JULY 2008

This publication was produced for review by the United States Agency for International Development. It was prepared by the Center for Energy Economics (The University of Texas at Austin) with input from PA Government Services Inc.
Role of Coal and Interregional Electricity Trade in Energy Security

In the inaugural issue of the ESQ, we have seen that fossil fuels will continue to dominate energy sectors around the world even as the world seeks ways to reduce greenhouse gas emissions associated with the traditional use of fossil fuels. As a relatively abundant resource and widely preferred fuel for power generation, coal is at the center of this balancing act because coal-fired power plants are one of the largest sources of greenhouse gas emissions. These considerations are at play in South Asia as well. India generates more than half of its electricity by burning coal; other countries in the region have coal resources that could contribute to enhancing energy security in the region if developed commercially. Integrating electricity grids in the region would further mitigate risks associated with depending on a single fuel or imported fuels, while balancing various generation sources in the region, including coal, hydro, natural gas, wind and other renewables. However, the coal sector in the region has limited private investment, lacks certain regulations and standards, and presents environmental challenges. In order for coal to help meet growing demand for electricity in the region, new investment along the coal value chain is needed as well as best practice mitigation of environmental impacts. In this issue of the ESQ, we will discuss global and regional coal industry trends and development of a regional power grid, two important and related topics.
International coal industry trends: South Asia’s position

Consumers around the world meet about 28% of their primary energy needs from coal. The electricity sector accounts for about two thirds of total coal consumption, generating more than 40% of electricity consumed in the world. The rest of coal is consumed mainly by industrial customers in energy intensive operations such as steel production. Residential and commercial use of coal is limited.¹

Coal plays an important energy security role

In recent years, rising costs of oil and natural gas underlined the critical contribution of coal in generation portfolios around the world. Even in countries rich with other resources such as Canada and Mexico, coal generates 15-20% of electricity. In OECD Europe, this share is around 30% and in the U.S. it is more than 50%. With negligible production of its own, Japan relies on mostly imported coal for about a quarter of its power generation. Recently, though, Japan has initiated a process of reviving its coal mining industry. In Europe as well, there is renewed interest in coal despite efforts to control greenhouse gas emissions. For example, Italy is expected to increase its reliance on coal from 14% to 33% over the next five years. In Germany, the government approved a €30 billion scheme for the construction of 26 new coal-fired power plants by 2020; interestingly Germany tries to meet its emission reduction targets while abandoning nuclear power. In the U.S., more than 150 new coal projects have been proposed over the last few years; about half have been dropped due to local opposition and difficulty of getting regulatory approvals but others are moving forward. Unlike Germany, nuclear power is attracting more attention in the U.S., also contributing to utilities’ reluctance to continue fighting for siting new coal plants.

There are fundamentally three reasons for this resurgence of coal:

1- Coal resources are relatively abundant and distributed around the world. World’s recoverable coal reserves amount to about a trillion tons.² As compared to oil or natural gas, proved coal reserves are expected to last a lot longer at current levels of consumption (about 150 years versus 40 years for oil and 60 years for natural gas). Although most of the countries in the world have some coal reserves, about 70 countries have recoverable reserves with ongoing production.

In Table 1, top ten producers and exporters, covering all continents of the world, as well as major importers are listed. China is expected to become a net importer in the next few years. If this transition follows a path similar to China’s transition into a net oil importer in the early 1990s, international coal trade will increase significantly along with the price of coal, at least until exporters catch up with increased demand.

Table 1 - Global coal market (millions tons, or Mt), 2006

<table>
<thead>
<tr>
<th>Major Producers</th>
<th>Production (Mt)</th>
<th>Exports (Mt)</th>
<th>Exports (%)</th>
<th>Major Importers</th>
<th>Imports (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>2482</td>
<td>63</td>
<td>3%</td>
<td>China</td>
<td>38</td>
</tr>
<tr>
<td>USA</td>
<td>990</td>
<td>45</td>
<td>5%</td>
<td>India</td>
<td>41</td>
</tr>
<tr>
<td>India</td>
<td>427</td>
<td>231</td>
<td>75%</td>
<td>Japan</td>
<td>178</td>
</tr>
<tr>
<td>Australia</td>
<td>309</td>
<td>69</td>
<td>28%</td>
<td>Korea</td>
<td>80</td>
</tr>
<tr>
<td>South Africa</td>
<td>244</td>
<td>92</td>
<td>39%</td>
<td>Taiwan</td>
<td>64</td>
</tr>
<tr>
<td>Indonesia</td>
<td>169</td>
<td>129</td>
<td>76%</td>
<td>UK</td>
<td>51</td>
</tr>
<tr>
<td>Poland</td>
<td>95</td>
<td>60</td>
<td>94%</td>
<td>Germany</td>
<td>41</td>
</tr>
<tr>
<td>Colombia</td>
<td>64</td>
<td>60</td>
<td>94%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: World Coal Institute, www.worldcoal.org

² In this report, we use metric tons (or tonnes). A metric ton is roughly equal to 1.1 short tons.
2- Coal-fired power plants meet base load requirements of electricity systems. Because of their technology, coal plants cannot be ramped up or down much, that is, they cannot follow the electricity load. Their operation costs are low although capital costs are relatively higher than many other options. Overall, they produce some of the cheapest and most reliable electricity in the world (Table 2). As a result, they are run constantly at high capacity to meet the base load needs of electricity systems. If future regulations force generators to add carbon emission (or control) costs into the production costs, coal plants will lose some of their comparative advantage.

Table 2 - Levelized Costs of Different Generation Technologies at 10% discount*

<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>Natural Gas</th>
<th>Nuclear</th>
<th>Wind</th>
<th>Micro Hydro</th>
<th>Solar</th>
<th>CHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>$35-50 per MWh</td>
<td>$40-63 per MWh</td>
<td>$30-50 per MWh</td>
<td>$45-140 per MWh</td>
<td>$65-100 per MWh</td>
<td>$200 (24% availability)</td>
<td>$30-70 per MWh</td>
</tr>
<tr>
<td>Inv</td>
<td>50%</td>
<td>Inv 20%</td>
<td>Inv 70%</td>
<td>O&amp;M</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O&amp;M</td>
<td>15%</td>
<td>O&amp;M 7%</td>
<td>O&amp;M 20%</td>
<td>13-40%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td>35%</td>
<td>Fuel 73%</td>
<td>Fuel 10%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


* Since the 2005 report, power plant construction costs have increased significantly, more than doubling in some areas. Natural gas and coal prices have also risen (the table is based on natural gas prices of $3.5-4.5 per million British thermal unit, or MMBtu). Accordingly, levelized costs, especially for coal and natural gas plants, should be inflated by at least 50%.

3- Coal prices have been relatively low and stable. Although since early 2007, the increase in the price of coal has caught up with that of oil and surpassed that of natural gas (Figure 1), this recent spike probably reflects a temporary adjustment in the coal market as the supply infrastructure (mines, railroads, ports and ships) tries to keep up with rapidly rising demand and, perhaps more importantly, the impact of some natural disasters (e.g., flooding of mines in Australia in early 2008, which may have reduced production by as much as 15 Mt). Also, coal is primarily traded via bilateral contracts, with prices traditionally negotiated for a period of one year, hence limiting the potential for speculative pricing.

Coal remains cheaper than oil and natural gas on a heat content basis, even when adjusted for efficiency differences.
between coal-fired and combined cycle gas-fired generation (Figure 2). Also note that the price of natural gas in some locations has been frequently much higher than the U.S. wellhead price reported in Figures 1 and 2; Russian gas to Europe may reach $11-12/MMBtu while Japan pays more for LNG since the price is linked to that of oil. In 2006 and 2007, Spain and South Korea paid $15-20/MMBtu for LNG cargoes on a spot basis.

**Coal in South Asia**

India, a major producer and importer of coal, has about 10% of the world’s total reserves, fourth after the U.S. (27%), Russia (17%) and China (12%). Currently, proved reserves in Pakistan, Bangladesh, Afghanistan and Nepal are quite small, accounting to less than 1% of total reserves in the world, but have long life as production is also very small. Indian reserves are mostly anthracite and bituminous coal while Pakistan has mostly lignite. In Bangladesh, domestic production is high quality bituminous used in power generation, while lower quality imported coal is used in brick kilns and steel re-rolling mills. In line with its reserves, only India in the region is a significant producer of coal; but all coal consuming countries in the region are net importers (Table 3).

Most of the exploration activities in South Asia are carried out by state-owned companies. For the most part, coal resources have not been appraised independently. There is a need to reassess the resource base and bring reserve classification systems on a par with international practices. In some cases, such a classification system may need to be created from scratch. For example, the Geological Survey of Bangladesh is working on establishing a detailed reserve classification approach and might seek technical assistance abroad in order to facilitate this effort. Such a resource assessment may also help identify the potential for coal bed methane (CBM) production.

Despite the current uncertainty about the reserves, coal resources in Bangladesh, Pakistan and Afghanistan are believed to be significant and could substantially add to power generation fuel mix if necessary investments are made in exploration and development. Reportedly low mine mouth cost of the coal in the region (less than $10/ton in Sindh in Pakistan and $13-20/ton in India compared to about $25/ton in Indonesia), renders domestic resources very attractive compared to imported coal. For example, domestic coal in India used for power generation costs $36 to $48/ton while imports can be

<table>
<thead>
<tr>
<th>Table 3 - Coal in South Asia (thousand tons), 2005/06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afghanistan</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Production</td>
</tr>
<tr>
<td>Net import</td>
</tr>
<tr>
<td>Reserves (% of world)</td>
</tr>
<tr>
<td>Production (% of world)</td>
</tr>
<tr>
<td>R/P (years)</td>
</tr>
<tr>
<td>Imports (% of cons.)</td>
</tr>
</tbody>
</table>

a Petrobangla; b there is a wide range of estimates for imports into Bangladesh, for example see http://www.bangladeshnews.com.bd/2008/02/17/sulphur-rich-imported-coal-polluting-air/

<table>
<thead>
<tr>
<th>Table 4 - Representative Coal Prices in South Asia ($ per ton), April 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
</tr>
<tr>
<td>Steam coal</td>
</tr>
<tr>
<td>Coking coal</td>
</tr>
</tbody>
</table>


3 Although there will be differences based on ambient climate, type of coal and other factors, in Figure 2, we assumed that combined cycle gas plants are on average 50% more efficient than coal plants in production of electricity. Also, we assume an average heat content of 25 MMBtu, or million British thermal units, per ton.

priced as high as $160/ton including cost, insurance and freight (CIF) as seen in Table 4. Most coal mined in the region has a calorific value of about 16 MMBtus per ton, while imported coal typically has 20 to 24 MMBtus per ton. But, even when adjusted for heat content, imported steam coal is more expensive than domestic coal (Figure 3).

Coking coal prices have also been rising globally since 2004; coking coal has historically traded at a premium over steam coal and this difference has become more pronounced in recent years (Figure 4). In fact, since January 2007, prices have increased by almost 150%, which is now reflected in the Indian market, where producers of coking coal asked for price increases of about 40%. Still, global prices for coking coal, recently spiking as high as $335 per ton for premium quality coking coal (Table 4), are on average more than twice as expensive as prices in India. The price spike in early 2008 is primarily caused by flooding in major mines in Australia after heavy rains, which may have reduced supplies as much as 15 Mt; but recent surge in ocean freight rates, which constitute a large portion of the final CIF price, has also been a factor. Among the factors contributing to increase in rates are freight capacity deficit, bottlenecks at ports and high fuel costs. In 2007 freight rates from Brazil to China increased almost 150%, while rates from Australia to China almost doubled. Freight capacity, planned to go online in the near future, might experience delays – there are signs that recently worsened credit conditions complicate financing of these projects.

Afghanistan, Bhutan and Nepal produce coal of higher heat content, similar to imports, but in much smaller quantities than the regional market needs. Moreover, the transportation of coal produced from these countries to India or Pakistan would be constrained by lack of transportation capacity.

**Trade infrastructure**

Although coal consumption in the world is significant, meeting about 28% of world’s primary energy needs, second only to oil, which supplies a little more than one third of world’s energy demand, coal is not traded in similar proportions. In fact, even the international natural gas trade has been larger and increasing faster than the coal trade in recent years, fueled by rising activity in the liquefied natural gas, or LNG, industry. About 16% of world coal consumption is currently being traded internationally, compared to about 29% of natural gas and 60% of oil. These trade numbers reflect the historical preference of producing countries using coal domestically and the smaller need for importing or exporting coal as many countries have some production. Also, as a bulk commodity, transportation of coal over longer distances has been costly; railways, barges, ports and ships necessary to complete the coal supply chain are capital intensive investments that require long-term certainty about markets’ viability.

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3 http://www.eia.doe.gov/emeu/international/RecentGrossHeatContentCoalProduction.xls.
6 Deutsche Bank AG. Commodities Outlook, January 11, 2008.
However, as rapidly growing economies around the world seek new supplies of energy, demand for coal has been increasing along with demand for oil and natural gas. Accordingly, global coal trade is projected to increase from 815 Mt in 2006 to more than 1,150 Mt in 2030.\(^7\) In Figure 5, major coal trading trends are depicted. Australia, where significant investment in new coal mining as well as railroad and port systems has been taking place, is expected to enhance its role as the major supplier of coal to the world. For now, though, infrastructure constraints add to consumer anxiety. For example, more than 70 ships were regularly in line at the port of Newcastle in Australia waiting as long as 20 days for loading in summer 2007; a new 30-Mt per annum expansion is now under way.

In South Asia as well, strategic investments in enhancing rail and barge capacity within and across countries could encourage investment in coal exploration and development across the region. Some of the constraints in the region are discussed further below. Traditionally, intrastate trade in South Asia is limited to export of rather insignificant volumes of coal from India to Bangladesh, Nepal and Bhutan. Pakistan and India import coking coal via marine terminals from abroad primarily for the metallurgical sector. The degree of openness of international coal trade in the region differs: India has recently decentralized export of coal, while Nepal imports coal strictly though the Royal Government. Export duties also play an important role: India levied a hefty 26.33% export duty to Bhutan, while Afghanistan banned coal imports from Pakistan.

\textbf{Figure 5 - Major Inter-regional Coal Trade Flows, 2002-2030 (million tonnes)}

\begin{figure}
\includegraphics[width=\textwidth]{coal_trade_flows}
\caption{Major Inter-regional Coal Trade Flows, 2002-2030 (million tonnes)}
\end{figure}


\(^7\) EIA IEO 2007
Coal trade

Nowadays about 55% of the world’s exports of steam coal is being imported by Asian countries, including India, and their share is projected to rise to 61% in 2030. China, which has been self-sufficient historically, will become a net importer in the near future, importing mainly from Australia. Indian demand for coal imports is projected to more than double from 2005 to 2030. As a result, the country, which receives most of its imports from Australia and Indonesia, is expected to increase its shipments from Australia.

Indonesia exports three quarters, or 129 Mt, of its production (Table 1). Its location and a large number of experienced, competitive mine operators make the country a perfect source of coal for countries in Asia (Table 5). Japan, Korea, Malaysia and the Philippines are long-time customers as is India. As Indonesia’s export potential is expected to increase, countries are taking positions in the country; for example, Tata Power Co. bought stakes in Indonesian companies, Arutmin and Kaltim Prima Coal for $1.3 billion in early 2007. Pakistan, Bangladesh and Sri Lanka are also well positioned to benefit from increased Indonesian coal production if long-term deals can be made and new import capacity can be built.

As important as Indonesia is, Australia is the key player in the world coal market, with 231 Mt of exports in 2006. In 2006-07, India imported about 21 Mt from Australia. Numerous companies operate mines in and export from Australia; in Table 5, some of the largest companies are listed. There has been significant consolidation in the mining industry over the recent years. As a result, several companies dominate the coal sector. BHP Billiton has formed alliances with other companies to account for more than 70 Mt of production in Australia. In addition, BHP works with Arutmin in Indonesia to market Arutmin’s production internationally; and owns operations in South Africa, South America and North America.

Table 5 - Major exporting companies that can serve South Asia (2006-07)

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Production</th>
<th>Web site</th>
<th>South Asian Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anglo Coal</td>
<td>Australia</td>
<td>34 Mt</td>
<td><a href="http://www.anglocoal.com.au">www.anglocoal.com.au</a></td>
<td>India</td>
</tr>
<tr>
<td>BHP Billiton</td>
<td>Australia</td>
<td>~9 Mt</td>
<td><a href="http://www.bhpbilliton.com">www.bhpbilliton.com</a></td>
<td>India</td>
</tr>
<tr>
<td>BMA*</td>
<td>Australia</td>
<td>~50 Mt</td>
<td><a href="http://www.bmacoal.com">www.bmacoal.com</a></td>
<td>India, Pakistan</td>
</tr>
<tr>
<td>Centennial Coal</td>
<td>Australia</td>
<td>15 Mt</td>
<td><a href="http://www.centennialcoal.com.au">www.centennialcoal.com.au</a></td>
<td>India</td>
</tr>
<tr>
<td>Ensham Resources</td>
<td>Australia</td>
<td>8.5 Mt</td>
<td><a href="http://www.ensham.com.au">www.ensham.com.au</a></td>
<td>India</td>
</tr>
<tr>
<td>RioTinto Coal</td>
<td>Australia</td>
<td>56 Mt</td>
<td><a href="http://www.riotintocoalaustralia.com.au">www.riotintocoalaustralia.com.au</a></td>
<td>India</td>
</tr>
<tr>
<td>Xstrata</td>
<td>Australia</td>
<td>48 Mt</td>
<td><a href="http://www.xstrata.com">www.xstrata.com</a></td>
<td>India</td>
</tr>
<tr>
<td>Adaro Indonesia</td>
<td>Indonesia</td>
<td>38.8 Mt</td>
<td><a href="http://www.kaltimprimacoal.co.id">www.kaltimprimacoal.co.id</a></td>
<td>Pakistan (0.66 Mt), India (0.47 Mt)</td>
</tr>
<tr>
<td>Kaltim Prima Coal</td>
<td>Indonesia</td>
<td>34.3 Mt</td>
<td><a href="http://www.adaro-envirocoal.com">www.adaro-envirocoal.com</a></td>
<td>India</td>
</tr>
<tr>
<td>Kideco</td>
<td>Indonesia</td>
<td>18.9 Mt</td>
<td><a href="http://www.kideco.com">www.kideco.com</a></td>
<td>India (~1 Mt)</td>
</tr>
<tr>
<td>Arutmin</td>
<td>Indonesia</td>
<td>16.3 Mt</td>
<td><a href="http://www.arutmin.com">www.arutmin.com</a></td>
<td>India</td>
</tr>
<tr>
<td>Berau Coal</td>
<td>Indonesia</td>
<td>15 Mt</td>
<td><a href="http://www.beraucoal.co.id">www.beraucoal.co.id</a></td>
<td>India</td>
</tr>
<tr>
<td>Bukit Asam</td>
<td>Indonesia</td>
<td>9.9 Mt</td>
<td><a href="http://www.ptba.co.id">www.ptba.co.id</a></td>
<td>India (~1 Mt)</td>
</tr>
<tr>
<td>Anglo Coal</td>
<td>South Africa</td>
<td>60 Mt</td>
<td><a href="http://www.angloamerican.co.uk">www.angloamerican.co.uk</a></td>
<td>India</td>
</tr>
<tr>
<td>BHP Billiton</td>
<td>South Africa</td>
<td>42.5 Mt</td>
<td><a href="http://www.bhpbilliton.com">www.bhpbilliton.com</a></td>
<td>India</td>
</tr>
<tr>
<td>Xstrata</td>
<td>South Africa</td>
<td>25 Mt</td>
<td><a href="http://www.xstrata.com">www.xstrata.com</a></td>
<td>India, Pakistan</td>
</tr>
</tbody>
</table>

* BMA is a 50-50 alliance between BHP Billiton and Mitsubishi and also operates BHP Mitsui Coal, an 80-20 alliance between BHP Billiton and Mitsui, producing about 8 Mt.

* A longer list of companies can be found at www.australiancoal.com/Pubs/DITR_Exports_full_June05.pdf.
BHP Billiton Energy Coal South Africa Ltd, one of the largest energy coal exporters in the world, owns and operates five collieries, and has a 37% stake in the Richards Bay Coal Terminal, the main export terminal for South African coal. Anglo Coal and Xstrata, two other global mining giants, have 27% and 21% stake respectively in this export terminal. Together with Rio Tinto, these four large companies have leading export operations in both Australia and South Africa, two largest sources of coal for South Asia outside Indonesia.

**Coal and the environment**

As in many other parts of the world, environmental damage due to coal mining operations has become a serious concern in South Asia. In Bangladesh, for example, the development of the Phulbari coal mine, with an estimated reserve of 572 Mt, using open-pit mining method is facing opposition from the local inhabitants and some civil society groups on the grounds of resettlement issues and negative environmental impacts. Artisanal mines in the region lack proper maintenance, often operate unofficially without control by authorities, and damage the surrounding water and ecological resources.

On the other hand, increased availability of high quality coal could have net positive environmental impacts if it replaces fuels that are more damaging to the environment; for example, brick manufacturers in the region use wood or used tires as fuel whenever coal is unavailable or prices are uneconomic, leading to deforestation and increased emissions. Brick kilns equipped with higher performance furnaces, scrubbers and good quality coal would not only prevent further deforestation but also reduce emissions. Brick kilns around the world has been successfully transformed from burning wood, tires and other products with inefficient technology to cleaner burning fuels and furnaces. Bangladesh has been pursuing a strategy of replacing other fuels with natural gas in kilns but limitations on pipeline networks and competition for natural gas from other users will likely continue to hinder this effort.

Overall, coal mine, brick kiln and similar energy-intensive operations need to be better regulated and monitored. The governments may mandate coal mine operators to submit environmental performance or mitigation bonds that would be gradually paid back throughout the development of a project. Such measures have been introduced in Bhutan in 2002. The Indian Bureau of Mines has recently developed liability bonds - a legal guarantee of a mine operator to comply with the approved mining closure plans. More efforts of similar kind should help improve environmental stewardship if well monitored.

In addition, best environmental practices in pre-combustion, combustion and post-combustion periods can reduce environmental impacts significantly. Pre-combustion, coal may need to be cleaned of impurities, which will not only increase the market value of coal but also improve its combustion efficiency and hence reduce emissions. This cleaning process is often called coal beneficiation, historically targeting sulfur and ash reduction. In addition to conventional methods of physical and chemical cleaning, biological cleaning is now emerging. Physical cleaning is usually done using water. When the coal is crushed and washed, the heavier impurities will separate from the coal. Grounding coal to powder, for example, removes up to 90% sulfur.

But such methods cannot remove nitrogen or sulfur that is chemically combined with the carbon. For removing such organic sulfur, chemical cleaning techniques such as molten-caustic leaching are used. Biological cleaning uses bacteria that “eat” the sulfur out of the coal. Scientists are experimenting with fungi and are trying to duplicate the enzyme inside of the bacteria that eat the sulfur. If successful, these enzymes can speed the cleaning process when injected into coal directly.

During and post-combustion, technologically, there are two basic approaches to using coal in a more environmentally friendly manner: 1- to reduce emissions by either reducing the formation of pollutants such as nitrous oxides (NO\textsubscript{X}) or cleaning the flue gases or both; 2- to increase the thermal efficiency of generation facilities (either by using a higher grade coal or technology and design improvements) so that less coal is used to generate the same amount of power. Clearly, a combined approach would yield best results. Some of the technologies include pulverized coal combustion, atmospheric pressure fluidized bed combustion, cyclone fired wet bottom boilers, stoker boilers, and integrated gasification combined

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cycle (IGCC) with carbon capture and storage (see box for further discussion).

Many other methods are more regulatory in nature such as requiring sorbent injection for sulfur dioxide (SO2) emissions reduction and particulates removal from flue gases; yet others require combining power generation with heat uses such as cogeneration in industrial facilities or for district heating. Also creating markets for emissions allowance trading can help; technologies for reducing various emissions are now available and it is often a question of creating incentives for industries to invest in installing these technologies. For example, the cap-and-trade approach reduced SO2 and NOx emissions in the U.S. and elsewhere significantly.

**Technological advances: carbon capture and storage**

It is estimated that burning coal caused about 40% of global carbon dioxide (CO2) emissions in 2004, and that coal could surpass oil by 2010 as the primary source of CO2 emissions. Although South Asian countries have ratified the Kyoto Protocol, they are only mandated to monitor and report emissions. Nevertheless, recent developments, such as "Washington Declaration" and the United Nations Climate Change Conference in Bali, focus increasingly on getting developing countries such as China and India to take actions to reduce emissions. Despite the ongoing debate about whether this request is fair given that the industrialized world has been mainly responsible for accumulation of greenhouse gases in the atmosphere, it is doubtful that goals such as stabilizing CO2 at 550 parts per million (ppm) by 2050 can be achieved without cooperation from China, India, and other developing countries.

Technology transfer and cooperation across the world can help. Carbon capture and sequestration (CCS) is a technology that would allow continued use of hydrocarbons as the CO2 emitted by their burning would be captured and pumped underground into sealed geologic formations such as depleted oil and gas reservoirs or brines for long-term storage. Large point sources of emissions such as coal-fired power plants are prime targets for CCS. China and India have been parties to the U.S. Department of Energy’s FutureGen project, which envisioned an IGCC plant with CCS. Since the project was promoted, the estimated cost of the project has almost doubled. As a result, the DOE changed its strategy to support only the CCS portion of privately funded power plants. China, though, recently announced the GreenGen project, an initiative by the state-owned Huaneng Group and seven power and coal companies. This 400-MW plant is basically the same as the FutureGen plant. The goal is to build it at the coastal city of Tianjin by 2015. Australia is also pursuing several CCS projects.

CCS technology is not commercially proven at this time but a handful of demonstration projects operating around the world, with a variety of site specifics, offer clues. It is estimated that CCS could reduce CO2 emissions up to 90%. The application of capture technology would add about 1.8-3.4 ¢/kWh to the cost of electricity from a pulverized coal plant, and 0.9-2.2 ¢/kWh from an IGCC plant. The transport and storage of CO2 would add up to 1 ¢/kWh to the cost (International Panel on Climate Change report 2007, p.343). These estimates should be revised upwards given the significant cost escalation experienced by capital projects in recent years; the proportion of incremental cost of CCS in total cost of integrated projects (e.g., a greenfield coal-fired plant with CCS) can be expected to remain the same.

An intermediary step for CCS is to use the captured CO2 for enhanced recovery of hydrocarbons such as oil and natural gas where this is feasible. The additional production of these valuable commodities adds economic incentives to capturing CO2 and hence decreasing the risks associated with adopting this relatively new technology. Mandating reductions in CO2 emissions via legislation will also help with faster deployment of these technologies although mandates could also raise costs more than necessary if they are not well designed. Once these incentives are put in place and CCS technology is deployed in large scales and at multiple sites in the U.S., China, Australia and elsewhere, the technology should be available for worldwide application.

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10 More information on various technologies can be obtained at www.iea-coal.org.uk/site/ieacoal/clean-coal-technologies.
Coal potential in South Asia

Using domestically available or imported coal was traditionally seen as a way to "ensure energy security" in the region, especially in India.\(^{11}\) Given India's relatively abundant reserves and status as the third biggest coal producer and consumer in the world, this thinking is probably well justified. However, the fast-paced growth of the Indian economy in recent years exposed many hurdles faced by the domestic coal industry that prevent further expansion of production and delivery capacity necessary to keep up with the growing demand. Recently, Bangladesh and Pakistan has also started placing emphasis on "ensuring the energy security of the country by developing the coal sector".\(^{12}\)

South Asia is a net importer of coal

All countries in the region, including India, are net importers of coal. Although most of coal imports in the region consist of coking coal, primarily for steel industry, increasingly more coal is imported for power generation. Only India has a high share of coal-fueled power generation (over 53%). The share of coal in Pakistan's energy balance has fallen at least five-fold since 1958 to 7% in 2006, and coal-fired generation represents only 0.2% of electricity production in the country.\(^{13}\)

The only coal-fired power plant in Pakistan is the 30-MW plant in Lakhra. In Bangladesh only the 250-MW minemouth plant at the Barapukuria mine is operating since January 2006, accounting for a little over 5% of generation in the country.

Both Pakistan and Bangladesh relied on domestic natural gas for meeting their growing energy needs; but depletion in existing fields and delays in new exploration and development investment limits the growth potential for natural gas. Until coal and natural gas reserves (including coal bed methane) are assessed and those found to be economically prospective are developed, coal imports using existing infrastructure offer a short-term panacea to the region's energy shortages.

India and China jointly account for 72% of the forecasted increase in world coal demand from 2004 to 2030. Almost 70% of the growth in India's coal demand is expected to be in power generation with the remainder mostly consumed in the industrial sector. It is estimated that coal consumption by power sector in India will grow by 2.4% per year, to 506 Mt in 2030, with additional 104 gigawatts of net coal-fired generation capacity to be built during this period.

The Integrated Energy Policy Committee in India has recently made a multi-scenario forecast on domestic coal demand until 2031-2032. The projected demand is 2.7 billion tons under the dominant coal scenario, 2.02 billion tons under the reference case and 1.4 billion tons under the low coal scenario. Under all scenarios lignite is assumed to constitute about 2-3% of total coal demand. Under the reference case the near-term demand is expected to grow 32% by 2012. In order to cover the gap between projected demand and supply, India is expected to import about 100 Mt in 2011-2012, more than doubling from 2006.

Both Pakistan and Bangladesh also project coal deficit in the mid-run, although primarily of coking coal, which is used in metallurgical and cement sectors. It is estimated that demand for thermal coal in Pakistan will increase to 14 Mt in 2008 due to increased demand from cement (5 Mt), power (3 Mt) and brick producers.\(^{14}\)

Coal to diminish power deficit: pricing of coal and electricity

Most countries in South Asia recognize a potentially crucial role for coal as a relatively low-cost fuel for power generation. India has encouraged captive mining associated with power generation for decades. Bangladesh's first minemouth coal plant started operation in early 2006 and a new mine is under development despite local and environmental opposition; the draft Bangladesh Coal Policy allows exports only after 50 years of domestic supply is guaranteed. Pakistan has started to pay increased attention to the subject as well. Further investment in the sector may depend on changes in administered pricing mechanisms for coal and electricity.

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\(^{12}\) For example, see Draft Bangladesh Coal Policy, Version 2, 23 January 2006, p. 5.


Coal pricing policies in the region has undergone some change in recent years. India, while keeping a regulated pricing regime for railroad and defense sectors, allowed the state-owned Coal India Ltd (CIL) to set prices for all power generators and 75% of other industries – 25% of coal used by the industrial sector can be acquired through auctions, tenders and imports. Only coking coal is allowed to follow an import parity pricing regime. The draft Bangladesh Coal Policy provides a pricing regime linked to international price for export purposes as well as for domestic consumption except for the mandatory minemouth power generation.

Electricity tariffs in most South Asian countries are set or approved by authorities after a competitive bidding process. In Pakistan, for example, the National Electric Power Regulatory Authority has recently set the levelized tariff for domestic coal-fired generation based in Sindh province at $0.078055 per kWh for long-term energy supplies, while in India the latest domestic coal plant was approved with the levelized tariff of $0.0498882 per kWh. The difference between the two tariffs is large and could possibly be due to the disparity between the administered price of coal in India and the market price of coal from private mines in Pakistan.

The tariff in India is competitive with gas-fired plants; for example, the Central Electricity Regulatory Authority of India has recently reconfirmed a tariff of $0.054745 per kWh for Agartala Gas Power Station, commissioned in 1999. In contrast, a levelized tariff of $0.0574772 per kWh was approved for 4,000-MW supercritical power plant in the Gujarat province developed by Tata Power Co Ltd. The higher tariff is justified because the project is to be fueled by imported coal and has higher capital costs due to the use of a modern and efficient technology (with lesser environmental impact). Overall, it is important that these tariffs satisfy investors' return expectations after covering all costs for investment flow to continue.

Infrastructure constraints

The major means of coal transportation in the region is the railroad system. Intrastate and especially interstate railroad systems in the region require upgrades and expansions. Coal transportation in India by rail has been steadily decreasing over the last few years. The country's railroad system is overloaded and accommodation of additional coal freights might represent a challenge. Already, due to insufficient capacity at some parts, coal is being transported by the more time-consuming and expensive rail-cum-sea route. Bangladesh Rail, in contrast, while moving approximately 3.5 Mt of freight per year over its entire network, has significant spare capacity. With certain improvements necessary for coal transportation and rehabilitation of certain parts of the rail system the country could import more coal or transport domestic coal into different parts of the country.

River systems in India and Bangladesh are conducive to extensive coal transportation. For instance, Bangladesh could barge most of its coal for export to marine terminals (or barge imported coal inland) without straining its railroad system. Bangladesh recognized the challenge and proposed a comprehensive coal related infrastructure study and plans to develop a Coal Zone in northern part of the country, where the majority of coal resources are located. In Bangladesh, the lack of sufficient domestic production and the absence of marine coal terminals made the government rely on the only available import route, which is by rail from India. Coal imported from India, though, contains sulfur at levels significantly higher than presently allowed by law.

Transportation congestion and bottlenecks and high freight rates made high quality imported coal the fuel of choice for consumers in coastal areas. Yet, capacity limitations in specialized coal terminals and lengthy approval processes for new terminals might restrict regional coal imports. In India, the government recognizes the need for new ports and terminals but the approval of a new coal terminal could take several years. The total transshipment capacity required in 2011-2012 is projected to be 1,100 Mt compared to the current capacity of 600 Mt. Accordingly, India has planned four coal terminals and births for 2006-2007, two of which went online so far.

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16 Public Private Partnership in Ports, presentation by the Secretary of Department of Shipping, Government of India, 20th May, 2006.
**Crucial role of regulatory agencies**

*An administered market: the case of India*

Until recently, demand and supply requirements in India were being set based on the dialogue between the producers and consumers and the Coal Linkage Committee. The Ministry of Coal on one side, and appropriate agencies regulating other industries, on the other, initially estimated supply capacity and demand requirements accordingly, and tried to match them. Such a planning process sometimes created imbalances. As a result coal supply was often diverted from “low priority” to “high priority” customers.

In order to improve the supply to final consumer groups, the linkage system was recently replaced by the mandatory bilateral commercial fuel supply agreements (FSA).¹⁷ All consumers are now obliged to negotiate a contract with a coal supplier, based on firm commitment and compensation in the case of default by either party. Consumers have a right to opt-out from the FSA system, in which case they will have to manage their supplies through agencies, nominated by the government, which, in turn, has to negotiate an FSA with a coal supplier. This transitional step might relieve coal deficit for certain consumer groups (in particular, brick manufacturers, the largest consumer group consisting primarily of small to mid-size enterprises with low lobbying power), optimize logistics and therefore reduce costs for all final consumers.

**Problems with resource allotment and siting of new projects**

India has rather lengthy and complicated approval procedures for new mining projects. For example, the allocation of coal blocks to private parties is done through the mechanism of an inter-ministerial body, known as the Screening Committee. Obtaining various approvals and permissions for new project siting takes a long time and delays from regular timeline is considered normal. In some cases it takes over three years for the companies to obtain environmental clearances alone for new projects. In contrast, the permitting process in Western Australia is scheduled to take up to 12 weeks.¹⁸

As a panel of Indian experts puts it, “procedures and processes need to be improved to expedite the allotment of the captive coal blocks in a transparent and effective manner.”¹⁹ It is necessary to simplify and streamline regulatory processes in order to reduce project timeline (mining leases, surface rights and the subsequent land acquisition). Although there were proposals to grant Coal India Ltd (CIL), as a major coal producer in the country, more financial and operational freedom and even exemption from regulatory siting processes, very little have been done to date. These privileges, on the other hand, would provide CIL with competitive advantage and would be inconsistent with the suggestions to open up the coal sector to new participation – both public and private. The progress in implementation of either strategy has been slow.

**Grading coal quality**

Decreasing quality of the coal mined, which has rather high sulfur and ash content and relatively low calorific value, is a major problem in the region. There are several reasons for this quality deterioration, mainly regulatory and technological. There are no incentives to apply grade enhancement techniques in the mines because of calorific value bands adopted in India are wide; producers can get the same price for coal that is closer to the lower boundary of a particular band as they would for coal that is closer to the upper boundary. Open-pit production methods do not provide for maintaining consistent quality of the coal. Public companies pursue quantitative goals rather than quality. In other countries, the situation is similar. This lack of well-defined standards for grading is one of the reasons why the demand for the metallurgical sector in the region has been increasingly met through imports of high grade coking coal.

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¹⁷ The new regulation is mandatory for all end users consuming over 4,200 tons a year.


¹⁹ The report of the Expert Committee on Road Map for Coal Sector Reforms, Ministry of Coal, Government of India, New Delhi, December 2005, Part 1, p. iii.
**Bringing in “new blood”**

*Industry is limited to very few, primarily state-owned players*

The coal industry in South Asia is mostly dominated by state-owned companies. In India, CIL with about 82% of total domestic production is the main player. Another state company, Singareni Collieries Company Limited accounts for another 8% of production. The third public company, NLC, is primarily involved in lignite production, and is responsible for about 3% of total coal production in the country. Despite partial liberalization of the coal sector from the mid-1970s, there was no significant private participation until recently. The share of private production increased from 3% in 1996 to about 6%. Private coal developments are primarily captive, that is, tied by back-to-back legal and commercial obligations by the end user (which is often the same as the exploration company), with priority given to power and steel sectors.

In Bangladesh, the state-owned Petrobangla’s coal subsidiary dominates the sector, operating the major Barapukuria underground mine with annual production of about one Mt per year. While encouraging new coal development, the draft coal policy in Bangladesh contemplates export only after 50 years of supplies have been guaranteed for the country. The Pakistani coal sector, in contrast, is formed mostly by private companies although the public sector is involved through federal and regional development corporations. The state-owned Pakistan Mineral Development Corporation accounts for about 10% of coal production in the country but block 1 of Thar coal field, which is the largest coal field in the country, is to be developed by Hasan Associates of Karachi, while exploration license for block 2 was granted to Associated Group of Lahore. The Pakistani government has recently decided to unbundle coal mining and power generation in the Thar basin, creating the Coal Mining Company. In Afghanistan, about 20% of coal production falls on state-controlled North Coal Department, while the coal industry in Bhutan is privatized.

**Technological challenges: setbacks in underground mining, low productivity in open-pit blocks**

In recent decades, the Indian coal sector has increasingly relied on open-pit mining due to certain setbacks in underground mining. Low productivity and reserve recovery in the production of coal from underground mines is explained by the “inadequate exploration and geotechnical investigations of coal horizons, roof and floor rocks and partly due to the foreign equipment supplier not matching the equipment with ground conditions.” At the same time, successful introduction of more efficient continuous miners raised expectations about increasing the production share of underground mining, which is highly desirable for sustainability of the industry in the long-term.

The draft policy in Bangladesh allows for open-pit mining but spells out pre-requirements before operations can start, including environmental and socio-economic impact assessment and mitigation strategies. Open pit mining is generally more cost-effective, reduces health and safety risks to mine personnel, and carries fewer technical risks.

In Afghanistan, the large number of small artisanal mines that use primitive technologies and equipment due to lack of adequate investment and regulation reduces productivity and increases environmental impact of coal mining operations

**Limited exploration efforts**

Pakistan plans to increase coal production from less than four Mt to 20 Mt by 2015 primarily using the Thar basin deposits. Similarly, Bangladesh aims to increase production from current one Mt to 20 Mt within the next decade. But, the pace of exploration and development of new coal mines has been falling behind the growing need for energy in the region. In India, exploration activity has been carried out almost exclusively by the Central Mine Planning & Design Institute Limited (CMPDI), an affiliate of CIL. Private companies have been denied any participation in exploration efforts. As such, private coal exploration experience is absent. The Geological Survey of Bangladesh has had limited success in exploration efforts. Although Pakistan allowed private companies to operate in the coal mining sector, the country’s coal resources remain underdeveloped. Afghanistan registered some success with development of coal resources, with international aid.

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20 According to the Coal Mines Act (1973) coal mining was exclusively restricted to public companies (Tata Steel and Indian Iron and Steel Company were exempt and continued coal mining as private companies). Later on, in 1976 and 1993, additional provisions to the act allowed captive mining for steel, cement and power industries.

21 The report of the Expert Committee on Road Map for Coal Sector Reforms, Ministry of Coal, Government of India, New Delhi, December 2005, Part 1, p. 11.

Having realized this handicap, there has been a recent push for policy change that would encourage new investment in this area. Newly drafted coal legislations in the region recognize the need to attract international companies not only in terms of financial resources but also for the skilled and experienced manpower, modern technologies and environmental best practices they can offer. India already allows 100% foreign equity in captive coal mining, yet restricts participation of foreign companies in non-captive projects.\textsuperscript{23} Recently CMPDI was approved to provide exploration services to private companies on a contract basis.

In India, a new Mineral Policy was recently approved by the government and a Commercial Mining Bill was introduced to the parliament to amend the Coal Mines (Nationalization) Act of 1973. The new legislation provides for auctioning of the coal fields instead of the current practice of allotting them to companies. It will also streamline the approval process for new leases. In the meantime, the government continues to pursue captive projects, allocating in 2006 15 blocks with total reserves of 3.6 billion tons to private parties in power sector and 23 more blocks with total reserves of 3.6 billion tons to private parties in other sectors (primarily steel production).\textsuperscript{24}

Bangladesh is also currently reviewing draft coal policy that allows for open cast mining and coal exports. New provisions, such as mandatory requirement for coal mine operators to built minemouth power plants, are aimed at mitigating the electricity deficit in the country. A flexible approach is desirable as mine operators are not traditionally in the business of building and running power plants; associated frameworks for coal-fired generation investment may be needed.

In Pakistan the National Minerals Policy was introduced in 1995, which contains favorable fiscal conditions for potential investors. The government has also established a Mineral Investment Facilitation Board and established provincial Departments of Mines and Minerals in order to facilitate license issuance and lease granting. Private sector is already operating the largest fields in Pakistan.

To realize South Asia’s coal potential, certain policy issues should be addressed

Although the resource potential is there, increasing coal supply in South Asia is faced with several constraints, especially in the largest producer, India:

- Lack of investment in exploration & development
- Decreasing productivity in producing mines (technology adoption is slow – lack of investment)
- Lax grading regulation decreases coal quality
- Main transportation option, railways, is congested; barging is limited
- Import terminals are not sufficient

These constraints are mainly caused by

- Absence of domestic private sector expertise in coal (state companies dominate)
- Trade restrictions curtail incentives for resource development in some countries
- Prices as well as supply allocation are administered centrally (inconsistencies with import prices)
- Approvals take long time for import terminals, new mining licenses (risks for private investors)

Overall coal picture in South Asia

There is significant coal production in South Asia, mostly in India but the region’s resource potential is larger than what is currently being accessed and imports from major producers such as Indonesia, Australia and South Africa are conveniently available. However, the investment needs are extensive and cover exploration for and development of new resources (including coal bed methane), increasing transportation capacity (rail and barges) within and across countries, coal import terminals, and electric power plants and transmission lines (see next section for further discussion on regional power pools). Accordingly, the countries in the region need to update their commercial frameworks in order to attract necessary investment and expertise along the coal value chain. Primarily, pricing of coal (based on international grading standards) and electricity need to reflect costs structures and licensing and other regulatory procedures need to be streamlined (see box for details).

Regional Electricity Trade

Increasing coal-fired generation capacity in South Asia, along with generation based on natural gas, hydro, and renewables such as wind and solar would contribute significantly to meeting growing energy demand in the region and improving the quality of life for the citizens of South Asian countries. These benefits can be enhanced via increased trade of

\textsuperscript{23} Australian Commodities, Volume 14, no. 4, p. 678.
\textsuperscript{24} Annual report 2006-2007, p. 33, Ministry Of Coal, Government of India.
electricity through an integrated grid, or power pooling. Coal, as a relatively cheap base load generation fuel, can provide an anchor for regional electricity trade over this integrated grid.

**Power Pooling**

Power pooling is coordination of activities of neighboring power grid operators in order to increase reliability of power supply and reduce costs. The degree of grid integration and the number and type of players in the power sector will determine how deep a pool will be. Power pools usually evolve from infrequent bilateral exchanges of electricity between utilities via few interconnecting transmission lines to central exchanges where many players (generators, consumers and traders) schedule power at varying prices throughout the day benefiting from a highly integrated grid that facilitates flow of electricity from and to many points on the system. Typically open access to the grid is required for enhancing trade and a regional regulator can ensure access and monitor other pool activities for fair and efficient operations.

The first power pool was created in North America in 1927. The North America now has three major reliability regions (or highly integrated grids) covering multiple states in the U.S. and provinces in Canada as well as some trade with Mexico. The North American Electric Reliability Corporation (NERC) is responsible for ensuring reliable operation of the transmission system in North America in close cooperation with utilities and regulators.

Internet sites for selected power pools:
- Southern African Power Pool: www.sapp.co.zw
- West African Power Pool: www.ecowapp.org
- Central American Electrical Interconnection System: www.eprsiepac.com
- North American Electric Reliability Corporation: www.nerc.com

Another major regional initiative is the NordPool which was established in 1993, the first multinational exchange for trading electric power. Currently, there are several other regional initiatives including the following: Southern and West African Power Pools (SAPP and WAPP), Energy Community of Southeast Europe, Greater Mekong Subregion Power Trade Organization in Southeast Asia, Central American Electrical Interconnection System (known with its Spanish acronym, SIEPAC), and South American Regional Energy Integration Commission. Another, the Mediterranean Power Pool (MPP) is expected to be completed by 2015 and will be supported by a ring of high voltage (HV) transmission lines around the Mediterranean Sea, bringing together the power grids of North Africa, Europe and the Middle East.

**Benefits of power pooling**

Fundamentally, power pools offer several interrelated and mutually reinforcing benefits: increasing reliability (sharing reserves, emergency assistance, joint planning of generation mix and transmission expansion), increasing efficiency and hence reducing operating costs (reducing the need for individual reserve margins, balancing peak loads across regions, regulating transmission and distribution losses), reducing investment costs and hence the long-term price of electricity (economies of scale with access to larger market, lower reserve margin needs), and environmental benefits (increased efficiency reducing emissions, easier investment conditions for renewables).

**Increased system reliability**

Load forecasting must guide decisions to invest in new generation and grid upgrades so as not to risk system outages during new peaks as demand grows; this type of planning is usually the job of the system (grid) operator and can be done in a more comprehensive manner for a regional grid. Exchanges of reserve capacity within a regional grid increase system reliability while lowering operating reserves to levels less than would be necessary under independent operation of the national grids; because peak load in different regions often fall on different times of the day due to particularities in electricity consumer profiles, time zone differences, and variations in weather conditions.

Interconnected power grids also offer "peace of mind" to participants in case of emergency events. Natural disasters, frequent in South Asia, such as floods, typhoons and earthquakes, fall within this category. Such events often lead to interruptions in electricity supply, increasing operational costs, mostly due to higher fuel expenses associated with
switching to reserve fuels, typically fuel oil, or using reserve generation capacity, such as diesel power stations. In many instances countries lack these options and end up with prolonged power shortages. For example, in 1992, a severe drought in the South African region, which relied at the time primarily on hydropower, led to a major energy crisis and triggered the integration of national grids in the region. The use of coal in South Africa and Botswana, natural gas in Angola, Namibia and Mozambique, combined with hydropower in majority of the countries in the region, especially from the Congo river (estimated to reach 150 GW), was seen as a strategy to mitigate similar energy crises in the future. However, investment needs to take place in long distance transmission lines, large hydroelectric facilities and natural gas pipelines for the realization of this strategy. Recent power shortages in South Africa underlined that the state utility, Eskom, could not keep up with rapidly growing demand in the country although the response to the crisis has been quite positive with many permanent efficiency improvements in generation facilities as well as large consumers.

**Increased efficiency**

Generally speaking, one of the major benefits of creating regional grids is the savings associated with pooling available generating capacity across the grid region. Two indicators that might be used to assess efficiency of a power pool include the total reserve margin that indicates "the adequacy of the available installed capacity and contracted supply in relation to the maximum system demand" and the local reserve margin that represent the total reserve margin excluding total export obligation of the country. For instance, SAPP, which started functioning in 2000, allowed the system to reduce both total and local reserve margins by 2003 – from almost 30% to about 15% accordingly.\(^{25}\) It is estimated that interconnection of power grids in Western Europe allowed to reduce capacity requirements by 7-10%.\(^{26}\) Accordingly, investments in power generation plants could also be postponed and optimized on the basis of least-cost development of regional energy resources and reduced costs of maintaining power generation reserves.

Efficiency can also be increased via reduction of transmission and distribution losses. Although this is fundamentally a challenge for distribution companies and local authorities, especially when non-technical losses are considered, regional system operators are likely to implement operational standards that would require generators as well as distribution companies to reduce at least their technical losses.

**Cost reductions**

The analysis of operations of various power pools suggests that power pooling leads to sizable reductions in electricity costs. The experience of the NordPool is representative. The countries within the pool exchange data on their marginal costs of production at different times of the day, and in case of a difference, a trade takes place at a price, which is calculated as the average of the two marginal costs. In Figure 6, a snapshot of NordPool prices are provided; although prices differ significantly at different locations, the average system price of €40.08 offers significant savings for most of the consumers in the region, mainly due to availability of excess hydropower at low marginal cost in parts of the grid. In short, a power supplier, a national utility or private supplier, can save costs by purchasing energy from another supplier with lower marginal cost due to lower fuel costs, more efficient power generation equipment, or due to availability of hydropower in excess of firm energy production levels.

Also, joint planning and coordination of construction plans and schedules within the power pool might result in significant economies of scale, since the implementation of large power generation facilities such as major hydroelectric plants

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requires less capital expenditure than the total cost of several small generation units, especially when they are in remote locations. For example, the initial SAPP plan of 2001 estimated costs of the integrated projects at $8 billion, while individual country projects were estimated to cost $11 billion.\textsuperscript{27}

\textit{Environmental benefits}

Grid interconnections could provide various environmental benefits, such as reduced or avoided air and water pollution, reduced impacts on biodiversity and wildlife, and positive effects on human health such as reduced morbidity and mortality.\textsuperscript{28} To the extent power pools reduce the need for new generation investment, decrease system losses and encourage efficiency they will help reduce emissions. In addition, the extended use of hydropower generation as well as renewables within a regional power pool would also reduce emissions due to reduced utilization of fossil fuel based power plants. It should be easier to incorporate a larger percentage of intermittent resources such as wind and solar into a regional grid as the peak load would differ across distant parts of the grid and the availability of variety of generation sources should help balance the occasional lack of wind or solar generation. It should also be possible to locate wind and solar facilities at locations where they are most productive (hence lowering per unit cost of electricity from these plants). If natural gas fired generation can be brought into the system replacing some of the base load coal generation would also reduce emissions. Perhaps more importantly, improved grid operations, including the reduction of technical and hopefully non-technical losses would also reduce the need for generation, especially localized diesel generation.

\textit{Potential for power pooling in South Asia}

South Asian countries can also benefit from a regional electricity pool. Per capita consumption of electricity in the region is significantly below the world average of roughly 2,400 kWh (first row, Table 6). Electricity shortages as demonstrated by frequent blackouts and load shedding are anemic in the region. The Central Electricity Authority of India estimated energy deficits in 2007 at 9.6% (67 terawatthours, or TWh).\textsuperscript{29} The situation is not much different in Pakistan or Bangladesh, where load shedding is the only way the system can be balanced due to shortage of generation capacity. A significant handicap is the large amount of system losses; official transmission and distribution losses for Bangladesh, India and Pakistan are about a quarter of generation (Table 6), as compared to 5-6% in developed countries. Although investment in new generation capacity is needed to keep up with growing demand, reducing these losses will help increase access to electricity in the short-run and reduce the need for new generation. Creating an integrated grid and operating efficiently would help with the reduction of losses.

\begin{table}[h]
\centering
\caption{Electricity in South Asia}
\begin{tabular}{|c|c|c|c|c|c|c|c|}
\hline
 & Afghanistan & Bangladesh & Bhutan & India & Maldives & Nepal & Pakistan & Sri Lanka \\
\hline
Annual consumption per capita (kWh) & 38 & 165 & 1,141 & 657 & 542 & 67 & 425 & 357 \\
\hline
System losses (%) & 40\% & 23\% & NA & 24\% & NA & NA & 24\% & NA \\
\hline
Net imports & 28\% & - & -1.3\% & 1\% & - & 5\% & - & - \\
\hline
\end{tabular}
\end{table}


In most countries in South Asia, electricity generation is dominated by one source (Figure 7). Bhutan and Nepal depend almost exclusively on hydro, which also dominates the generation portfolio in Afghanistan and plays a significant role in Sri Lanka and Pakistan. Sri Lanka depends on oil for about 60\% of its needs, depending on the seasonal availability of hydro capacity. Bangladesh depends heavily on natural gas while India uses coal for more than half of its generation needs. Natural gas also plays a very important role in Pakistan.

\textsuperscript{27} SAPP Annual Report 2007, p. 5.
\textsuperscript{29} Central Electricity Authority of India. Annual Report 2006-2007, p.48.
Electricity is already traded in the region on a bilateral basis. Afghanistan imported more than a quarter of its consumption from Iran, Turkmenistan, Uzbekistan and Tajikistan; a new trade agreement is under development for bringing electricity from hydro sources of Tajikistan to Pakistan via Afghanistan. India provided grant assistance to Bhutan for building 1,416 MW of hydro facilities, out of which it imported 5.7 TWh. There was also two-way trade between India and Nepal, the latter importing 266 GWh and exporting 101 GWh.30

This trade can be enhanced further with a regional grid. In addition to Bhutan and Nepal, neighboring countries such as Tajikistan and Kyrgyzstan have hydro potentials that surpass their domestic needs significantly. India, Pakistan, and Bangladesh can develop further thermal capacity, mostly based on natural gas, if more investment in domestic resources takes place, and international gas pipelines and LNG import terminals are built connecting the resources in the region as well as other parts of the world with consumers. As discussed before, regionally produced or imported high quality coal can further diversify fuel portfolio in the region.

This hydro-thermal mix at the regional level would enhance system reliability (e.g., balancing seasonal fluctuations in water levels), increase electricity availability, reduce the need for oil imports, and generate revenues for hydro exporting countries, Bhutan and Nepal. Even the incorporation of renewables into the generation fleet can be enhanced with a regional grid; one of the most commercially viable renewables, wind energy, is intermittent and does not necessarily follow electricity demand through the day; but it can be better accommodated in a larger transmission system serving many customers with varying demand profiles. Overall, such a system should also help reduce emissions associated with central and distributed power generation and other economic activities.

A regional electricity hub

In addition to potential South Asian regional power pool, there are initiatives to create a Central Asia – South Asia Regional Electricity Market, the initial stage of which provides for a pilot electricity trade project from Central Asian states,
that have excessive hydro generation, via Afghanistan to Pakistan. In November 2007 an agreement was signed in Kabul to implement a $500 million electricity connection between Central and South Asia to transfer 1,300 MW from Tajikistan and the Kyrgyz Republic to Afghanistan and Pakistan. The countries agreed to run a feasibility study of the project, which would comprise a 750-kilometer high voltage direct current (HVDC) transmission system between Tajikistan and Pakistan via Afghanistan; a DC-AC converter station in Kabul; and an AC transmission link between Kyrgyz Republic and Tajikistan to supply Kyrgyz electricity to South Asia via Tajikistan; and the overall institutional framework for this electricity trade to take place. They also decided to establish an Intergovernmental Council (IGC) that will provide the policy oversight for the project, and a Secretariat under the IGC to develop the project. Work on establishing this electricity trade from Central Asia via Afghanistan is moving forward.

**Capitalizing on seasonality differences**

Peak loads in the region often fall on different seasons of the year. For example, hydropower from Bhutan and Nepal to neighboring countries during wet season that lasts from June to September, matches peak of power demand in India, Pakistan and Sri Lanka. At the same time, peak demand in Nepal falls in December and January, when generation capacity of its hydro plants is low. Therefore, Nepal and Bhutan could rely on electricity imports in winter, reversing energy flows and exporting power in summer seasons.

**The central location of India’s power grid**

India has 14,150 MW of inter-regional transmission capacity (Figure 8). About 10,000 MW were added during the last five years. The country plans to build 5,200 km of 765-kV transmission lines and 24,500 MVA of 765-kV transformation capacity by 2011-12 to increase the interregional capacity up to 40,150 MW by 2012. The interregional exchange in India equaled almost 17 TWh in 2006-2007, which represents about 3% of total energy consumption for the period. With its central location in South Asia, large size and expansive and growing transmission network, India can play an important role for facilitating the flow of electricity on a regionally integrated grid.

**Hydropower bonanza**

The most promising resource that can serve the whole region via an integrated power pool is hydro. It could be easier to attract the investment necessary for the construction of large dams and the associated generation facilities and transmission lines if the market for the electricity they will produce is enlarged via the integration of the national grids into a regional system. Currently, the countries with relatively most abundant hydro resources such as Nepal do not have the demand that would justify large investments (Table 7). Only India has tapped into its hydro resources on a large scale, yet still leaving about 66% of its hydro potential undeveloped. Although Bangladesh and Sri Lanka has taken advantage more of their hydro potential, their hydro bases are among the lowest in the region. Pakistan, Nepal and Bhutan are in the process of making major investments in hydropower. Pakistan, for example, has scheduled nine projects with total capacity of 826 MW to be completed or commissioned by the fiscal year 2008-2009. At the same time, an ambitious program of
development until 2025 provides for developing eight more projects with total capacity of 19,939 MW. In 2003 India launched a 50,000 MW program consisting of 162 hydropower projects; feasibility studies and detailed project reports for nine projects have been prepared by 2007.

In addition to large hydropower projects, most countries in South Asia have micro hydro development programs. Afghanistan, for example, has recently completed three micro hydro projects with total capacity of 480 kW. Moreover, some countries, such as Bhutan, Sri Lanka and Nepal, managed to employ Clean Development Mechanism (CDM) for implementation of small hydropower generation projects.

The practice of intrastate hydropower investment projects in South Asia goes back to 1974, when the Governments of India and Bhutan signed an agreement to construct a 336 MW Chukla project, which was commissioned in the late 1980s. The major 1,028-MW Tala project was initiated in 1996 and went on-line in 2006, and represents an example of a mutually beneficial project for both sides. The Indian Government fully covered the billion-dollar project as a combination of a long-term loan and grant (40/60), and effectively obtained a source of relatively cheap and environmentally friendly energy; the tariff for India is set at $0.049/kWh. The project is managed by autonomous Tala Hydroelectric Project Authority (THPA); three out of seven members of the authority’s board are appointed by the Government of India, while the rest are nominated by the Royal Government of Bhutan. Successful implementation of the Tala project and its many smaller predecessors encouraged the Government of Bhutan to announce plans to increase power generation capacity in the country from about 1,500 MW at present to 5,000 MW by 2020. These plans are supported by a commitment of the Indian Government to import 5,000 MW by that year.

The development of hydropower generation jointly with India gave significant boost to economic development of Bhutan. In 1997-2002 revenues from hydropower exports to India amounted to 45% of total national revenue. Exports of electric power grew from 1,560 MW in 2002 to 1,943 MW in 2006. A number of additional indirect benefits are associated with the implementation of these hydropower projects. The number of electricity consumers in Bhutan increased from 39,700 to 64,300, or 10% of the total population during the same period, whereas per capita consumption surged from 808 kWh to 1,141 kWh.

Development of joint bilateral international hydropower projects is also a worldwide trend. In Table 8, some of these projects are listed, covering a wide geography. An interesting sub-category here is Border River Hydro Projects, originated in the 1950s. The most prominent and well known example of this type of development is, probably, the 12.6-GW Itaipu project on Parana, marking the border between Brazil and Paraguay.

<table>
<thead>
<tr>
<th></th>
<th>Hydroelectric Total Potential (MW)</th>
<th>Installed Capacity (MW)</th>
<th>Realized Potential of Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>555</td>
<td>230</td>
<td>65.71</td>
</tr>
<tr>
<td>Bhutan</td>
<td>30,000</td>
<td>444</td>
<td>1.48</td>
</tr>
<tr>
<td>India</td>
<td>75,400</td>
<td>25,407</td>
<td>33.70</td>
</tr>
<tr>
<td>Nepal</td>
<td>83,290</td>
<td>560</td>
<td>0.67</td>
</tr>
<tr>
<td>Pakistan</td>
<td>40,000</td>
<td>5,010</td>
<td>12.52</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>2,000</td>
<td>1,129</td>
<td>56.45</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>231,245</strong></td>
<td><strong>32,780</strong></td>
<td><strong>14.17</strong></td>
</tr>
</tbody>
</table>

Source: Adapted from India’s Power Sector & Cross Border Linkages. Presentation by Professor Mahendra P. Lama, Jawaharlal Nehru University. Bishkek, 26 April 2007.

Setting up power pools

One of the most important success factors in setting up power pools is the establishment of a common legal and regulatory framework, shared by all members of the pool. This framework includes but is not limited to contract and payment guarantees, arbitration practices and force majeure clauses. Based on the history of existing regional power pools, it is typical that countries start by trading energy within a bilateral cooperative framework, when they exchange data on marginal operating costs. Eventually power pools transition to multilateral competitive exchanges, where the buyers and sellers bid for energy services. Such services may include exchanges of reserve capacity among national power utilities, exchanges in spot energy, firm energy supply services (that is, the exchange of a specified amount of electric power and associated energy on a “take or pay” basis in the medium or long term) and power wheeling services.

Having abovementioned conditions met without having a physical infrastructure in place would not succeed in creating a regional power pool. Cross-border interconnection facilities and operational rules for interconnected national grids have to be in place for intrastate trading in electricity and other energy services, as well a hardware and software systems for metering, data collection, and processing of information in real time. For instance, the Motraco-Mozambique Transmission project aims at the construction and operation of power transmission lines that will interconnect three countries, South Africa, Swaziland, and Mozambique in southern Africa and supply power from South Africa to Mozambique. The operator of the 300-kilometer, 400-kV project is a joint-venture between the three national power companies: Eskom of South Africa, Electricidade de Mocambique (EdM), and the Swaziland Electricity Board (SEB). These projects are aimed at increasing power trade under bilateral agreements within SAPP.

As of now only India has a developed interconnection power lines with some of the South Asian countries. There are two 220-kV lines interconnecting Indian

### Table 8 - Examples of Joint Intrastate Hydropower Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Countries</th>
<th>Resource Owner</th>
<th>Capacity</th>
<th>Project Cost</th>
<th>Countries to receive power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Itaipu project</td>
<td>Brazil, Paraguay</td>
<td>Brazil, Paraguay</td>
<td>12.6 GW</td>
<td>$16 billion</td>
<td>Brazil, Paraguay</td>
</tr>
<tr>
<td>Yacyretá-Apipé</td>
<td>Argentina, Paraguay</td>
<td>Argentina, Paraguay</td>
<td>4,050 MW</td>
<td>$20 billion</td>
<td>Argentina, Paraguay</td>
</tr>
<tr>
<td>Epupa Falls</td>
<td>Angola, Namibia</td>
<td>Angola</td>
<td>380 MW</td>
<td>$500 million</td>
<td>Angola, Namibia, South Africa</td>
</tr>
<tr>
<td>Baankum Barrage</td>
<td>Thailand, Laos</td>
<td>Laos</td>
<td>n/a</td>
<td>n/a</td>
<td>Thailand, Laos</td>
</tr>
<tr>
<td>Manantali Dam</td>
<td>Senegal</td>
<td>Senegal</td>
<td>200 MW</td>
<td>$500 million</td>
<td>Mali, Mauritania, Senegal</td>
</tr>
<tr>
<td>Gabčíkovo-Nagymaros Dams</td>
<td>Hungary, Czechoslovakia</td>
<td>Hungary, Czechoslovakia</td>
<td>720 MW</td>
<td>n/a</td>
<td>Hungary, Czechoslovakia</td>
</tr>
<tr>
<td>Paunglaung Power Project</td>
<td>Myanmar, China</td>
<td>Myanmar</td>
<td>280 MW</td>
<td>$170 million</td>
<td>Myanmar, China</td>
</tr>
</tbody>
</table>

**What does it take to establish the necessary frameworks for a regional power pool?**

Although the process is dynamic and iterative and there are many details to settle in each, there are some logical steps: 1- a memorandum of understanding between the governments to permit their utilities to participate in the power pool and enter into contracts, and to guarantee the financial and technical performance of the utilities; 2- a memorandum of understanding between participating utilities to define ownership of assets and other rights; 3- an agreement between member utilities to define governance structure and funding for pool operations and to determine system planning, operational and commercial responsibilities under normal and emergency conditions; 4- selection of a host country for the power pool coordination center and the associated agreement; and 5- investment to build critical interconnections for power pool to start operating and facilitating trade of electricity.*

power grid with Bhutan, and a 50-MW transmission line Duhabi-Kataiya between India and Nepal, that was upgraded by 40 MW at the end of 2007.\footnote{http://english.people.com.cn/200706/09/print20070609_382563.html.} Although the initial capital investment to increase these interconnections can be sizeable, the benefits are likely to yield a quick payout. Regional backing of such projects would also render their financing relatively easier.

Role of Coal and Interregional Electricity Trade in Energy Security - Putting it all together

Energy security in South Asia can be significantly enhanced if domestic coal resources can be developed, coal imports can be increased and a regional power pool can facilitate electricity trade supported by a diverse generation portfolio of coal, hydro, natural gas and renewables. Coal will allow countries to diversify away from imported oil and natural gas, provide a power generation fuel, the price of which has historically been more stable than those for oil or natural gas, and help domestic industries. However, best environmental practices in coal mining, transportation and combustion should be adopted. A regional power pool, which can use cheap hydro resources and stable coal generation to meet the base load, would make power available to more consumers around South Asia in a more reliable manner and at a lower cost. Although these strategies require large capital investments and cross-border regulatory coordination, long-term benefits are likely to be worth the effort. In order to secure the flow of funds into building necessary infrastructure, some policy and regulatory adjustments such as rationalizing pricing of coal and electricity (as well as other energy services) and streamlining licensing procedures appear necessary.

It would be worthwhile for stakeholders in the region to regularly convene at various forums (peer exchange programs, capacity building programs, workshops) to discuss possibilities in the region, identify technological, environmental and socio-economic issues and develop strategies to move forward with establishing legal and regulatory frameworks necessary to make regional electricity trade and development of clean coal projects a reality. The Regional Clean Coal Partnership Programme of SARI/E promises to be such a forum. Also, ESQ will continue to be a resource for international best practices in clean coal and regional energy trade areas as well as other topics pertinent to enhancing energy security in South Asia.