid and liquid by-products and produce salable by-products should have an advantage in the future. For example, at EPRI we are seeing an increased interest in funding R&D related to finding new uses for fly ash. Rather than incur a disposal cost ranging from $5 to $40 per ton, ash sales can generate revenues of similar magnitude. Thus, a liability is turned into an asset. In a competitive industry, this means money and the opportunity to sell more "clean" electricity. This same conclusion applies to FGD systems that produce a salable gypsum. Further, water is becoming a more limited resource and CCTs that have higher cycle efficiencies and produce less lower volume discharges will also be favored.

5. Competition/Industry Restructuring

While not an environmental issue per se, the rapid restructuring of the electric utility industry, particularly in the US, has environmental issues intertwined within it. For example, it has been argued that, in a deregulated market, midwestern power plants that rely heavily on coal (and have relatively lower cost electricity) will increase their capacity factors at the expense of higher cost plants in the eastern US. In turn, these midwest plants will generate increasing amounts of NOx which may be transported eastward, thus making it even more difficult for these regions to attain the ozone ambient standards. As mentioned above, the OTAG process is examining the role of transported pollutants. Depending on the outcome of these studies and the pace of restructuring, deployment of low NOx technologies (SCR, SNCR and advanced burner designs) on coal plants could be rather extensive.

Gas seems to be the fuel of choice now for new generation. However, speculation abounds on the length of the gas bubble. Renewables are still expensive. Thus, when the time comes for new coal capacity to be built, competitive companies will be looking for CCTs that offer significant environmental and cost advantages. As the industry increasingly comes to grips with its new business environment, I believe there will also be those who will be willing to select CCTs which offer significant cost and environmental benefits to gain competitive edge.

6. Public Image/Toxics Release Inventory

Coal has always been viewed as "dirty." The USEPA is also now planing to require all oil- and coal-fired power plants to report emissions from a list of over 600 chemicals as part of the Toxics Release Inventory (TRI). Given the number of chemicals which must be reported and the large amount of coal burned, the reported quantities for even "clean coal plants" could be large which will place many coal burning utilities high on the lists of "polluters" and do nothing to enhance the image of coal as a clean fuel. What impact this issue may have on CCT deployment is unclear at this point. But combined with the NIMBY issue, siting for new coal-based power plants could be difficult both in the US and many other parts of the world. There also appears to be a growing interest in "green marketing" of clean energy which again puts coal-based generation at a disadvantage. CCTs which greatly minimize air, solid and water emissions could find some favor even if their economics are very close to standard, but more polluting designs. The degree to which such a market could emerge is not clear.

7. Growing Population/Demand for Resources

As developing economies expand and population continues on its exponential growth curve, the environmental implications are enormous. Demand for energy resources, water, and food will continue to grow. Coal obviously must play a role in supplying energy needs and CCTs will be critical in that capacity. This issue is one issue that I will let you debate as part of this conference as it is politically and economically very contentious. The global climate issue and this much broader one can potentially be the two largest issues affecting CCT deployment in the early parts of the next century.

8. Role of Electrotechnologies

This is one issue which is not necesarily considered when it comes to environmental issues affecting clean coal technology deployment. From the introduction of the electric car, to the silicon resolution, to infrared drying, to efficient lighting, to electric arc furnaces, electricity is likely to gain increasing use in our everyday lives. Studies have shown that not only are there cost advantages in the use of electro-technologies, but environmental advantages as well.

III. SUMMARY

Environmental issues are what initiated the DOE CCT program and will continue to be a major factor in CCT deployment. Environmental issues could either be a boon or a bust to CCT deployment depending on the degree and pace of environmental regulation in the US. Deregulation/restructuring of the electric utility industry will also have an effect on deployment but to what degree it is not clear. It is likely that retrofit CCTs for NOx in particular will have a significant market given existing and proposed emissions limits. Opportunities for advanced SO_2

technologies (such as Chiyoda, SHU and the Pure Air process which were demonstrated in the DOE CCT program) will also depend on some of these emerging regulatory scenarios. Advanced generation CCTs with their inherent environmental advantages are now too expensive and the market for new generation is now primarily gas.

Internationally, how environmental issues will affect deployment is less clear. I am not aware of any other environmental issues affecting deployment outside the US that I have not discussed in the context of the US. It now appears that lending institutions such as the World Bank are becoming the international EPA in terms of SO_2, NOx and particulate standards for a new coal-based generation. Global climate is the issue which is the most international in scope and certainly is the key one in terms of how CCT deployment will be driven in the future.

Thank you for this opportunity to share my thoughts with you. I am not sure I raised any environmental issues which are new to anyone in this audience. My charge was to set the stage and to make sure all issues are on the table now so their implications can be debated as the conference proceeds.

Luncheon Address

Issue 4: CCT Deployment: From Today Into The Next Millennium

CLEAN COAL TECHNOLOGY DEPLOYMENT: FROM TODAY INTO THE NEXT MILLENIUM

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I. INTRODUCTION

The Department of Energy's clean coal technology (CCT) program succeeded in developing more efficient, cleaner, coal-fired electricity options. The Department and its private partners succeeded in the demonstration of CCT--a major feat that required more than a decade of commitment between them. As with many large-scale capital developments and changes, the market can shift dramatically over the course of the development process.

The CCT program was undertaken in an era of unstable oil and gas prices, concern over acid rain, and guaranteed markets for power suppliers. Regulations, fuel prices, emergence of competing technologies, and institutional factors are all affecting the outlook for CCT deployment.

I've been asked by the organizers to identify the barriers to CCT deployment and to challenge the speakers in Panel 4 to consider how these barriers might be overcome. Below, I discuss the major barriers, and then introduce some possible means to surmount the barriers.

II. BARRIERS

The growth in the market share for clean coal technologies will be driven by institutional/regulatory structure, environmental issues, and costs (both capital and fuel).

The demand for new capacity is addressed by another panel. Bechtel's capacity addition forecasts show that 95 percent of new coal-fired capacity will be built in two of our four geographic regions--1. Europe, Africa, Middle East and East Asia and 2. Asia Pacific (Table 1). The largest markets for coal-fired capacity within these regions will be India, China, and Indonesia, with markets also in Eastern Europe, and South Africa. Only one-third of world capacity additions will be coal-fired. Natural-gas-fired capacity is expected to be the technology of choice in North and South America, as well as much of Western Europe and the Middle East.

Institutional Barriers

Deregulation

Let's examine the institutional/regulatory issues in the US, where we've made the large investment in developing clean coal technologies, in the expectation that they would meet a significant need in the US.

Today, the market for new capacity additions in the US is not large. The major political factor influencing the US electricity market is deregulation. Uncertainty over the impact of deregulation on utilities is causing them to postpone many capacity additions. In addition, deregulation affects the independent power producers, while they await the impact of deregulation on issues such as future cost recovery.

Deregulation of the US market will lead to a big market shake-up during the next five to seven years. A larger number of players have entered the market in the past few years and more are likely to follow, leading to increased competition in the near-term. It will be a buyers' market--increased competition disfavors longer-term purchase agreements. Under such market instability, suppliers won't commit to building large coal-fired power plants (>400 MWe). Even if a supplier wishes to build one, without an assured long-term market, the supplier is unlikely to get external financing. The market outlook will certainly be too risky to use equity financing. The independent power producers have already exploited most of the desirable sites for coal-fired power plants (e.g., next to a large industrial user). Easily installed capacity in modest sizes (i.e., gas turbines) will be the technology of choice in early phases of deregulation.

In the later stages of deregulation, competition could result in large generators' (i.e., utility) mergers, and a shake-out of IPPs, meaning there would be fewer suppliers in the market. However, technology choice might also begin to affect the market, i.e., centralization versus decentralization. For example, continued progress in "mini" turbines, fuel cells, and alike, could allow businesses, housing complexes, and even homes to have a power plant in their basement, which might be a very attractive choice if the power quality problems (expected to occur with deregulation) don't get solved.

Deregulation is spreading. In Western Europe, the United Kingdom is privatizing their power market, and new players (such as North Sea oil and gas producers) are entering the market (although new, coal-fired power plants are still being built, as well.). The extensive deregulation occurring in the US may well spread to other OECD countries, assuming there are positive results from US deregulation.

Other Institutional Factors

In the two largest markets, India and China, institutional factors can affect capacity choices in other ways. In India, regulations are quite specific to individual states.

Building a standardized power plant in several states may be difficult, which can pose barriers to building optimized, inexpensive (i.e., standardized) CCT plants.

World Bank financing, a common source in India, can favor CCTs, by requiring that environmental factors be taken into consideration for capacity choices.

China prefers to build its own boilers and other components, which will favor cheap, simple technology, a barrier to CCT. However, outside financing and international institutions could accelerate the adoption of local regulations that would promote the use of CCT.

Growing developing country markets pose a problem to national governments as well as outside investors. Despite the rationalization of prices encouraged by development banks, there is still a tension between increasing the standard of living by providing cheap electricity versus recovering full costs in major capital investments. Perceived political risk in certain countries will also disfavor large, fixed, capital investments in one country by outside investors.

Environmental Barriers

As stated earlier, the CCT program was undertaken when acid rain was a major concern, especially with respect to burning higher sulfur coals. The clean coal program successfully demonstrated virtual elimination of precursors to acid rain. Today, global warming has emerged as a major environmental driver. Carbon dioxide is seen by the public and some of the technical community as the key component in global warming. Carbon dioxide emissions has therefore become one of the biggest technical challenge to future, environmentally-benign coal consumption .

Coal-fired electricity generation releases relatively more greenhouse gases than does combined-cycle, combustion-turbine technology (CCCT). However, the efficiency increases of CCT will decrease CO2 emissions significantly, relative to standard coal technologies, such as atmospheric fluidized bed combustors. Therefore, CCT certainly helps with the greenhouse gas problem resulting form coal consumption, but doesn't solve it as shown in Table 2.

If the international community ever agrees upon greenhouse gas emissions quotas, the quotas could encourage use of CCT relative to conventional coal capacity, but perhaps generally discourage coal use, relative to natural gas use.

The joint implementation (JI) program is off to a rather weak start. JI could, however, subsidize CCT in developing markets, where the technology of choice might have been conventional coal technology. JI could also favor more natural gas technology, however.

Repowering and retrofitting have been proposed by many as one of the solutions to revitalize the aging US power industry. However, there are other environmental considerations that affect the market for CCT. Environmental regulations in the US discourage retrofits of coal-fired power plants. For example, retrofitting a plant makes it subject to updated emissions requirements, and also requires asbestos removal, etc. These regulations/environmental factors discourage retrofitting older coal-fired capacity with new CCT.

Cost Barriers

Table 3 shows Bechtel's projections of levelized life-cycle cost per kilowatt hour for a number of electric generating technologies. The figure demonstrates that cost poses a significant barrier to CCT adaptation, even though the cost of CCT could approach that of conventional coal-fired generation on a levelized life-cycle cost basis.

Capital Costs

The capital costs of coal technologies are at least twice the capital costs of CCCT (i.e., 2.2 to 2.9 c/kwh for coal-fired capacity compared to 1.1 c/kwh for CCCT). From a front-end investment standpoint, the cost of coal-generation certainly disfavors coal-fired capacity relative to gas-fired generation. Capital investment is also the major factor in choosing capacity type if outside financing is sought.

The near-term potential to decrease the capital cost for CCT lies in system optimization (e.g., be less conservative in redundant systems while maintaining reliability). Total system optimization can be difficult to achieve until a number of CCT plants are built, however. Even then the system optimization improvements won't halve CCT capital costs. If one expands the definition of "system" from the power plant components to a more expanded system, including fuel production, delivery, combustion, and electricity transmission, there are further economies to be captured. Whether this integrated energy system based on coal can compete with integrated systems based on natural gas remains to be seen.

The longer-term potential to decrease CCT capital costs will come from new technologies, such as ceramic membrane technology to decrease the cost of oxygen production for technologies that can benefit from an enriched oxygen source, such as IGCC. Unless we invest in these developments, however, these new technologies won't be built.

O&M Costs

O&M costs (excluding fuel) are not major differentiators for the capacity choices. The further development of "smart" operating systems are likely to further decrease the costs of running electric generators. This enhancement should benefit all technologies, but CCT, which tend to be more complex, should benefit more.

Fuel Costs

Fuel costs are relatively a much larger component of the total cost of electricity from natural-gas fired plants than they are for coal. In the absence of any decrease in capital costs, natural gas costs would have to increase significantly for a sustained period to " level the playing field" (on a levelized life-cycle cost basis) between CCCT and CCT. Natural gas costs would have to increase by about 50 percent (about $1.5 per MM Btu) relative to coal to make CCT competitive with CCCT. The natural gas price increase would have to be sustained. However, long-term natural gas price expectations generally are fairly flat. Deployment of advanced natural gas processing technologies (e.g., Fischer Tropsch) could help ensure natural gas price stability at current levels. This outlook for natural gas prices makes CCCT hard to beat on a life-cycle-cost basis, except in markets with an abundance of cheap coal and/or wastes for combustion in CCT.

III. CHALLENGES TO MARKET INTRODUCTION OF CCT

The foregoing has demonstrated the significant barriers that are presented for the widespread introduction of CCT. The question then is how does one make coal more competitive with its fossil competition? How can widespread market introduction be accomplished? This can be done by looking at the differences between coal and the alternatives and developing strategies to minimize these. The challenges below are technical ones; an alternative or complementary approach is to pursue regulatory or policy changes to effect some of the institutional barriers outlined above.

Make Coal "Look" Like Other Fossil Fuels

The variability of coal makes it difficult to take full advantage of standard plant designs (which are the cheapest). Therefore, one needs remove, as much as possible, the differences among coals of equal rank. This entails beneficiation, washing, etc. Coal blending is one method already being practiced in some cases to improve plant availability and stabilize sulfur control systems.

An additional consideration is that natural gas and oil are delivered by suppliers in an integrated manner. Therefore, we need to use an integrated, systems approach to coal preparation and delivery (mining, grinding, cleaning, transport, and the method of utilization), i.e., break apart the old "silo" approach among mining firms, transportation (railroads), and utilities/IPPs. Coal-water slurries are one example of such integration. CCT's, such as IGCC and PFBC have already demonstrated the ability to use slurries to feed coal at high pressure.

Improve Coal's Environmental Performance

The most important need here is to increase the overall efficiency of coal utilization thereby decreasing the pollutant unit per kwh or per ton of coal. As stated earlier, CCT have increased efficiency, but current initiatives by DOE, included in Combustion 2000 (and other programs) will further increase the fuel efficiency for pressurized, fluidized bed combustion, IGCC, and other CCT.

Removing coal variability as proposed above also enables more of a standardized approach to CCT. CCT is fairly flexible, for example, with minor design changes it can handle coals range from 1 to 4 percent sulfur and beyond. Further fuel flexibility could improve plant standardization.

"Blending" coal with other fossil fuels can also mitigate environmental impact. Blending can be done in a dual fuel approach or in an incremental approach as noted below. The use of natural gas in the pressurized fluidized bed topping cycle is an example of blending that improves environmental performance.

Reduce Costs on a Net Present Value (NPV) Basis

For certain technologies, we could look at how the plant can be built for dual-fuel capability in one of two ways. The first approach is to build a CCCT plant leaving space to add coal handling equipment to convert to coal as fuel prices change. The second approach is to build the plant for dual-fuel capability right from the start and mix and match as fuel prices and national interests dictate. The latter approach is a variant of the solar hybrid concept (in reverse).

Another way of improving the NPV is through environmental subsidies, i.e., recognizing that the use of indigenous fuels is desirable, but that such fuels (coal) are only competitive in the current market if environmental pressures are relaxed, a policy could be developed which would give incentives for the use of state of the art CCT. Such incentives may be provided by the Global Environment Facility, or other lending agencies involved in the country under question.

Yet another way to incrementally improve the NPV of CCT is by developing a market for the CCT with low-price fossil fuels other than coal, i.e., heavy oils, petroleum coke, orimulsion, biomass, etc. This expansion of the market for CCT could speed plant optimization. A recent announcement by GE and Toshiba that they plan to partner to market IGCC technology demonstrates this approach. Under the agreement, GE and Toshiba expect to furnish the turbine-generator equipment, and to broaden their IGCC market penetration.

IV. CONCLUSION

The implementation of clean coal technologies will be difficult for a variety of reasons as we have seen. Innovation and new approaches to commercialization, standardization, and improved environmental performance are keys to more widespread use in the next millenium.

Table 1. Regional capacity additions in gigawatts (based on orders, 1997-2002)

	Total	Natural Gas	Coal-fired	Nuclear	Hydro
North America	46	39	4	-	3
Europe, Africa, and East Asia	124	87	27	6	4
Asia Pacific	165	36	95	24	10
Latin America	57	26	2	1	28

Table 2. Relative Levels of CO2 Contributed to Greenhouse Emissions

	GTCC	PCF w/ FDG	AFBC	PFBC	IGCC	APFBC
Power, MWe	500	500	500	500	500	500
Heat Rate, BTU/kW	8030	10040	10190	8320	7940	7190
Efficiency, %	42.5%	34.0%	33.5%	41.0%	43.0%	47.5%
Fuel Heat Content, MM Btu/hr	4,015	5,020	5,095	4,160	3,970	3,595
Fuel	Nat Gas	Coal*	Coal*	Coal*	Coal*	Coal*
Heat Content, Btu/lb	23,840	13,260	13,260	13,260	13,260	13,260
Fuel Feed, lb/hr	168,410	378,580	384,240	313,730	299,400	271,120
Carbon, lb/hr	126,310	279,390	283,570	231,530	220,960	200,090
Sulfur Content, lb/hr	0	7,950	8,069	6,588	6,287	5,694
Ca/S	0	1.01	2.6	1.3		1.9
Limestone required, lb/hr	0	26,690	69,750	28,470	0	35,960
CO2 from Fuel	463,140	1,024,430	1,039,760	848,940	810,190	733,660
CO2 from Limestone	0	11,740	30,690	9,640	0	8,330
Total CO2	463,140	1,036,170	1,070,450	858,580	810,190	741,990
Normalized of AFBC	43.3%	96.8%	100.0%	80.2%	75.7%	69.3%

* Based on Pittsburgh Seam Coal

Table 3. Levelized lifecycle costs for alternative electric generating technologies

400-600 MW range

	PC (steam coal)	**CCCT (nat. gas)**	**PFBC (waste/low grade coal)**	**IGCC (waste/low grade coal)**
Capital c/kWh	2.2	1.1	2.6	2.9
O&M c/kWh	0.6	0.4	0.6	0.9
Fuel c/kWh	1.2-2.2	2.0-3.4	0.6-1.2	0.5-1.0
- based on deliv'd $/MMBtu range:	1.50-2.50	2.50-3.80	0.60-1.20	0.60-1.20
Total lifecycle busbar cost	**4.0-5.2**	**3.5-4.9**	**3.8-4.6**	**4.3-4.8**

1400 MW range

	LNG CCCT	Nuclear ABWR
Capital c/kWh	1.6-1.2 (2x1400 MW)	4.5-4.0 (2x1400 MW)
O&M c/kWh	0.5	1.0
Fuel c/kWh	2.5-3.3	0.6
- based on deliv'd $/MMBtu range:	3.50-4.50	0.60
Total lifecycle busbar cost	**4.2-5.4**	**5.6-6.1**

Note: The cost competitiveness of these technologies will depend for a large measure on local fuel availability and pricing. Fuel is the most widely varying cost factor for all technologies except nuclear.

Panel Session 1

Issue 1: International Markets For CCTs

REGIONAL TRENDS IN THE TAKE-UP OF CLEAN COAL TECHNOLOGIES

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ABSTRACT

Using surveys of the electricity industry taken in major OECD coal producing/coal consuming regions of North America, Europe, Southern Africa, and Asia/Pacific, this paper reports on the attitudes of power plant operators and developers toward clean coal technologies, the barriers to their use and the policies and measures that might be implemented, if a country or region desired to encourage greater use of clean coal technologies.

I. INTRODUCTION

The Coal Industry Advisory Board (CIAB) serves the International Energy Agency (IEA) as an advisor on issues related to the coal and electricity industries. The CIAB is made up of representatives selected by the governments of the IEA member countries. A series of three papers on industry attitudes toward clean coal technologies for power generation and the factors affecting the take-up of these technologies have been produced by the CIAB for the IEA. As a result of the information put forth in those papers, the IEA Secretariat requested the CIAB to provide its perspective on the potential for the electric power industry to take-up advanced, energy efficient, coal-fired power generation technologies (hereafter referred to as "clean coal technologies") in the near and medium time frame. The CIAB has prepared a report, which is now under review, that presents a region by region assessment of the evolution of these energy efficient, coal-fired technologies by identifying the attitudes towards them, barriers to their take-up, and policies and measures that might be adopted to overcome these barriers. The regional assessment approach is based on the generally accepted premise that the adoption of clean coal technologies will be a function of differing technological, environmental and economic constraints from region to region. While actions on these policies and measures may involve many players, the IEA is particularly interested in CIAB's views on those actions which governments and industry might consider.

The CIAB solicited the views of its members as well as others with electric power industry expertise within four OECD regions of the world, North America, Europe, Southern Africa and Asia/Pacific. Because the previous CIAB studies indicated that a significant amount of the growth in electric generating capacity was projected to occur in the non-OECD countries and particularly the Asia/Pacific region, the CIAB decided to devote a special effort to assessing the attitudes towards the clean coal technologies held by those independent power producers (IPP) who would most likely construct power generation facilities in the developing countries of the Asia/Pacific region. However, the results of the IPP survey are not reported here, but can be found in a paper entitled "Increasing the Efficiency of Coal-Fired Power Generation, State of the Technology: Reality and Perceptions? prepared by Shell Coal International, London, England and SEPRIL Services, Chicago, Illinois.

The clean coal technologies assessed include:

- retrofitting of enhanced controls/repowering existing plants
- the installation of advanced, more efficient steam cycle plants as described in Industry Attitudes To Steam Cycle Clean Coal Technologies, Survey of Current Status (OECD/IEA 1995)
- the development and commercial application of combined cycle technologies as described in Industry Attitudes To Combined Cycle Clean Coal Technologies Survey of Current Status (OECD/IEA 1994)

Again, because the Asia/Pacific region is projected to experience a significant increase in the amount of electric power generating capacity and the technology that is expected to be utilized most often is conventional subcritical pulverized fuel (PF) technology, the CIAB decided to contrast the capital costs, operation and maintenance expenses, reliability of operation and environmental emission characteristics for the conventional PF technology with those of one commercially available clean coal technology, supercritical PF. These results can also be found with the IPP survey results referenced above.

As was deemed appropriate for each region the assessments include:

- consideration of the growth in the demand for electricity in the region and the corresponding generating capacity that will supply that demand segregated by fuel type and technology to the extent possible.
- consideration of the degree of take-up of the clean coal technologies before 2015.
- consideration of likely relative capital costs and the effect on the price of electricity from the clean coal technologies, compared with existing technologies (e.g. taking into account the higher rates of return on investment required to compensate for the perceived extra risk).

- consideration of any extra environmental advantages of the newer technologies. This consideration would need to consider the possibility of the development of more stringent future environmental standards within the region.
- identification of government and private-sector policies, measures and incentives that would enhance the adoption of the clean coal technologies.

This paper summarizes the results of the regional assessments.

II REGIONAL ASSESSMENTS

The attitudes of power generators, both utility and independent power producers, towards the clean coal technologies is expected to be different from region to region because attitudes are influenced by differing technological, environmental and economic constraints. The following discussion is an assessment of these differing attitudes and their implications on the take-up of the clean coal technologies in each region.

OECD North America

Regional attitudes in North America were assessed by examining Canada and the United States.

Canada

The attitudes of the Canadian utility industry towards the take-up of the clean coal technologies is taken from a report entitled "The Potential for Energy Efficient Coal-Fired Power Generation in Canada", prepared by Edmonton Power. This assessment is a compilation of responses from utilities in Canada which collectively represents almost 97% of Canada's electricity generation and all existing coal-fired generation.

Canada is extremely large geographically and, therefore, a diverse nation in many respects, not the least of all in electricity generation. Coal, natural gas and hydro power are readily abundant depending on the Province in question. Nuclear power has been developed extensively in Eastern Canada. Since 1980, new generating capacity has been installed in all parts of the country embracing all "conventional" technologies" with hydro, nuclear and subcritical PF being the dominant technologies. Only one advanced technology has been installed during this period, a 182 MW AFBC unit in Nova Scotia during 1995.

Generating capacity is forecasted to increase 2.8% by 2000 with further increases of 3.0%, 4.3% and 3.4% respectively in each 5-year block until 2015. This represents a modest annual growth rate of 0.68%, while energy consumption is expected to increase by 1.38% per year until 2015. Of the new capacity being added, 15.9% is expected to be coal-fired and 49.8% is expected to rely on natural gas. Repowering with the addition of a gas turbine and life extension with improved unit efficiency will also play major roles in fulfilling new capacity requirements.

In choosing the types of new capacity, capital and fuel costs were cited as the top two determining factors, followed by environmental considerations, plant availability, return on capital invested, construction time, and security of fuel supply. In those Provinces where deregulation is occurring, the higher risk of not recovering costs makes the reduction of investment risk through shorter planning, design and construction times a key factor. CO2 is considered the most important environmental factor, followed by SO2, NOx and siting considerations.

The potential for the take-up of the clean coal technologies in Canada is relatively low with the limited addition of coal based capacity. The expressed interest is in IGCC technology to be installed after 2006. Interest in the other technologies will be dependent on their commercial maturity and economics in the same time frame.

The barriers to the clean coal technologies are increased deregulation of the electric industry with the delay of long-term decisions due to uncertainty, increasing environmental limitations and costs associated with coal-fired technologies, increasing complexity of financing arrangements and in a deregulated market, gas will be very competitive with coal.

In those locations where gas is readily available and competitively priced, it will act as a barrier to the take-up of clean coal technologies. In addition, proof of performance in the areas of environment, reliability, operability and power cost at a commercial scale in a utility environment is needed. Similarly, the capital cost and construction time of the clean coal technologies must be reduced. Proposals under consideration to control/tax greenhouse gases are seen as limiting the opportunities for coal based technologies.

Government policies to overcome these barriers should address two areas; funding a substantial portion of up-front R&D and demonstrations consistent with long-term environmental policies and favorable tax/depreciation for environmentally sound technologies requiring penetration assistance.

United States

The attitudes of electricity producers in the US towards the take-up of advanced energy efficient, coal-fired technologies is assessed in the report entitled "Regional Trends in the Evolution of Energy Efficient, Coal-Fired Power Generation Technologies in the United

States", Prepared by Peabody Holding Company, Inc. The assessment is based on published information which reports the results of surveys of electric utilities and independent power producers attitudes towards clean coal technologies. Since 1986 the US Department of Energy (DOE) has been administering a government/industry co-funded program to demonstrate clean coal technologies at a utility scale. The Clean Coal Technology (CCT) program has resulted in a US $6.9 billion effort for the first-of-a-kind or early commercial demonstration of the clean coal technologies that the CIAB has previously reported to the OECD/IEA. The attitudes reported here are influenced by the experiences learned in the CCT program.

Kilowatt hour sales in the US are expected to increase by 31% for the period 1995 to 2015. During that same period net generating capacity additions are expected to increase by 22% or 167 gigawatts (GW). New capacity additions plus replacement capacity for retired units is expected to be 252 GW. Coal-fired capacity additions are projected to increase by 5% or 15 GW. Natural gas-fired capacity will dominate with a 69% increase or 166 GW while nuclear capacity will decrease by 36% or 35 GW. The majority of the nuclear reductions are projected to occur after 2010 when most of the plants' current licenses expire. The projections do not reflect any changes that may occur as a result of the deregulation of the US electric industry.

The potential for the take-up of the clean coal technologies exists in the 252 GW of new or replacement capacity. However, this potential is influenced by a number of attitudes of the user community. The opportunities for base load units are limited before 2000 and increase to some extent between 2000 and 2005. The clean coal technologies are viewed as having higher capital and operating costs relative to subcritical PF technology. Subcritical PF appears to be the coal technology of choice despite the fact that supercritical PF is viewed as a proven, reliable technology. IGCC is viewed as somewhat proven/reliable, while PFBC is viewed as not proven. Strong interest exists in life-extension and improving performance at existing plants. In addition, deregulation is delaying, indefinitely, long-term decisions for additional generating capacity.

The barriers identified to the take-up of the clean coal technologies are many. Coal continues to a have a poor public and political image even though the clean coal technologies offer the promise of significant efficiency improvements and reduced environmental impact. Coal remains the fuel-of-choice for base load applications. Where natural gas is readily available and competitively priced, natural gas will continue as the fuel-of-choice for incremental capacity additions. Concern exists over the future regulation of CO2. Life cycle costs are less important and decisions are being driven by short-term considerations related to financial risk.

Policies and measures that could be implemented center around two areas - technology transfer and economic incentives. The attitudes of the electric utility industry indicated a lack of knowledge and perhaps an excessive degree of risk aversion concerning the commercial status, costs and reliability of the clean coal technologies and, in particular, supercritical PF. A better job needs to be done to market the clean coal technologies by providing more information on risks and costs. This program should be targeted at non-utility generators because of their future role in providing new capacity additions. Finally, without some program of cost sharing to reduce risk, the clean coal technologies are unlikely to be taken-up to any significant extent before 2005. Financial incentives that have been explored are subsidies and special tax/depreciation treatment.

OECD Europe

In Europe, the attitudes of 16 OECD member countries were solicited and the findings are contained in the report entitled "Regional Studies on Evolution of Power Generation, OECD Europe", S-K Power, Denmark. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Spain and the UK responded to the request for information and these 13 countries represent OECD Europe for purposes of this paper. In addition, information was requested for the 20 year period 1995 through 2015. However, not all respondents were willing to provide information for the 2010-2015 timeframe and those that did respond, had strong reservations about the reliability of the data. Therefore, the time frame for OECD Europe information is 1995 through 2010.

The OECD Europe electric power industry expects a fairly constant load growth over the period from 1995-2010, to the order of some 16% growth in capacity and a higher 27% growth in energy use.

As a consequence of the on-going transition of the industry from one of monopolies to a deregulated competitive market, power companies have redefined their earlier strategic/politically based objectives (technological reliability/availability, fuel flexibility and use of indigenous fuels) to economic ones like return on investment and capital cost. At the same time, environmental considerations are expected to continue to play an important role in the future choice of generating capacity.

European power companies expect oil to lose ground as an energy source in Europe over the next 15 years; while coal and nuclear should maintain the status quo; and hydropower should see a small increase. Capacity based on renewable fuels will enjoy a large increase, but even so, it will remain an incremental energy source.

Natural gas fired technologies with their relatively low capital costs and environmentally friendly image will supply most of the growth. This is remarkable because even though most European power companies agree that "Europe is becoming too dependent on imported natural gas", they still plan to select natural gas as their fuel for new capacity.

In comparison to gas, the expectation for the installation of new coal based capacity is low. Coal-fired capacity, that will be built over the next 10 years, will be supercritical PF technology. After 2005, the choice of clean coal technologies will be dependent on their state of development at that time.

The main barriers to the enhanced take-up of the clean coal technologies are economic in nature (e.g. high capital costs) and except for countries already hosting demonstrations of clean coal technologies, a skeptical view of the maturity of the PFBC and IGCC exists. Furthermore, coal has a public/political image problem.

Various proposals have been put forward by the power companies to overcome the barriers to the take-up of the clean coal technologies. As regards high capital costs, suggestions include political support of the continued development and dissemination of the clean coal technologies through subsidies, financing or funding. Preferential treatment in the market place of the electrical output from the clean coal technologies is another possible approach.

When it comes to overcoming the skepticism on the maturity of PFBC and IGCC technologies, the fact that countries hosting the technologies have a strong confidence in their virtues could indicate that a better dissemination of demonstration plant locations could constitute an effective way of proving their commercial readiness to a broader audience.

Finally, proposals to overcome environmental (including public and political image problems) barriers entail providing more information on the virtues of coal as a fuel, e.g. the large and geographically widespread resource base and the advanced technological state of today's coal mining and coal usage facilities. Further, the implementation of closed handling systems at harbors and power plants might be beneficial to coal's image.

Southern Africa

The Southern Africa assessment presents the views of developing countries whose primary emphasis is regional development and the role that power generation plays in that development. Limited information is presented for 15 sub-Saharan Africa countries and detail information is presented for South Africa in the report entitled "Evolution of Power Generation, Southern Africa Study", prepared by the ESKOM Technology Group. During 1995, South Africa accounted for 76% of the generating capacity for the region and produced 83% of the electrical generation. As a result the regional information is to be considered quantitative at best.

The perspective from the Southern Africa region is fundamentally different than for developed OECD countries. Development is focused on local and regional issues and attempts to maximize international cooperation to ensure that development is optimized. This entails securing clean coal technologies during development with the incremental costs above conventional technology being borne by the developed countries. This approach has been referred to as "Activities Implemented Jointly" in the context of reducing environmental impacts.

The 1995 electricity supply and demand situation for the 16 sub-Saharan African countries is one of significant over supply. The region has a total of 46 GW of installed capacity and electricity production totaled 207,545 GWh which represents 52% of the potential production. Under current projections, it is unlikely that additional capacity will be required in the region before the year 2010. Excess capacity in the region may be optimally utilized via the Southern African Power Pool. However, issues such as the reliability of long transmission lines, coupled with individual national priorities could result in additional capacity being built before 2010. Any increase in capacity will, in all likelihood, be met predominately by coal in South Africa and by hydro in the other countries in the region. In addition, South Africa has introduced a demand side management program as an alternative to capacity additions.

In spite of the over supply situation and because future growth is highly uncertain, supply side options are being evaluated for future applications. Clean coal technologies are being evaluated with the objective of reducing lead time, capital and operating costs, environmental impacts and optimizing unit size and load following capability. Environmental impacts focus on local and regional impacts with a lower priority on global impacts.

Clearly the most significant barrier to the take-up of clean coal technologies in Southern Africa is the excess of generating capacity which is expected to exist until after 2010. Other potential barriers include: perceptions of unreliability and higher operating costs, limited local skills and infrastructure, competition from other fuels such as hydro, gas and possibly nuclear. Also the existing capacity is relatively new (11-15 years) and retirement and replacement with clean coal technologies has a low potential.

Realizing that capacity is not needed in Southern Africa till after 2010, options open to both governments and industry to overcome the barriers from a developing nations point of view include means to catalyze economic growth, funding of the premium for the installation of clean coal technologies by the developed nations, demonstrations in developing countries, a robust program for disseminating information on the technologies and development of human capabilities in developing countries.

OECD Asia/Pacific

The assessment of the OECD Asia/Pacific region consists of a compilation of attitudes in three countries: Australia, New Zealand and Japan.

Australia/New Zealand

Australia and New Zealand constitute a region of the world where government has recently promoted competition in the electric power industry. This has developed an opportunistic approach and less certainty in the type and timing of new generation plant additions. The assessment of the take-up of clean coal technologies reflects this change in the electric industry and is presented in detail in the report entitled "Regional Studies On Evolution Of Power Generation Australia and New Zealand", prepared by Sligar and Associates Pty. Ltd., New South Wales, Australia on behalf of CRA Limited.

Load growth in Australia and New Zealand is expected to average 2% per year through 2015. This low predicted growth, coupled with existing reserve margin in some areas and the developing highly competitive situation, will lead to new generation initiatives in the near future. New generation will be incremental in nature and with the deregulation of the Australian gas industry will favor gas as the fuel-of-choice. A major portion of the coal capacity has recently been retrofitted and further refits are scheduled before 2000. The retrofits consist of minor technology advances and it is unlikely that these refits will employ any clean coal technology, e.g. IGCC.

Before deregulation, the energy mix was under the control of the two countries' governments, but now the competitive market will dictate the mix of capacity additions. In this competitive environment, organizations are somewhat reluctant to release their capacity addition plans, but an estimate of minimum likely new generation has been made based on a number of sources and statements in interviews. Likely new generation in Australia is projected to total 16.6 GW by 2015 with 2.2 GW coal, 6.8 GW gas, 5.6 GW renewables, and 2 GW uncommitted. There is 1.5 GW of gas generation available in eastern Australia and 1.0 GW in western Australia which is expected to be utilized by 2000. Installation of gas-fired generation after 2000 will depend on the discovery and development of the production and transmission systems. The likely installation of a new generating plant in New Zealand by 2015 will total 1.7 GW with 0.6 GW gas, 0.4 GW renewables, and 0.7 GW of uncommitted.

Attitudes towards the clean coal technologies in Australia and New Zealand are dominated by the competitive market place and, as a result, clean coal technologies are not under active consideration in either country. However, if that situation were to change, existing and potential generators would evaluate the clean coal technologies using the following factors in their order of importance: required return on investment, environmental and political considerations, and capital costs. Under environmental factors, CO2, then NOx, SO2 and others are the emissions of concern in their order of importance. Where coal technology is under consideration for new capacity, subcritical PF is the technology of choice through 2000. IGCC is projected to be introduced beginning in 2005 and it will become the preferred alternative by 2010. AFBC and PFBC are thought to have limited application.

The barriers to the take-up of the clean coal technologies in Australia and New Zealand are again a direct result of the competitive situation in the electricity industry and can be divided into competition/economic and technical issues. The competitive/economic barriers center on whether the clean coal technologies can provide an acceptable return on investment, competitive capital costs, reduced construction period, and be competitive with gas-fired generation. On the technical side, barriers such as unit size greater than 500 MW, proven reliability, and a lack of information on the technical and cost characteristics are the primary issues. In some instances, existing or new generators had a limited understanding of the attributes of the clean coal technologies.

Beyond the competitive/economic issues, the environment also has a strong influence on the take-up of new technology. The environmental anti-coal lobby is becoming a growing force that must be considered. In addition, there are low cost CO2 mitigation strategies that will be considered before coal-fired technologies.

Consideration of policies and measures to overcome the barriers to the take-up of the clean coal technologies is not a well developed concept in Australia and New Zealand because the clean coal technologies are not under active consideration. In keeping with that situation, there appears to be a limited base of knowledge about the clean coal technologies that needs to be addressed by a better dissemination of pertinent information.

Japan

The assessment for Japan is taken from yearly reports to the Ministry of International Trade and Industry (MITI) prepared by the 10 regional electric utilities. Data on regional demand and demand growth is reported and organized by fuel type. Information concerning the take-up of the clean coal technologies was provided by both major equipment suppliers and the regional utilities. This information has been compiled into a report entitled "Study on Evolution of Energy-Efficient, Coal-Fired Generating Technology (Regional Studies Asia-Pacific)", prepared by the Electric Power Development Company.

The expansion of electricity generation installed capacity will continue to be driven, at least until the beginning of the 21st century, by the concept of diversification of the fuel mix to increase the security of supply. Power generation capacity in Japan is expected to increase by 101 GW through 2010. During the period 1996 through 2005, 70.7 GW of capacity will be added with 10.1 GW hydro, 21.7 GW coal, 26.5 GW LNG plus LPG, 0.4 GW of Orimulsion, 0.1 GW of geothermal and 14.6 GW of nuclear At the same time oil and other gas capacity will decrease by 2.0 GW.

Clean coal technologies will play a major role in the coal-fired capacity being planned. Ultra supercritical steam cycle (USC) technology and PFBC will play a major role in the new coal-fired capacity additions. Candidate projects, so dubbed because all details of the installations have not been finalized, account for 4.6 GW of capacity, 4.1 GW USC and 0.5 GW of PFBC. Japan currently has 16.6 GW of supercritical and USC and 400 MW of AFBC capacity operating in the country as well as a 70 MW PFBC unit. Two additional 350 MW PFBC units are in the planning stage.

Environmental regulation in Japan is becoming more and more severe. Citizen groups are taking a more active role in shaping agreements between the local authorities and the utilities. In some situations power plants have had to install a dry flue gas desulfurization system based on scrubbing with activated char. This advanced emission control system has similar capital costs to FGD and SCR but has higher operating costs due to the activated char.

The Japanese Government has supported the take-up of the advanced flue gas desulfurization and selective catalytic reduction technologies, so far, by establishing a shorter depreciation period of 7 years as opposed to the normal 15 years. In addition, MITI often provides financial support for the demonstration of the clean coal technologies. However, recent moves to deregulate the electricity industry in Japan constitutes a new barrier to clean coal technologies in Japan. As a result, the cost factor and increased competition is causing the utilities to become more conservative in their choice of clean coal technologies and less able to accept long-term returns.

IV. CONCLUSIONS

The following discussion presents specific conclusions from the regional assessments:

OECD North America

- Growth in generating capacity in the region until 2015 is projected to be 204 GW with 21 GW of coal-fired capacity.
- The attitude towards the clean coal technologies is shaped by the following factors:
    - ➪ deregulation is delaying long-term decisions on capacity.
    - ➪ little need for base load capacity.
    - ➪ capital costs, reliability, fuel costs and environmental constraints are key criteria for selecting technology for new capacity additions.
- Barriers to the take-up of the clean coal technologies are:
    - ➪ increased availability of natural gas and relatively lower capital costs for natural-gas fired technologies.
    - ➪ high capital costs of PFBC and IGCC.
    - ➪ lack of commercially demonstrated reliability and operability.
    - ➪ lack of awareness of attributes by potential developers.
- Policies and measures that could overcome the barriers are:
    - ➪ change negative attitude of government and public towards coal.
    - ➪ provide financial and regulatory incentives, e.g. tax relief, specialized depreciation, financial support, and permitting relief for the early commercial applications (first 3 to 5 installations).
    - ➪ implement a program to inform IPP's and other developers on the virtues of the clean coal technologies.

OECD Europe

- Growth in generating capacity in the region until 2015 is projected to be 82 GW with 1 GW of coal-fired capacity.
- The attitude towards the clean coal technologies is shaped by the following factors:
  - ➪ deregulation has redefined priorities from reliability/availability to economic.
  - ➪ environmental limitations remain a strong consideration.
  - ➪ natural gas appears to have advantages in some countries where it is available and competitively priced.
  - ➪ countries with demonstration projects have a higher confidence in the clean coal technologies.
  - ➪ supercritical PF viewed as a proven technology in some countries.
- Barriers to the take-up of the clean coal technologies are:
  - ➪ low capital costs of natural gas-fired technologies.
  - ➪ opportunity for the installation of base-load coal-fired capacity negligible.
  - ➪ economic competitiveness in question.
  - ➪ uncertainty of commercial status and reliability of PFBC and IGCC.
- Policies and measures that could overcome the barriers are:
  - ➪ reduce capital cost through favorable financial incentives.
  - ➪ harmonize emission limits and energy taxes.
  - ➪ virtues of coal should be publicized.
  - ➪ conduct pilot/demonstration projects in more countries.

Southern Africa

- Growth in generating capacity in the region until 2015 is projected to be 24 GW with 18 GW of coal-fired capacity.
- The attitude towards the clean coal technologies is shaped by the following factors:
  - ➪ local and regional development takes precedent over technology choices.
  - ➪ coal and hydro are the preferred choices when capacity is required.
  - ➪ clean coal technologies are viewed favorably, but must be proven against competing options on a cost, availability and reliability basis.
- Barriers to the take-up of the clean coal technologies are:
  - ➪ no generating capacity required until after 2010.
  - ➪ existing capacity is relatively new.
  - ➪ hydro focus in the region.
  - ➪ perception is of high operating costs.
  - ➪ limited worker skills and supporting infrastructure.
  - ➪ deregulation and competition defer decisions and increase risk avoidance.
  - ➪ demonstration of acceptable environmental performance on local coal.

- Policies and measures that could overcome the barriers are:
  - ➩ catalyze economic growth.
  - ➩ apply joint implementation/activities implemented jointly provisions of the UN FCCC.
  - ➩ increase the communication of RD&D technology information.
  - ➩ improve costs, availability and reliability.
  - ➩ direct government intervention, e.g. financial incentives.

OECD Asia/Pacific

- Growth in generating capacity in the region until 2015 is projected to be 303 GW with 45 GW of coal-fired capacity and 43 GW of that installed in Japan.
- The attitude towards the clean coal technologies is shaped by the following factors:
  - ➩ deregulation/competition is becoming a significant factor in capacity choices.
  - ➩ environmental limitations are important.
  - ➩ Japan's capacity choices driven by national goal of diversification of fuel mix to increase the security of supply.
  - ➩ return on investment, environmental, politics and capital cost drive capacity decisions.
- Barriers to the take-up of the clean coal technologies are:
  - ➩ deregulation/competition in electricity industry.
  - ➩ lack of proven availability and financial risk at unit sizes greater than 500 MW.
  - ➩ trend toward cost cutting.
- Policies and measures that could over come the barriers are:
  - ➩ government financial incentives.
  - ➩ encourage market competition between technologies.
  - ➩ better methods for disseminating information.

V. REFERENCES

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INTERNATIONAL ENERGY AGENCY
COAL INDUSTRY ADVISORY BOARD

INDUSTRY PERSPECTIVES ON INCREASING THE EFFICIENCY OF COAL-FIRED POWER GENERATION

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ABSTRACT

Independent power producers will build a substantial fraction of expected new coal-fired power generation in developing countries over the coming decades. To reduce perceived risk and obtain financing for their projects, they are currently building and plan to continue to build subcritical coal-fired plants with generating efficiency below 40%. Up-to-date engineering assessment leads to the conclusion that supercritical generating technology, capable of efficiencies of up to 45%, can produce electricity at a lower total cost than conventional plants. If such plants were built in Asia over the coming decades, the savings in carbon dioxide emissions over their lifetime would be measured in billions of tons.

IPPs perceive supercritical technology as riskier and higher cost than conventional technology. The truth needs to be confirmed by discussions with additional experienced power engineering companies. Better communication among the interested parties could help to overcome the IPP perception issue. Governments working together with industry might be able to identify creative financing arrangements which can encourage the use of more efficient pulverised clean coal technologies, while awaiting the commercialisation of advanced clean-coal technologies like gasification combined cycle and pressurised fluidised bed combustion.

EXECUTIVE SUMMARY

- New generating capacity required globally between 1993 and 2010 is estimated to be around 1500 GW, of which some two-thirds will be outside the OECD, and some 40% in the Asian non-OECD countries. Coal is likely to account for a substantial fraction of this new generation, and with liberalisation of electric power markets driven by the need for inward investment, independent power producers are likely to build a substantial number of the coal-fired power plants in developing countries.

- Today's state-of-the-art supercritical coal-fired power plant has a conversion efficiency of some 42-45%, about 5 percentage points higher than that of the conventional subcritical plants which continue to be built in most projects in non-OECD countries. If supercritical plants were to be built instead, the amount of incremental carbon dioxide not released to the atmosphere over the next few decades as a result of electricity generation would be measured in the billions of tons, without constraint on energy and economic growth. Depending on the generating efficiencies achieved, the CO_2 emission reductions over the lifetime of the plants built during one decade of growth in Asia alone could amount to 5-10 billion tons.

- With more than 350 supercritical units operating world-wide today, and more than two decades of experience and development of this technology, their reliability today is assessed by authoritative observers and operators of power plants to be at least as good as that of conventional sub-critical plants.

- A new engineering assessment by an international power engineering firm concludes that the capital cost increase associated with a supercritical or ultra-supercritical pulverised coal power plant compared to a conventional subcritical plant is small to negligible. The reason is that capital cost increases specific to the supercritical plant (e.g. associated with superior materials and other design features) are counter-balanced by the capital cost savings associated with the fact that the boiler and ancillary equipment can be smaller due to the increased efficiency.

- The increased efficiency associated with the supercritical plant leads to an actual reduction in the total cost of electricity generated in cents/kWh, relative to a conventional plant. In fact, depending on fuel price, an ultra-supercritical plant with flue gas desulphurisation, selective catalytic reduction for post-combustion NOx control, and a high efficiency baghouse for particulate control, can produce marginally cheaper electricity than a conventional subcritical plant with only an electrostatic precipitator for particulate control.

- Despite this, the independent power sector continues to build subcritical plants and has no near-term plans to increase the efficiency of power plants in the projects it is developing. There is a clear perception among IPP companies that supercritical technologies are both more expensive and contain more risk than subcritical technologies. Part of the reason for this appears to be innate conservatism among their technology suppliers and project financiers.

- IPP companies' decision-making is driven primarily by the issues of reliability, technology cost, government regulation, and lender attitudes or financing constraints. Generating efficiency is perceived to be of second-order importance.

- Advanced clean coal technologies such as integrated gasification combined cycle and pressurised fluidised bed combustion will be selected for independent power projects only in very specific circumstances, where their technology and other risks are fully covered and their incremental costs are recovered in the price of electricity. Market penetration on a wider scale is seen by the IPPs as being in the 2005-2010 timeframe or beyond.

- It appears that the only way to accelerate this is to complete a number of successful demonstrations which, in particular, show that advanced clean coal plants can be operated reliably and with superior performance, and specifically that their present estimated capital costs can be reduced substantially to a point where they are competitive with state-of-the-art pulverised coal technologies. These second- or third-of-a-kind demonstrations are likely to require financial support by governments if they are to be realised.

I. INTRODUCTION

The CIAB's Global Climate Committee was asked by the IEA to assess the evolution of energy-efficient coal-fired power generation in non-OECD countries.. The primary market for coal over the coming decades will be electricity generation, especially in the newly industrialising countries of the developing world. Estimates of the amount of new generation required between 1993 and 2010 are in the region of 1500 GW, of which more than 700 GW are in the non-OECD countries (Figures 1, 2). Coal is expected to account for a large proportion of new electricity generation (Figure 3).

The global issues of sustainable development and the enhanced greenhouse effect are topics of importance to IEA Member governments and CIAB members. Coal, as a fossil fuel with a reserve base measured in centuries rather than decades, is an important part of the global economic-energy-environment equation. It is clear that for the newly industrialising economies to sustain the major growth phase now in progress, coal must play its part as an efficient and environmentally sound source of energy.

Today's state-of-the-art supercritical pulverised coal-fired power plant has a conversion efficiency of some 42-45% (lower heating value - LHV), about 5 percentage points higher than that of the conventional subcritical plants which continue to be built in most projects in non-OECD countries. The main question addressed by this paper is, what would be needed to have state-of-the-art technology accepted for new power projects in these countries? If this were achieved, the amount of incremental carbon dioxide not released to the atmosphere over the next few decades as a result of electricity generation would be measured in the billions of tons, without constraint on energy and economic growth.

The necessary growth of electricity generation capacity in the industrialising countries will require very substantial inward investment. In order to attract this investment, generation of electricity is being privatised in an increasing number of countries. The involvement of independent power producers (IPPs) in private power projects in a number of countries is an important part of this process.

The CIAB took a two-pronged approach to the issues related to improving generating efficiency in new coal power generation in non-OECD countries. A consultant, SEPRIL, jointly owned by the Electric Power Research Institute and Sargent & Lundy), was engaged to provide an analysis of costs and other issues in the comparison of subcritical, supercritical and ultra-supercritical pulverised coal plants in these countries. At the same time, in order to benefit from the insights which IPPs have gathered as a result of their experience to date in private power projects and business development in newly industrialising countries, the CIAB designed a relatively simple survey by telephone interview. The most appropriate people to respond to such a survey were identified and the interviews carried out between April and July 1996.

The results of the IPP Survey are summarised in the next Section. The findings of the cost and performance comparative analysis are presented in Section III.

II. OVERALL SUMMARY OF SURVEY RESULTS

A total of fourteen companies took part in telephone interviews and/or provided written responses to the CIAB Questionnaire. The companies taking part in the Survey were:

ABB Carbon	AES Corporation
Babcock and Wilcox	Black and Veatch
Community Energy Alternatives	CMS Generation
Duke Energy	Edison Mission Energy
Elsamprojekt	Entergy Power Systems
IVO Energy International	National Power
NRG Energy	Southern Electric International

The majority of those interviewed represented independent power producing companies involved in developing power projects in non-OECD countries. However, representatives of several power engineering/construction companies and technology suppliers also participated. Those who agreed to take part in the Survey were assured that the anonymity of their responses would be protected, and that the results of the Survey would be shared with them as soon as possible.

There was a high degree of consensus among the participants in their response to the questions, which makes it relatively simple to draw broad conclusions. The main lessons to be drawn from the Survey are the following:

1. Technologies used or foreseen

The vast majority of projects use or plan to use sub-critical pulverised coal technologies for larger plants, with some smaller projects using atmospheric fluidised bed combustion (AFBC) technology. Supercritical pulverised coal technology is viewed as technically commercialised but riskier and more costly, and needing incentives such as high priced fuel to be the technology of choice. Pressurised fluidised bed combustion (PFBC) and integrated coal gasification combined cycle (IGCC) technologies may be used in special circumstances (e.g. government support) in the coming years, but are unlikely to come into widespread use by IPPs until 2005-2010 or beyond.

2. Environmental Requirements

The World Bank Environmental Guidelines play a major and increasing role in most countries. Most IPPs and developing countries are aware of a 1995 draft of these which is stricter than the 1988 official version, and believe these new guidelines will be implemented shortly. Some IPPs have corporate environmental guidelines which go beyond the World Bank ones; however, to go too far beyond raises economic competitiveness issues.

3. Main Factors influencing Technology Selection

The results of a poll included in the Survey, on the principal factors influencing technology selection and their relative importance in decision-making, are shown in Table 1 below.

TABLE 1

CIAB IPP Survey Responses
Impact of Different Factors on Coal Power Generation Technology Selection
1 = Not important 5 = Extremely important

Response No.	1	2	3	4	5	6	7	8	9	10	11	12	14	15		Mean	S.D.
Environment	4	4	3	4	2	4	5	3	4	3.5	4	4	5	5		3.9	0.83
Efficiency	4	3	3	4	2	3	4	3	5	4.5	3	5	4	3		3.7	0.9
Reliability	4	4	4	5	5	5	4.5	5	5	5	3	5	4.5	5		4.6	0.6
Maintainability	3	5	4	5	4	5	4	5	4	4	3	4	4	5		4.2	0.68
Technology Cost	5	5	5	4	4	5	5	4	5	5	5	4	3.5	5		4.6	0.55
Technology Maturity	3	4	4	4	5	3	4	4	4	4	4	5	3	5		4	0.65
Technology Risk	3	4	4	5	5	3	3	4	4	4	4	4	5	5		4.1	0.7
Build Time	4.5	4	3	4	3	3	3	3	5	4	3	4	3	3		3.6	0.78
Fuel Flexibility	2.5	4	2	4	2	3	5	3	3	3	3	5	5	2		3.3	1.07
Operational Flexibility	3	3	3	4	2	3	3	3	4	3.5	3	4	3	3		3.2	0.56
Need for Skilled Operators	3	4	1	3	3	4	3	3	3	3.5	3	4	3	5		3.3	0.88
Customer Specifications	4	5	5	4	5	2	3	3	4	4	3	4	3	3		3.7	0.88
Financing Constraints	4.5	5	4	4	3	5	5	4	5	5	4	5	5	5		4.6	0.62
Lender Attitudes	4	4	3	4	4	4	5	4	4	4	4	5	5	3		4.1	0.59
Government Regulation	3.5	4	5	5	4	5	5	4	5	5	4	5	5	1		4.4	1.08

S.D. = Standard Deviation

Reliability, technology cost, and financing constraints were voted the most important factors (averaging 4.6 on a scale of 1 to 5 in importance). The standard deviation in the responses was relatively small, of the order of 0.6, indicating a strong consensus on these factors. The next most important factors were government regulation (4.4), maintainability (4.2), technology risk and lender attitudes (both 4.1), technology maturity (4.0), and environment (3.9). Interestingly, the need for skilled operators scored relatively low in the poll (3.3), the IPP view being that it is relatively easy to find and train operators.

4. Power Plant Conversion Efficiencies

Most coal-fired power plants being planned or built today use sub-critical technology and have conversion efficiencies in the range of 37-39% on a lower heating value (LHV) basis (9200-8700 Btu/kWh). Responses on future trends in efficiency over the next 5-10 years were mixed, though few expect increases of more than a few percentage points.

5. What it would take to improve Generating Efficiencies

The present cost of fuel in non-OECD countries is perceived to be a disincentive to achieving significant increases in generating efficiency. Only when fuel is expensive will competitive pressures by themselves lead to efficiency improvements. Stricter environmental requirements could play a role (especially constraints on carbon dioxide emissions). Governments can mandate efficiency standards, but this is not seen as likely unless there is a strong national or international reason for doing so.

There is a common perception of higher capital and operating cost, and risk of reduced plant operating reliability, associated with supercritical pulverised coal technologies, both among IPPs themselves and, perhaps more important, among their engineering and technology supply partners. The latter are normally expected to bear the technology risk in an IPP project, which tends to bias them towards conservatism. Some of the higher cost may also in fact be due to the higher perceived risk premia in project-financed IPP plants. There may be an information gap here that could be bridged by further dialogue.

The responses to the IPP Survey have highlighted a perception that supercritical pulverised coal technology is both costlier and riskier than conventional subcritical technology. How justified is that perception? The other part of this assessment, described in Section III. below, attempts to respond to this question.

III. Comparison of Supercritical Versus Subcritical Plant performance

In order to assess the cost-effectiveness and environmental performance of SC and USC coal-fired generating plants versus a "conventional" subcritical plant of the type used in most IPP projects today, an analysis of comparative performance and cost was carried out using the SOAPP data-base, for a 600 MW PC-fired plant in an Asian location. The plant capacity factor is 81%. The coal sulphur content is 0.9%.

For this case study, the following scenarios were evaluated:

(1) 2400 psig subcritical plant with an electrostatic precipitator for particulate control and low-NOx burners, but no post-combustion sulphur or nitrogen oxide controls (Conventional Plant).

(2) 3500 psig supercritical plant (SC).

(3) 4500 psig ultra supercritical plant (USC).

(4) 4500 psig ultra supercritical plant with spray dryer FGD, SCR, and baghouse for particulate control (USC w/FGD, SCR).

The analysis was carried out for two variants of capital cost and for two types of coal. The higher level of capital cost (~$800/kW for a subcritical plant without FGD) corresponds to that for a plant built in an advanced OECD country, and the lower capital cost (~$620/Kw) to that for a similar plant constructed in a developing country such as China. The lower priced coal (~$15/short ton, heating value 7900 Btu/lb) might be that for a minemouth coal plant, and the higher coal price (~$40/short ton, heating value 12000 Btu/lb) might be the landed price of internationally traded coal at a coastal power plant.

1. Plant Efficiency

The plant efficiency comparison is shown in the Figure 4. Compared to the conventional subcritical plant's 38% efficiency, a supercritical plant can readily achieve 41% and an ultra-supercritical one 45% on an LHV basis. It would be possible for a subcritical plant to achieve greater efficiency via higher temperatures (up to about 40%). The "conventional" plant in this comparison, however, is intended to represent one typical of many IPP coal plants currently in operation, construction, or project development.

2. Fuel Consumption

The plant efficiency improvements result in significant reduction in fuel consumption. A 600 MW conventional plant has a primary fuel feed rate (100% load) of ~ 750,000 lb/hr. The more efficient USC plant has a primary fuel feed rate of 645,000 lb/hr. This translates to over ~375,000 short tons/year of coal not combusted, which results in a fuel cost savings of approximately $6 million/year for a USC plant vs. a conventional plant based on a fuel cost of $15 per ton delivered (calorific value 7900 Btu/lb), or approximately $10 million/year if the fuel cost is $40/ton (calorific value 12000 Btu/lb).

3. CO_2 Emissions

With the recent attention focused on the international greenhouse issue, emissions of CO_2 from coal-fired power plants have received increasing attention. The annual mass CO_2 emissions for the conventional, SC and USC plants are ~5.2 million short tons, 4.8 million tons, 4.4 million tons, respectively (Figure 5). This represents 8% emission reduction for the SC and 15% for the USC plant relative to the conventional subcritical technology. Consequently, even the intermediate step of the supercritical plant reduces CO_2 emissions by almost a half million tons per annum for a 600 MW plant, or 0.7 million tons/GW. Over the 40 year lifetime of 1 GW of new coal generation, 28 million tons less CO_2 would be emitted. Asia alone may need to construct 15 GW per year of new coal generation over the next two decades, according to the IEA's World Energy Outlook (9). Thus one year's incremental generation would produce 420 million tons less CO_2 during its lifetime, and the savings from one decade of this growth would amount to almost 5 billion tons of CO_2. And going to ultra-supercritical plants would double this. The stakes are clearly rather high.

4. SO_2 and NOx Emissions

Emissions of gaseous pollutants are also reduced by building more efficient plants. The emission control equipment required for a plant depends on the coal selected and the applicable emission regulations. Currently, most plants in Asia are being installed without FGD Systems and with low NOx boiler burner equipment. This approach is based on the use of low sulphur coal, the cost, and current national air emission regulations or World Bank environmental guidelines. Emissions of both conventional pollutants (SO_2, NO_X, particulate, etc.) and carbon dioxide are lower for the more efficient supercritical plants than for the traditional subcritical plant. When comparing plants without post-combustion air pollution controls, mass emissions of SO_2 are reduced by 3300 tons/year, and emissions of NO_x by 1180 tons/year for a USC plant compared to a conventional plant (Figure 6).

With the use of state-of-the-art air pollution controls, emissions of conventional pollutants can be reduced to ultra-low levels. The USC plant equipped with a lime spray dryer, SCR, and baghouse can produce emissions of 0.11 lb/MBtu SO_2, 0.06 lb/MBtu NO_X, and 0.005 lb/MBtu particulate. The emissions could be reduced by up to ~90% with this percentage sulphur coal. This low emissions boiler would be able to satisfy the most stringent regulatory requirements. The additional capital cost for this system on a 600 MW unit with low sulphur coal fuel (0.9%) would be approximately $130/kW. This cost increment is relatively low because the spray-dryer/baghouse combination is substituted for the precipitator included in the other cases.

5. Plant Reliability

Though this was not a variant in this assessment, it is worth a brief mention of the issue of supercritical versus subcritical power plant reliability. Experience with the higher temperatures and pressures involved in supercritical technology has grown substantially over the past two decades, and earlier technical problems have been to a large extent overcome by improvements in materials and design. There remain some corrosion problems stemming from the higher temperatures, which makes supercritical less suitable for high slagging or corrosion coals. Coal with greater than about 2% sulphur has caused some superheater and reheater difficulties. However, these difficulties are not necessarily specifically related to the sulphur content - coal chlorine and other constituents can have a major impact on the corrosion rates.

There are options which boiler manufacturers can employ with more corrosive coals to mitigate these problems. Boiler design optimisation options include a larger furnace for lower gas temperatures entering the reheater and superheater, use of higher alloy materials which have recently become available, tube shields, a tube cooling screen before the superheater and reheater, boiler water and steam circuitry to reduce high gas temperatures because of uneven gas and steam/water exchange in the combustion and other heat transfer zones, and other means.

Boiler tube leaks are a major issue for plant operation, often being the cause of loss of reliability. There is occasionally a tendency to generalise the difficulties caused by tube leakage problems, e.g. water wall leaks are not differentiated from superheater and reheater problems. However, tube leaks are often caused by water chemistry problems and not directly related to the coal quality. Many units have switched to "oxygenated" cycle chemistry, which has proven to reduce tube leaks very substantially.

It is possible that commercial risks for a supercritical plant burning greater than 2% sulphur coal might be subject to greater premiums owing to less historical experience. However, many of the plants to be built in Asia over the coming decades will use relatively low sulphur coal, so this issue may be only be encountered for plants attached to some specifically higher sulphur reserves.

IV. COST COMPARISON OF SUPERCRITICAL VERSUS SUBCRITICAL PLANTS

The capital costs differences (higher capital cost case) are shown in Table 2, which also separates out the main items for which the cost increases in the supercritical and ultra-supercritical plants relative to the conventional plant.

Table 2. Capital Costs of Supercritical versus Subcritical Generating Plants

$/kW		Subcritical	Supercritical	Ultra-Supercritical	Ultra-Supercritical with FGD System & SCR
Boiler (incl.steel;, air heater, etc.)		$142.94	$153.09	$163.52	$163.52
% compared to base		Base	107.1%	114.4%	114.4%
Boiler plant piping		$27.81	$31.03	$31.81	$31.81
% compared to base		Base	111.6%	114.4%	114.4%
Feedwater systems		28.06	$28.62	$29.18	$29.18
% compared to base		Base	102.0%	104.0%	104.0%
Turbine-Generator		$79.20	$82.37	$83.95	$83.95
% compared to base		Base	104.0%	106.0%	106.0%
Turbine plant piping		$16.25	$15.44	$15.43	$15.43
% compared to base		Base	95.0%	95.0%	95.0%
Subtotal for boiler, turbine, high pressure piping, feedwater systems		$294.26	$310.38	$323.91	$323.91
% compared to base		Base	105.5%	110.1%	110.1%
Remainder of Plant		$509.17	$500.69	$487.17	$604.76
% compared to base		Base	98.3%	95.7%	118.8%
Total Plant Cost		$803.43	$811.07	$811.08	$928.67
% compared to base		Base	101.0%	101.0%	115.6%

The plant would have two units with low NOx burners, high efficiency particulate collection equipment, once through sea water cooling, including the switch yard and all the facilities for a new site location, and a 60 month construction schedule. The capital costs in Table 2 include the plant equipment, structures, switchyard, and coal unloading facilities.

The increases in cost for the higher pressure cycles plants are not as high as was evident in previous evaluations performed several years ago, because of better materials, equipment designs and other technological knowledge, and growing experience with the higher pressure and temperature cycles. Another factor is the beneficial impact of the higher efficiency cycle on the overall plant costs, in the form of reduced costs for smaller coal handling systems, precipitators, and cooling systems, etc. These cost reductions offset the increased costs for the higher pressure and temperature cycle boiler, turbine, piping, pump, feedwater heater, etc. equipment. This is shown graphically in Figure 7.

It is of course a valid question as to whether the substantial cost savings realised during recent years in subcritical plant design and construction may not be easily translated to supercritical and ultrasupercritical designs. While it is unlikely that plant designs for supercritical have reached the same "off-the-shelf" sophistication which the construction engineering firms now offer for subcritical plants, there is no a priori reason why the same competitive forces which led to these offerings should not come into play as soon as there is a demand for cost-effective supercritical plants.

Table 3 summarises the economic parameters used to calculate the cost of electricity generated from the different types of plant.

Table 3. Economic Parameters uses in the Comparison

Plant Operating Period = 30 Years	Fuel Cost A = \$15.20/ton, B = \$40/ton
Plant Operating Hours = ~ 85% availability	Interest during construction = 9.8%
Capacity Factor = ~80%	O&M Escalation 2%
Fixed Charge Rate = 13%	\$5/ton Waste Disposal Costs
O&M (fixed) = ~ \$13/kW-year	

Capital charges and fixed O&M are higher for the SC and USC cycles, while total fuel costs are lower for the SC and USC because of the higher efficiencies. The O&M cost estimate was developed using the methods and data typically used for economic comparisons for new projects. The average availability for all three pulverised coal generating cycles included in this study is 85% and the capacity factor for all the units is 80%. This target is based on data from existing plants.

The results are shown in Figure 8(a) and (b) for the lower coal price and Figure 9(a) and (b) for the higher coal price. In each of these Figures, (a) is the higher capital cost case and (b) the lower capital cost case. As expected, the effect of fuel price is very significant. When the higher level of capital cost is used in the analysis, going from conventional to supercritical in the lower coal price case reduces the electricity cost by 0.08 cents/kWh, and in the higher coal price case by 0.23 cents/kWh - almost a factor of three. The corresponding reductions in going from conventional to ultrasupercritical are 0.14 cents/kWh in the lower coal price case and 0.48 cents/kWh in the higher coal price case. Figure 9 shows that the ultrasupercritical plant with state-of-the-art sulphur and nitrogen oxide controls and a high efficiency baghouse for particulate control can produce cheaper electricity than a conventional plant with only a precipitator for particulate control!

When the lower capital cost is used in the analysis, the corresponding reductions in going from conventional to ultrasupercritical are 0.15 cents/kWh in the lower coal price case and 0.46 cents/kWh in the higher coal price case, implying that the choice of whether to use subcritical or supercritical technologies is not very sensitive to general capital cost levels.

V. CONCLUSIONS

The independent power sector has been and remains reluctant to employ advanced clean coal technologies for power generation projects. The current standard appears to be a subcritical pulverised coal plant with flue gas clean-up adequate to meet World Bank Environmental Guidelines. Only minor improvements in generating efficiency are expected by the IPP sector over the next five years.

Advanced clean coal technologies like PFBC and IGCC are expected by independent power producers to be selected only in special cases where their risks are fully covered and incremental costs recovered in the price of electricity produced. Their market penetration on a wider scale without special treatment is seen by the IPPs as being in the 2005-2010 timeframe or beyond. It appears that the only way to accelerate this is to complete a number of successful demonstrations which, in particular, show that advanced clean coal plants can be operated reliably and with superior performance, and specifically that their present estimated capital costs can be reduced substantially to a point where they are competitive with state-of-the-art pulverised coal technologies.

Supercritical pulverised coal technology is perceived as available but more costly and containing added risk in terms of reliability. Also, there are few incentives to employ it in non-OECD countries, especially where coal is inexpensive. There appears to be a perception problem, possibly due to lack of information, which may need to be addressed by the IEA and others, if the advantages of supercritical generating efficiency improvements, both environmental and economic, are to be realised in the near future.

An economic analysis of subcritical versus supercritical state-of-the-art pulverised coal power plants, carried out for the CIAB by SEPRIL, has suggested that supercritical generation is less costly in terms of cost per kilowatt hour of electricity generated. This is especially marked for higher fuel cost but still significant for lower cost fuel.

Two types of action are being undertaken to overcome the perception barrier with regard to supercritical generating technology:

(1) Development of communication among the stakeholders - governments, IPPs, major international construction engineering companies and technology suppliers - to confirm the cost and reliability figures for supercritical versus conventional subcritical technology;

(2) Discussion with financing entities - private banks, multilateral funding organisations, and government export credit agencies - to identify the risk issues and possible creative financing incentives which would encourage the use of more efficient generating technologies.

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7. *Particle Erosion Technology Assessment*, EPRI Report TR-103552, December 1993.
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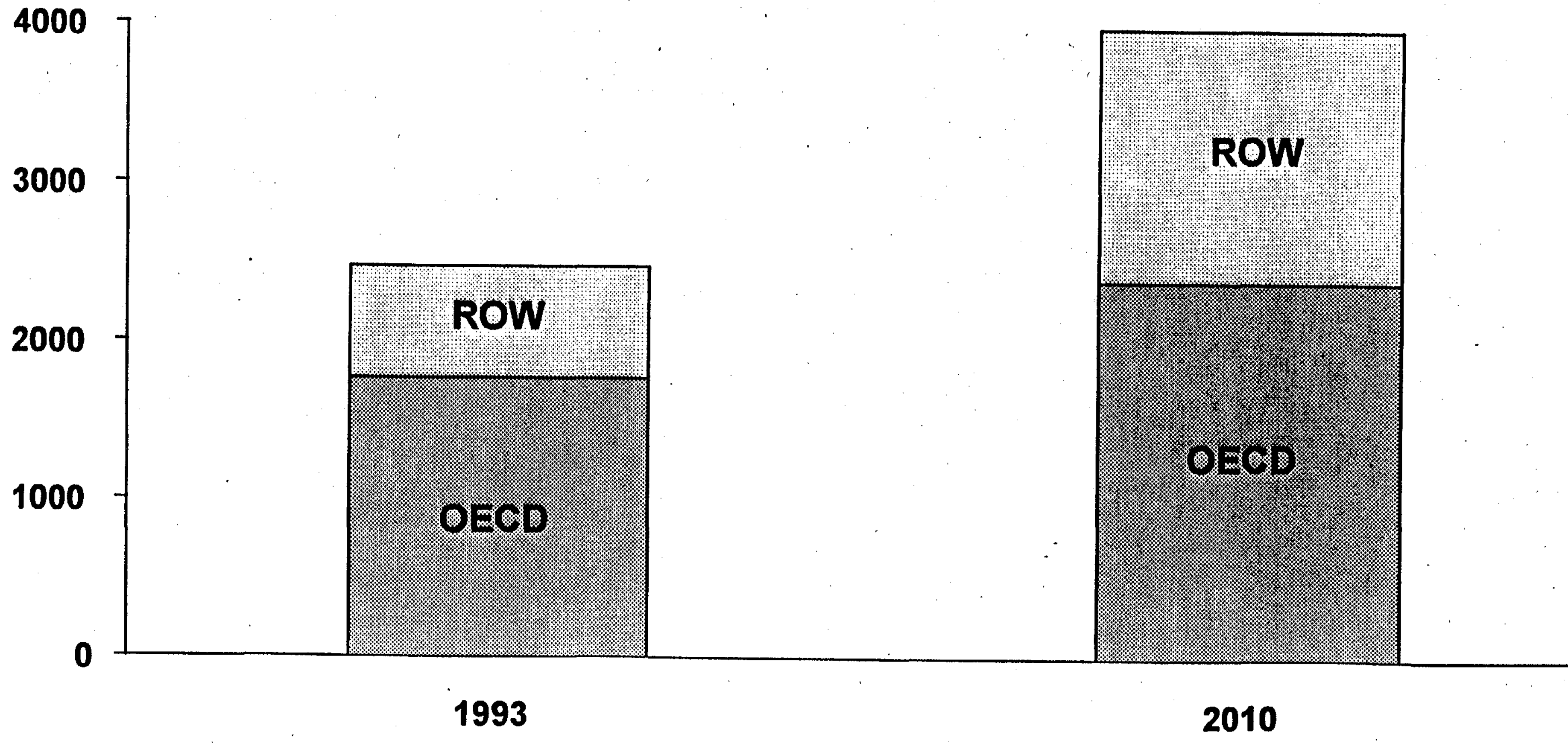
Figure 1

Electricity Generating Capacity Growth (GW)

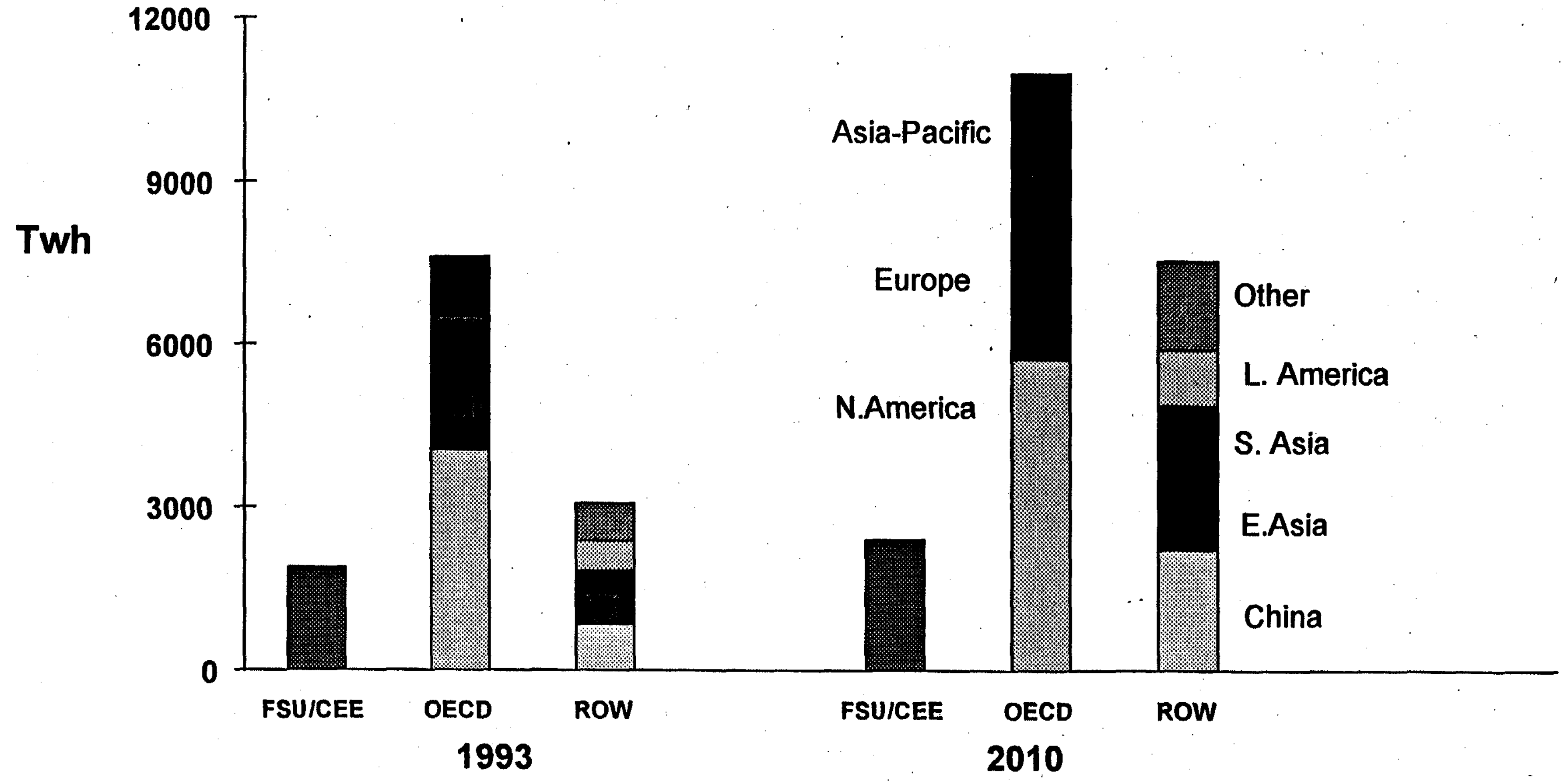
1993 - 2010



Source : IEA World Energy Outlook 1996

Figure 2

Electricity Output by Country/Region(TWh)
1993 - 2010

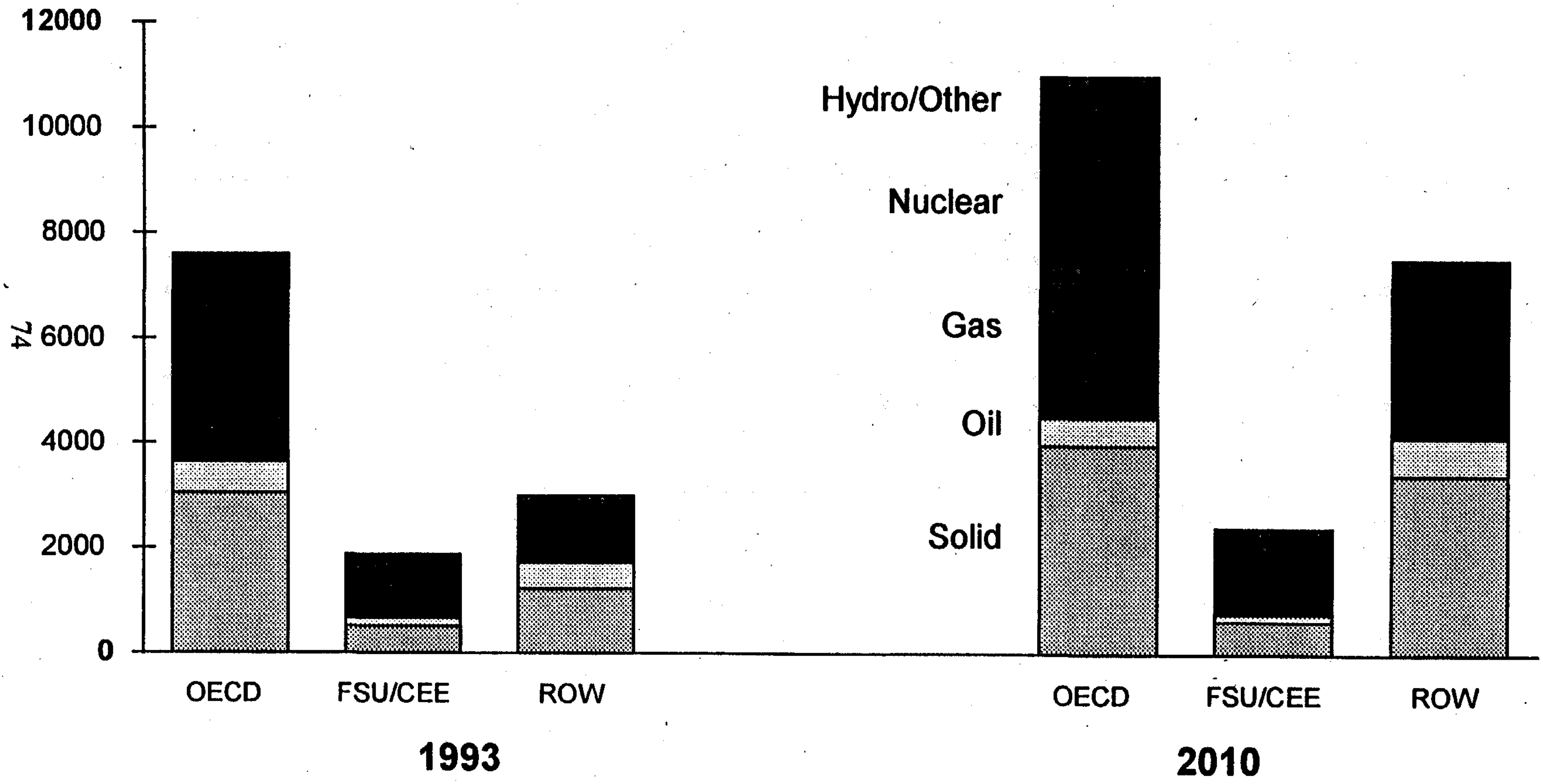


Source : IEA World Energy Outlook 1996

Figure 3

Primary Energy Shares in Power Generation (TWh)

1993 - 2010



Source : IEA World Energy Outlook 1996

Figure 4

Plant Efficiencies (LHV)
Supercritical Versus Subcritical

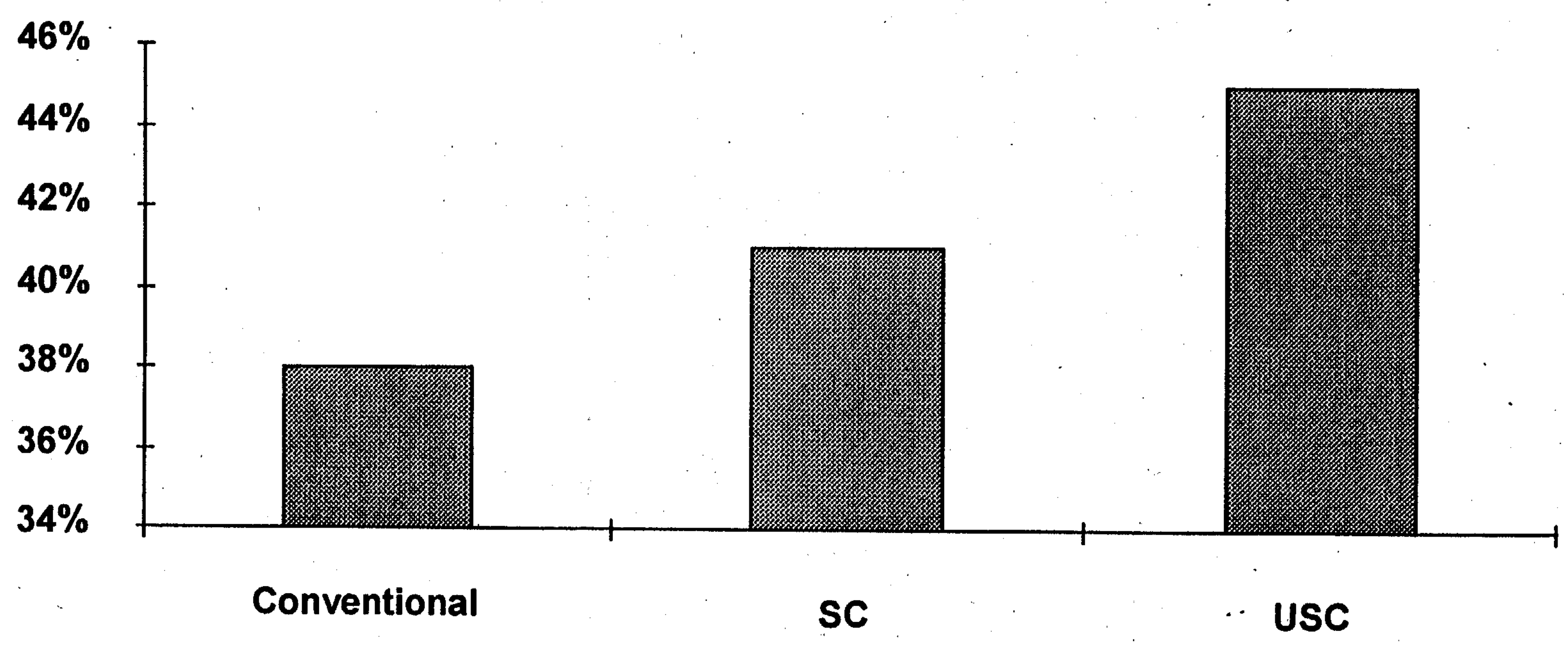


Figure 5

Carbon Dioxide Emissions
(Million Tons/year, 600 MW Unit)

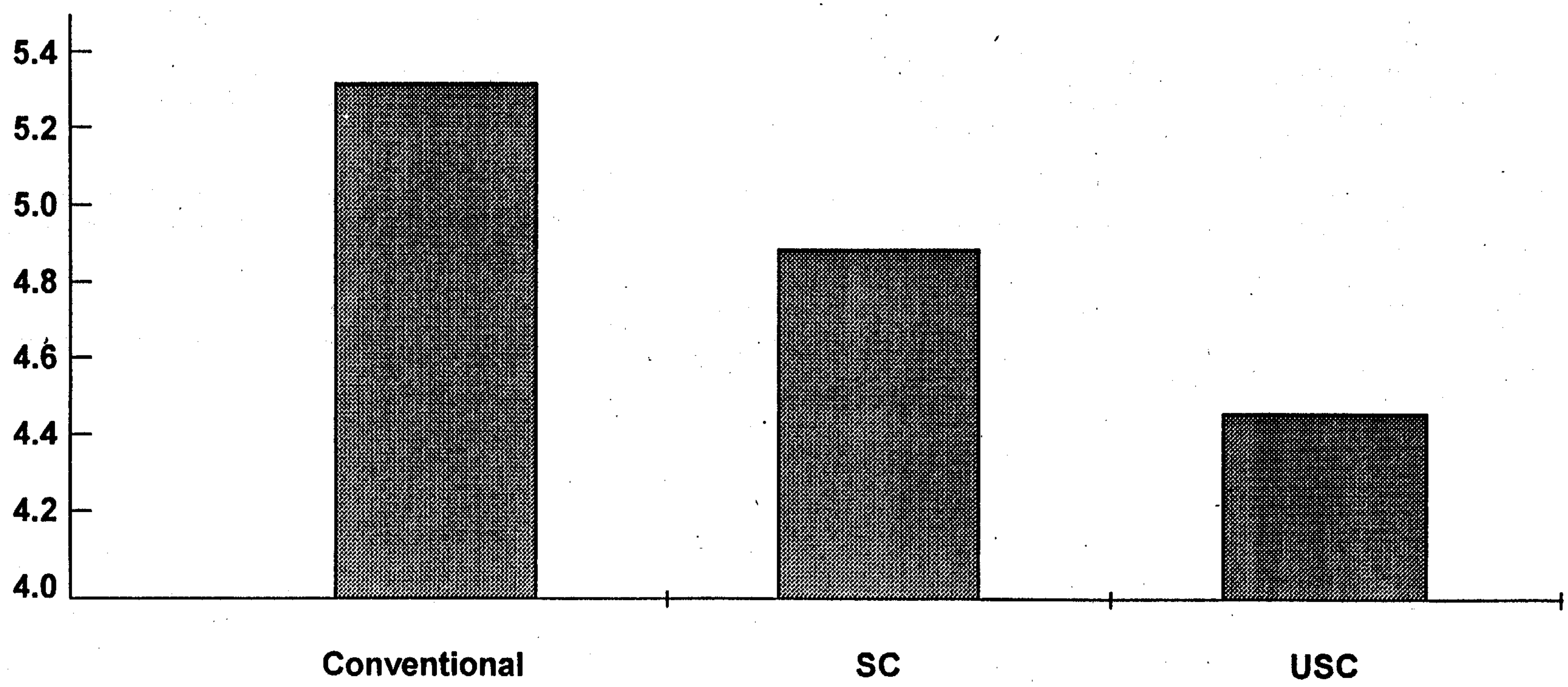


Figure 6

SO_2 & NO_X Emissions (1000 tons/year, 600MW Unit)

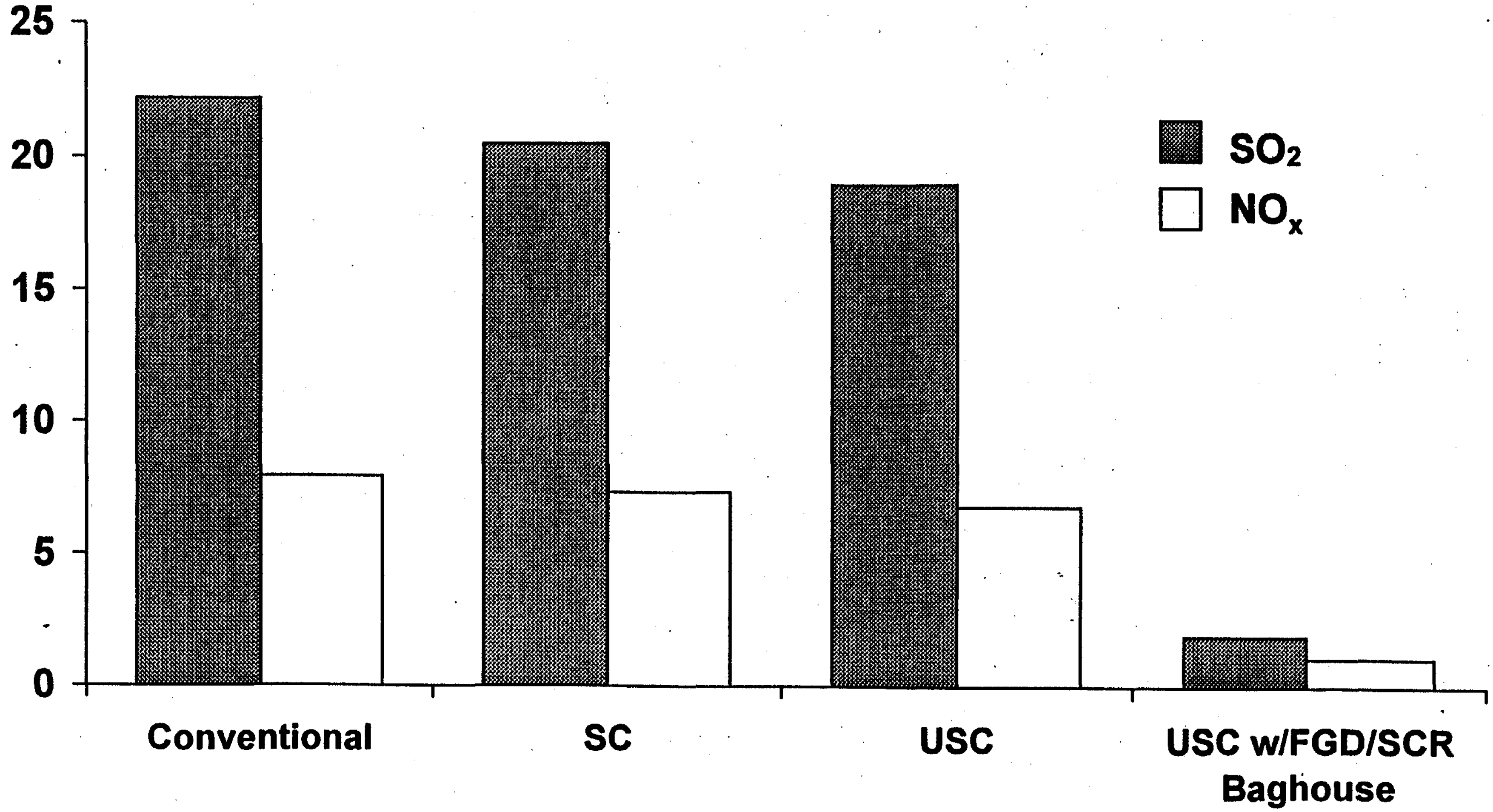


Figure 7

Capital Cost Comparison for 2x600 MW Coal Fired Powerplant

Higher Capital Cost Case

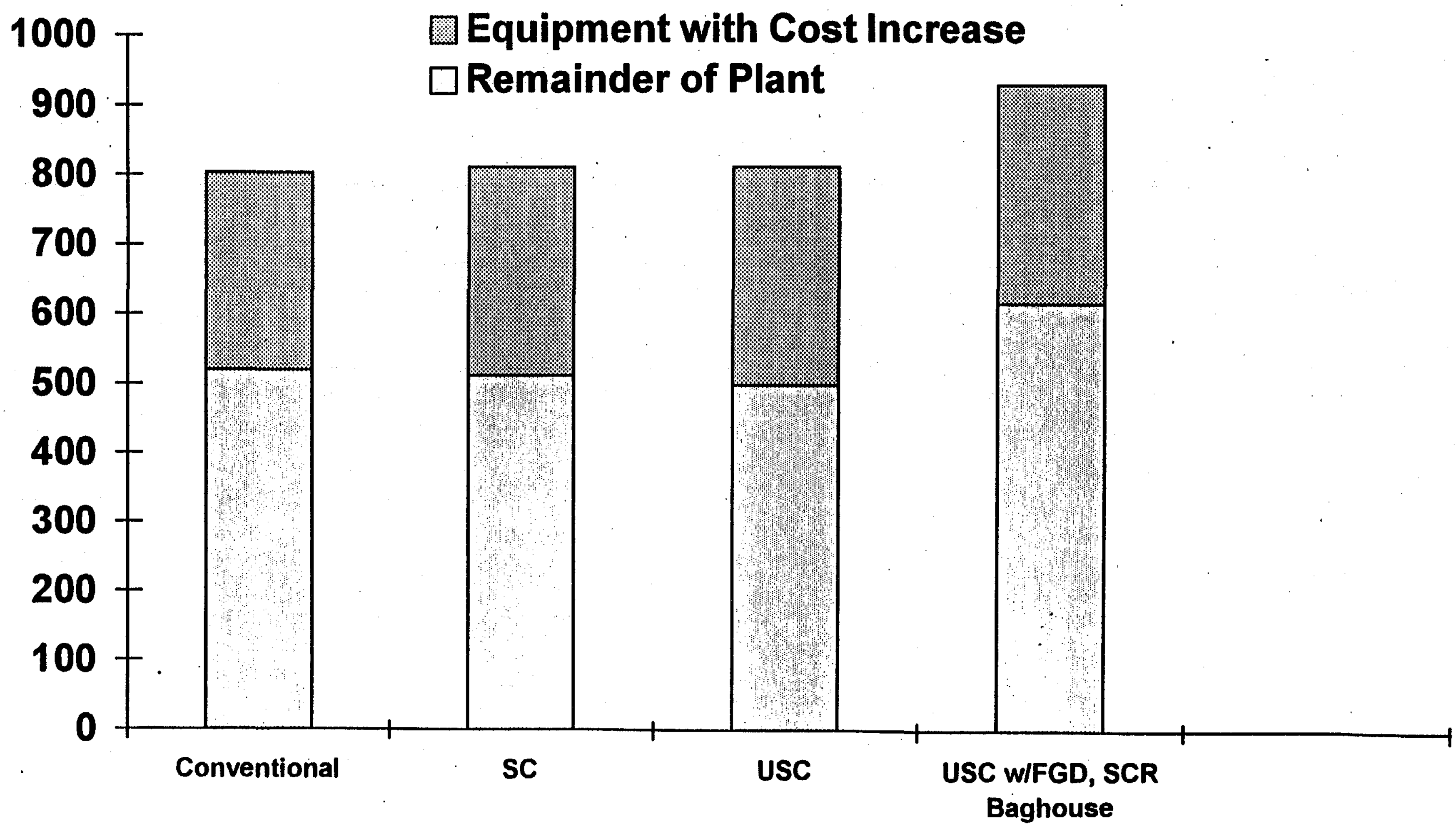


Figure 8 (a)

Cost of Electricity (cents/kWh)

Lower Fuel Cost ($15/ton)
Higher Capital Cost Case

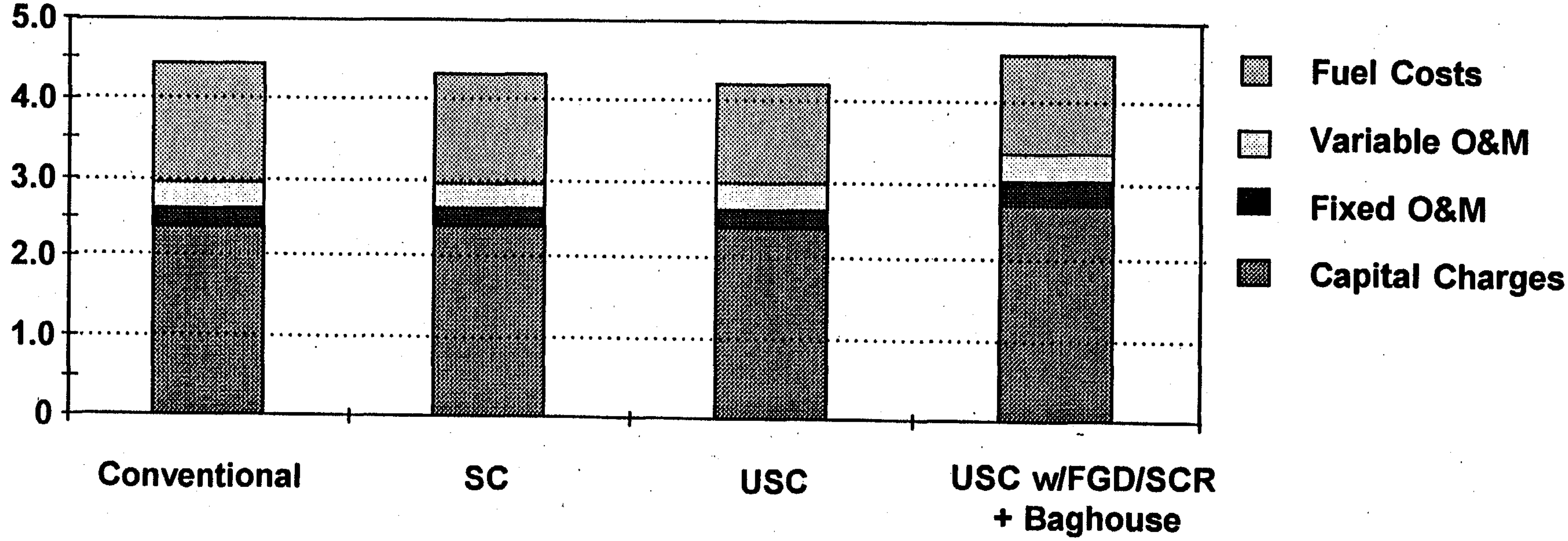


Figure 8 (b)

Cost of Electricity (cents/kWh)

Lower Fuel Cost ($15/ton)
Lower Capital Cost Case

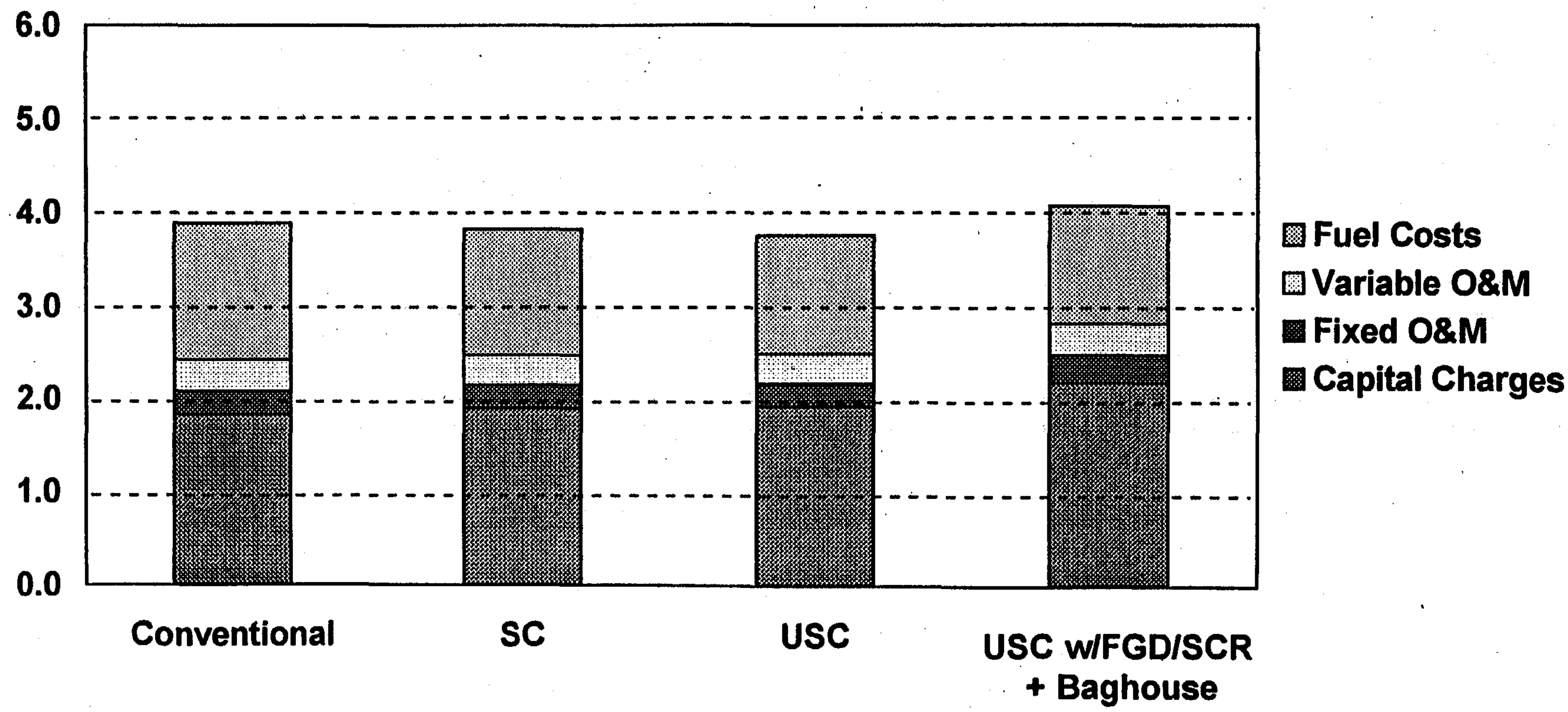


Figure 9 (a)

Cost of Electricity (cents/kWh)

Higher Fuel Cost ($40/ton)
Higher Capital Cost Case

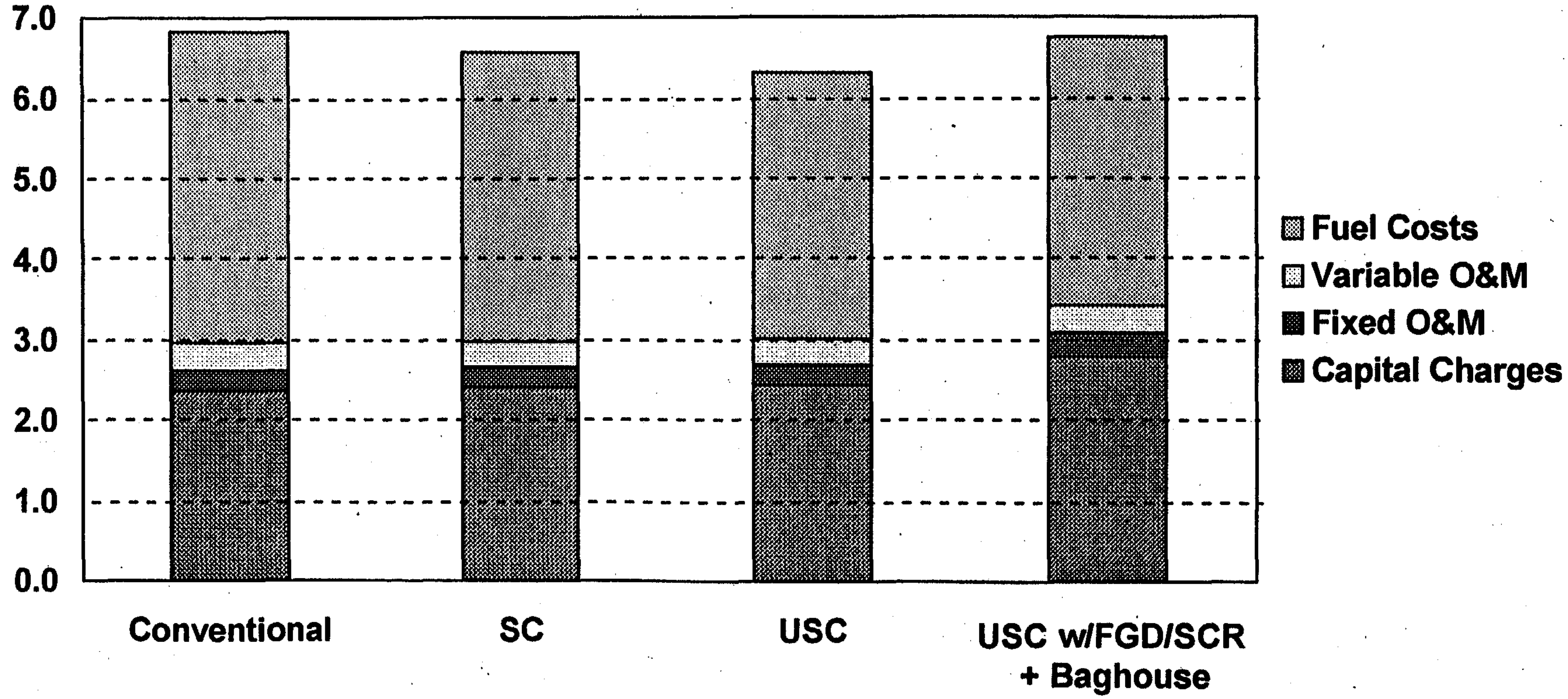
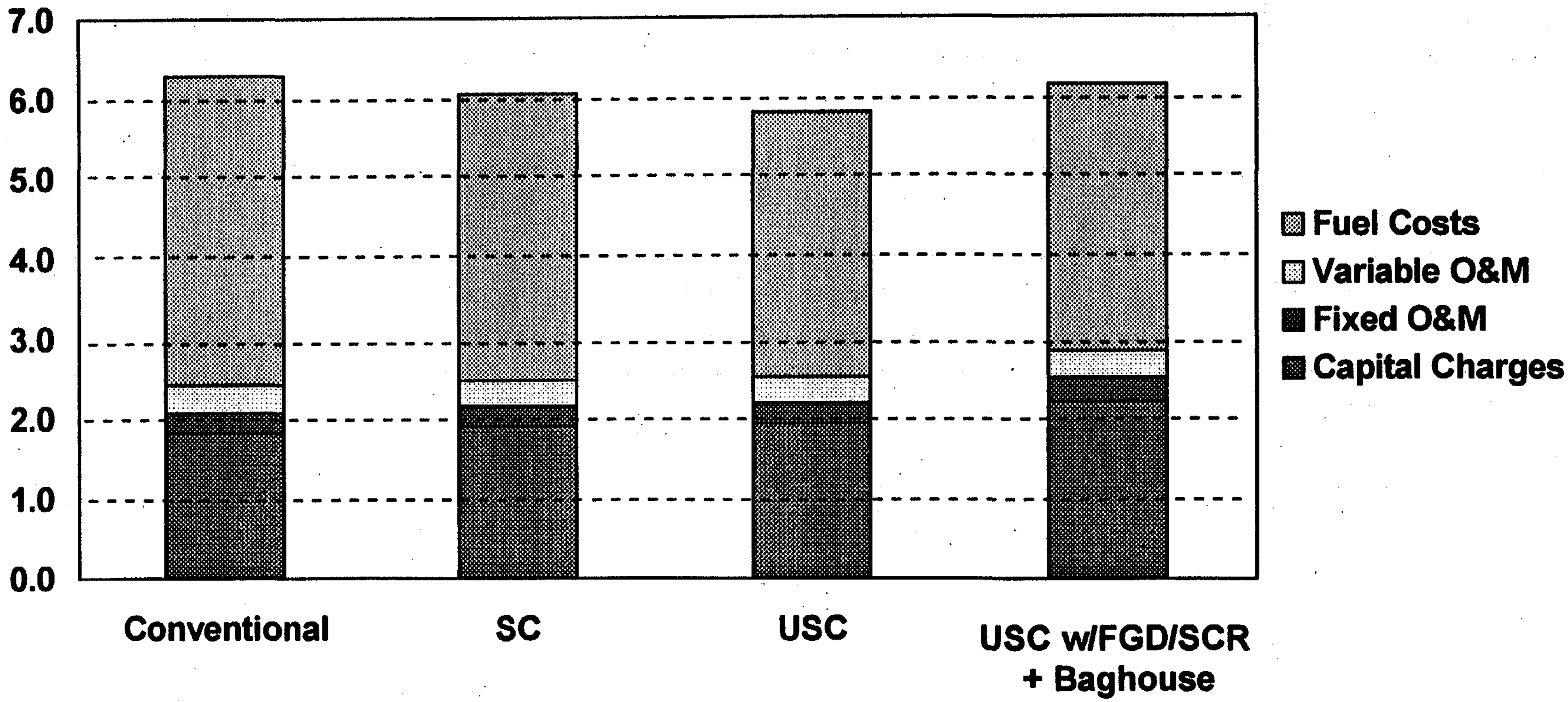


Figure 9 (b)

Cost of Electricity (cents/kWh)

Higher Fuel Cost ($40/ton)
Lower Capital Cost Case

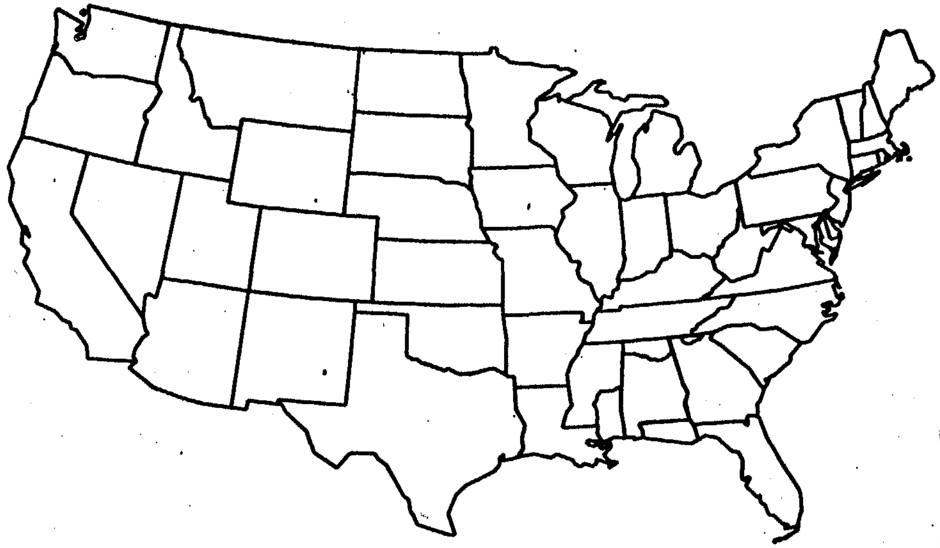


INTERNATIONAL PROSPECTS FOR CLEAN COAL TECHNOLOGIES
(Focus on Asia)

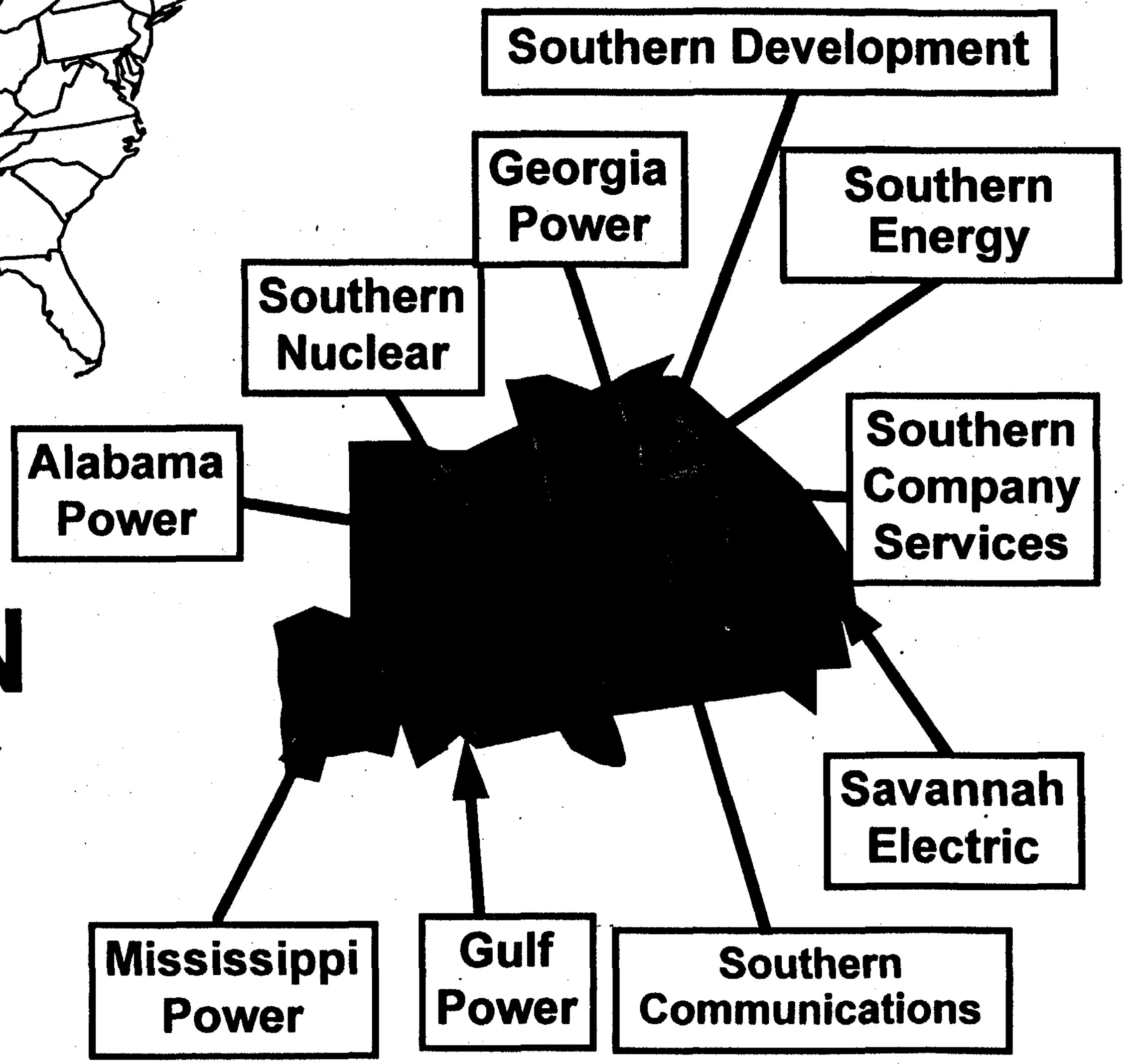
Presented by:
David T. Gallaspy
Southern Energy, Inc.

Objectives

- Propose Asia as focus market for commercialization of CCT's
- Describe principles for successful penetration of CCT's in international market - based on "CEPA" experience
- Summarize prospects for CCT's in Asia and other international markets



SOUTHERN COMPANY SYSTEM



Statistical Highlights

	Southern Energy	Southern Company System	Total
Assets	$5.0B	$25.6B	$30.6B
Annual revenues	$0.6B	$8.6B	$9.2B
Generating capacity (MW)			
Own	1,476	31,126	32,602
Operate	2,729	36,208	38,937
T&D	31,000 mi.	161,000 mi.	192,000 mi.
Employees	4,382	26,500	30,882
Service area		120,000 sq.mi.	
Population served		11M	

Worldwide Locations

Southern Company Clean Coal Commitment

- Largest purchaser of coal in U.S. (50mm tons/year)
- Wilsonville coal research heritage
  - Coal liquefaction/Solvent refined coal
  - Advanced coal cleaning
- Four Clean Coal projects
  - Low NOx combustion (2 projects)
  - Advanced FGD
  - Selective catalytic reduction
- Wilsonville Power Systems Development Facility

Acquisition of CEPA

- Consolidated Electric Power Asia (CEPA) is the largest and most successful IPP in Asia
- Executive Chairman - Gordon Wu
- Currently operates 3,995 MW in China and the Philippines (approx.. 2,000 equity MW)
- Southern Energy has agreed to acquire 80% interest in CEPA, effective January 31, 1997

With CEPA acquisition, Southern Company will extend its commitment to coal-fired generation into the fastest growing markets

What Are the International Prospects for CCT's?

- Developed countries currently represent too small a market to drive commercialization of CCT's
- Move to open access competitive markets works against coal and advanced CCT's
- Government subsidies for demonstration projects will dwindle under open markets, privatization

Near-term prospects for CCT's lie in high growth emerging markets -- primarily Asia

Widespread Commercialization of CCT's Requires ...

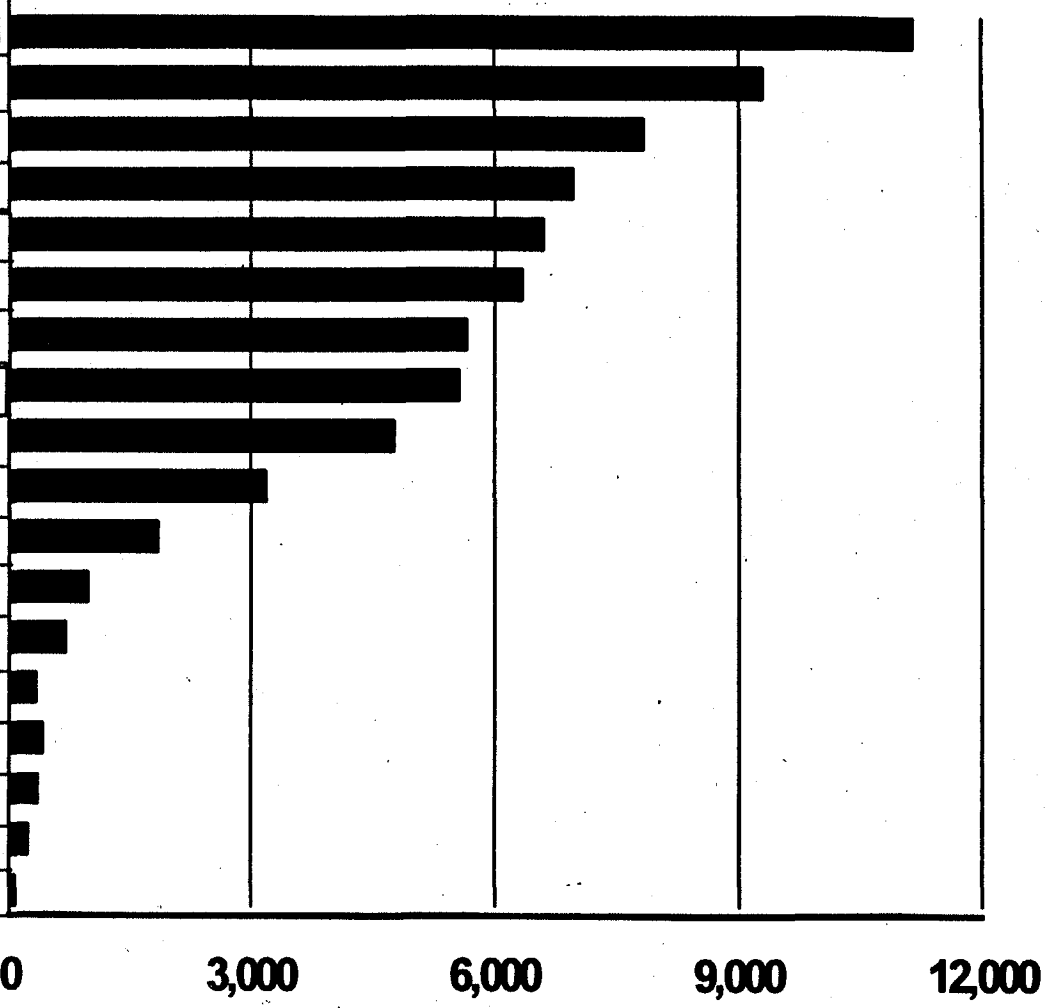
- **Rapid growth in demand for new power generation**
  - **large-scale projects**
  - **high utilization factor**
  - **ability to replicate plants**
- **Availability of/dependence on coal**
- **Need for environmental improvement**
- ***Asia has all these - should be viewed as premier market for CCT application***

The Key: Growth

- Three of the four most populated countries in the world are located in the Asia region (China, India and Indonesia)
- Asia is and will continue to be the fastest growing economic region in the world
- The major source of energy for Asia is coal
- Asia has strongest, growing need for environmental improvement
- There is a tremendous and growing demand for electricity

1993 CONSUMPTION OF ELECTRICITY PER CAPITA

Country	Million kWh*	Population Million*	kWh/ Capita
USA	2,882,211	258.2	11,161
Australia	163,139	17.5	9,307
France	449,500	57.4	7,835
Germany	566,000	81.2	6,970
Singapore	18,964	2.9	6,608
Japan	788,260	124.3	6,342
Hong Kong	33,500	5.9	5,660
U.K.	322,730	58.0	5,564
Taiwan	99,203	20.8	4,765
S. Korea	140,434	44.1	3,187
Malaysia	34,305	18.6	1,844
Thailand	57,000	58.6	973
China**	812,680	1,165.0	698
Philippines**	21,780	65.7	332
Pakistan**	49,270	119.1	414
India**	314,000	870.0	361
Indonesia**	44,660	191.2	234
Bangladesh	8,776	119.3	74



*1995 Economist Diary from the Economist Newspaper Ltd.
**CEPA active

World Total Net Electricity Consumption by Region
(Billion Kilowatt-hours)

Region/Country	1990	1993	1995*	2000*	2005*	2010*	2015*
OECD							
OECD North America	3,257	3,422	3,584	3,809	4,130	4,471	4,870
OECD Europe	2,116	2,196	2,374	2,708	3,022	3,343	3,680
OECD Pacific	918	970	1,066	1,275	1,423	1,548	1,667
Non-OECD							
EE/FSU	1,907	1,656	1,523	1,689	1,850	2,022	2,205
Non OECD Asia	1,263	1,532	1,733	2,345	3,037	3,829	4,781
Middle East	190	196	245	293	339	381	426
Africa	285	299	304	362	430	507	593
C. and S. America	448	490	527	608	690	776	863
Total	10,382	10,761	11,355	13,090	14,922	16,877	19,087

Note: OECD= Organization for Economic Cooperation and Development.
EE/FSU=Eastern Europe/Former Soviet Union

* Projections

Sources: Energy Information Administration (EIA), DOE/EIA-0219(93), International Energy Annual 1993, Annual Energy Outlook 1996, DOE/EIA-0383(96) and World Energy Projection System (1996).

CEPA Experience in Asia --Illustrates Successful Application of CCT's

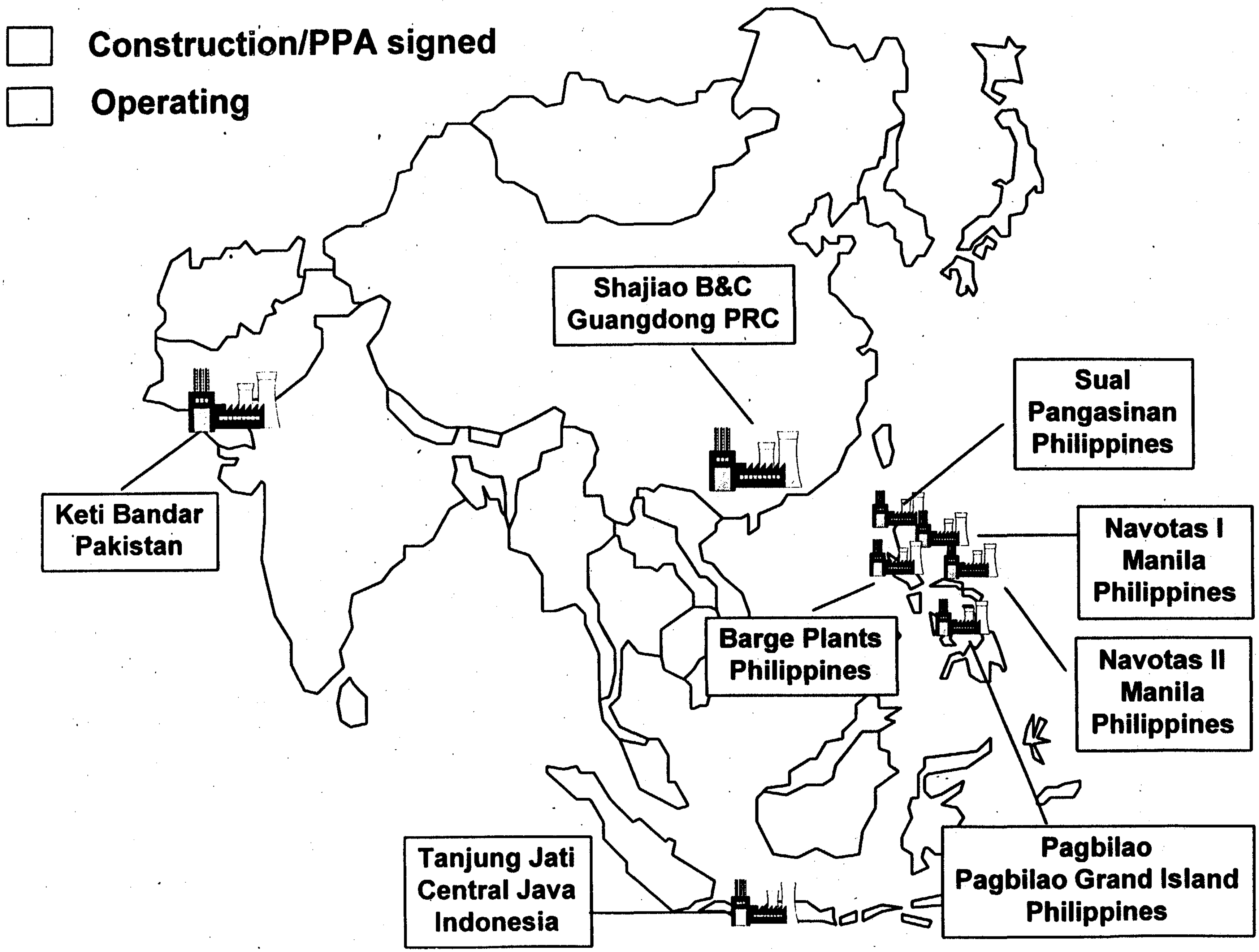
- Premier private power company in Asia, with predominantly coal base
- Has consistently led a very competitive market
- Commitment to increasing application of CCT's while meeting market price
- *But ... environmental technologies limited to commercially proven, low cost*

CEPA
PROJECT LIST

Project	Location	Size	Fuel	Operation Date
Shajiao B	Dongguan, PRC	2x350MW	Coal	7/87
Shajiao C	Dongguan, PRC	3x660MW	Coal	6/96
Navotas I	Manila, Philippines	3x70MW	Oil	3/91
Navotas II	Manila, Philippines	1x100MW	Oil	3/93
Power Barges	Various, Philippines	9x30MW	Oil	2/93
Pagbilao	Quezon, Philippines	2x367.5MW	Coal	7/96
Sual	Pangasian, Philippines	2x600MW	Coal	6/99
Tanjung Jati B	Central Java, Indonesia	2x660MW	Coal	2000
Pakistan	Sindh Province	2x660MW	Coal	2001

*Under Construction
**PPA signed

Total MW	7,835
Equity MW	5,139


Construction/PPA signed
Operating
Shajiao B&C
Guangdong PRC
Keti Bandar
Pakistan
Sual
Pangasinan
Philippines
Navotas I
Manila
Philippines
Navotas II
Manila
Philippines
Barge Plants
Philippines
Pagbilao
Pagbilao Grand Island
Philippines
Tanjung Jati
Central Java
Indonesia

Basis for Success

- Early entry into difficult markets
- Application of reference plant concept to achieve scale and procurement economies (famous “12-pack”)
- Welcome involvement of multilaterals, export credit agencies
- International procurement of technology, with financing
- Project finance on commercial terms, with fair allocation of risks
- Apply well proven, but state-of-the-art technologies

CEPA Application of CCT's

- Commitment to being environmental leader
- Beginning with Sual project, all CEPA projects include:
  - low-NOx combustion
  - FGD
  - high thermal efficiency
- Contrasts with many developers in Asia, where goal is to meet the minimum environmental standards

What Will Determine the Penetration of CCT's in the Private Power Industry?

- Financing (debt and equity)
- Market Forces
- Fuel Availability and Price
- Technology Characteristics
- Government Policy

Consider each in turn ...

Financing

- ECA led: often dictates sourcing and type of technology
- Project finance implies commercial technology only, EPC wrap
- Financing typically dictates environmental standards (World Bank)--achievable without advanced CCT's

The Market

- Competitive bidding is the rule; negotiated deals going away
- Severe downward pressure on price as competitors increase, market is established
- Long term fixed price contracts support high capital cost
- But ... initial moves toward competitive market in electricity (Philippines)

Example: Evolution of Market Pricing in the Philippines

Plant	C.O. Year	Fuel	cents/kWh
Pagbilao	1996	Coal	6.9
Sual	1999	Coal	5.1
Ilijan	2002	Gas	3.1

Note: CEPA lost bid for Ilijan on rebid to Korea Electric. Ilijan is competitive with coal even if LNG is used.

Fuel Characteristics

- Use of indigenous coal supports important macroeconomic objectives
  - Indigenous coal often very poor quality (e.g., Pakistan, India)
- Incentive for developing countries to export best coal, utilize worst coal
- Relatively low coal prices put lower premium on thermal efficiency

Coal Production
(millions tons)

	1980	1990	1993
Australia			
Domestic Production	79.8	175.0	196.1
Imports	n.a.	n.a.	n.a.
Exports	47.6	114.6	145.3
Brown Coal	36.3	50.7	53.0
China			
Domestic Production	684	1,190	1,258
Imports	2	2	2
Exports	7	19	22
India			
Domestic Production	125.7	233.2	270.8
Imports	0.7	6.3	n.a.
Exports	0.1	0.1	n.a.
Brown Coal	5.3	15.5	14.9
Indonesia			
Domestic Production	0.3	11.6	30.4
Imports	n.a.	0.9	n.a.
Exports	0.1	5.4	18.5
South Africa			
Domestic Production	126.9	203.7	200.6
Imports	n.a.	n.a.	n.a.
Exports	32.2	54.5	58.9

U.S. coal production

1. Nearly two-thirds of all U.S. coal production is a high-ranking bituminous product.
2. Nearly two-thirds of all coal is produced from surface mine operations.
   - Current production of 1.0 billion tons per year is dominated by over 600MM tons of surface production.
3. Coal consumption in the U.S. is dominated by electricity generation plants. Nearly 900MM tons/yr are consumed by these facilities.

Coal Consumption for Major Markets (Million short tons)

Region/Country	1990	1993	1995*	2000*	2005*	2010*	2015*
United States	895	926	937	990	1,046	1,082	1,120
Japan	130	128	126	142	150	157	160
Former Soviet Union	854	569	562	550	547	540	531
China	1,125	1,273	1,380	1,685	2,036	2,465	2,998
India	259	298	335	400	483	560	619
Other Asia	187	206	225	228	233	263	315
Middle East	7	8	10	10	12	13	13
Africa	157	157	156	166	174	183	193

* Projections

Sources: Energy Information Administration (EIA), DOE/EIA-0219(93), International Energy Annual 1993, Annual Energy Outlook 1996, DOE/EIA-0383(96) and World Energy Projection System (1996).

Technology

- Financing requirements and risk allocation dictate commercially proven technology
- Competitive bidding requires technology with multiple suppliers (not single source, royalty bearing technologies)
- Technology must be reasonably "cookie cutter," even with changing fuel and site conditions

Technology (cont)

- Growing emphasis on local manufacturing capability (e.g., China, India)
- CCT technologies must be integrated into a complete plant, with a single turnkey wrap

Government Policy

- Governments in growth markets are concerned about meeting demand at low price
- Not willing to pay extra for environmental performance
- R&D subsidies usually for manufacturing, education -- not clean coal demonstrations
- Governments have macroeconomic concerns -- favor local fuels and manufacturing

Implications - Opportunities for CCT's in International Marketplace

- Aim for high growth markets to maximize opportunities and replicate projects
- Integrate CCT's into reference plants with turnkey EPC backing
- Trade off maximum efficiency and environmental performance for low cost, high reliability

Implications (cont)

- Achieve scale economies through:
  - high unit output (300 - 500MW +)
  - emphasis on manufactured components, systems
  - worldwide sourcing
- Achieve export credit financing
  - proven technology
  - constructor/supplier guarantees

Implications (cont)

- Transition to local manufacturing capability
  - simplify designs
  - export more technology, less hardware
  - establish JV's with local suppliers (as FW, Westinghouse, others have done)
  - import highly engineered equipment

Implications (cont)

- Develop/adapt CCT's for low quality indigenous coals, fuel flexibility
  - Reduced premium on efficiency
  - Opportunity for coal upgrading technologies!
- Work with development agencies (World Bank, ADB, CDC, etc.) to meet their agendas
  - Highest growth markets are the developing countries!

Conclusion - Opportunities for CCT's Internationally?

- Wherever MW's are being added, there should be opportunities for CCT's
- Key: Aim technologies for growth markets--not mature markets--and meet their needs
- Remember that the constraints which cannot be overcome are NOT technical:
  - Market price
  - Financing

Gas Turbine Power Plants - Perfect Example of Commercialization Drivers

- What other technologies have seen such rapid and continuous improvement in:
  - Scale/size (from 20 to 200 MW in a single engine)
  - Specific power output
  - Reliability, operability and maintainability
  - Application of advanced manufacturing processes and technologies
  - Environmental emissions performance
  - Innovativeness and technology evolution
  - Engineering and applications support
  - Improved guarantees, warranties and manufacturers' backing

....all accompanied by....

- A reduction of both installed capital cost and energy cost by perhaps 50%
- No wonder this is a major success story for energy technology!!