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FROM THE AMERICAN PEOPLE

DESIGNING A
CLEANER
FUTURE
FOR **COAL**

Solutions for Asia that Address Climate Change



October 2007

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ACRONYMS

ADB	African Development Bank
AFOC	ASEAN Forum on Coal
APEC	Asia-Pacific Economic Cooperation
CCS	Carbon capture and sequestration
CCT	Cleaner coal technology
CFB	Circulating fluidized bed
CO ₂	Carbon dioxide
ESP	Electrostatic precipitators
FGD	Flue gas desulfurization
GW	Gigawatt
HHV	Higher heating value
IGCC	Integrated gasification combined cycle
kW	Kilowatt
kWh	Kilowatt hour
MPa	MegaPascal
MW	Megawatt
NTPC	National Thermal Power Corporation of India
O&M	Operation and maintenance
OECD	Organisation for Economic Cooperation and Development
PC	Pulverized coal
RMB	Renmimbi (People's Currency) (China)
SC	Supercritical
SO ₂	Sulfur dioxide
USAID	United States Agency for International Development
USC	Ultra-supercritical

EXECUTIVE SUMMARY

Coal use in developing Asia is rising sharply. By 2030, the burning of coal to meet energy demand is expected to increase four-fold in the region resulting in 13 billion metric tons of carbon dioxide being emitted into the atmosphere every year.¹

The USAID ECO-Asia Clean Development and Climate Program (CDCP) commissioned this discussion paper to build upon the findings of a regional analysis that explored a wide range of options for six developing Asian countries to address climate change.² Of all the options identified, one held the greatest medium-term potential to reduce climate changing emissions: the use of technologies to make coal combustion cleaner and to increase the efficiency of coal powered plants. Since the burning of coal by the power sector produces more carbon dioxide (CO₂) than any other source, it is estimated that technologies that increase plant efficiency in existing and new plants could slash harmful emissions by one billion metric tons a year.³

This discussion paper examines how the use of cleaner coal technologies in power generation can help developing Asian countries advance their efforts to address climate change. Divided into three sections, the discussion paper begins with a review of the present and proposed use of cleaner coal technologies in the Asian region. It then identifies the barriers impeding the deployment of these technologies before concluding with a series of recommended initiatives to address these barriers.

KEY FINDINGS

A review of current and planned use of coal by China, India, Indonesia, Philippines, Thailand, and Vietnam confirms the need to take immediate measures to reduce the impact of coal combustion in the power sector. Coal currently supplies nearly half (48%) of the primary energy in these countries, and even if the use of coal is gradually phased out to deal with concerns about climate change, the continued use of coal to produce electric power is vital to the current and future economic growth of these countries. Therefore, it is essential to take viable and cost-effective steps to increase the efficiency of coal combustion and reduce the local and greenhouse gas pollutants associated with coal combustion.

The following issues were identified as being key impediments to the wide-scale deployment of cleaner coal technologies (CCTs).

- **Inadequate Monitoring and Enforcement of Environmental Regulations.** There is wide variation in the environmental regulations currently in place within the six countries. In some cases, such as Thailand, regulations are at par with those of developed nations while in other countries there is much room for improvement. At the same time, while the regulations could and should be improved in some of the countries, a more important issue is the lack of effective monitoring and enforcement of the existing regulations. Inadequate and ineffective application of regulations tends to burden those actors who comply while giving non-complaint actors unfair advantages. Finally, in all the countries, there is a notable absence of regulations and guidelines concerning the efficiency of power plants and their CO₂ emissions. Taken together, these regulatory gaps and omissions are impeding the deployment of cleaner coal technologies and slowing efforts to address climate change.

1. USAID, May 2007, *From Ideas to Action: Clean Energy Solutions for Asia to Address Climate Change*, Bangkok, p. 31.

2. The regional analysis was focused on China, India, Indonesia, Philippines, Thailand, and Vietnam.

3. USAID, May 2007, *From Ideas to Action: Clean Energy Solutions for Asia to Address Climate Change*, Bangkok, p. 99.

- **Lack of Pricing Incentives for Coal Cleaning:** Coal cleaning is not used as widely as it should be due to lack of appropriate pricing policies. Coal prices should reflect coal quality and resulting pollution. If cleaner coal cannot be sold at a higher price, the coal producer or supplier has less incentive to clean the coal.
- **Lack of Attention to Power Plant Maintenance and Rehabilitation:** Regulations provide no incentive for rehabilitation of existing power plants or improvement of their efficiency. Lack of funding for operation and maintenance activities, and rehabilitation contribute to rapidly deteriorating plant performance. Very often, it is easier (or preferable) to build a new power plant with a much higher initial investment than to invest in life extension and performance improvement of existing power plants.
- **Perception Barriers to Adoption of High-Efficiency Technologies:** High-efficiency pulverized coal designs (supercritical and ultra supercritical) are not used, mainly because of the perceptions that they are costly, unproven and unsuitable for use with local coals. Consequently, many countries prefer conventional technology (e.g. sub-critical pulverized coal). These views persist despite the evidence of international experience, which demonstrates that supercritical and ultra-supercritical designs are commercially proven and competitive, especially when coal prices are high, as they are presently. Experience is lacking only in the case of Indian coals, but even in this case, there should be gradual use of high-efficiency designs starting from supercritical and moving to ultra-supercritical.
- **Financial Barriers to Adoption of IGCC:** Higher costs compared with other power generation options make financing of integrated gasification combined cycle (IGCC) plants challenging. At the same time, IGCC is an important technology for the sustainable use of coal and deserves to be developed and demonstrated. If carbon capture and sequestration are desired outcomes of cleaner coal technologies, then IGCC holds promise for higher efficiency as well as easier and less expensive capture of CO₂ to help address climate change.

The recommendations below are based on the above findings, as well as input provided by the participants of two conferences⁴ which explored how issues of regional interest can be addressed.

RECOMMENDATIONS FOR REGIONAL ACTION

- **Regional dialogue is needed on environmental standards.** Areas to be explored include: (1) harmonization of emission standards, (2) establishment of guidelines or requirements for minimum efficiency of new coal-fired power plants, (3) learning from experience related to regulation-setting, monitoring and enforcement, and (4) use of market-based instruments (e.g. emission cap-and-trade, emission fees, carbon taxes).
- Support is needed for the **deployment and scale-up of cleaner coal technologies and practices.** Many countries are beginning to experiment with cleaner coal technologies including pilot scale rehabilitation of older power plants and high efficiency pulverized coal designs. Targeted technical assistance is needed to maximize the climate change mitigation potential of these efforts and put in place the frameworks – to evaluate decisions relating to technology, material, labor and fuel choices – and information to replicate these efforts and scale-up in a short period of time and make CCT the “minimum standard” in the future.

4. The two conferences were the Asia Clean Energy Forum in Manila, Philippines, held on June 26–28, 2007, and organized by the Asian Development Bank (ADB), U.S. Agency for International Development (USAID), and Asia-Pacific Economic Cooperation (APEC), and the International Conference on Cleaner Coal in Chiang Mai, Thailand, held on July 19–20, 2007, and organized by the Association of Southeast Asian Nations (ASEAN) Forum on Coal (AFOC) and USAID.

- An urgent need exists for a **network for sharing information and addressing research needs** facing power companies in the region. The severe environmental problems facing the region, along with climate change, provide the impetus needed to initiate such an institution.
- A need also exists for **better dissemination of information**, such as best practices, lessons learned, and news in general related to cleaner coal use in the region. Various options should be explored, including workshops, online communities of practice, targeted newsletters, etc.
- **Development of innovative financing instruments is** necessary for supporting CCT projects. Such options may include soft loans, carbon financing,⁵ risk mitigation instruments, etc. Carbon financing for such options as coal cleaning, plant rehabilitation, and high-efficiency coal-fired power plants deserves more attention.

INITIATIVES FOR THE ECO-ASIA PROGRAM

The ECO-Asia Program is prepared to address some of the above needs by working with key agencies in each country and the region (e.g., APEC, ASEAN, and AFOC), as well as financial institutions (primarily ADB and the World Bank) and global organizations (e.g., World Coal Institute, World Energy Council, and International Energy Agency, Clean Coal Center). The following specific activities are envisioned:⁶

- **Facilitate dialogue on harmonization of emission standards and establishment of minimum plant efficiency guidelines or requirements.** A first step in this direction began with USAID's co-sponsorship of the ASEAN Forum on Coal, an International Conference on cleaner coal that was held in July 2007 in Chiang Mai, Thailand.
- **Provide targeted technical assistance and organize workshops to facilitate dissemination of information** and dispel mistaken perceptions on the readiness of high-efficiency power technologies. The first step in this direction was a regional workshop on supercritical pulverized coal technology, which was held in Hanoi, Vietnam, in October 2007. Following the workshop, participants had the opportunity to go on a study tour to Japan where they visited high-efficiency power plants.
- Work with financial institutions to **facilitate use of innovative financial instruments** in the deployment of CCTs and disseminate relevant information.
- Develop and support **a regional research network** on cleaner coal.
- Facilitate knowledge sharing through an **online portal** and a **regional newsletter**.

A CLEANER FUTURE FOR COAL IN ASIA

During late 2006 and early 2007, the ECO-Asia Clean Development and Climate Program project team met with more than 200 key energy stakeholders in the six focus countries, and found a clear majority view about the role of coal in Asia's energy future: while the use of coal is associated with significant local and global pollutants, Asia's coal plants cannot be shut down overnight, and coal will continue to be an important fuel for the power sector over the medium-term.

5. In late 2007, the Clean Development Mechanism under the Kyoto Protocol approved methodologies for qualifying carbon emissions reductions from new supercritical coal plants.

6. Subject to approval by USAID.

Moreover, coal-based power generation is set to expand significantly over the next 25 years. The consensus was that, given the relatively low efficiencies of current and planned coal plants in developing Asia, it is essential to take immediate action to increase plant efficiencies in existing and new plants and thereby mitigate the impacts of coal combustion. These views are backed-up by compelling scientific evidence, which suggests that simply ignoring the impact of coal use and carrying-on business-as-usual would severely undermine international efforts to slow climate change. More importantly, a comparison of options to mitigate climate change revealed efforts to increase the efficiency of coal-fired plants could slash one billion metric tons of projected (CO₂) a year by 2035.⁷

Taken together, the initiatives proposed in this discussion paper are clearly insufficient to result in the changes required to reverse the impacts of developing Asia's projected coal use on climate change. Nevertheless, it is hoped that these efforts will prompt governments, industry and donors to re-examine how a cleaner future for coal in Asia can become a pillar of their efforts to address climate change.

7. USAID, May 2007, *From Ideas to Action: Clean Energy Solutions for Asia to Address Climate Change*, Bangkok, p. 99.

A CLEANER FUTURE FOR COAL: SOLUTIONS FOR ASIA THAT ADDRESS CLIMATE CHANGE

I. INTRODUCTION

The purpose of this discussion paper is to review the present situation and future plans regarding use of cleaner coal technologies in the Asian region, identify the issues facing these technologies, and recommend regional initiatives to address these issues.

The discussion paper was commissioned by the USAID ECO-Asia Clean Development and Climate Program (referred to in this report as the ECO-Asia Program (CDCP)), which the International Resources Group is implementing. This three-year regional program is intended to promote clean energy technologies, policies, and best practices, especially related to climate change in six countries of Asia: China, India, Indonesia, Philippines, Thailand, and Vietnam. As a first step, the ECO-Asia Program undertook a comprehensive analysis of clean energy development in the region, which resulted in the report entitled *From Ideas to Action: Clean Energy Solutions for Asia to Address Climate Change*.⁸ By exploring answers to three questions, this report provides a thorough analysis of clean energy options:

- Which clean energy technologies and sectors hold the greatest potential to mitigate climate change, reduce pollution, and improve energy security and what initiatives should be launched?
- What specific or thematic policy, financial, technical, and incentive-based initiatives would be most effective in addressing these priorities?
- What regional networks and alliances can be leveraged to implement these initiatives strategically?

This analysis helped identify two key clean energy technology areas as the most urgent and promising regarding climate change mitigation: energy efficient lighting and cleaner coal technologies (CCTs) for electricity generation (Box I provides definitions of terms for CCTs). The ECO-Asia Program will provide more in-depth support in these two technical areas for the duration of the program (2006-2009). This discussion paper is part of this effort to assess the issues associated with deployment of cleaner coal technologies, develop an agenda for regional action, and catalyze regional initiatives to address these issues.

The information for each country was collected through a literature review, and data were provided by government agencies to the ECO-Asia CDCP Country Coordinator in each of the six countries. Experts were also contacted regarding the issues facing each country. A draft report was presented at the Asia Clean Energy Forum, organized by Asian Development Bank (ADB), United States Agency for International Development (USAID), and APEC in Manila, Philippines, on June 26–28, 2007. Participants in the International Forum on Cleaner Coal, organized by AFOC and USAID in Chiang Mai, Thailand, on July 19–20, 2007 also discussed the draft report, and the current discussion paper incorporates feedback from participants of both events.

This discussion paper contains four sections. After this introduction, Section 2 describes the present situation and future plans in power generation in the six countries. More specifically, it reviews the existing power generation system along with planned additions of new power plants and present CCT use. The section also reviews environmental standards affecting the design of new power plants and requirements for existing plants, because they have a direct impact on CCT use. Section 3 reviews all the issues and barriers facing uptake of CCTs in the six Asian countries, and Section 4 offers preliminary recommendations on how to overcome some of these issues and barriers through regional initiatives. Existing national and regional institutions could play an important role in such initiatives.

8. USAID, May 2007, *From Ideas to Action: Clean Energy Solutions for Asia to Address Climate Change*, Bangkok.

DEFINITIONS OF CLEANER COAL TERMS

Cleaner coal technologies (CCTs) is a widely used term, often with different meanings. In this report and the ECO-Asia CDCP in general, CCTs has been defined to mean every option capable of reducing emissions upstream, downstream, or within the power generation (energy conversion) process. This is a broad definition and includes such options as coal cleaning, boiler and combustion system tuning/optimization, rehabilitation of existing power plants, post-combustion environmental controls, high-efficiency pulverized coal designs (e.g., supercritical and ultra-supercritical), integrated gasification combined cycle, and carbon capture and sequestration (CCS). The most common CCTs encountered include the following:

1. POWER GENERATION OPTIONS:

High-efficiency pulverized coal plants characterized as **supercritical** or **ultra-supercritical**. These names reflect elevated steam conditions (pressure and temperature), which are required to achieve high efficiency.

Circulating fluidized beds (CFBs). This is a specific type of boiler that captures SO₂ emissions using limestone and does not require additional SO₂ control equipment downstream of the boiler.

Integrated gasification combined cycle. This process involves gasification of coal and then combustion in a gas turbine; a steam turbine is also used, hence the term “combined cycle.”

2. ENVIRONMENTAL CONTROL OPTIONS:

Particulates are removed either through **electrostatic precipitators** (ESPs) or **bagfilters** (baghouses). ESPs are the most commonly used option.

Sulfur dioxide (SO₂) emissions are captured mainly through **flue gas desulfurization** (FGD) equipment installed downstream of the boiler. Use of low-sulfur coal or limestone injection in the boiler can also reduce SO₂ emissions.

Nitrogen oxides (NO_x) emissions are reduced through combustion system modifications (combustion system tuning, over-fire air, low NO_x burners, and re-burning), **selective catalytic reduction**, and selective non-catalytic reduction.

The term **emissions** is also general and includes most air pollutants, such as particulates (which usually affect the immediate vicinity of the power plant), acid rain pollutants (SO₂ and NO_x), and greenhouse gases; however, this report in general focuses more on greenhouse gases.

Many greenhouse gas-reducing options have as a co-benefit the reduction of other pollutants (local and/or acid rain pollutants). In this context, the report will consider all emissions, but emphasize greenhouse gases more.

2. PRESENT SITUATION AND FUTURE PLANS

2.1 EXISTING AND FUTURE POWER PLANTS

Coal presently makes the highest contribution to the power generation mix in the region. Coal contributes 63-80 percent of the power generation in China and India (Table 1). In the Southeast Asian countries (Indonesia, Philippines, Thailand, and Vietnam), coal's contribution to the energy mix is lower but still substantial (18–42 percent), and coal's contribution to the energy mix is expected to increase significantly in the future.

TABLE 1. POWER GENERATION OF ASIAN COUNTRIES

Power Generation Capacity (MWs) as of end of 2006							
Country	Total	Coal	Gas	Oil	Hydro	Nuclear	Renewables
China	517,185	375,715	10,220	5,435	117,380	6,840	1,595
India	127,753	67,692	13,582	2,746	33,642	3,900	6,191
Indonesia	14,937	4,971	4,980	2,859	1,575	0	552
Philippines	15,803	4,177	2,763	3,602	3,257	0	2,004
Thailand	26,554	5,713	18,062	278	1,945	0	556
Vietnam	11,261	2,221	4,402	483	4,155	0	180
TOTAL	713,493	460,489	54,009	15,403	161,954	10,740	10,898

Power Generation Capacity (%) as of end of 2006							
Country	Total	Coal	Gas	Oil	Hydro	Nuclear	Renewables
China	100	72.65	1.98	1.05	22.70	1.32	0.31
India	100	52.99	10.63	2.15	26.33	3.05	4.85
Indonesia	100	33.28	33.34	19.14	10.54	0	3.70
Philippines	100	26.43	17.48	22.79	20.61	0	12.68
Thailand	100	21.51	68.02	1.05	7.32	0	2.09
Vietnam	100	19.72	39.09	4.29	36.90	0	0

Power Generation (gigawatt hours) in 2006							
Country	Total	Coal	Gas	Oil	Hydro	Nuclear	Renewables
China	2,497,528	1,972,199	47,006	24,525	396,400	53,088	4,310
India	732,336	467,871	64,675	67,870	113,315	18,605	0
Indonesia	106,227	43,725	21,329	26,662	8,532	0	5,979
Philippines	56,782	15,294	16,366	4,664	9,938	0	10,520
Thailand	136,810	24,410	94,376	7,806	7,947	0	2,271
Vietnam	52,578	12,683	23,044	721	16,130	0	0
TOTAL	3,582,261	2,536,182	266,796	132,248	552,262	71,693	23,080

Power Generation (%) in 2006							
Country	Total	Coal	Gas	Oil	Hydro	Nuclear	Renewables
China	100	78.97	1.88	0.98	15.87	2.13	0.17
India	100	63.89	8.83	9.27	15.47	2.54	0.00
Indonesia	100	41.16	20.08	25.10	8.03	0	5.63
Philippines	100	26.93	28.82	8.21	17.50	0	18.53
Thailand	100	17.84	68.98	5.71	5.81	0	1.66
Vietnam	100	24.12	43.83	1.37	30.68	0	0

Source: USAID, May 2007. *From Ideas to Action: Clean Energy Solutions for Asia to Address Climate Change*, Bangkok.

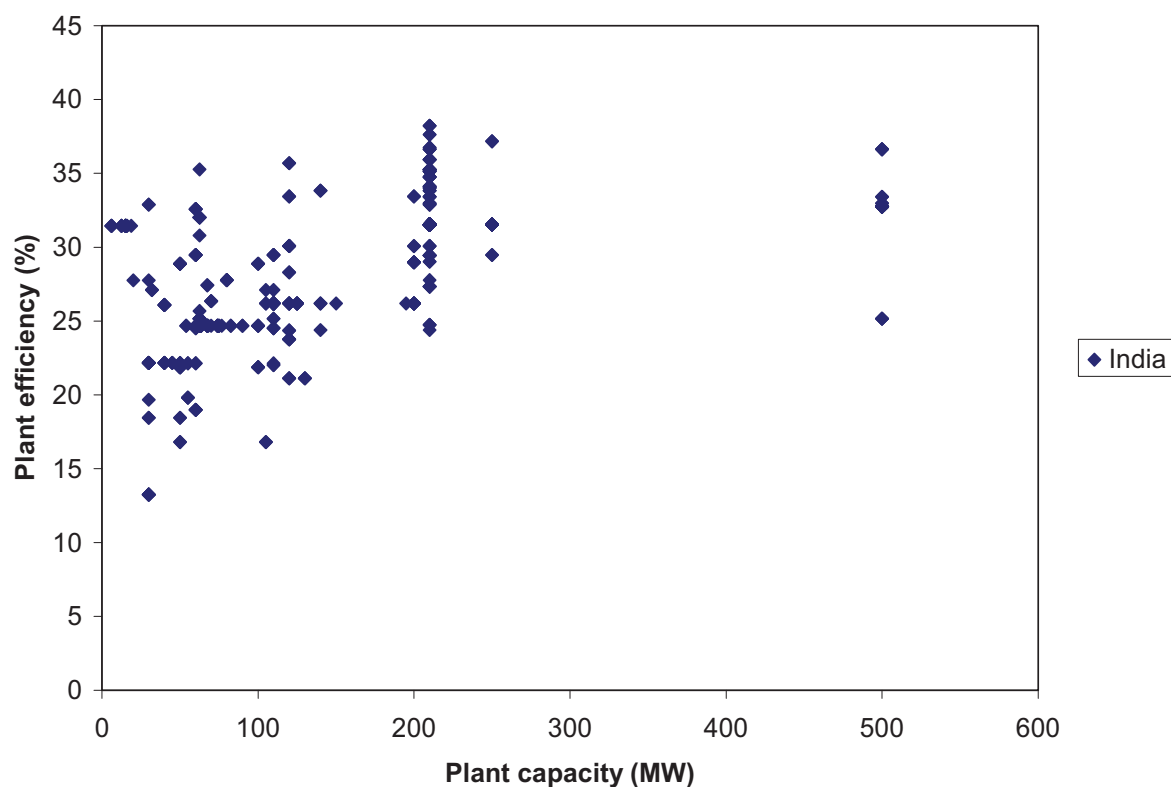
Note: Totals may not add up due to rounding.

Existing plants have been designed for low efficiencies; with time, the actual efficiency falls significantly below the design efficiency. Although statistics are not available on all plants, the majority of existing power plants are relatively small (100–300 MWs each). The implication of this is that they are also inefficient, because smaller size plants are designed for lower steam temperatures and pressures and, hence, lower efficiency. For example, power plants larger than 300 MWs are typically designed for efficiency in the 32–35 percent range;⁹ smaller units are designed for 25–32 percent. **Figure I**, which provides actual plant data for India, illustrates the relationship between unit size and efficiency.

Of course, plant operating practices and age also affect efficiency; as the units age and operating and maintenance (O&M) practices are not adequate, it is common for plant efficiency to decline by 2–4 percentage points below the “design efficiency.” This partly accounts for the wide spread of data for each unit size in **Figure I**.

Member countries of the Organization for Economic Cooperation and Development (OECD) have an average efficiency of 36 percent (e.g. the United States averages 34–35 percent), and power plants built recently in OECD countries have much higher efficiencies.

FIGURE I. PLANT EFFICIENCY OF INDIAN POWER PLANTS, 2005



Source: Data from the Platts UDI database (2005).

Future expansion will add significantly more coal-fired power-generating capacity; the efficiency of these plants will impact greenhouse gas emission levels for many years to come. The existing coal-fired power generating capacity of 460 gigawatts (GWs) - of a total of 713 GWs - in the six Asian countries is expected to exceed 1,000 GWs by 2020 and approximately 1,600 GWs by 2030. The most significant additions will occur in the following countries:

9. Efficiency refers to net efficiency higher heating value (HHV) basis.

- China plans to increase its coal-fired generating capacity from 376 GWs in 2005 to 540 GWs in 2010 and 780 GWs in 2020.
- India projects that coal-fired capacity will increase from the present 68 GWs to 90 GWs in 2010, 200 GWs in 2020, and 400 GWs in 2030.
- Indonesia, a coal-exporting country, has only about 5 GWs of installed coal-fired capacity, but is planning to increase investment in new coal-fired plants substantially. As a result, the country expects to build approximately 30 GWs of new coal plants by 2025.
- Vietnam plans to add approximately 18 GWs of coal-fired capacity by 2020.

The situation in the Philippines is similar but it cannot be predicted how much of the new capacity will be coal fired because the indicative generation expansion plan does not specify type of fuel, which is decided by the private sector. In Thailand, coal is the least-cost option; however, strong local opposition has led to the official generation expansion plan projecting only 2.7 GWs of new coal-fired capacity by 2020.

With approximately 1,600 GWs expected to come on line by 2030, these power plants are of great importance for the six countries examined in this report. For every additional percentage point in plant efficiency, a 1,000 MW unit with 80 percent capacity factor would release 160,000 tons of CO₂ a year less than a similar unit with a percentage point lower efficiency. So, if the new coal-fired plants planned for construction in the six Asian countries are designed for three percentage points higher efficiency (a reasonable goal in terms of commercially available technology and supported by favorable economics), it will reduce CO₂ by 768 million tons/year.

2.2 ENVIRONMENTAL STANDARDS

This section provides an overview of the environmental standards that directly impact power plant design and deployment of cleaner coal technologies. **Table 2** summarizes the emission standards affecting both existing and new coal-fired power plants.

Maximum emission limits apply to each unit; as such, they affect the unit's design, including design features that fall in the category of cleaner coal technologies. Some of the countries have emission standards only for new coal-fired power plants (e.g., Indonesia); others (e.g., China and Thailand) have standards for both new and existing plants. Emission standards for new plants are stricter than for existing plants, because it is easier to design a plant for low emissions, rather than retrofit it to reduce its emissions.

TABLE 2. EMISSION STANDARDS FOR COAL-FIRED POWER PLANTS (mg/Nm³)

Pollutant	China ^a	India ^b	Indonesia	Philippines	Thailand ^c	Vietnam	United States
Total suspended particulates	Period I: 200–300 Period II: 200 after 2005 Period II: 50 after 2010 Period III: 50 (except plants with FGDs: 100)	150	150	200 (150 in urban or industrialized areas)	Existing: 320 (except Mae Moh ^d : 180) New: 120	200	30–50
Sulfur Dioxide (SO ₂)	Period I & II: 2,100 after 2005 Period I: 1,200 after 2010 Period II: 400 after 2010 Period III: 400	NA	750	Existing: 1,500 New: 700	Existing: 700 (except Mae Moh: 320–1,300) New: 320–640	500	400–800 (but new plants are built for less than 100)
Nitrogen oxides (NO _x)	VM>20%: 450 100<VM<20%: - Period I: 1,100 - Period II & III: 650 VM<10%: - Period I: 1,500 - Period II: 1,300 - Period III: 1,100	NA	850	Existing: 1,500 New: 1,000	Existing: 400 (except Mae Moh: 500) New: 350	650 (1,000 for VOC<10%)	210 (0.15 pounds/MBtu) (but new plants are built for less than 100)

Note: Abbreviations in the table indicate the following: "mg/Nm³" milligrams/standard cubic meter; FGD, flue gas desulfurization; SO₂, sulfur dioxide; NO_x, nitrogen oxides; VM, volatile matter; VOC, volatile organic compound; and MBtu, million British thermal unit.

a. China's emission standards (GB 13223-2003) introduce the following three categories:

- First period: Power plants approved before December 31, 1996
- Second period: Power plants approved between 1997 and 2004
- Third period: Power plants after January 2004.

The third period includes new construction, extension or reconstruction of construction projects whose environmental impact reports were examined and approved during the second period. Yet, it has been five years since the approval date and they have not commenced construction before the implementation of this standard.

b. No emission standards are available for SO₂ and NO_x

c. SO₂ regulations for new plants depend on size as follows: >500 MW: 320 mg/Nm³; 300–500 MW: 450 mg/Nm³; <300 MW: 640 mg/Nm³.

d. Mae Moh is the largest lignite-fired power plant in Thailand.

Source: Compiled from multiple resources

China and Thailand have emission standards comparable to OECD countries in terms of SO₂ and NO_x emissions. India has no SO₂ and NO_x standards. Regarding particulates, most of the countries have emission standards in the 120–200 mg/Nm³ compared with 30–50 mg/Nm³ in OECD countries. Considering that particulates continue to be a serious problem in many countries and cities of Asia, something clearly must be done to reduce this pollutant. The challenge facing most countries is to determine the appropriate environmental regulation and emission standards that will reduce emissions from existing power plants in a cost-effective manner, while forcing the oldest and most polluting ones to retire. Achieving this objective has not been easy.

It is noteworthy that no Asian or OECD country has minimum plant efficiency requirements. China has incorporated goals for use of efficient power plants in its five-year plans but these are neither laws nor firm requirements. The European Union is considering minimum efficiency requirements and provisions for future incorporation of CCS (“capture-ready”), but such requirements have not been included in a directive yet.

Additional Regulatory Instruments. In addition to emission standards, some countries have applied annual emission caps. China and the United States are good examples of such regulatory tools. In the United States, SO₂ and NO_x caps allowing individual power companies to optimize their emission compliance plans have resulted in significant cost reductions. China has applied such SO₂ caps, too. More specifically, it created the “acid rain control regions” and “sulfur dioxide control zones” (commonly known as “two control zones”) covering 1.09 million km² (14.4 percent of China’s land mass) and 61 large cities. Provinces included in the acid rain region or SO₂ control zones are required to limit SO₂ releases. Specific targets are specified in the five-year plan of the government.¹⁰ **Table 3** shows the SO₂ emission targets for 2005 relative to 2000, which were set in the Tenth Five-Year Plan (2001–2005) of the Central Government. Actual emissions in 2005 were 26.5 million tons.

TABLE 3. CHINA'S TOTAL SO₂ TARGETS FOR 2005 (thousands of tons)

	2000 Actual	2005 Target
China	19,950	17,950
Acid rain control zone	7,868	6,302
SO₂ control zone	5,296	4,234
Two control zones	13,164	10,536

Source: State Council (2001).

The “two control zone” policy was promulgated through a circular, which includes specific targets and schedules, but it is not a law, so it is uncertain to what extent provincial governments will follow it. The lack of continuous emission monitoring systems in power plants and other emitting facilities makes it difficult to monitor and enforce a quantity-based regulation.

According to China’s Academy of Environmental Planning, the total SO₂ emissions from the power sector should be reduced further in the future (**Table 4**).

Furthermore, China has introduced an SO₂ emission fee of RMB 0.65/kg and pays higher electricity prices to coal-fired plants with flue gas desulfurization (RMB 0.015/kWh).

10. W. Jinnan, Y. Jinnan, S. Benkovic-Grumet, J. Schreifels, and M. Zhong, *SO₂ Emission Trading Program: A Feasibility Study in China*, Beijing: China Environmental Science Press.

2.3 USE OF CLEANER COAL TECHNOLOGIES

Use of cleaner coal technologies is already taking place in Asia, but significantly more progress is needed. China leads the way in use of high-efficiency pulverized coal (PC) designs (supercritical and ultra-supercritical), flue gas desulfurization, and circulating fluidized beds. India has started ordering supercritical plants, but not USC. Vietnam and Thailand are also planning to use supercritical PC technology in the next generation of power plants.

TABLE 4. CHINA'S SO₂ TARGETS FOR THE POWER SECTOR, 2000–2020 (thousands of tons)

Base Year	SO ₂ Target
2000 (base year)	8,900
2005	8,000
2010	7,300
2015	6,700
2020	6,300

Source: J. Yang and J. Schreifels, 2003, Implementing SO₂ Emissions in China, OECD, Paris, France. Originally presented at the Global Forum on Sustainable Development: Emissions Trading, March 17–18, 2003.

The following section summarizes the key developments regarding CCT deployment in each country:

China. China has an aggressive program for acquisition and adaptation of CCTs. The following are the main motivating factors behind these efforts:

- Recognition that acid rain has a significant impact on agricultural products (especially rice) and the Chinese economy in general.
- Acknowledgement that climate change is an issue that needs to be addressed immediately.

As a result, China has taken the following actions:

- China has introduced environmental regulations to reduce acid rain pollutants. FGD technologies have been used and adapted to China's requirements. Reports on installed FGD capacity vary widely. Up to 34 percent of the total coal-fired capacity reportedly involves FGDs as of the end of 2006; this represents approximately 160 GWs of installed capacity.¹¹ Numerous local manufacturers have entered into licensing agreements with overseas suppliers and have adapted the design of FGDs to fit China's requirements.
- China has continued to use coal cleaning before the coal is transported to the plant. By the end of 2005, 700 million tons of coal were cleaned;¹² this represents about 32 percent of the total coal produced. During the Eleventh Five-Year Plan (2006–10), coal cleaning capacity was to expand to 1 billion tons/year, representing 70 percent of the coal produced. In Shanxi province alone, 52 coal-cleaning plants are to be established, with total incremental processing capacity of 251.6 million tons/year and a total investment of RMB 12 billion.¹³ The provincial government is planning to build major cleaning centers in Datong, Qizhou, and Suozhou.
- Low NO_x burners are used in new coal-fired power plants, but the emission standards do not require any action by existing power plants. No other NO_x reduction is being pursued (in

11. Yijun Zhang, "The Prevention and Control of Air Pollution of Coal-Fired Power Plants in China" presented at the International Conference on Cleaner Coal in Chiang Mai, Thailand, July 19–20, 2007.

12. Xue Zhongjin, 2006, "Sustainable Development of Coal Industry and Clean Coal Industry in Shanxi!"

13. China's Eleventh Five-Year Plan.

addition to low NO_x burners in new plants), except for a few isolated cases of selective catalytic reduction, such as those installed by the Dongfang Boiler Industrial Group in the Guangdong Hengyun power plant (2 x 300 MW) in 2004 and in the Huadian Group's Changsha power plant (2 x 600 MW) in 2005.

- The use of supercritical and ultra-supercritical pulverized coal plants are increasing sharply in China, especially by the five large power generating companies. For example, 60 percent of the new plants that started construction in 2005 and representing a total of 37.8 GWs (600 MW each) are supercritical plants. These units are designed for efficiencies of 38–42 percent (higher heating value [HHV] basis, net). By 2007 there would be 16 ultra-supercritical units of 1,000 MW each in operation (Yu Huan plant, four units; Zouxian, two units; Taizhou, two units; Waigaoqiao, two units; Ninghai, two units; Beilungang, two units; and Beiqiang, two units). Chinese manufacturers have developed joint ventures and licensing agreements and so the majority of the equipment will be manufactured in China.¹⁴
- Circulating fluidized bed technology, which is suitable for reducing acid rain pollutants while burning a variety of coals and low-quality fuels, has been used extensively in China up to unit sizes of 300 MW.
- Integrated gasification combined cycle is a technology that China has identified as a critical option for the future; however, even though a number of proposed IGCC demonstration projects for power generation exist, none has reached financial closure. In the meantime, many coal gasification facilities operate in China in chemical industries and fertilizer plants. The most recent announcement was an order by Shenhua Ningxia Coal Industry Group (the largest coal producer) to Siemens for two gasifiers to produce 830,000 tons/year of dimethyl ether. This is the first production line of a three-production line complex, which will produce up to 3.2 million tons of liquid fuels when it is completed in 2009.¹⁵ Four proposals (listed below) for IGCC demonstrations have reportedly been submitted to China's National Development and Reform Commission, but no decision has been taken:

1. The China Power Investment Corporation's two times 400 MW Langfang (power and heat, as well as CO₂ capture and sequestration)
2. Greengem's 250 MW Tainjin (domestic technology, as well as CCS)
3. Greengem's 400 MW Yantaid
4. 250 MW in Zhejiang (domestic technology).

In parallel, China is participating in the U.S. FutureGen Program, which seeks to build IGCC plants and implement CCS.

- CO₂ sequestration. China is also participating in assessments of the potential for carbon capture and sequestration, as well as pilot projects. For example, Shanxi Energy (a state-owned company involved in coal production, coal chemicals, renewable energy, and cleaner coal technologies) in collaboration with Petromin Resources is studying CO₂ sequestration in coal mines that are no longer in use.¹⁶

14. More specifically, Shanghai Boiler Works has teamed-up with Alstom and Siemens; Harbin Boiler Group will work with Mitsubishi; and Dongfang Boiler Industrial Group will work with Hitachi.

15. *Coal Age Magazine*, 2007, "(MISC) NEWS," (May), p. 5.

16. *bid.*, p. 12.

The above developments are impressive, but they relate mostly to new power plants. Of course, with such a rapidly expanding economy and increasing demand for electricity, the new power plants will soon be the overwhelming portion of the power generation system. Further, the new plants will operate for 30–50 years and so any significant improvement on these plants will have long-lasting impacts. This does not mean, however, that existing power generation facilities do not offer opportunities for emission reductions. Although some of them need to be retired (either because they are at the end of their operating life or are too small and inefficient), a significant portion of the existing power plant fleet needs rehabilitation emphasizing efficiency and reliability improvement. Some rehabilitation projects have been implemented in recent years, but most of them were supported by foreign aid (e.g., German and Japanese). With the assistance of multilateral banks, a more systematic effort is underway to overcome the barriers that keep rehabilitation projects from implementation.

India. Most of India's coal is not cleaned. Studies have shown that even screening of the rocks that are often included in the coal would improve the economics of coal transport significantly. Recently, Coal India decided to wash the coal in all new coal mines.¹⁷ Also, the Government of India (Ministry of Environment and Forest) requires that coal shipped more than 1,200 km from the mine should be washed. As a result, it is projected that coal washing will reach 55 million tons this year (2007) and 163 million tons by 2012.¹⁸

The first supercritical PC plant is under construction in India, and more are planned. For example, National Thermal Power Corp. of India (NTPC) employs supercritical technology at the Sipat and North Karanpura projects (3 × 660 MW each). The Sipat plant is expected to be commissioned in early 2008. Furthermore, the Government of India has specified supercritical PC for five ultra-megapower plants (4,000 MW each), which are planned for the near future.

There are no ultra-supercritical power plants in the country yet. One power plant of Reliance Energy (Dahanu Thermal Power Station) employs FGD; this is a voluntary application, because the country has no SO₂ emission regulations. Also, CFB technology is used; two times 120 MW and two times 30 MW CFB plants are presently operating.

In addition, regarding IGCC, Bharat Heavy Electricals has developed a pilot plant of coal-based IGCC of 6.2 megawatts electrical at its research and development center located at Trichy using pressurized fluidized bed gasifier technology. Design of 125 MW IGCC demonstration plants is being pursued with this technology, but no final approval has been received. Expansion of this design to a 125 MW IGCCC demonstration plant has been proposed. Suitable investment plans are pending.

Indonesia. The country has extensive experience in coal cleaning, but it is used exclusively for cleaning coal that is being exported. Coal presently provides about 40 percent of Indonesia's power generation, but it expects to increase its share significantly in the next 20 years. About 10,000 MWs of new coal-fired capacity is expected to come on line before 2010. Efficiency of these plants, however, is low, which is typical of subcritical technology. The only CCT technology deployed in Indonesia so far is CFB; many such plants are planned in the 7–150 MW size range.

Philippines. About 24 years ago, one of the world's first fluidized bed combustion (FBC) boilers was installed on the island of Cebu, Philippines (33 MWs). Another FBC plant (CFB type) of 200 MWs is planned for construction in the Visayas by 2009. Under a deregulated generation context, the design features of future plants are not specified and left for the private sector to decide; hence, it is difficult to determine how many of the new power plants will be coal fired and which may use CCTs. It is expected that one or two CFBs will be built, one of them 200 MW. The PC plants are relatively small (200–350 MW) and are likely to be subcritical; some of these plants may include FGDs, but not all of them.

17. Ibid., p. 8.

18. Badal Sanyal, 2007, "Coal India's profits for 2006–07 may dip, (March 15), available at <http://www.thehindubusinessline.com/2007/03/15/18hdline.htm>.

Thailand. Reflecting relatively tight environmental regulations, Thailand has taken steps to use CCT. FGDs have been installed in all the operating units of the Mae Moh plant, the largest plant in the country, representing approximately 2,400 MW. FGDs are installed also in the BLCP Power plant, a 1,434 MW, privately owned power plant. New coal-fired power plants planned are likely to burn imported coal and deploy supercritical technology with FGDs. In addition, CFB technology is used in a paper factory and is expected to be used in both coal and biomass applications.

Vietnam. Vietnam employs mostly subcritical PC technology, but future plants will be supercritical, using imported coal; depending on the sulfur composition, the former may also use FGDs. CFB technology is already used in Vietnam with 2 x 100 MW units operating at Na Duong. Many more CFBs are planned, burning mostly local anthracite. Vietnam has tested a number of coal-cleaning techniques (drum separator with magnetite medium at Vinacomin and “barrel separator with autogenous medium” at Nuibeo mines), but coal cleaning is not widely used. In addition, Vietnam has been evaluating the potential production of coal-water mixture using anthracite and coal cleaning wastes. A pilot-scale facility is under construction at the Institute of Mining Science and Technology.¹⁹

3. ISSUES ASSOCIATED WITH USE AND FINANCING OF CLEANER COAL TECHNOLOGIES

3.1 COAL CLEANING

Coal cleaning methods are commercially available, and no technology-related risks exist, except for some coals, such as Indian, or upgrading of low-rank Indonesian coal. In most cases, coal cleaning positively affects plant performance and reliability. Many coal-cleaning processes are available; however, each has different characteristics, costs, and benefits. For example, dry processes (which do not increase the moisture content of the coal and remove unburned material and sulfur) are clearly beneficial, because they reduce the transportation cost and usually remove sulfur cost-effectively. These processes may positively impact plant efficiency, especially if the combustion efficiency is low. Other coal-cleaning processes increase the moisture content of the coal, and plant efficiency is reduced. Clear distinction is needed regarding the characteristics of each coal-cleaning process, including its costs and benefits.

The most commonly used physical cleaning methods include jigging, heavy-medium separation, and flotation. In the past, coal cleaning focused on removal of sulfur and unburned material (ash) to reduce transportation costs. Sulfur removal of up to 20–25 percent has been achieved by conventional coal-cleaning methods and a higher percentage by advanced (chemical and biological) methods. But sulfur removal depends highly on the chemical composition of the coal, especially whether sulfur is bound with organic or inorganic material (ash).

Coal cleaning raises three issues:

- **Lack of appropriate pricing policies** is a key issue. If cleaner coal cannot be sold at a higher price, the coal producer or supplier has no incentive to clean it.
- **Lack of water in arid areas** is another barrier to coal cleaning, given that most methods require water.
- **Coal cleaning rejects** are the by-products of coal cleaning and usually accumulate close to the coal-cleaning plant or mine, constituting an energy loss (through the carbon wasted) and an

19. L.T. Hung and K. K. Truc, “Strategy to Promote Clean Coal Technology in Vietnam,” presented at the International Conference on Cleaner Coal in Chiang Mai, Thailand, July 19–20, 2007.

environmental hazard. However, recent development of technologies such as CFB make the use of coal cleaning rejects practically feasible; if the regulatory framework allows for power generation by small facilities burning such fuels, this issue of rejects could be eliminated.

3.2 ENVIRONMENTAL CONTROLS

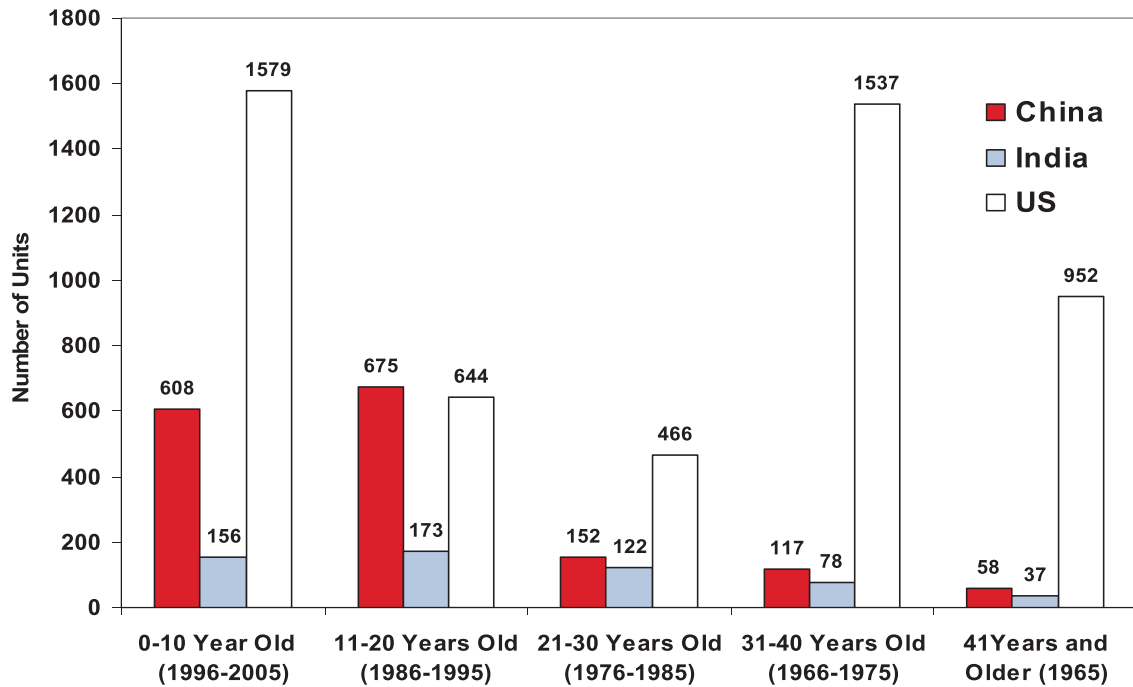
Environmental controls include technologies that reduce particulate, NO_x and SO_2 emissions. Most of these options (with the exception of low NO_x burners, which also improve combustion efficiency) do not increase revenue, and it is impossible to justify them on the basis of a project-specific financial analysis. Justifications for such projects are usually provided by economic analyses, which include environmental damage costs. Also, environmental control projects are carried out to comply with environmental regulations. The key issues associated with environmental controls in the region are related to three questions.

Q. Are the environmental regulations appropriate? It is beyond the scope of this discussion paper to comment on the appropriateness of the environmental regulations of each country; such an assessment requires a very comprehensive analysis and involves subjective considerations, such as the willingness to pay for a cleaner environment, monetary damages associated with loss of human health and/or life, adverse impact on agricultural production, and damages to plants and buildings, etc. The following general observations, however, can be made about the environmental regulations of the six Asian countries:

- China's environmental standards, although not as strict as OECD countries, are probably adequate for the country's stage of economic development. It is likely that NO_x emissions will be identified as the next serious environmental issue that should be addressed, as urban pollution increases. In the future, greater reduction of NO_x emissions from power plants and automobiles will be needed.
- Thailand has already adopted strict environmental controls for SO_2 and NO_x emissions.
- India has no standards for SO_2 and NO_x emissions. Although Indian coal has low sulfur content, the massive development of coal-fired power plants would certainly have adverse environmental impacts. Also, standards for particulates are 150 mg/Nm^3 , and are lax compared with the more widely used level of 50 mg/Nm^3 . There are reports that increased pollution is affecting historic monuments and human health. A reassessment of the country's emission standards is therefore warranted.
- Particulates continue to be a serious issue in all countries of the region. China has reduced the allowable level for new power plants to 50 mg/Nm^3 , but it continues to allow older power plants to emit at much higher levels (up to 300 mg/Nm^3). The situation is similar in most other countries of the region, which allow even new power plants to emit $120\text{--}150 \text{ mg/Nm}^3$. While a site-specific assessment is needed to determine the impact of particulates on the vicinity of the power plant, it is well established that most of the countries of the region suffer from high dust loadings in the air.

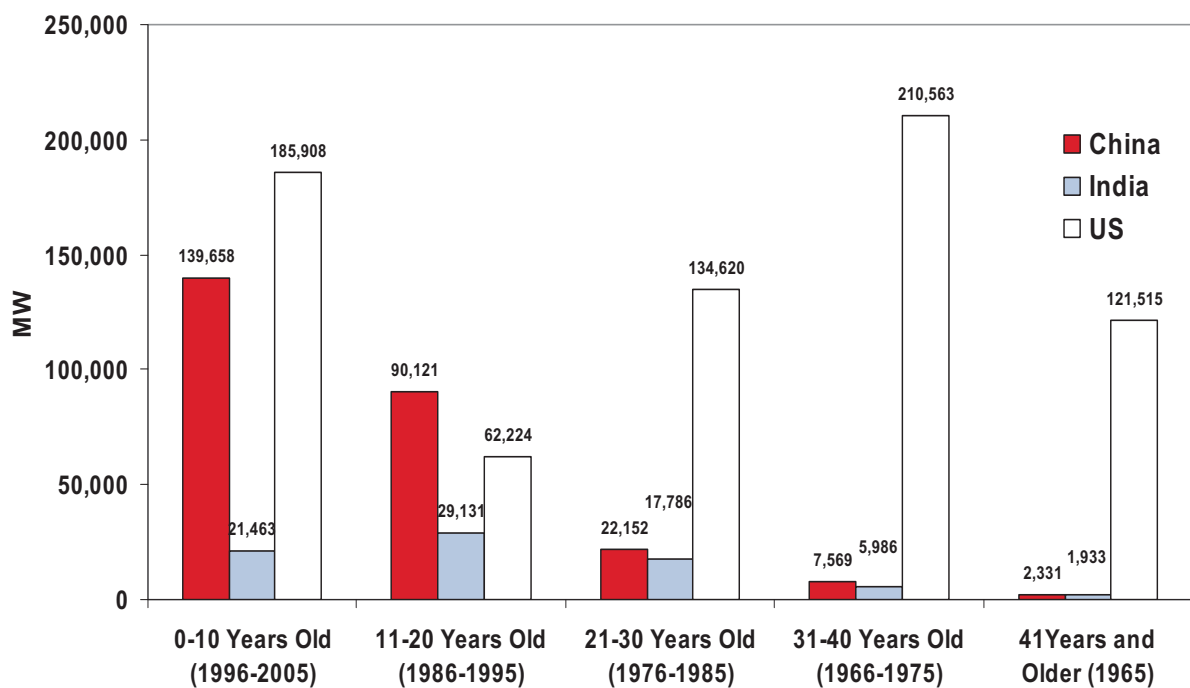
Q. Are the environmental regulations monitored and enforced adequately? Monitoring and enforcement have been identified as the "Achilles Heel" in all the countries of the region. Although equipment of new power plants with continuous emission monitors (CEMs) is required, most older plants do not have such instruments. Even the CEMs in operation are not calibrated frequently and adequately. Also, no adequate quality control of the data exists before they are transmitted to a central site where the environmental authority can monitor them. In most cases, the central facilities receiving the data are not equipped with adequate analysis tools to screen the data and identify noncompliance cases.

FIGURE 2. NUMBER AND AGE OF EXISTING COAL-FIRED UNITS IN INDIA, CHINA, AND THE UNITED STATES, 2005



Source: Platts UDI database (2005).

FIGURE 3. CAPACITY AND AGE OF COAL-FIRED PLANTS IN INDIA, CHINA, AND THE UNITED STATES, 2005



Source: Platts UDI database (2005).

Most important, the environmental authorities in charge of monitoring and enforcement do not have the authority, adequate budget, staff, and expertise to be effective. They are also often not independent enough to focus on their primary responsibility, environmental protection. For example, environmental protection bureaus (EPBs) in China report to the local authorities, which usually favor economic development over environmental protection. In addition, the environmental authorities either have not set up an adequate system for penalties or do not enforce them. As a result, violators of the environmental regulations either go undetected or avoid violations by applying political pressure or employing corrupt practices.

Q. Is there a mechanism or fair market framework to recover investments in environmental controls? To answer this question, a distinction should be made between regulated and deregulated markets. In a well-functioning regulated market, reasonable investments associated with environmental controls are reflected in tariff adjustments; so the investments are recovered. In deregulated markets, no guarantee for investment recovery exists. In this case, it is essential to have a level playing field, so private companies can make the right decisions about the technologies and fuels they want to use. Regarding environmental controls, this means perfectly clear environmental regulations that are monitored and enforced without exception for all power producers.

Transitional issues also need to be addressed; for example, if a market is transitioning from regulated to deregulated, existing plants that may not have environmental controls tend to be less expensive to operate and, hence, have an unfair competitive advantage over facilities with environmental controls (especially FGDs). Such market conditions could result in the following:

- Higher emissions released into the environment due to preferential use of cheaper, polluting plants.
- Cleaner plants becoming stranded assets, because they are more expensive to operate.

In general, these issues are more relevant to FGDs for existing power plants since that requires significant investment (typically in the \$200–\$300/kW range). Low NO_x burners and ESP upgrading are less expensive (low NO_x burners less than \$10/kW and ESP upgrading less than \$30/kW). Also, low NO_x burners usually improve combustion efficiency, so an economic benefit can be derived from their implementation.

Among the countries of the region, these issues are being faced mainly in China, which has a significant number of existing power plants and whose environmental regulations require these plants to be retrofitted with environmental controls. Also, its market structure is changing, creating the potential for transitional issues. Weak environmental monitoring and enforcement make the situation more challenging.

So, in summary, the main issues associated with environmental controls are:

- Lack of adequate monitoring and enforcement of environmental regulations
- Lack of mechanisms to recover investments in environmental control projects
- In some cases, unfair competitive advantage conferred on power plants without environmental controls.

All these issues require policy initiatives. A vast experience on how similar initiatives (related to environmental regulation setting, monitoring, and enforcement) have been implemented in other (mostly OECD) countries provides adequate information to design and implement appropriate policies and regulations successfully

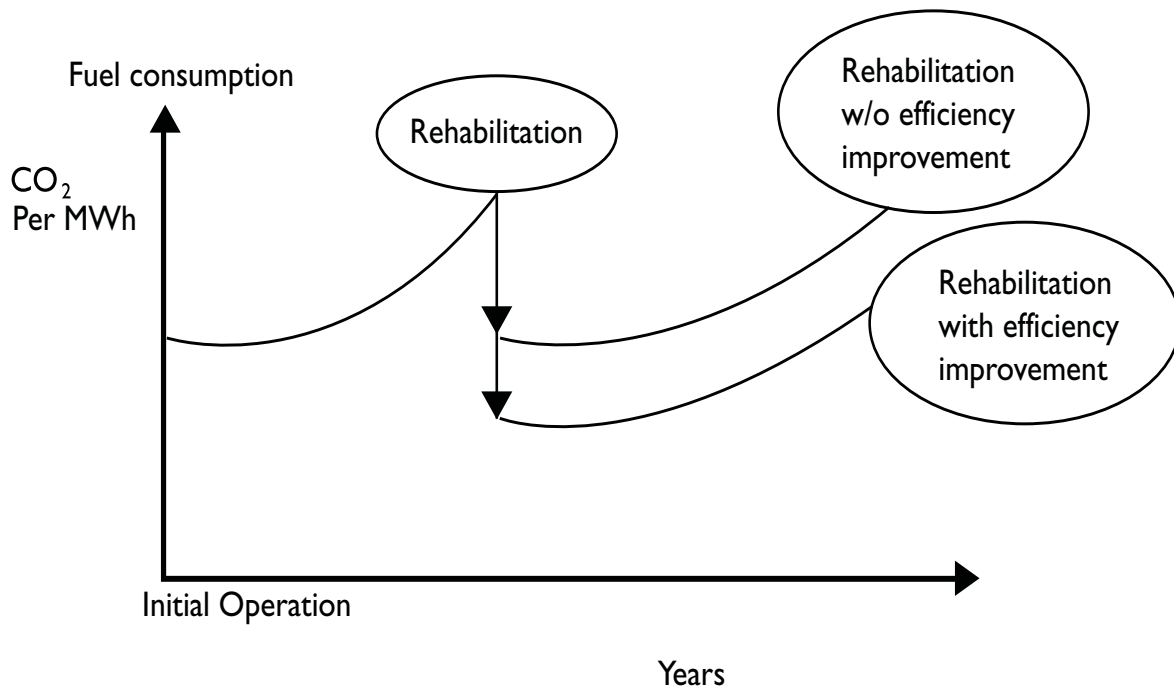
3.3 REHABILITATION OF THERMAL POWER PLANTS

As mentioned earlier for China, existing thermal power plants represent a significant percentage of the power generation system and are faced with a number of unique issues. As **Figure 2** and **3** show, the number of units in the 10–30 year age range in China and India is significant; 539 units in China (representing 102 GWs) and 216 units in India (representing 42 GWs) are 10–30 years old. These units are certainly not at retirement age.

At the same time, their efficiency, reliability, and often maximum output are declining with time. Good operations and maintenance (O&M) practices could slow down, but cannot reverse, the rate of decline, unless investments are made in rehabilitation. Many examples exist in India, where good O&M practices and rehabilitation have increased the capacity factors from 20–40 percent to 65–80 percent.²⁰

Rehabilitation of power plants represents an opportunity to reduce CO₂ emissions significantly in a cost-effective way, while increasing plant efficiency and availability. Although site-specific assessments are needed to determine the appropriate scope and investment, many studies and actual rehabilitation projects have concluded that rehabilitation is the “low-hanging fruit” in terms of CO₂ reductions. For example, a recent APEC study²¹ concludes that “50 percent of the APEC region plants would be able to achieve a 3.5 percentage point CO₂ reduction at a negative or zero net cost. This conclusion leads to the assertion that the 165 million ton CO₂ projected reduction would be achievable at approximately zero net cost.”

FIGURE 4. FUEL CONSUMPTION DURING LIFE OF THE POWER PLANT



The major challenges associated with rehabilitating existing power plants include the following:

- **A decision should be made to retire plants that are old and inefficient, especially smaller plants with very low efficiency.** Some of the smaller plants may not be very old (as is the case in China), but economic and environmental considerations dictate that many of these plants should be shut down.

20. R. K. Jain, “Generation Renovation & Modernization,” NTPC presentation at India Electricity 2006 Conference, May 11, 2006, New Delhi, India.

21. G. Boncimino, W. Stenzel, and I. Torrens, 2005, “Costs and Effectiveness of Upgrading and Refurbishing Older Coal-Fired Power Plants in Developing APEC Economies,” Project EWG 04/2003T, PowerHouse Engineering Ltd.

- **Another group of existing plants needs rehabilitation to improve plant efficiency** (at least to the “design level”), availability, and emissions. Reduction of particulates, NO_x, and possibly SO₂ (depending on the country environmental regulations) could be part of the rehabilitation program. Selecting which plants should retire and which need to be rehabilitated is a key challenge for decision makers.
- **Introduction of modern O&M plant practices is needed throughout the power sector.** This is essential for reversing the declining efficiency and availability of the plants and maintaining them in good operating condition.
- **Retiring and rehabilitating existing power plants and enhancing O&M practices** require significant investments. Lack of financing is often a major obstacle.

Defining the scope of the rehabilitation is another challenge. Rehabilitation of thermal power plants involves a spectrum of options, ranging from doing what is necessary for plant safety and reliability to doing what is optional. The required items should be implemented as part of regular maintenance, either during plant operation or as part of regularly scheduled outages. Optional items are usually more capital intensive and require management decisions. Some of them are clearly cost-effective; others are not. As **Figure 4** shows, it is natural for plant efficiency to deteriorate with time, and rehabilitation can bring it back close to “design level”; however, more aggressive rehabilitation involving potentially optional items could improve plant efficiency further. Deciding on the appropriate scope and time is the challenge.

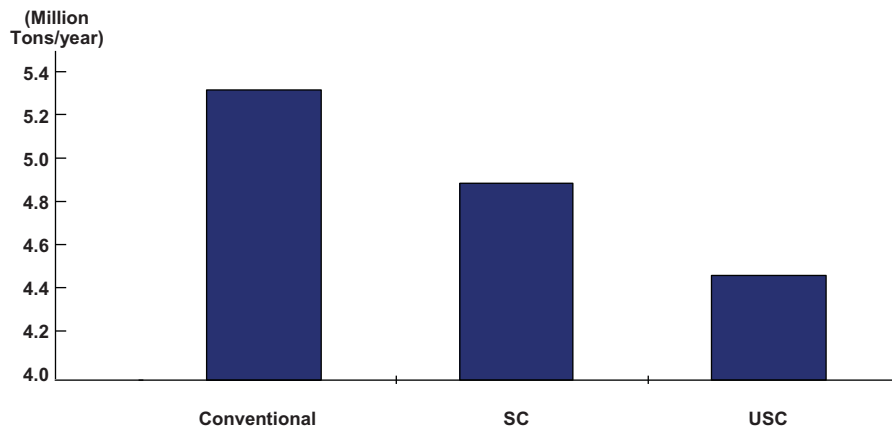
The issue in most countries is that rehabilitation is not being pursued, even if it is cost-effective. Factors that contribute to this include the following:

- **No incentive usually exists to improve plant efficiency.** Fuel costs are either passed to the consumer or the tariff is negotiated independently from plant efficiency. Also, reporting plant efficiencies to the regulatory authority is often not required.²² New policies are needed to encourage higher plant efficiency.
- **Lack of emphasis and budget for adequate O&M management.** As **Figure 4** shows, plant efficiency deteriorates with time, but good O&M management slows deterioration and, hence, could delay the need for rehabilitation and increase plant operating life. A management culture focuses on appropriate maintenance of plant equipment and emphasizes better efficiency is needed.
- **Lack of tools, methods, and training to make rehabilitation decisions:**
 - Which plants need to retire and when?
 - What is the scope of rehabilitation?
 - When should it be done?
 - How much should be spent?

Such tools and methods are well developed in some countries and could be transferred to developing countries through well-focused training programs or participation of third parties in O&M contracts or rehabilitate-own-operate or rehabilitate-operate-transfer schemes.

- **Lack of funding for rehabilitation.** Power companies are very often more willing to invest in new power plants than invest a small fraction of the cost in improving the efficiency and expected life of existing plants. Recent emphasis on climate change and CO₂ control may provide an additional incentive and funding sources (through sale of certified CO₂ emission reductions) for rehabilitation.

22. A.P. Chikkatur and others, “Tariff-Based Incentives for Improving Coal-Power-Plant Efficiencies in India,” *Energy Policy*, Jan 8, 2007.

FIGURE 5. CARBON DIOXIDE EMISSIONS FOR A 600 MW UNIT

Source: IEA/CIAB.

Note: Figures given represent pressure in MegaPascals [MPa]/superheat temperature/reheat temperature. Higher plant efficiency results in lower CO₂ emissions (figure 5).²³

A number of ongoing projects are addressing the above issues in China and India. In China, the World Bank through the Global Environment Facility (GEF) is considering a \$19.7 million grant for demonstration projects and barrier removal activities (e.g., policies to promote plant efficiency improvement, dissemination of information, decision-support tools and methods, etc.). Co-financing by Chinese organizations and a WB loan brings the total amount for this program to \$163.0 million.

A similar program is under implementation in India, where GEF is considering a \$45.4 million grant to co-finance rehabilitation projects.²⁴ Part of this grant (\$37.9 million) is for co-financing and the remaining (\$7.5 million) is for technical assistance and removal of barriers activities. GEF funding leveraged an additional \$299.7 million from the World Bank and the Indian Government, bringing the total to \$345 million.

The need for rehabilitation of existing thermal plants in the region is vast, and the hope is that rehabilitation projects in China and India will eliminate certain perceptions, help introduce the right policy initiatives, and provide an incentive for owners and operators to finance similar projects. It is also possible that rehabilitation projects may generate certified emission reductions, in which case, an additional motivation would exist to implement rehabilitation projects focusing on efficiency improvements. The decision to approve the relevant methodology by the United Nation Framework Convention on Climate Change is pending.

3.4 PULVERIZED PLANT DESIGN DECISIONS (SUBCRITICAL VS. SUPERCRITICAL VS. ULTRA-SUPERCRITICAL)

After the decision has been made to build a pulverized coal (PC) plant, additional decisions need to be made regarding its specific design configuration, especially its steam conditions (pressure and temperature), which significantly affect the plant efficiency. Typical options for pulverized coal plant designs include the following:

- Subcritical PC with efficiency ranging from 34 to 37 percent
- Supercritical PC with efficiency ranging from 37 to 40 percent

23. I. M. Torrens and W. C. Stenzel, 2001, *Increasing the Efficiency of Coal-Fired Power Generation, State of the Technology: Reality and Perceptions*, International Energy Agency/Coal Industry Advisory Board, Paris, France.

24. ECOAL, 2007, "World Bank Action Plan: Clean Energy for Development" (June) p. 3.

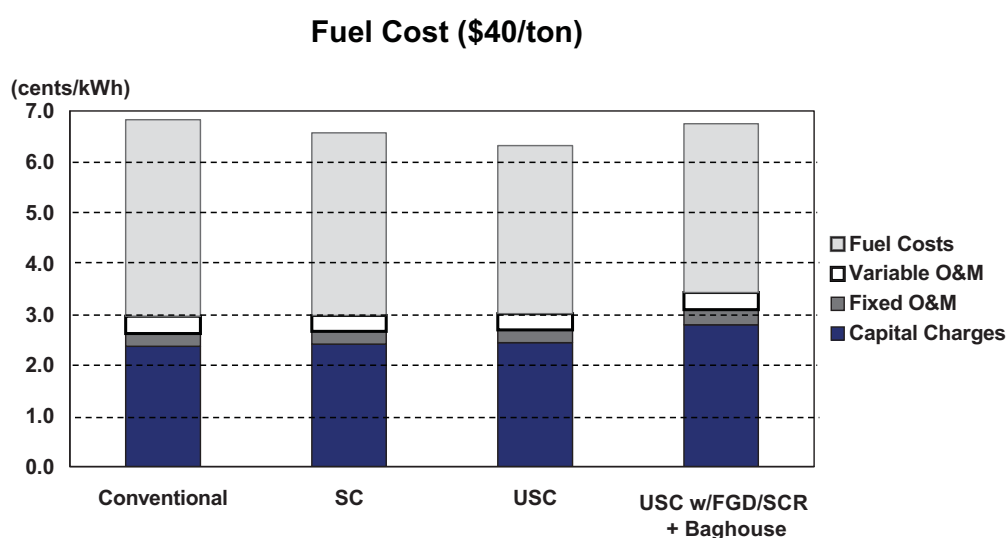
- Ultra-supercritical PC with efficiency ranging from 40 to 43 percent.

Within these categories, typical steam conditions may be the following:

- Subcritical: 16.7 MPa/538°C/538°C with an efficiency of 36 percent
- Supercritical: 24.2 MPa/538°C/565°C with an efficiency of 38 percent
- Ultra-supercritical: 31 MPa/600°C/600°C with an efficiency of 42 percent.

But, what are the economics of high-efficiency pulverized coal plants? Investment requirements of power plants are site and country specific, reflecting design specification preferences, labor and material costs, and different commercial requirements (e.g., guarantees). Also, it is noteworthy that in the past three to four years, prices of power plant equipment (of all types) have in general increased greatly, reflecting significant increases in material prices, as well as lack of experienced engineers and manufacturing facilities to respond to high demand. The price increase has, however, not changed the competitiveness of the various power generation options relative to each other:

FIGURE 6. COST OF ELECTRICITY FOR CONVENTIONAL, SUPERCRITICAL, AND ULTRA-SUPERCRITICAL PC



Source: IEA/CIAB.

Note: U.S. dollars are as of the end of 2000. Recently coal fuel prices have almost doubled suggesting that high efficiency options have become even more cost effective.

Figure 6 illustrates typical costs of electricity for conventional (subcritical) PC, supercritical PC, and ultra-supercritical PC. It is clear that the SC and USC design have an advantage over the conventional subcritical PC. Under present market conditions when the coal price is higher than shown in the above illustration (presently in the \$55–\$60/ton range), SC and USC have an even greater advantage. Furthermore, if the value of CO₂ reduction is taken into account, the advantage of the higher efficiency options will increase further. Nevertheless, many decisionmakers worldwide continue to prefer the conventional design, claiming higher costs and risks associated with SC and USC. Although for some fuels there may not be adequate operating experience on USC (e.g., Indian coals) and there may be some risks associated with it, most of the risks are perceived. Such perceptions can be overcome through thorough study and systematic planning and implementation of USC projects. With the elevation of climate change as a high-priority issue, all new coal-fired power plants should use SC or USC technologies except when site-specific circumstances and requirements justify a different choice.

In conclusion, the key issues facing high-efficiency power plants, especially ultra-supercritical, are the following:

- **Perception that higher efficiency designs are more expensive and risky.** With present fuel prices, the increased efficiency of most high-efficiency designs actually compensates for the slightly higher capital costs; if CO₂ reduction is considered, high-efficiency designs have further advantages. In addition, the risks do not exceed the risks of any commercially available technology, as many power plants employing these technologies have operated for years. These perceptions can be eliminated through awareness-raising activities, as well as assessment of actual experience from existing power plants, site tours, and site-specific engineering assessments.
- **For some fuels (such as Indian coal), no experience exists for ultra-supercritical designs.** In this case, it may be wise to use supercritical design first and then upgrade to USC.
- **It is not clear whether use of high-efficiency coal-fired designs, instead of conventional subcritical, generates certified emission reductions under the Clean Development Mechanism (CDM).** This uncertainty will be addressed soon through the resolution of two applications, which have decisions pending from the United Nation Framework Convention on Climate Change.²⁵

3.5 CIRCULATING FLUIDIZED BED COMBUSTION

CFB plants are very similar to pulverized coal plants, but they differ in that limestone is injected in the boiler where it absorbs the sulfur and does not require additional equipment such as FGDs downstream of the boiler. Sulfur compounds are removed as solid by-products in the particulate collection device (ESP or bagfilter). CFBs can be designed for similar steam conditions as the pulverized coal plants (subcritical and supercritical) and have been used extensively around the world, including in some of the Asian countries.

CFBs have higher costs than pulverized coal plants without FGD; but they are competitive if FGD is required. A significant advantage of CFBs is that they are fuel flexible; they can burn a variety of fuels, especially low-quality fuels that cannot be burned in a PC plant. Such fuels include coal-cleaning wastes, petroleum coke, and anthracite. Also, a number of biomass fuels (e.g., municipal solid wastes and wood wastes) could be used either by themselves or in co-firing mode.

CFBs are offered commercially up to 300 MWs per unit. It is likely that CFB technology will be scaled up to at least 500 MW per unit in the near future, but it is difficult to predict when. For the time being, it is fair to assume that 300 MWs will be the limit of commercial offerings. This is not a major barrier for deployment of the technology, because CFBs are mostly used with low-quality fuels that are more suitable for small to medium plants. Also, multiple CFB boilers can be connected to one steam turbine if power plants larger than 300 MWs are needed. For example, in Vietnam CFB plants are planned that use four 250 MW CFB boilers and two 500 MW steam turbines for 1,000 MW plants.

The perception that CFB technology is relatively new and risky has been eliminated now that so many CFB installations exist worldwide (including in such countries as China, India, and Thailand). Nevertheless, careful consideration should be given to the specification, design, and operation of these facilities to ensure a problem-free project.

25. In late 2007 the Clean Development Mechanism under the Kyoto Protocol approved methodologies for quantifying carbon emissions reduction from new supercritical coal plants. This should pave the way for these projects to qualify as CDM projects.

TABLE 5. COMMERCIAL-SIZE IGCC PLANTS

	Gasification Technology	MW (gross)	Startup Date
SEP/Demkolec, Buggenum, The Netherlands	Shell	253	Early 1994
Wabash River, Indiana, USA	Destec	296	10/1995
Tampa Electric, Florida, USA	Texaco	312	9/1996
ELCOGAS, Puertollano, Spain	Krupp-Uhde Prenflo	335	12/1997 on coal
ISAB Energy, Sicily, Italy	Texaco	512	2001
Sarlux, Sardinia, Italy	Texaco	548	8/2000
API Energia, Falconara, Italy	Texaco	280	2001

Source: S.Tavoulares, "Financing Cleaner coal Technologies in China," Unpublished report, World Bank, Washington, D.C.

3.6 INTEGRATED GASIFICATION COMBINED CYCLE

In the past, technologies referred to as "advanced power generation" included USC, pressurized fluidized bed combustion, and integrated gasification combined cycle. USC has several installations worldwide and is a commercially available option, as described earlier in this discussion paper. Pressurized fluidized bed combustion is theoretically available, but is still under development and not being promoted commercially. Some of the demonstration projects in the 1990s and early 2000s experienced operating problems, and the outlook of this technology remains unclear. This leaves IGCC as the key technology in this category. A number of large-scale IGCC plants have been operating worldwide (Table 5).

All these projects, however, have received some type of financial support to make them viable. The reason is that both capital and O&M costs of IGCC continue to be higher than similarly sized pulverized coal plants by 10–20 percent. For example, recently released reports from DOE and MIT²⁶ estimate IGCC to have 18 percent higher capital costs resulting in production costs of 78 mills/kWh for IGCC, compared with 64 mills/kWh for pulverized coal.

The following three examples of IGCC project financing illustrate that a few key elements are necessary for such projects to achieve financial closure.

EXAMPLE 1: THREE IGCC PROJECTS IN ITALY (ISAB, Sarlux, and API Energia)

The three IGCC plants in Italy (Table 5) were financed through limited recourse project financing. What made them financially viable is Italy's Law 9/91 and CIP6/92, which required ENEL (the national power company) to sign take-or-pay power purchase agreements (PPAs) for 15–20 years with "incentive tariffs." As a result, the IGCC projects were able to sign PPAs with the following terms: average price over 20 years of 7.0 cents/kWh²⁷ (based on 1995 values and an exchange rate of US\$ 1 = 1,550 Lyra Italian). During the first eight years, the tariff is 9.0 cents/kWh, while during the remaining 12 years, it drops to 5.7 cents/kWh.²⁸

26. See http://www.fossil.energy.gov/news/techlines/2007/07057-DOE_Issues_Plant_Performance_Repor.html and <http://web.mit.edu/coal/>

27. This wholesale price is clearly above market prices, and it approaches the retail price to industrial consumers in Italy (8.6 cents/kWh in 1999).

28. *Modern Power Systems*, 1998, "api Energia IGCC Plant Is Fully Integrated with Refinery" (June).

TABLE 6. SELECTED IGCC DEMONSTRATIONS IN THE UNITED STATES

	Wabash River	Tampa	Pinon Pine
Location	W. Terre Haute, Indiana	Polk County, Florida	Reno, Nevada
Size (MW gross)	296	316	107
IGCC technology	Destec	Texaco	M. W. Kellogg
Startup	11/95	9/96	1/98
Project cost (millions of dollars)	438	303	336
DOE share (%)	50	49	50
Host utility	PSI Energy	Tampa Electric	Sierra Pacific Power
Other team members	Dynegy	General Electric, Air Products, Monsanto Env-Chem, and Bechtel	Foster Wheeler, M. W. Kellogg, and Bechtel

Source: DOE/Cleaner coal Technology Program.

EXAMPLE 2: US IGCC DEMONSTRATION PROJECTS

Another example is the Cleaner Coal Technology Demonstrations of the U.S. Department of Energy (DOE): Wabash River, Tampa, and Pinon Pine IGCC Demonstrations. These three IGCC demonstration plants were funded by the U.S. DOE CCT Program and are similar in terms of financing. **Table 6** summarizes the key characteristics of these projects.

The host utility mainly financed these projects with DOE support. The DOE contribution under the Cleaner coal Technology Program was approximately 50 percent of total project costs and covered the cost differential between conventional technologies and IGCC, as well as the demonstration costs and some technology-related risks. The project participants assumed the remaining technology risks. It should also be noted that all three projects were developed under a regulated environment, which allowed full cost recovery by the electric utilities owning these plants.

A noteworthy contractual arrangement is the one adapted by the Wabash River project between the two leading members of the project consortium, PSI Energy (the host utility) and Destec²⁹ (the IGCC technology supplier): a gasification service agreement specifying the responsibilities of the two parties, as follows:

PSI Responsibilities

- Build power generation facility to an agreed schedule
- Own and operate the power generation facility
- Furnish Destec with a site, coal, electric power, water, wastewater facilities, and other utilities and services.

Destec Responsibilities

- Build gasification facility on an agreed schedule
- Own and operate the gasification facility
- Guarantee operating performance of the coal gasification facility, including product and by-product quality

29. After the Wabash project started Destec sold the IGCC technology and rights to the project to Global Energy. Subsequently, the technology was sold to ConocoPhillips.

- Deliver specified amount of syngas and steam to the power generation facility.

This contractual arrangement puts the power company in charge (as owner and operator) of the power plant portion of the plant and the gasification supplier in charge of the gasification island. The agreement also specified the amount and quality of products being exchanged across the “contractual fence” dividing the plant, including syngas, steam, auxiliary power, water, coal, etc.

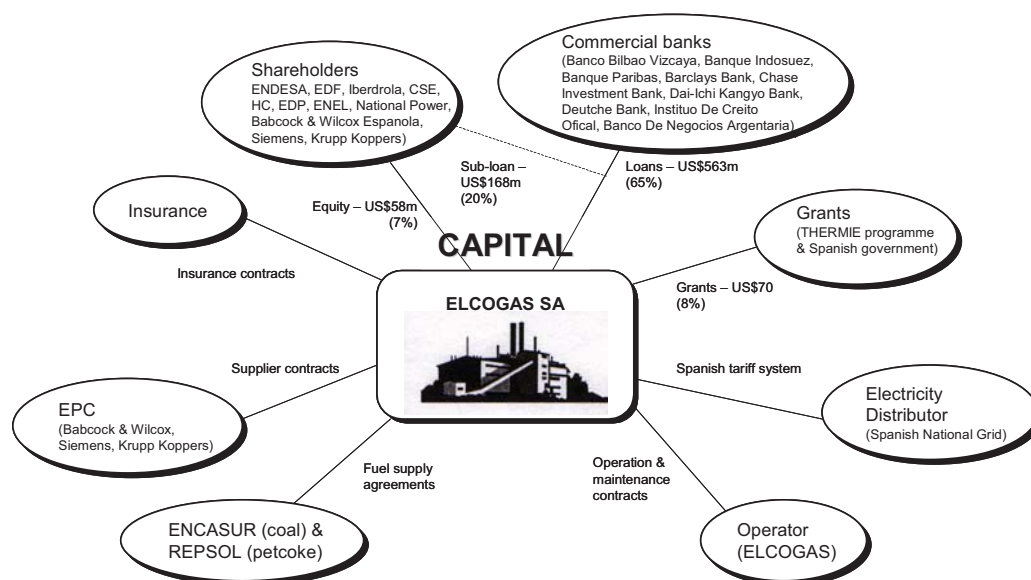
EXAMPLE 3: PUERTOLLANO IGCC, SPAIN

The Puertollano IGCC demonstration project is a 335 MW plant, which started operating in 1998. A special purpose company, ELCOGAS SA, was set up to develop, finance, construct, and operate the project. Major partners and shareholders of ELCOGAS are ENDESA, Electricite de France, Iberdrola, EDP of Portugal, ENEL of Italy, National Power of the United Kingdom, Babcock Wilcox Espanola, Siemens, and Krupp Koppers. The last three partners provided \$58 million for a 7 percent equity position in ELCOGAS, mainly to participate in the project and share technology-related risks.

The total project cost was approximately \$860 million.³⁰ Figure 7 shows the project finance structure. Commercial bank loans repayable in 12 years financed 65 percent of the project. Subordinated loans provided \$168 million (20 percent of the project cost); the ELCOGAS partners provided this amount to ELCOGAS in the form of a credit line for 25 years, accounted from the date of financial closure of the project (July 21, 1994). The European Union provided the remaining \$70 million as grants (approximately 8 percent of the project cost) through its THERMIE Program.

ELCOGAS received a bridge loan along with the subordinated debt in 1993, and the project reached financial closure in 1994. After starting up in 1998, the project was refinanced with a ELCOGAS shareholders guaranteed loan.

FIGURE 7. PROJECT FINANCE STRUCTURE FOR THE PUERTOLLANO IGCC DEMONSTRATION PROJECT



Source: S.Tavoulaareas, “Financing Cleaner Coal Technologies in China,” Unpublished report, World Bank, Washington, D.C.

30. IEA, 1999, Clean Coal Technologies/Financing, Paris, France. U.S. dollars are as of the end of 1997.

Construction-related risks were assumed by ELCOGAS and its shareholders. There was no turn-key contract; instead, ELCOGAS had separate construction contracts with the suppliers of the five major components of the plant (combined cycle unit, gasifier, air separation unit, cooling tower, and system integration, instrumentation, and controls).

All project risks, including construction and operating risks, were assumed by the equity partners of ELCOGAS, including the equipment suppliers (Babcock Wilcox Espanola, Siemens, and Krupp Koppers). The exposure of the equipment suppliers, however, was limited to the extent of their equity participation in ELCOGAS (maximum of 8 percent). Siemens and Krupp Koppers were awarded maintenance contracts, which covered operating risks of the combined cycle and the gasifier, respectively.

Furthermore, no PPA was signed. Instead, the off-take risk was managed through a guarantee by ENDESA of an agreed price, which was based on a "cost-plus" formula. After startup of the plant, deregulation of the power sector increased the off-take risk, because ENDESA was reluctant to continue paying a premium for the power produced by Puertollano. In early October 1998 ELCOGAS reached an agreement with the Ministry of Industry and Energy, which allowed them to recover \$300 million in euros in return for the local benefits of the project (mainly employment in the mining industry). The economic viability of the plant will eventually depend on cost recovery regulations of stranded assets.³¹ Most likely, a 10-year transition period may be provided during which accelerated amortization may be allowed.

In summary, IGCC for power generation applications would require a few more demonstration plants and a way to address the higher capital and operating costs compared with PC plants; so financing would continue to be an issue. In some countries, especially in India, IGCC technology is not near the demonstration stage and more technology development is required. The lack of significant efficiency advantage over USC makes deployment of this technology difficult in the short term.

If CCS becomes a requirement for climate change mitigation, it may have a significant effect on IGCC competitiveness. CCS is not required yet, and many uncertainties are associated with it too. It is likely, however, that CCS may be required in the next 10 - 20 years, in which case it would make IGCC more competitive.

4. REGIONAL ISSUES AND RECOMMENDATIONS

From the previous two sections, a number of conclusions can be drawn regarding issues of regional interest and potential actions that should be taken. Considering the objective of this discussion paper and the ECO-Asia Program in general, this section provides the following:

- Key findings and conclusions about regional issues and options
- General recommendations for regional action, in general
- Specific activities that the ECO-Asia Program may pursue.

4.1 KEY FINDINGS

A review of current and planned use of coal by China, India, Indonesia, Philippines, Thailand, and Vietnam confirms the need to take immediate measures to reduce the impact of coal combustion in the power sector. Coal currently supplies nearly half (48 percent) of the primary energy in these countries, and the continued use of coal to produce electric power is vital to the current and future economic growth of these countries. Therefore, it is essential to take viable and cost-effective steps to increase the efficiency of coal combustion and reduce the local and greenhouse gas pollutants associated with coal combustion.

31. Stranded assets are power plants that cannot compete in a deregulated environment; hence, they cannot fully recover their fixed investment costs. For more on this topic, see S. Tavoulares, 2000, "Policy Recommendations to SPDC Regarding the Deployment of CCTs in China," Unpublished report. World Bank, Washington, D.C.

The following issues were identified as being key impediments to the wide-scale deployment of cleaner coal technologies (CCT).

- **Inadequate Monitoring and Enforcement of Environmental Regulations:** There is wide variation in the environmental regulations currently in place within the six countries. In some cases, such as Thailand, regulations are at par with those of developed nations (i.e. Organization for Economic Cooperation and Development (OECD) countries); while in others there is much room for improvement. However, while the regulations could and should be improved in some of the countries, a more important issue is the lack of effective monitoring and enforcement of the existing regulations. Inadequate and ineffective application of regulations tends to burden those actors who comply while giving an unfair advantage to actors who don't. Finally, in all the countries, there is a notable absence of regulations and guidelines concerning the efficiency of power plants and their CO₂ emissions. Taken together, these regulatory gaps and omissions are impeding the deployment of cleaner coal technologies and slowing efforts to address climate change.
- **Lack of Pricing Incentives for Coal Cleaning:** Coal cleaning is not used as widely as it should be due to lack of appropriate pricing policies. Coal prices should reflect coal quality and resulting pollution. If cleaner coal cannot be sold at a higher price, the coal producer or supplier has less incentive to clean the coal.
- **Lack of Attention to Power Plant Maintenance and Rehabilitation:** Regulations provide no incentive for rehabilitation of existing power plants or improvement of their efficiency. Lack of funding for operation and maintenance activities and rehabilitation contribute to rapidly deteriorating plant performance. Very often, it is easier (or preferable) to build a new power plant with a much higher initial investment than to invest in life extension and performance improvement of existing power plants.
- **Perception Barriers to Adoption of High-Efficiency Technologies:** High-efficiency pulverized coal designs (supercritical and USC) are not used, mainly because of the perceptions that they are costly, unproven and unsuitable for use with local coals. Consequently, many countries prefer conventional technology (e.g. sub-critical pulverized coal). These views persist despite the evidence of international experience, which demonstrates that supercritical and ultra-supercritical designs are commercially proven and competitive, especially when coal prices are high, as they are presently. Experience is lacking only in the case of Indian coals, but even in this case, there should be gradual use of high-efficiency designs starting from supercritical and moving to ultra-supercritical.
- **Financial Barriers to Adoption of IGCC:** Higher costs compared with other power generation options make financing of integrated gasification combined cycle (IGCC) plants challenging. At the same time, IGCC is an important technology for the sustainable use of coal and deserves to be developed and demonstrated. If carbon capture and sequestration are desired outcomes of cleaner coal technologies, then IGCC holds promise for higher efficiency as well as easier and less expensive capture of CO₂ to help address climate change.

The recommendations in this paper are based on the above findings, as well as input provided by the participants of two conferences which explored how issues of regional interest can be addressed.³²

4.2 RECOMMENDATIONS FOR REGIONAL ACTION

- **Regional dialogue is needed on environmental standards.** Areas to be explored include: (1) harmonization of standards, (2) establishment of guidelines or requirements for minimum efficiency of new coal-fired power plants, (3) learning from experience related to regulation-setting, monitoring and enforcement, and (4) use of market-based instruments (e.g. emission cap-and-trade, emission fees, carbon taxes).
- Support is needed for the **deployment and scale up of cleaner coal technology and practices.** Many countries are beginning to experiment with cleaner coal technologies including pilot scale rehabilitation of older power plants and high efficiency pulverized coal designs. Targeted technical assistance is needed to maximize the climate change mitigation potential of these efforts and put in place the frameworks - to evaluate decisions relating to technology, material, labor and fuel choices and information to replicate these efforts and scale-up in a short period of time and make CCT the “minimum standard” in the future.
- An urgent need exists for a **network for sharing information and addressing research needs** facing power companies in the region. The severe environmental problems facing the region, along with climate change, provide the impetus needed to initiate such an institution.
- A need also exists for **better dissemination of information**, such as best practices, lessons learned, and news in general related to cleaner coal use in the region. Various options should be explored, including workshops, online communities of practice, targeted newsletters, etc.
- **Development of innovative financing instruments** is necessary for supporting CCT projects. Such options may include soft loans, carbon financing,³³ risk mitigation instruments, etc. Carbon financing for such options as coal cleaning, plant rehabilitation, and high-efficiency coal-fired power plants deserves more attention.

4.3 INITIATIVES FOR THE ECO-ASIA PROGRAM

The ECO-Asia Program is prepared to address some of the above needs by working with key agencies in each country and the region (e.g., APEC, ASEAN, and AFOC), as well as financial institutions (primarily ADB and the World Bank) and global organizations (e.g., World Coal Institute, World Energy Council, and International Energy Agency, Clean Coal Center). The following specific activities are envisioned:³⁴

- **Facilitate dialogue on harmonization of emission standards and establishment of minimum plant efficiency guidelines or requirements.** A first step in this direction began in July 2007, with the co-sponsorship of the ASEAN Forum on Coal in Chiang Mai, Thailand.
- **Provide targeted technical assistance and organize workshops** to facilitate dissemination of information and dispel mistaken perceptions on the readiness of high-efficiency

32. The two conferences were the Asia Clean Energy Forum in Manila, Philippines, held on June 26–28, 2007, and organized by the Asian Development Bank (ADB), U.S. Agency for International Development (USAID), and Asia-Pacific Economic Cooperation (APEC), and the International Conference on Cleaner Coal in Chiang Mai, Thailand, held on July 19–20, 2007, and organized by the Association of Southeast Asian Nations (ASEAN) Forum on Coal (AFOC) and USAID.

33. In late 2007 the clean development mechanism under the Kyoto Protocol approved methodologies for quantifying carbon emissions reduction from new supercritical coal plants. This should pave the way for these projects to qualify as CDM projects.

34. Subject to approval by USAID.

power technologies. A first step in this direction was a regional workshop on supercritical pulverized coal technology organized with ADB held in Hanoi, Vietnam, in October 2007. Following the workshop, participants had the opportunity to go on a study tour to Japan where they visited highefficiency power plants.

- Work with financial institutions to **facilitate use of innovative financial instruments** in the deployment of CCTs and disseminate relevant information.
- **Develop and support (a regional research network) on cleaner coal**
- Facilitate knowledge sharing through an **online portal** and a **regional newsletter**.

4.4 A CLEANER FUTURE FOR COAL IN ASIA

During late 2006 and early 2007, the ECO-Asia Clean Development and Climate Program project team met with more than 200 key energy stakeholders in the six focus countries and found a clear majority view about the role of coal in Asia's energy future: while the use of coal is associated with significant local and global pollutants, Asia's coal plants cannot be shut down overnight, and coal will continue to be an important fuel for the power sector over the medium-term.

Moreover, coal-based power generation is set to expand significantly over the next 2-3 decades. The consensus was that, given the relatively low efficiencies of current and planned coal plants in developing Asia, it is essential to take immediate action to increase plant efficiencies in existing and new plants and thereby mitigate the impacts of coal combustion. These views are backed-up by compelling scientific evidence, which suggests that simply ignoring the impact of coal use and carrying-on business-as-usual would severely undermine international efforts to slow climate change. More importantly, a comparison of options to mitigate climate change revealed efforts to increase the efficiency of coal-fired plants could slash one billion metric tons of projected (CO₂) a year by 2035.³⁵

Taken together, the initiatives proposed in this discussion paper are clearly insufficient to result in the changes required to reverse the impacts of developing Asia's projected coal use on climate change. Nevertheless, it is hoped that these efforts will prompt governments, industry and donors to re-examine how a cleaner future for coal in Asia can become a pillar of their efforts to address climate change.

35. USAID, May 2007, *From Ideas to Action: Clean Energy Solutions for Asia to Address Climate Change*, Bangkok, p. 99.

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