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The Expanding International Coal Market

Jude Clemente

Department of Homeland Security
JTC Energy Research Associates, LLC
San Diego State University, California
USA

1. Introduction

“Coal is the single largest source of primary energy in the world, and in absolute terms coal use has grown faster than use of any other fuel for most of this decade. As the developing world industrializes and struggles to meet seemingly insatiable demand for power, coal has become the fuel of choice. An expanding seaborne trade in coal has started to connect previously isolated regional markets.....[and].....reflects the internationalization and commoditization of the coal market, in a transformation reminiscent of that of the oil market in the 1970s and 1980s,” (Stanford University, Program on Energy and Sustainable Development, 2009)

Coal provides nearly 30% of the world's primary energy and generates over 40% of global electricity (IEA, 2010a). Historically a domestically produced and consumed resource, the international coal market meets just 16% of total consumption (World Coal Association, 2011a). Global coal trade patterns can be parsed into two distinct regions, the Atlantic region and the Pacific region. The Americas and Europe are the primary demand centers in the Atlantic, while Asia, dominated by Japan, South Korea, India, and China, is the hub in the Pacific. Geography has been critical when deciding which producers serve which markets, with suppliers generally serving only one region. The United States, holding roughly 30% of the world's coal endowment, is considered the “swing supplier,” balancing markets when supply is short (BP, 2010). There are also two parallel coal markets; thermal (steam) coal is used to generate electricity, and metallurgical (coking) coal is used to manufacture steel and iron. In the past 20 years:

- The seaborne trade in thermal and coking coal has increased by 7% and 1.6% per year respectively (World Coal Association, 2011a).
- Global coal consumption has increased by more than 50% – from 2,235 million tonnes of oil equivalent (Mtoe) to 3,430 Mtoe (IEA, 2010a).
- Asia Pacific has extended its share of world coal consumption from 37% to 66% and will account for basically all of the incremental demand increase over the next 20 years (IEA, 2010a).

Today, coal is the fuel of choice in the developing world, and a widening array of suppliers has the international coal market in the midst of a rapid and dramatic transformation. The relatively high cost supply source of the United States will give lower cost producers the edge in Asia, where the dependence on coal for incremental electricity is stunning. Looking forward, “Chindia” will play the central role in determining global trade flows and prices.

China and India, with 36% of humanity (The World Bank, 2010), will increasingly rely upon coal to feed their flourishing economies – coal already generates 80% and 70% of their power respectively (IEA, 2010a). As a result, these nations will dominate the growth in coal-based electricity over the next several decades. And, importantly, a parallel expansion of coal consumption in Asia will occur in the industrial sector where the demand for coal to manufacture steel, cement, and liquid fuel is soaring. From 2008 to 2030, the International Energy Agency (IEA, 2010a) projects that global coal consumption will expand by over 1,600 Mtoe – roughly as much incremental energy as natural gas, nuclear, wind, and solar will provide together. The IEA’s Coal Industry Advisory Board (2009) succinctly states the reality of the world’s coal situation:

- “The future use of increasing quantities of coal worldwide is inevitable if the world is to avoid a damaging energy crunch and support the development needs of poorer nations.”
- “All major studies that have examined the outlook for world energy demand indicate that the world will remain dependent on the continued use of coal for many decades to come.”

Developing nations realize that breaking the pattern of systematic poverty depends upon available and affordable energy in general and access to reliable electricity in particular. On a per capita basis, The World Bank (2010) reports that China consumes 17% as much power as the United States, and India uses 8% as much as the European Union (EU). With the devastating consequences of electricity deprivation well documented, the international coal market will continually expand as China and India strive to raise the quality of life of their people (see Morse & He, 2010). For example, Platts (2005) cites the Asia Pacific region specifically as the driving force behind the now thriving coal derivatives market, whether in futures or over-the-counter contracts. In addition to having the fastest growing consumers, Asia Pacific also retains the two largest coal exporters, Australia and Indonesia (see Figure 1). The present chapter examines the three main factors that are now converging to expand the international coal market: 1) the need for more electricity, 2) the need for more coal, and 3) the need for more coal imports in China and India. Developing nations have made clear that poverty reduction goals will not be sacrificed for climate change mitigation. India, for instance, has 400 million citizens without access to electricity – more people than the United States and Germany have combined.

Top Exporters (million tonnes)				Top Importers (million tonnes)			
Country	Thermal	Coking	Total	Country	Thermal	Coking	Total
Australia	134	125	259	Japan	113	52	165
Indonesia	200	30	230	China	102	35	137
Russia	105	11	116	S. Korea	82	21	103
Colombia	69	0	69	India	44	23	67
S. Africa	66	1	57	Chinese Taipei	57	3	60
USA	20	33	53	Germany	32	6	38
Canada	7	21	28	UK	33	5	38

Fig. 1. The International Coal Market, 2009
Source: developed from World Coal Association, 2011a

2. The need for more electricity

“Electrification greatly improves the quality of life. Lighting alone brings benefits such as increased study time and improved study environment for schoolchildren, extended hours for small businesses, and greater security,” (The World Bank, 2008)

Electricity is the *sine qua non* of modern society. Electricity is essential to gains in quality of life, economic well-being, and a cleaner environment. The U.S. National Academy of Engineering (2004) identified societal electrification as the “most significant engineering achievement” of the 20th Century – a century that saw a population swell of over four billion people, the rise of the metropolis, a transportation revolution, historic improvements in medical care, and the emergence of a vast system of electronic communication. As recognized by the Global Energy Network Institute (2002), “Every single one of the United Nations Millennium Development Goals requires access to electricity as a necessary prerequisite.” The socioeconomic benefits of the U.S. Rural Electrification Act of 1936 alone demonstrate the scope of electricity’s importance to living a longer and better life. Access to electricity brought about a sea change to the American quality of life, ranging from childhood survival to clean drinking water to literacy. Arguments that some states, such as California, have grown their economy and flattened electricity consumption through efficiency policies are largely rhetorical. Regression analyses confirm that approximately 80% of California’s lower per capita use of electricity is due to unique characteristics like higher prices, milder weather, and smaller homes with more people (see Mitchell et al., 2009). Electricity is unique and employed in ways that no other energy form can be:

- High quality and convertible to virtually any energy service – light, motion, heat, electronics, and chemical potential
- Permits previously unattainable precision, control, and speed
- Provides temperature and energy density far greater than those attainable from standard fuels
- Has no inertia – instantaneous access and 100% convertible to work

Electricity has wide ranging environmental benefits. Electro-technologies are more efficient than their fuel-burning counterparts and, unlike standard fuels, have no waste products at the point of use. No smoke, ash, combustion gas, noise, or odor. Electrification increases the efficiency of a society’s primary energy consumption and decreases emissions of pollutants and greenhouse gases (GHGs). Electro-technologies produce less carbon dioxide (CO₂) per unit of Gross Domestic Product (GDP), leading to findings by the Electric Power Research Institute (2003) that “technology innovation in electricity use is a cornerstone of global economic progress” and “deploying the technology of an enhanced electricity infrastructure would include.....a 13-25% reduction in carbon dioxide emissions” and “a 10% increase in real GDP.” Environmental management depends upon electricity for the movement of water and waste. A sustainable environment requires clean water and sanitation facilities. Electricity is the key to providing these services and pollution controls, and power consumption is directly related to their corresponding environmental benefits. Given the extraordinary virtues of electricity, it is no surprise that demand for power will remain a steady drumbeat across the globe (see Figure 2).¹

¹Even under the IEA’s (2010a) 450 Scenario, which optimistically assumes that “collective policy action is taken to limit the long-term concentration of greenhouse gases in the atmosphere to 450 parts per

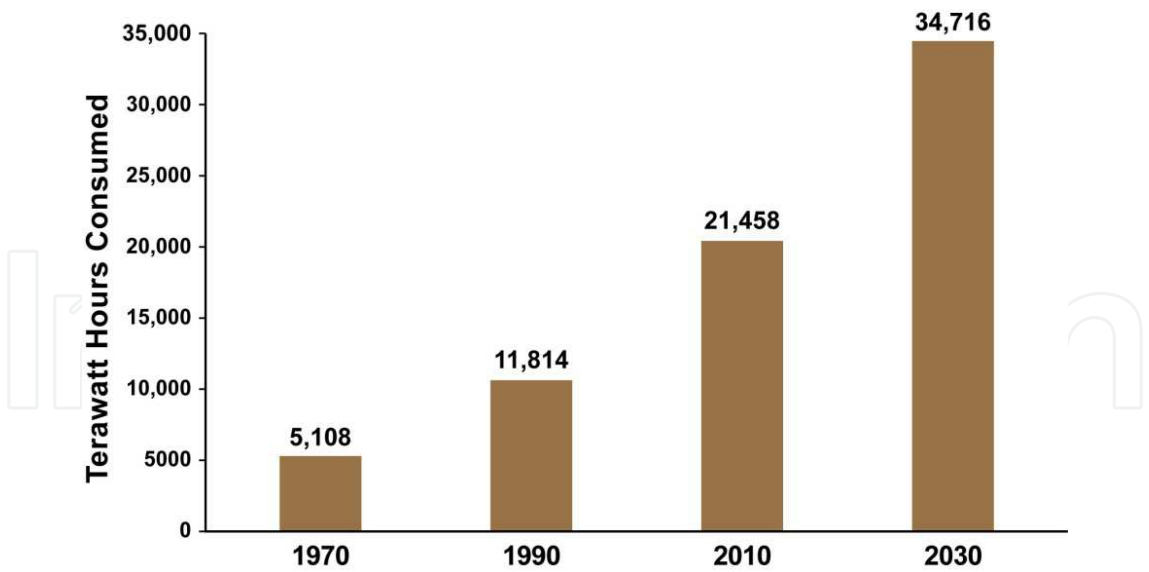


Fig. 2. The Constant Increase in Global Electricity Consumption, 1970-2030
Source: developed from International Energy Agency, 1999; 2010a

The depth of global poverty and energy deprivation is difficult for most Westerners to comprehend. The world is confronted with a human crisis at a horrific scale – 2,600 million people live on less than \$2 (all \$ in USD) a day, 2,000 million have minimal access to electricity, and 1,400 million have no electricity at all (The World Bank, 2010). In addition, another 2,000 million people will be born in the next several decades. In developing countries, household tasks requiring energy – gathering wood, carrying water, and cooking – are typically delegated to women and their children. Chores made all the more easier, safer, and healthier with the availability of electricity. The lack of electricity perpetuates the cycle of poverty because it not only blocks access to electronic communication but also means inadequate illumination for reading and studying at night. Access to electricity is a necessary condition for economic and human progress. Societies with more access to electricity survive childhood, eat better, drink cleaner water, and learn to read. Women and children are among the greatest beneficiaries of electrification as new doors of opportunity open for these particularly vulnerable segments of the population. At least 70% of all people living in poverty are female (The Global Poverty Project, n.d.). This problem of “feminization of poverty” will be impossible to resolve unless households have adequate access to electricity and other forms of modern energy. Thus, the major challenge of our time is not merely to reach 2050 with a significant reduction in GHGs emissions but to also create electricity access for the vast multitude of men, women, and children who toil grimly in the dark. Access to electricity should be a human right: every 10-fold increase in electricity use is linked to a 10-year increase in life expectancy (Boyce, 2010).

As noted by the IEA (2002), a “lack of electricity exacerbates poverty and contributes to its perpetuation, as it precludes most industrial activities and the jobs they create.” The consequences of abject poverty and energy deprivation continue to devastate around the world. UNICEF (2009) reports that 24,000 children die each day from preventable causes. To put this amount in perspective, consider the cumulative effect of child deaths: 8,760,000

million of CO₂-equivalent,” the world is sill projected to require 30,170 terawatt hours of electricity in 2030, or 40% more than it did in 2010.

children die each year from causes that electricity could help eliminate, a sum equal to the urban population of New York City. Pasternak (2000) found that a per capita annual consumption rate of at least 4,000 kilowatt hours (kWh) of electricity is required for a nation to reach a significant Human Development Index of 0.9. Electricity deprivation is thus a global blight (see Figure 3). Well over four billion people, at least 60% of the world’s population, use fewer than 2,350 kWh per year, or only one-third as many as a typical resident of the EU (The World Bank, 2010). The challenges put forth transcend national borders and are calamities for humanity at large. While the *Copenhagen Accord 2009* stated that the eradication of poverty should be the “first and overriding” priority of developing nations, there is strong reason to argue that it did not go far enough (United Nations, 2009). The elimination of poverty and energy deprivation is a global responsibility. Based on the Accord, the path forward for nations is clear:

- Eliminate energy poverty as a first-order priority
- Create access to energy for everyone, everywhere by 2050
- Advance all energy forms for long-term access
- Promote advanced generation technologies to reach near zero emissions from coal and natural gas power plants

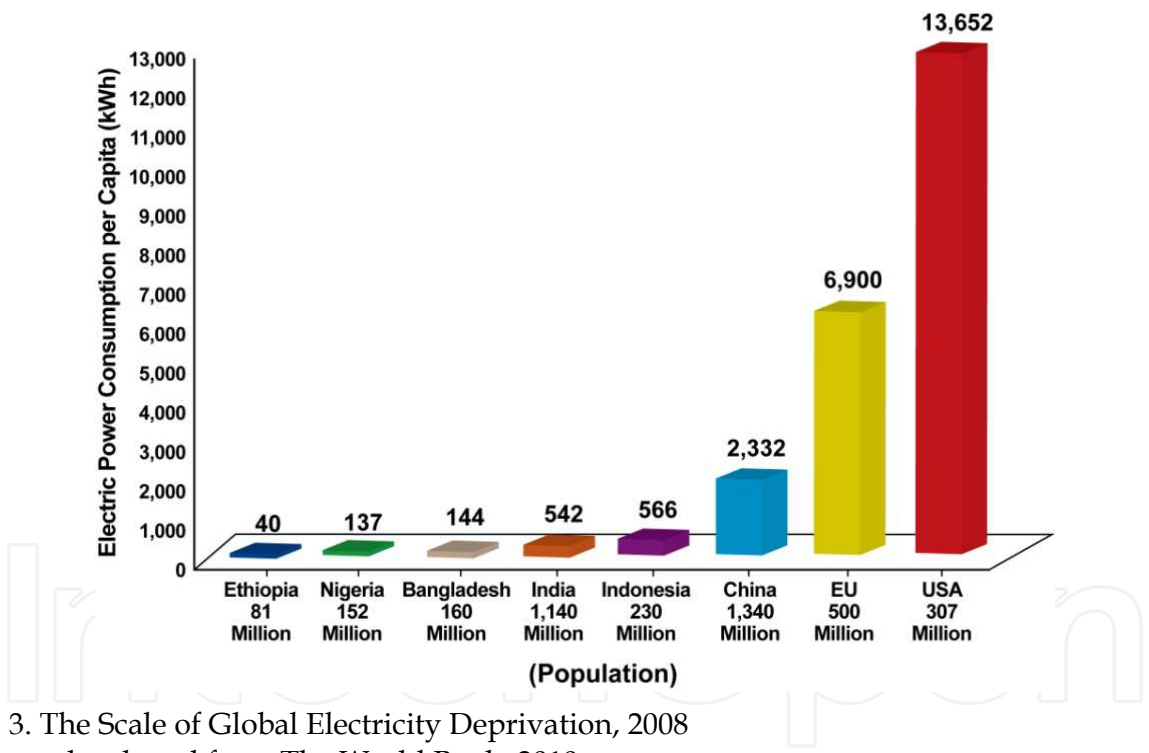


Fig. 3. The Scale of Global Electricity Deprivation, 2008
Source: developed from The World Bank, 2010

3. The need for more coal

“In the past quarter of a century, China has created wealth for many of its people, lifted many out of poverty, and helped drive and sustain global economic growth. Coal has underpinned China’s massive and unprecedented growth in output, fuelling an economic miracle that has helped to improve the standard of living in many countries,” (IEA, 2009)

If the goal of eliminating abject poverty and energy deprivation is ever to be attained, the supply and affordability of energy, particularly electricity, must improve dramatically.

Although the scale that will be required to meet these goals cannot be met by just one fuel, coal will stay the strategic choice since it generally has the lowest cost on a heat equivalency basis. The provision of adequate and affordable electricity to the 8.2 billion people who will inhabit the planet in 2030 will depend upon the increased availability, production, and consumption of coal-based electricity. Developing nations will increasingly lean on coal because it has the abundance, technology, and scalability to meet their enormous power generation challenges. From 2008 to 2030, the IEA (2010a) projects that coal will provide an additional 6,500 terawatt hours of electricity, nearly twice as much as the current total generation of the EU. This is more incremental power than natural gas, nuclear, wind, and solar will generate over that span combined. Indeed, for coal, the past is prologue. Coal has been, is now, and will continue to be a fundamental building block of socioeconomic development throughout the world. Over the half century from 1980-2030, despite a population increase of 3.7 billion people, economic growth of \$121 trillion, and energy demand increase equivalent to more than 10,000 million tonnes of oil, coal will have actually extended its contribution to global energy production from 25% to 29% (IEA, 2010a; EIA, 2010a). The IEA (1999; 2010a) reports that coal has maintained roughly a 40% share of world electricity generation since 1970 and is on pace to provide 43% in 2030.

The importance of the low cost electricity that can be derived from coal cannot be overstated.² For the industrialized nations, high electricity prices disrupt family budgets and erode the ability of domestic firms to compete in their increasingly competitive global industries. It is in the developing world, however, where high electricity prices *wreck the most havoc since the people* have almost no capacity to absorb them. Data gathered from the U.S. Energy Information Administration's (EIA) *International Energy Outlook 2010* indicate that China's per capita GDP (2005 US\$) in 2010 was \$6,027 and India's was \$2,963. By comparison, the average American made over \$45,100, and the average EU citizen made over \$30,000. Electric lighting is far less expensive and consumes less fuel than the kerosene lamps that are commonplace in the developing world. And light bulbs cut indoor air pollution. According to the World Health Organization (2005), the burning of solid biomass fuels is responsible for 1.6 million deaths a year and 2.7% of the global burden of disease. Low cost electricity powers water pumps, allowing the distribution of potable water and reducing waterborne parasitic diseases. Cost-efficient power also promotes the use of modern computers, information systems, and electric motors in manufacturing, thereby substantially improving productivity. Today, virtually all societies seek to enhance their "Three Es" – energy, economy, and environment. Coal is the fuel of choice for measurable reasons:

Abundance and Accessibility – BP's *Statistical Review of World Energy 2010* reports that coal is the most prevalent and widely distributed fossil fuel, accounting for 64% of global economically recoverable fossil resources, compared to 19% for oil and 17% for natural gas. The amount of proven recoverable coal reserves is enormous and exceeds 820 billion tonnes. Coal is distributed across every continent and every region of the world. For example, the Western Hemisphere and Asia Pacific each have about 260 billion tonnes of coal, Russia has 157 billion, Europe has 73 billion, and South Africa has 31 billion. The world consumed a total of 6.8 billion tonnes of coal in 2009 (World Coal Association, 2011b).

²In January 1930, when he was Governor of the state of New York, Franklin D. Roosevelt wrote an article in *The New York Times*, stating that: ".....high rates, of course, bear hard on the individual. But from a social standpoint they are chiefly to be regretted because they restrict the use of electricity. Rate schedules should be so adjusted as to induce the freest possible use of electricity both in the home and on the farm."

Secure Energy – As stated by the IEA (2008), “It is widely acknowledged that the oil and natural gas markets provide risks that undermine security of supply in the medium and long term.” The widespread physical distribution of coal, on the other hand, readily enhances energy security across broad political arenas by being a buffer against supply disruptions. For example, the three largest nations, China, India, and the United States, have 40% of the population and 50% of the coal but only 4% of the oil and 5% of the natural gas (The World Bank, 2010; BP, 2010). By comparison, the Middle East (including Egypt) and Russia have just 6% of the population but control 62% of the oil and 65% of the natural gas (The World Bank, 2010; BP, 2010).

Reliability – Coal’s abundance and even distribution, added to its low and stable price pattern, set the stage for a prolonged and reliable supply of energy. In many countries, coal-based generation is one of the first sources to be dispatched throughout the electric grid, as predictability makes coal a very attractive baseload fuel. Compared to other sources, the amount of electricity that can be generated from coal significantly exceeds its relative capacity. In 2008, for instance, coal accounted for 31% of total generation capacity but produced 41% of the world’s electricity (IEA, 2010a). The EIA (2010b) concludes that in 2016 all three types of coal-fired plants (conventional, advanced, and advanced with carbon capture and sequestration, CCS) will have capacity factors of 85%, compared to just 34% for wind and 25% for solar.

Affordability – For example, based on IEA (2010b) analyses of levelized costs of electricity, supercritical coal-based plants are some of the most affordable sources of power in China, \$33 per megawatt hour, versus \$39 for natural gas (combined cycle combustion turbines), \$50 for hydro, \$53 for nuclear (Westinghouse AP1000), and \$71 for wind. Both China (Large Substituting for Small, LSS) and India (Ultra Mega Power Plants, UMPP) have implemented national strategies to deploy larger and more efficient supercritical and ultrasupercritical coal plants to capitalize on economies of scale. From 2008 to 2030, the great bulk of the combined 1,050 gigawatts of new coal capacity that “Chindia” is projected to add will be these more CCS-ready advanced units (IEA, 2010a).

Versatility – Countries around the world have been initiating an increasing number of coal projects converting coal-to-liquids (CTL), substitute natural gas, or chemicals. The scale of China’s coal conversion plans is especially informative since various conversion efforts could utilize an additional few billion tonnes of coal over the next decade. CTL projects in particular will become more important with the approach of global peak conventional oil production – new petroleum finds are getting more complex, deeper, and smaller. China wants a 50 million tonne per year CTL industry by 2020 (Royal Society of Chemistry, 2007). The need for more oil from the destabilizing Middle East is a concern for both China and India.

Steel – Coal is vital to the production of steel, accounting for almost 70% of global output (World Coal Association, 2011c). And steel is a core component of our rapidly urbanizing world. In 2050, the global urban population is projected to be 70%, up from 50% today (World Health Organization, 2010). Urbanization will make huge demands on infrastructure – more buildings, roads, pipes, and machines. This equals more steel, which in turn means more coal. In addition, Dargay et al. (2007) project that the world will have 2,080 million vehicles in 2030, up from 960 million in 2007 – the average vehicle contains over 1,600 pounds of steel (Automotive News, 2007). Constant industrial development quadrupled the price of export coking coal from \$44 in 2000 to over \$176 a tonne in 2010 (Metals Consulting International, 2011).

4. Rising coal imports in China and India

“The seaborne thermal coal market is experiencing a transformation which may be as significant as that which occurred for the iron ore market over the past decade. In a similar way, we believe China and India together could transform the demand landscape for thermal coal over the next decade, displacing current western importers and evolving to dominate the industry,” (Deutsche Bank, 2010)

Led by China and India, the EIA (2010a) projects that Asia’s share of world coal imports will increase from 59% to 70% in the next 25 years. Although the region imports a growing majority of the world’s thermal coal used for power generation, there is also immense potential for coking coal. The urbanization process continues apace in China and India, with more steel and cement translating into more coal. Simply put, the overwhelming reliance of these two nations on their domestic resources is unsustainable (see Figure 4). China accounts for 14% of global coal reserves but 47% of both production and consumption (BP, 2010). The central government therefore plans to cap coal output during the 12th Five-Year Plan (2011-2015) at between 3.6 and 3.8 billion tonnes, compared to 3.2 billion tonnes mined in 2009 (Reuters, 2010). India, meanwhile, in equilibrium holding and producing 7% of the world’s coal (BP, 2010), must rely upon inefficient Coal India for over 80% of national output (Coal Explorer, 2011). India’s coal minister, Sriprakash Jaiswal, claims coal is India’s “most notorious” sector, consistently under-producing due to mismanagement, bloated bureaucratic operations, corruption, and theft (Daily News & Analysis, 2010). Many factors suggest that “Chindia” will increasingly require the international coal market to feed its insatiable appetite for energy.

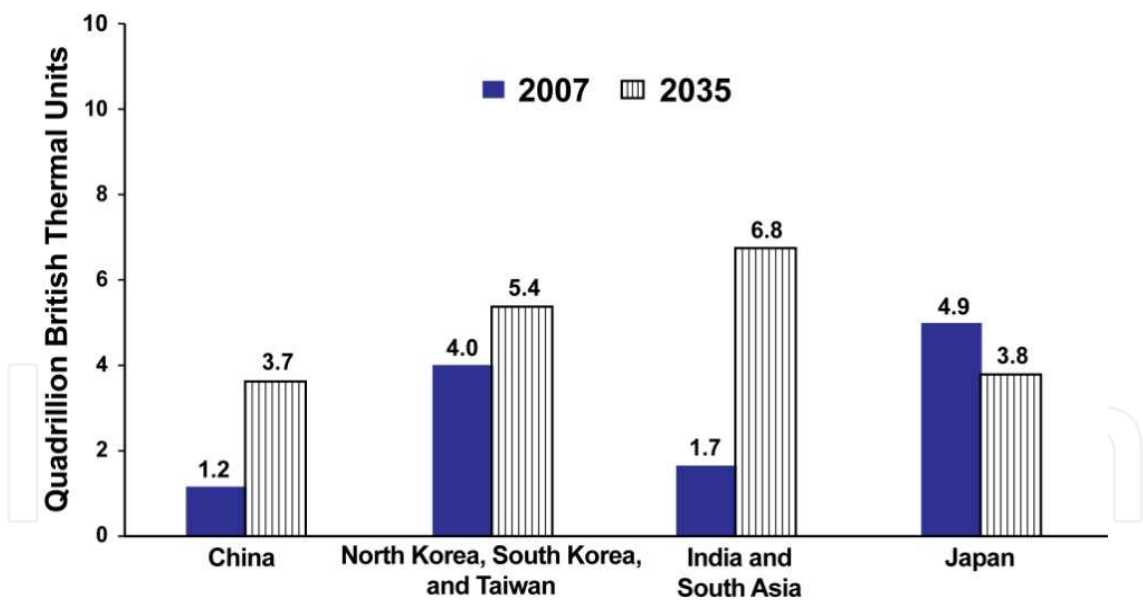


Fig. 4. Asia and the Growing International Coal Market, Coal Imports, 2007-2035
Source: developed from U.S. Energy Information Administration, 2010a

4.1 China

China’s coal imports began to increase at the close of 2008, while accelerating the closure of smaller, inefficient, and less safe mines in Shanxi, historically the country’s most productive province. In 2008, China installed a \$586 billion economic stimulus package for infrastructure projects and other stimulus measures to bolster domestic demand (The

Economist, 2008).³ Coal imports tripled to over 130 million tonnes in 2009 (Xinhua News Agency, 2010) and grew to 150 million in 2010 (Jin, 2011). The EIA (2010a) conservatively projects that China's imports will triple in the next 25 years. Wood Mackenzie (2010) expects that the first major shift in the international coal market will occur sometime in 2011 or 2012 when China overtakes Japan to become the world's largest thermal coal importer. Looking forward, there are at least three reasons why China will need more foreign coal:

- **Infrastructure Issues** – Perhaps the greatest challenge facing China's coal industry today is the transportation of coal from the distant producing regions, mostly in the North and West, to the high demand areas, located in the South and East. Escalating demand has rail lines heavily overburdened by coal transport, so more trucks are being used to take coal from Inner Mongolia and Xinjiang, energy-rich autonomous regions in North China, to population centers. In 2010, over 10,000 trucks moving coal from Inner Mongolia to Chinese cities got stuck in a 120 kilometer long traffic jam for nine days (Yahoo Finance, 2010). Gridlock is common in China and roads need repaired from the heavy coal traffic. Now, China's largest coal-producing region, the remote Inner Mongolia is becoming more crucial as an energy base and holds a staggering 1,080 billion tonnes of prospective coal reserves (Sinoc, 2005). China will need to invest some \$150 billion in coal infrastructure by 2020 (China Business News, 2010). Importantly, the cost of coal transport in China can constitute as much as 60% of the fuel's final delivery price (Stanway & Wong, 2011).
- **Higher Costs** – China has a rather complex distribution chain, and non-coal costs can have an unusually large impact. Improving safety and environmental standards, for instance, have helped double China's coal production costs to \$47 a tonne in the last five years (Stanway & Wong, 2011). Recently, the decommissioning of small mines in Shanxi, rising labor costs, and a greater reliance on road transport have all exacerbated the issue – coal trucks are twice as expensive as rail. Further, China's shallow-lying, cheaper reserves are depleting. Miners are now burrowing as deep as 1,500 meters in search of coal. In stark contrast to India, coal over-production has been the concern in China, where the central government wants a 3-5% resource tax to slow companies – China could reach peak coal production by as early as 2020 (Peng, 2010). As noted, foreign coking coal costs quadrupled in the 2000s, and in 2009 JPMorgan Chase estimated that higher global demand for thermal coal would lift prices from \$77 to \$94 per tonne in 2011 (Mining Exploration News, 2011). By March 2011, however, Sify Finance (2011) was reporting that only the catastrophic Japanese earthquake (i.e., weakened demand) was preventing thermal coal prices from reaching the \$145 level.
- **Rising Steel Needs** – China is in the midst of the largest and fastest infrastructure build out in world history. In 2009, China imported about 35 million tonnes of coking coal, a whopping 400% increase from 2008 (Metal First, 2011). Industry consolidation led to new facilities strategically located in coastal areas, so steel plants now have greater flexibility to utilize the international coal market. Steel from coal is China's fundamental material to build up, out, and down. An unprecedented urban influx that will see 325 million more Chinese living in cities in less than a generation will use coal to produce

³The impact that the economic stimulus will have on energy demand in China is particularly noteworthy. As stated by Keidel (2008), China's consumption should increase accordingly because the money is "going into the real economy, not into the balance sheets of troubled financial institutions," as occurred in the United States.

steel for skyscrapers and other urban accoutrements (Moody & Lan, 2010). By 2025, McKinsey & Company (2008) report that China will have 219 cities with a population in excess of one million people (Europe now has just 35). Rio Tinto says that China could build 50,000 skyscrapers before 2030, the equivalent of 10 New York Citys (Teather, 2008). With 390 million vehicles, Dargay et al. (2007) project that China will have the world’s largest vehicle fleet by 2030 – a 10-fold leap from today. China already accounts for nearly half of world steel *production*.

4.2 India

India’s coal supplies and transportation systems are struggling to keep pace with surging domestic demand, and foreign coal will be needed to fill the gap. Electricity and steel comprise the vast majority of India’s total consumption. India’s long-term demand for thermal coal stems from a massive coal-fired power station build out and continued cost inflation pressures on the domestic coal industry. The demand for coking coal will arise from India’s quickly urbanizing population; McKinsey & Company (2010) project that India’s urban population will increase from 340 million in 2008 to 590 million by 2030. Steel pipemaker Jindal SAW estimates that India will need 200 million tonnes of steel by 2020, a 210% increase from the existing base (Metal First, 2010). According to India Coal Market Watch (ICMW), the country’s overall coal imports in 2010 increased by 14% from 2009 to 78 million tonnes, 70% of which were of the thermal variety (Sethuraman, 2011). ICMW projects that India’s total coal imports will rise to more than 90 million tonnes in 2011, with an additional 4,000 megawatts of coal-fired electricity capacity coming online (Sethuraman, 2011). Wood Mackenzie (2010) believes that India’s demand for imported thermal coal will eclipse that of China before 2020. According to the EIA (2010a), India will surpass Japan as the world’s largest importer of coal by 2025 and be importing four times 2008 levels in 2035. India’s unmatched latent demand for coal-based electricity is simply overwhelming (see Figure 5).⁴

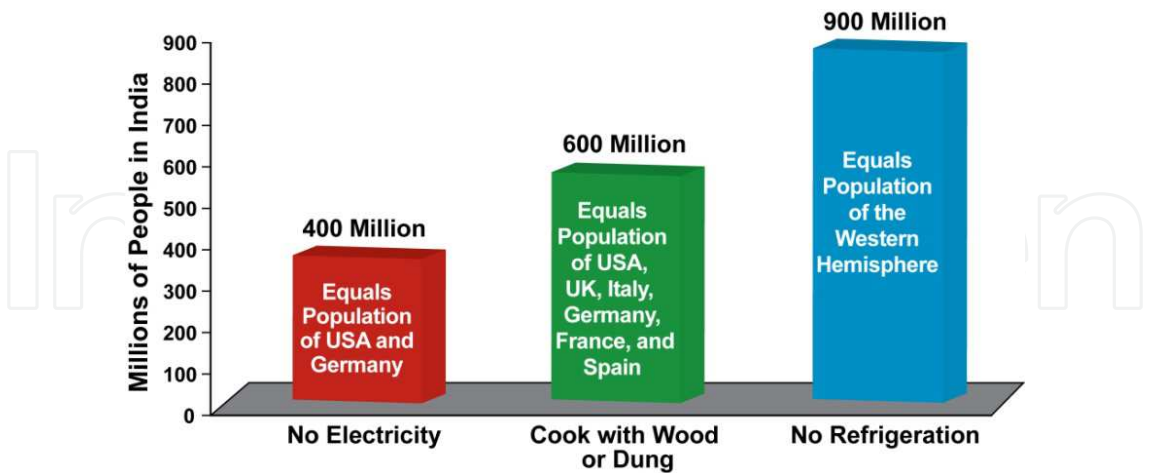


Fig. 5. The Scale of Latent Demand for Coal-Based Electricity in India
Source: developed from International Energy Agency, 2010a; The World Bank, 2010

⁴The IEA (2010a) projects that electricity from nuclear energy (10%/year) and natural gas (6%/year) will grow at impressive rates from 2008-2035, but coal will still easily be the dominant source of India’s power under any foreseeable scenario.

Gearing up for the vast expansion of coal imports, India's ongoing improvements in infrastructure include the extended use of smaller ports and the construction of deeper ports. In fact, UMPP focuses specifically on coal imports because more efficient plants require higher quality coal to achieve full load. Larger plants can obtain the economies of scale needed to compensate for the increased costs associated with foreign coal. Most boilers in India are oversized (because of the elevated ash content of the country's coals), and these units cannot use better quality imported coals without blending in the domestic varieties. And because India's domestic thermal coal is just half the price of imports, Chikkatur & Sagar (2009) recommend a "bifurcated" approach: "wherein using imported coal with high-efficiency global technologies.....will serve as a complement to the existing pathway of adapting such technologies for Indian coals." According to the Harvard researchers, the popular belief that India has ample reserves of coal should be tempered by a number of factors:

- With the need to move toward more expensive underground mining, a significant expansion in India's coal mining capacity faces technical/environmental hurdles and social/environmental constraints. Problems related to displacement (rehabilitation and resettlement) have been persistent in India. Too much opencast mining, due to its lower costs and reduced losses, has stagnated underground mining. Technical and institutional problems have limited mechanized longwall technology. India's underground mining output requires a "quantum jump" from 0.45 to 2.7 tonnes per man year (Bucyrus, 2010).
- Despite India's substantial coal endowment, the real size is likely smaller than generally assumed. India's resources are often assessed geologically, not techno-economically. It is the latter form of assessment, however, that indicates the amount of coal that can be feasibly extracted under prevailing technical and economic conditions. Technical terms like "resources" and "reserves" have been routinely misused in India, so it is by no means clear exactly how much coal the country really has. Some more recent Indian coal resource inventories have even included coal that had already been mined (see Chikkatur & Sagar, 2009).
- As noted, the quality of Indian coals is poor. Chikkatur & Sagar (2009) report coals typically have high ash content (40-50%), high moisture content (4-20%), and low calorific values (2,500-5,000 kcal/kg). The ash content has been increasing in recent decades due to more opencast mining and a greater reliance on inherently inferior grades. India's coal does have low sulfur content (0.2-0.7%) but the low calorific value leads to lower boiler efficiency, meaning more coal is needed for the same amount of electricity generated. With India's own coking coal supply on the decline, domestic reserves constitute just 18% of the country's total coal endowment (Steel Exchange India, 2002). India's demand for coking coal is expected to double from 2011-2014 (Kumar, 2010).

5. Concluding remarks

"The spike in Chinese demand for imported coal.....requires careful examination.....the unique structure of the Chinese coal market creates a series of key arbitrage relationships.....Developments in China's domestic coal market will be a dominant factor determining global coal prices and trade flows.....and by implication power prices in many regions.....The nature of Chinese demand for international coal is.....fundamentally different from India, the other source of dramatic demand growth in international coal markets.....In other words.....the unique politics and economics of the

Chinese coal market are now therefore by necessity the politics and economics of the global market," (Richard Morse & Gang He, Stanford University, 2010)

It is no coincidence that the world's electric power system will remain built upon coal. Consumers prefer low cost, reliable energy, and the producers that can provide these services continue to prosper. Coal was the backbone of the Industrial Revolution in England during the 18th Century, America's emergence as a major economic power during the late 19th and 20th Centuries, Germany's manufacturing prowess during the early 20th Century, and coal is now fueling the 21st Century economic miracles rapidly unfolding in both China and India. Following the overall trend of globalization, the expanding international coal market is now in a state of transition. In the years ahead, geological realities suggest that "Chindia" will be scrambling to meet soaring needs with domestic reserves, as more electricity and steel will steadily translate into more imports. Specifically, as the world's largest coal arbitrageur, the international price of coal will be increasingly linked to the domestic price in China. Higher prices will be a problem for importers. With rising prices, exporters are unlikely to accommodate long-term supply contracts and block off reserves to ensure supply for the entire lifetime of a coal plant – which can be up to 50 years.

For the world's top suppliers, significant challenges pose the question of whether or not coal infrastructure expansions will keep pace with higher import demand. All three leading exporters, Australia, Indonesia, and Russia, require major investments to increase exports. In fact, with an emerging economy and a population of 240 million people, Indonesia wants to preserve its coal for future needs – and South Africa's Mineral Resources Minister wants laws to impose the same strategy. Colombia has been mostly focused on the lower cost European market, and the country's low sulfur coal is not much of an advantage for fast growing India, for instance, because India already has a substantial low sulfur reserve base. In the United States, higher costs and a heightened risk aversion to coal export projects could limit the availability of the world's leading coal endowment. For example, the largest U.S. coal producer, Peabody Energy, faces resistance in its attempt to use Wyoming's coal-rich Powder River Basin to serve Asia through an export terminal in the state of Washington.

Analysis of the dangers posed by a society's use of fossil fuels and the emission of CO₂ generally focuses on the potential for climate change impacts. It is important, however, in the context of assessing the risk of anthropogenic CO₂ emissions, to also examine the reasons why CO₂ is emitted in the first place. CO₂ is not released in a socioeconomic vacuum. CO₂ is emitted because it is the inevitable by-product of combusting fossil fuels. The generation of electricity from coal, for instance, results in CO₂ emissions but it also yields significant benefits for the health and welfare of the people. Thus, it is important to strike a balance in the equation – both an assessment of the dangers posed to the atmosphere by CO₂ emissions and the powerful benefits created by the energy usage that results in CO₂ emissions. Electricity produced from fossil fuels – namely coal – has been, is, and will continue to be a cornerstone of global development. Going forward, the developing nations will need full access to the very same diverse range of fuels that has empowered their industrialized counterparts to raise the living standards for, and extend the lives of, billions of people.

The material reduction of CO₂ is a global challenge but is tractable through advancing technologies. The commercialization and deployment of clean coal technologies as they develop will accelerate environmental improvement and progress toward the goal of near zero emissions. In the area of power generation, the two processes of (a) higher efficiency through supercritical and ultrasupercritical coal power plants and (b) CCS presents a unique opportunity to not only meet the climate change goals delineated at Copenhagen in 2009 but

to also propel the world toward the Accord's objective of eradicating poverty and energy deprivation. The synergy between these twin forces can help solve constraints in electricity, natural gas, and liquid fuel supplies. Developed nations need to work within the global context to deploy clean coal technologies as quickly as possible: current IEA (2010a) projections indicate that 1.2 billion people will still be without electricity in 2030. Indeed, coal's story is far from told.

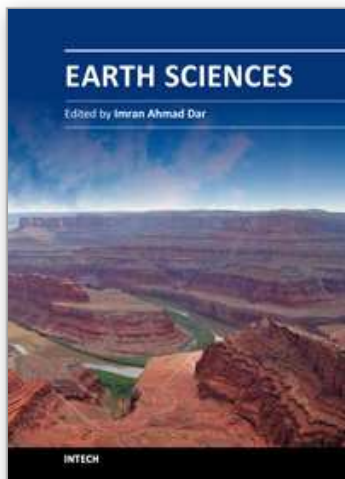
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The studies of Earth's history and of the physical and chemical properties of the substances that make up our planet, are of great significance to our understanding both of its past and its future. The geological and other environmental processes on Earth and the composition of the planet are of vital importance in locating and harnessing its resources. This book is primarily written for research scholars, geologists, civil engineers, mining engineers, and environmentalists. Hopefully the text will be used by students, and it will continue to be of value to them throughout their subsequent professional and research careers. This does not mean to infer that the book was written solely or mainly with the student in mind. Indeed from the point of view of the researcher in Earth and Environmental Science it could be argued that this text contains more detail than he will require in his initial studies or research.

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