OUT OF POVERTY:
Coal’s Contribution to China is a Model for the Developing World

“Every single one of the United Nations’ Millennium Development Goals requires access to electricity as a necessary prerequisite.”—Global Energy Institute, 2008

“The power of China’s economy – and the power of its example – will advance the fight against poverty…China has become one of the developing world’s best customers. [430 billion] in annual imports comes from developing countries…Indeed, China runs a trade deficit with the developing world.”
—Foreign Policy, 2005

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# Out of Poverty

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MODERNITY, EQUALITY AND A BETTER LIFE

The United States Led the Way

“I had seen first hand the grim drudgery and grind which had become the common lot of American farm women … growing old prematurely; dying before their time … I (seek) the emancipation of hundreds of thousands of farm women.” —Senator George Norris, sponsor, Rural Electrification Act of 1936

China Now Follows:

Coal Based Electricity is Improving the Life of Women and Children in China

AND OPENS NEW OPPORTUNITIES FOR THE WORLD

“We’re better off if China is rich than if it is poor. China’s ascension is our opportunity. We have much to sell to the Chinese and they, us. Trade with China is helping raise our productivity and lower our prices.” —Richard Fisher, President, Dallas Federal Reserve Bank, 2005
Out of Poverty:

Coal’s Contribution to China as a Model for the Developing World

Précis

“We cannot accept that poor people perish every day because they lack shelter, basic medicines and safe drinking water. The world does have the means to eliminate poverty.” —The Vatican Plea on Poverty, 2007

Energy in general, and electricity in particular, represent the lifeblood of modern society. Both economic and social progress depend upon energy that is available, adequate, reliable and affordable. Across the globe, energy deprivation takes a heavy toll on the human condition as billions toil grimly in the dark. People in nations without access to sufficient energy are far more likely to live shorter lives, drink contaminated water, fall ill, suffer hunger and be illiterate than their more fortunate counterparts in other parts of the world.

Access to Electricity and the Quality of Life

People in Societies with Greater Access to Electricity:

<table>
<thead>
<tr>
<th>Access to Improved Sources (%)</th>
<th>Under Nourished (%)</th>
<th>Literacy Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>94</td>
<td>14</td>
<td>98</td>
</tr>
<tr>
<td>78</td>
<td>25</td>
<td>78</td>
</tr>
<tr>
<td>54</td>
<td>70</td>
<td>54</td>
</tr>
<tr>
<td>16</td>
<td>80</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
<td>2</td>
</tr>
</tbody>
</table>

Indeed, leading organizations have explicitly drawn the connection between electricity and socioeconomic progress:

- In 1999, the U.S. Academy of Engineering identified societal electrification as the “most significant engineering achievement” of the past century
In 2000, the United Nations identified a series of global Millennium Development Goals that were contingent upon adequate and affordable energy.

In 2004, the Global Energy Network stated, “Every single one of the United Nations Millennium Development Goals requires access to electricity as a necessary prerequisite.”

As the debate over the impact of energy development continues, it behooves us to remember the cost of not having enough energy can be measured in the most bleak terms — hunger, illness, poverty, despair and premature death.

**The Energy Driven Sea Change in China**

In 1970, China was in the world’s socioeconomic backwater:

- Over 600 million people lacked electricity
- The under 5 death rate was 120 per thousand children
- Only 1 in 500 people had a telephone
- The GDP per capita was $122

Through a series of energy oriented Five Year Plans, however, China utilized increased energy production, especially coal-based electricity, to catapult itself to the center of the world’s economic stage. In just 15 years, for example, China provided access to electricity to over 450 million people— one and one-half times the population of the United States.

This unprecedented expansion of the electricity supply system positively impacted virtually every community, institution, business, family and individual in China. The electrification of both the cities and the countryside established an energy infrastructure that underlies China’s historic move toward modernization and sets a role model for other developing countries.

“The electrification of China is a remarkable success story… the electrification goal [is] part of its poverty alleviation campaign… the most important lesson for other developing countries [is] that electrified countries reap great benefits, both in terms of economic growth and human welfare… China stands as an example.”

—IEA, 2007

**Coal is Fueling China’s March out of Poverty**

To meet the ever burgeoning need for energy China turned to its most plentiful, stable, versatile and affordable resource—coal. China has only 3 percent of the world’s oil and natural gas but has over 12 percent of the coal.
Chinese policy makers recognized this asset early on and are committed to making the country a “moderately well off society” by 2030. Coal is seen as the continuing lever to move forward.

“Coal is a basic industry in China, and it is an urgent need to increase supply capacity… reduce environmental pollution, increase resource utilization efficiency and build a new coal industry… China is the largest developing country in the world, and developing the economy and eliminating poverty… remain the main tasks for the Chinese government.” —State Council of the People’s Republic of China, 2007

It is undeniable that this plan is working. In terms of absolute numbers, no nation has made more progress toward the U.N. Millennium Development Goals than China. Coal consumption has grown from 13 quadrillion Btu in 1980 to 20 quads in 2005. By 2030, Chinese coal consumption will reach 95 quadrillion Btu.

Utilization of its coal resource enabled China to double energy output from 1990 to 2005. Coal provided 65 percent of that increase —i.e. more energy than Japan produces in an entire year. Further, coal will fuel over 60 percent of the increase through 2030.
China is using coal to develop its industrial base

One of the key elements behind China’s remarkable economic growth since 1980 has been the utilization of locally abundant coal supplies. The scale of industrial growth in China is unmatched in human history. China is now the world’s leading producer of steel, non-ferrous metals, cement and various other materials, which are contributing to the construction of a modern manufacturing base and associated technology, communication and service industry infrastructure. As a result, China is the largest consumer of food and raw materials in the world. China generates most of its electricity from coal and more than half of China’s electricity use occurs in manufacturing:

Composition of China’s Electricity Use, 2006
Further, the industrial use of coal is also expansive in China. Coal-based industrial development is the direct result of an explicit national development strategy that takes advantage of China’s rich coal resource endowment.

For example, steel is the most prevalent industrial material in the world and is used in a wide array of manufactured products, including automobiles, bridges, buildings, containers and thousands of other durable goods. Steel is synonymous with strength, providing the backbone of infrastructure, such as skyscrapers and bridges. It is very versatile because it is easy to shape into many different forms.

The growth in steel production in China over the past decade has been explosive. During the late 1990s China began to consistently exceed 100 million tons in raw steel production, slightly ahead of total US steel production. During 2006, China produced four-times that amount, nearly 420 million tons, more than a third of world output of 1.24 billion tons.

Steel production is energy intensive and coal gives China an important advantage:

![Energy Use in Chinese Steelmaking](chart.png)

**Chemical Industries**—The broad use of a wide array of chemical products is the hallmark of an advancing economy. These products are used in thousands of consumer and producer products. Instead, to meet this higher demand for chemical feed stocks, China is leading a renaissance of coal-based chemical production.
This expansion in the use of coal for chemical production in China will continue. For instance, coal-based ammonia production will more than double in coming years. These planned facilities alone will require more than 20 million tons of additional coal per year. This use of coal to produce chemical fertilizers will help insulate China from cost-push inflation of raw material costs that is currently weighing heavily on North American and European manufacturers of these products. This is contributing to a migration of these industries to access natural gas reserves in the Middle East.

China is also pioneering the production of dimethyl ether (DME) synthesized from methanol produced from coal. DME is an excellent substitute for diesel fuel oil and liquid propane gas (LPG). The energy infrastructure requirements for DME are very similar to LPG. The extensive LPG network in China will likely facilitate widespread adoption of DME. China plans to produce more than 7 million tons of DME per year. The associated coal requirements would approach 30 million tons per year.

This supportive policy environment and favorable economic conditions imply a robust future for coal conversion to fuels and chemicals in China. Within 5 years, China will likely consume over 230 million tons of coal in these activities. This market could triple by 2020 and approach 1.5 billion tons in 2030.
In China, the Energy Future Belongs to Coal

Given the confluence of: (1) escalating demand for energy, (2) availability and affordability of coal, (3) recognition of the asset base by officials, (4) the versatility of coal conversion and (5) the continuous emergence of clean coal technologies, there is little brooking the fact that coal will maintain and expand its role as the cornerstone of China’s energy supply—especially electricity.
Coal as the Foundation of Both China’s Energy Production and Economic Growth through 2030

Increases in coal based energy will track increases in all energy production – Both growing by 119% in 25 years and supporting 370% increase in China’s GDP.

Growth in China Benefits the World and Stimulates World Trade

China’s economic expansion and integration into the global economy has had far reaching benefits not only for its neighbors but the world in general:

- **Latin America** continues to benefit from China’s economic growth and expanding domestic demand. Brazil’s exports to China have quadrupled. (U.N. Economic Commission on Latin America, 2007)
- For **Africa**, China is now a major market, financier, investor, contractor, builder—and donor. Africa’s exports to China are soaring. (International Monetary Fund, 2008)
- In **Asia**, “China is purchasing heavily from neighboring trading partners…Taiwan, South Korea, Singapore.” Philippines, Thailand, Indonesia. ASEAN [have] accumulated a trade surplus with China. (Congressional Research Service)
- In **Europe**, “China is …an essential partner...for the EU, offering growth and employment opportunities” (European Union, 2008)
- In the **United States**, “We are now major beneficiaries of China’s rapid development. U.S. manufacturers, farmers and service providers have seen exports grow to an average of 22 percent a year since China joined the WTO.” (Susan Schwab, U.S. Representative to WTO, 2006)
China as a Customer (Imports, 2000-2007)

China has become a showcase… on how trade can reduce global poverty”

*Foreign Policy* journal

China is emerging as a major purchaser of industrial machinery, raw materials, agricultural goods and electronic components. The growing Chinese economy is particularly spurring imports of basic commodities—especially soybeans, copper, oil and, recently, natural gas.

### China’s Top Imports (2007)

<table>
<thead>
<tr>
<th>Item</th>
<th>Value in Billions of U.S. Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Machinery and Equipment</td>
<td>257</td>
</tr>
<tr>
<td>Power Generation Equipment</td>
<td>124</td>
</tr>
<tr>
<td>Mineral Fuel and Oil</td>
<td>105</td>
</tr>
<tr>
<td>Optics and Medical</td>
<td>70</td>
</tr>
<tr>
<td>Ores, slag, ash</td>
<td>54</td>
</tr>
<tr>
<td>Plastics</td>
<td>45</td>
</tr>
<tr>
<td>Chemicals</td>
<td>45</td>
</tr>
<tr>
<td>Iron and Steel</td>
<td>31</td>
</tr>
<tr>
<td>Copper</td>
<td>27</td>
</tr>
<tr>
<td>Vehicles</td>
<td>22</td>
</tr>
</tbody>
</table>
China is increasingly buying products from neighbors. Indeed, seven of China’s 10 leading import sources are in Asia.

**China’s Leading Import Suppliers**
*(2007)*

<table>
<thead>
<tr>
<th>Country</th>
<th>Value in Billions of U.S. Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>134</td>
</tr>
<tr>
<td>South Korea</td>
<td>104</td>
</tr>
<tr>
<td>Taiwan</td>
<td>101</td>
</tr>
<tr>
<td>United States</td>
<td>69</td>
</tr>
<tr>
<td>Germany</td>
<td>45</td>
</tr>
<tr>
<td>Malaysia</td>
<td>29</td>
</tr>
<tr>
<td>Australia</td>
<td>26</td>
</tr>
<tr>
<td>Philippines</td>
<td>23</td>
</tr>
<tr>
<td>Thailand</td>
<td>23</td>
</tr>
<tr>
<td>Russia</td>
<td>20</td>
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</tbody>
</table>

Countries such as the Philippines, Thailand and Indonesia have seen their annual exports to China escalate dramatically in the past five years. China’s internal demand for basic commodities from nearby countries has been a boon for millions of Asians seeking to escape the vise of poverty.

**CHINA’S USE OF ELECTRICITY TO REDUCE POVERTY IS A MODEL FOR THE DEVELOPING WORLD**

China is providing a template of how coal can be used to pull people out of poverty and propel an entire society toward higher living standards. India and many other countries around the world are learning from China’s example. They, too, are using low-cost coal resources to fuel the production of material-intensive infrastructure, providing electricity to millions of households and developing complex manufacturing and service industries on modern electricity grids utilizing the latest information technology.
The World has a Long Way to go in Terms of Electricity Consumption

Over 5 billion people average less than 1,500 kWh per person – 17 times the population of the U.S.

And Coal Is the Fuel of Choice for Billions

The Developing World is Turning to Coal Based Generation

80% of all coal power plants planned and under construction are in developing nations

Source: Data Demand from Platt’s Proprietary Database
Works Consulted


Chapter One

Energy and Economic Development

The link between energy and economic development can be viewed from a variety of perspectives. Conventional neoclassical economic theory argues that exogenous technological progress is the main driver of economic growth, which implies that energy consumption is a consequence, not a cause, of growth.

Alternative theories that consider energy and materials as factors of production (along with labor and capital) find that energy prices affect productivity and thereby economic growth. Indeed, empirical studies of the business cycle find that a substantial increase in energy prices preceded all U.S. recessions since World War II.

Scholars examining long-term historical trends see a different and more complex reality involving a growth engine, which is a positive feedback loop involving declining costs of inputs and increasing demand for lower priced outputs, which then drives costs down further due to economies of scale and learning effects. This growth engine fueled by low cost, abundant coal resources appears to be one of the core forces propelling the Chinese economy to new heights.

Indeed, China is providing a template of how coal can be used to pull people out of poverty and lift an entire society to higher living standards. India and many other countries around the world are learning from China’s example. They, too, are using low-cost coal resources to fuel the production of material-intensive infrastructure, providing electricity to millions of households, and developing complex manufacturing and service industries connected with modern electricity grids and information networks.

The purpose of this report is to explain how China is using coal to develop its industrial base and how its people are benefiting from this progress. This chapter provides the conceptual framework built around the following five mechanisms:

- Although coal and electricity industries are capital intensive, they greatly expand the scale of energy availability with economies of scale that drive costs down
- These price declines allow households to switch from subsistence fuels to commercial energy services, generating significant improvements in human welfare and substantial increases in the quality and quantity of labor services.
- More productive labor and low-cost energy allow the production of energy-intensive materials for developing the infrastructure and the industrial base
- With infrastructure in place, such as electricity, transportation, and communication networks, manufacturing and service industries prosper
The economy then achieves take-off and the development process accelerates as long as economic policies remain supportive of the pillars underlying this growth.

While many factors affect economic growth, this chapter will demonstrate that using abundant, low-cost fuel supplies plays an important role.

**Coal as the Spark**

Energy provides basic services for human existence, such as light for reading and fuel for cooking. Barnes and Floor (1996) describe a continuum of different fuels used through various stages of economic development, known as the “energy ladder.” For subsistence cultures, energy tends to come from harvested or scavenged biological resources, such as wood and dung. During the intermediate stage, processed biofuels, such as charcoal, animal power and some commercial fossil fuels are consumed. Liquid fuels, natural gas, and electricity delivered via expansive distribution networks are widely used during the last stage of industrialization.

These stages entail different resource requirements with labor intensity falling and capital intensity rising as the economy advances. For example, households relying upon wood for cooking devote considerable amounts of labor to collect firewood. During the intermediate stages, some capital outlays are required for kerosene lamps or coal-fired cook stoves. Much more capital is required during the final stage of development to build electricity and natural gas supply networks. These resource requirements suggest that the supply of energy services depends upon resource availability and upon the availability of capital to build energy infrastructure and to acquire energy consuming durables.

Coal mining and electricity industries are capital-intensive industries. For coal, large capital investments are required to build the mine, acquire mining equipment and develop the necessary transportation to ship the coal to end-users. Likewise, electricity networks require large capital expenditures for electric generating plants, transmission towers and local distribution lines. Both industries enjoy increasing returns to scale over substantial volumes of production so that the unit costs of energy services decline with higher levels of output. This means that while building a power plant may divert capital and labor from other sectors of the economy, the associated aggregate output loss from this diversion is more than offset by the energy service cost reductions.

The efficient provision of energy is critical during the early stages of economic development because less developed countries lack capital resources. Utilizing low cost, abundant fuels, therefore, provides the needed spark for the economy to take-off toward higher levels of development. As the most abundant fuel on the planet, coal has provided that spark. 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 early 20th centuries, German manufacturing prowess during the early 20th century, Japan’s emergence at the same, and now coal is fueling the remarkable economic miracle unfolding in China during the 21st century.
Driving this expanding use of coal in China has been a sharp decline in real coal prices (see Figure 1.1) in part reflecting the economies of scale realized from expanding coal production. Government subsidies and price controls also contributed to these lower real prices for coal in China. These lower relative coal prices contribute to expanding coal use, decrease electricity prices and prices for manufactured goods and services.

Figure 1.1:
China’s Coal Use and Relative Coal Industry Prices

Expanding energy supply creates new capabilities and opportunities for households and firms that collectively generate even greater productivity gains throughout the economy.

Household Efficiency Gains

In many ways, households resemble businesses. For example, providing heat for warmth or light for reading requires the consumption of fuel. The household does not buy fuel to consume directly but to use in devices that provide these services for the home. In many less developed regions of the world, attaining these services is inefficient, requiring households to devote considerable labor time in gathering fuels and then using them in very inefficient devices. This diversion of household labor time to gather fuel incurs a number of opportunity costs. For example, the time spent gathering fuel by women and children could be used to improve their education and attain skills valuable in the market economy.
Subsistence energy systems involve large investments of household labor time, notably the time of women and children, in gathering poor-quality fuels. Modern power generation systems substitute for these activities and, most importantly, provide a quantum increase in the scale and quality of energy services, which contribute to substantial reductions in the cost of delivered energy services. There is likely a threshold income level at which a society can afford the required specialization of functions necessary to operate mines, refineries and electricity grids. Getting to this threshold, however, is greatly facilitated by a reduction in the effective cost of energy services.

Expanded energy availability leads to a disproportionate increase in productivity and economic growth. The first source of these gains arises from the expanded use of commercial energy by households. Consider the shift from kerosene to electric lighting. As the price of light declines, more illumination services are consumed, which leads to a direct increase in economic welfare. For example, households can read and learn during the evening hours. There is a second round effect stemming from the productivity enhancements that light provides. For example, households can divert hours once spent gathering firewood to working in the market economy, which generates income for the household and labor services for the economy. In addition, with inexpensive illumination household members can devote time at night to improving literacy and education capacity. These productivity enhancements lead to an additional increase in the demand for lighting that contributes even more economic welfare for society.

Several studies have estimated the benefits of improved electrification in developing countries. A World Bank study of the economic and social benefits of rural electrification in the Philippines conducted a detailed survey-based study and found very significant benefits from rural electrification. These benefits reported below are overlapping because the benefits from lighting affect the education and entertainment benefits from electrification.

**Table 1.1:**

<table>
<thead>
<tr>
<th>Benefit Category</th>
<th>Value (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less expensive and higher levels of radio and television use</td>
<td>19.60</td>
</tr>
<tr>
<td>Adult education and electricity wage - income returns</td>
<td>37.07</td>
</tr>
<tr>
<td>Time savings of household chores</td>
<td>24.50</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>81.17</strong></td>
</tr>
<tr>
<td>Less expensive &amp; higher levels of lighting</td>
<td>36.75</td>
</tr>
<tr>
<td>Improved productivity for home business</td>
<td></td>
</tr>
<tr>
<td>Existing home business</td>
<td>34.00</td>
</tr>
<tr>
<td>New home business</td>
<td>77.00</td>
</tr>
<tr>
<td><strong>Average Household Income</strong></td>
<td><strong>177.00</strong></td>
</tr>
</tbody>
</table>

*Source: World Bank Energy Sector Management Assistance Program, 2002*
The first three categories listed below are reasonably independent so that their sum, $81.17, provides a conservative estimate of the benefits of electrification. What is significant is that these benefits comprise more than 45 percent of household income. Assuming half the benefits of more lighting per se are independent of the first three benefit categories and taking the benefits derived from improving the productivity of home businesses brings the lower bound estimate to $133 or 75 percent of household income and for households creating new businesses from electricity provision, the benefits rise to just about total household income. Overall, these economic benefits from electrification are very substantial.

The research by Barnes et al (2002) also finds substantial benefits from electrification, comprising more than 50 percent of household income in India. Finally the study by the World Bank (1999) examining the importance of various infrastructure services finds that electricity service is among the most important. Both electrification and sanitation have positive synergies with education. In other words, education is more productive when the services derived from electricity and other infrastructures are high quality and relatively inexpensive.

These estimates can be used to estimate the direct benefits from household electrification in China. Given China’s population of roughly 1.3 billion people, average household size of 3 people, and average annual household income of $1,400, the direct or intrinsic benefits from complete electrification of households in China are at least $56 billion.

In summary, for developing countries, increased availability of different kinds of energy services enhances the productivity of human capital. The availability of electricity for cheaper and better lighting can increase the productivity of education and lead to multiplicative impacts in human capital provision. Increased availability of electricity services improves public health, and therefore, the productivity of workers. Specific pathways of such improvement include:

- Shifting effort from fuel collection to education, income generation, and specialization of labor services
- Utilizing night time hours for education or work
- Improving public health by reducing smoke exposure, increasing clean water supplies, and expanding the use of refrigeration
- Increased refrigeration and associated reductions in food-borne illness and improvement storage of medicines
- Improving diets with low costs for food

All of these effects enhance the quantity and most particularly the quality of human capital and labor services, which unleash powerful macroeconomic forces for higher income and wealth generation over the long term.
Building the Industrial Base

Besides raising households from the depths of poverty, increased energy availability contributes to the construction of infrastructure and buildings and the fabrication of durable producers equipment. These durable assets are made from materials, such as steel, aluminum, copper, concrete and glass. Producing these materials requires significant amounts of energy. Utilizing abundant energy supplies, helps lower the cost of materials, structures and equipment, which facilitate the accumulation of capital assets.

All economies advancing into the industrialization stage go through this phase of infrastructure development. For example, during the period from 1880 to 1920 the United States experienced material intensive economic development so that energy intensity, or the ratio of energy consumption to gross domestic product, was rising. China is at a similar stage in recent years. Figure 1.2 illustrates that more than 54 percent of total energy consumption by the manufacturing and mining sectors of the Chinese economy is consumed in mining and quarrying and in the production of ferrous and non-ferrous metals, non-metallic mineral products, and plastics.

Figure 1.2: Materials Industries Share of Manufacturing and Mining Energy Consumption in China during 2005

Producing these materials using low-cost energy provides the Chinese with a key competitive advantage because it lowers the cost of capital investment. As will be demonstrated below a very significant share of energy use in these sectors is coal. Higher capital investment increase productive capacity and enhances the productivity of labor, energy, and materials in all sectors of the economy.
Endogenous growth theory emphasizes the role of factor augmentation through research and development, education and the provision of public goods. Increased energy use has the same multiplier effects, augmenting the productivity of labor and capital. There are several pathways in which the increased availability and quality of energy can augment productivity and effectively increase the supply of physical and human capital. For industrializing societies, fuels and electricity can facilitate the use of more modern machinery and techniques that expands the capital to labor intensity and labor productivity.

Greater energy availability also may enhance the productivity of energy infrastructure investments, leading to lower transportation costs and improving the geographic size, scale and efficiency of markets. Efficient electricity networks also generate powerful economic externalities by lowering the costs of telecommunications and information, which in turn generate additional productivity enhancements.

Many cases studies done by OTA and others provide definitive evidence of how energy service availability spurs economic growth. For example, the 1994 World Development Report (World Bank, 1996) discusses the importance of infrastructure provision to economic development. The Office of Technology Assessment studies (OTA, 1991; 1992) identify how much labor time is invested in subsistence energy provision and how much inefficient manual labor is used for activities that could be accomplished with simple machines powered by external energy sources.

On the business side of the economy, greater supplies and lower costs for energy services foster:

- Economies of scale from larger scale energy provision, such as petroleum refineries and electric power generation
- Lower transportation costs and more competitive manufacturing
- The development of communication networks that generation powerful productivity enhancements across broad swaths of the economy

There, household and business sector impacts contribute to an overall increase in the quality of life, including better health, less drudgery, more leisure, greater communication and increased social status.

**Electrification**

Schurr (1984) maintains that the increased use of more flexible energy forms, liquid fuels and especially electricity enhanced “the discovery, development, and use of new processes, new equipment, new systems of production, and new industrial locations.” The effect was powerful enough in terms of raising labor and capital productivity that the energy intensity of output fell. In other words, changes in the quality of energy services drive broader economic productivity, apart from the physical availability of energy.
Jorgenson’s studies (1981; 1984) introduces the concept of electricity-using productivity growth. Jorgenson finds that for 23 of 35 sectors of the economy, technical progress tended to be electricity using, which emphasizes an apparent connection between electrification and broader economic progress. In addition, 28 sectors had technical progress that were non-electric energy using. So the relationship between technical change and energy use is complicated. Nevertheless, Jorgenson’s studies clearly demonstrate that technical progress is closely linked with energy use. Overall, Jorgenson finds that for 32 of the 35 sectors of the economy, energy-using technical change or progress occurred. This suggests that higher energy prices act as a drag on productivity growth.

Another important dimension is energy reliability, especially for electricity. The costs of electricity supply interruptions per lost megawatt hour are several orders of magnitude larger than the cost of base load or peak electricity supply costs (OTA, 1990). These costs arise from the need to maintain backup generators that could be more productively employed under greater system reliability.

While the growing use of microcomputers and the Internet get a good share of the credit for the impressive productivity growth in the U.S. economy since the late 1980s, based upon the findings of Schurr (1984) and Jorgenson (1991, 1994), falling real electricity prices at least should be considered as an important contributing factor. Indeed, the deceleration in productivity growth since 2000 could be associated with rising real electricity prices (see Figure 1.3) and rising real oil and natural gas prices.

Figure 1.3:
Multifactor Productivity and Real Electricity Prices in the U.S.
The Growth Engine

The first industrial revolution based upon coal and steam power operated through rapidly declining fossil fuel and mechanical power costs. The growth path continued with oil discoveries and new applications through the 19th and 20th centuries with internal combustion engines and the most potent of all—electrification. Cheaper electricity due to cost reduction from economies of scale in coal mining and improvements in power plant efficiencies spurred the development of electric lighting, radio and television, and the modern information sector. During each of these periods, economies rebounded to higher levels of prosperity, which then lead to even greater levels of energy and material consumption. This has been the experience of highly developed economies, such as the United States, Japan and the European Union.

For developing countries, where some two billion people still remain without access to electricity, the benefits of electrification take on a more personal dimension and are proportionately much larger because the base level of development in many cases is so low. At a local level, plentiful and affordable energy is widely viewed as an essential factor in economic development. Energy enables families to escape the clutches of poverty to become healthier, better educated, and more productive members of society. A more productive labor force improves the productivity of all factors of production, thereby generating income and wealth for future generations.

Human and physical capital formation develops with information networks that run on electricity. The inherent technical advantages of electricity in the provision of goods and services stimulate innovation and technological change. The study by Ayers, et al. (2002) finds that energy consumption and electric power consumption in particular have had an enormous impact on past economic growth. The mechanism responsible is the rebound effect in which increasing energy efficiency lowers costs that then triggers increasing demand that often results in greater energy consumption in the long run.

This effect is illustrated in cross country comparisons of per capita gross domestic product (GDP) and per capita energy use, which show a strong positive association, i.e., as per capita GDP rises so does per capita energy use (see Figures 1.4). The line of causation, however, goes both ways. As economies expand the higher levels of economic activity contributes to higher levels of energy use. Likewise, as the above discussion suggests, greater energy availability contributes to greater productivity, economic growth, and higher GDP. This two-way linkage is the virtuous cycle that energy service provision stimulates for a wide range of developing countries.
This growth engine is not unique to China. Emerging industrial powers, such as South Korea and Brazil show growth rates for GDP and energy use per capita moving in lock step. Developing nations with much lower per capita GDP, such as India and Egypt, are experiencing the same productivity gains from increased energy availability and electrification. While most countries are experiencing progress, others are not so fortunate. Warfare and destruction of energy infrastructure in the Congo contributed to plummeting energy use and GDP per capita. This counter example illustrates the close and fragile connection between energy availability and economic growth.
Works Consulted


Chapter Two
Coal as the Continuing Cornerstone of China’s Energy Supply

“Coal is a basic industry in China, and it is an urgent need to increase supply capacity... reduce environmental pollution, increase resource utilization efficiency and build a new coal industry... China is the largest developing country in the world, and developing the economy and eliminating poverty ... remain the main tasks for the Chinese government.” —State Council of the People’s Republic, 2007

China has marched to the center of the world’s economic stage

The emergence of China as a global economic force is widely recognized. In less than two decades, the rapidly growing Chinese economy has become increasingly integrated into the world economy—especially since 2001 when China joined the World Trade Organization in 2001 (IEA, 2007). In 1980, for example, China accounted for only 1 percent of the world’s foreign direct investment (FDI). By 2005, FDI reached 12 percent. Further, as Figure 2.1 demonstrates, a combination of increased domestic consumption and the rise of manufactured exports has led to a steady escalation in the development of energy intensive manufacturing, especially steel and cement.

Figure 2.1
China’s Growing Importance in the Global Economy
Percentage of World Total

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>3</td>
<td>9</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>Trade</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Steel Production</td>
<td>8</td>
<td>13</td>
<td>16</td>
<td>31</td>
</tr>
<tr>
<td>Cement Production</td>
<td>9</td>
<td>34</td>
<td>38</td>
<td>47</td>
</tr>
<tr>
<td>Telecom equipment</td>
<td>--</td>
<td>--</td>
<td>7</td>
<td>20</td>
</tr>
</tbody>
</table>

Source: IEA, 2007

This economic growth, and the rise of energy intensive industries, has spurred dramatic increases in energy demand. From 1990 to 2005, for example, China’s energy consumption grew by 40 quadrillion Btu—almost twice the current energy consumption of Japan.
Even more dramatically, by 2030, China will consume an additional 78 quads of energy. To put the scale of this increased demand in perspective, all of Europe consumed 86 quads in 2005. And, in terms of absolute numbers, 78 quads are equivalent to:

- 13 billion barrels of oil each year—or the equivalent of over 36 million barrels per day
- 78 trillion cubic feet of NG—four times U.S. production.
- Almost 1,000 nuclear power plants—the entire world has 440
- Over 250 Three Gorges Hydro Electric Projects—and the water to move the turbines
- Over 3 billion tons of coal—three times U.S. production

Yet, some have argued that official forecasts conservative:

“The EIA number is too low. They [China] are doubling their energy every five years.” — J. Brock, CERA, 2008

Despite this substantial growth, however, China’s energy consumption on a per capita basis is still relatively modest in global terms:
Thus, China has a long way to go in terms of energy consumption. As per capita energy use approaches that of modernized societies, total consumption will accelerate accordingly. In order to meet that demand China’s clear policy is to utilize what locals refer to as the “virtuous fuel.”

**Coal as the cornerstone of Chinese energy supply**

Coal is the stable backbone of the world’s energy system. In 2005, coal met 25 percent of global energy demand and by 2030, 25 percent will still be met by coal.

In China, however, this continuing dependence on coal is even more profound. In 2005, about 63 percent of China’s demand was met by coal. In 2030, 63 percent will continue to be supplied by coal.

Coal has propelled China forward, as an increasing share of global coal consumption has been paralleled by dramatic economic growth.
Figure 2.4  
China’s Growing Global Economic Role is Fueled by Coal

<table>
<thead>
<tr>
<th>Year</th>
<th>Coal Consumption</th>
<th>Percent of World Total</th>
<th>GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>17</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>21</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>25</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>36</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

Source: EIA, 2007

Further, in just 25 years Chinese coal consumption has increased 200 percent—by 1,367 million tons or more than twice U.S. production.

Figure 2.5  
China’s Coal Consumption versus U.S.

The extent to which coal is woven into the energy fabric of China can be readily documented. Coal:

- Provides over 62 percent of energy supply
- Generates over 78 percent of electricity
Is a core energy source for manufacturing—providing 600 million tons to a rapidly industrializing nation to make iron, steel, aluminum and concrete

Is embedded in China’s the future plans

China uses over 2 billion tons of coal each year and this low-cost energy is the most overlooked linchpin to China’s remarkable economic growth. By using coal, China is avoiding nearly 19 million barrels per day in oil imports.

**Coal is the Logical Fuel in China**

The energy realities facing China are clear:

1. **Oil**—China’s super giant field, Daqing, is in irreversible decline, with production projected to drop from 908 kb/d in 2005 to 600 kb/d in 2010.

2. **Natural Gas**—“There is little possibility to increase natural gas production in large scale.” — China’s State Council Development and Research Center, 2006

3. **Renewables**—“Renewable energy cannot solve any problems before 2020.” — Chinese Academy of Social Sciences, 2006

Clearly, China’s degrees of freedom to meet its escalating energy demand are relatively limited. With 20 percent of the world’s population but less than 3 percent of its oil and NG, China must draw on its leading domestic resource—coal, where it can claim over 12 percent of the world’s reserves.

**Figure 2.6**

**Coal is China’s only Energy Advantage**

<table>
<thead>
<tr>
<th>Resource</th>
<th>China’s Share in the World’s Energy Reserves</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium</td>
<td>0.3%</td>
<td>BP, 2006</td>
</tr>
<tr>
<td>NG</td>
<td>1.3%</td>
<td></td>
</tr>
<tr>
<td>Oil</td>
<td>1.3%</td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>12.6%</td>
<td></td>
</tr>
</tbody>
</table>

The only important natural resource of which China’s per capita availability is relatively high is coal (Bergsten, 2006)
Given these realities, it is no surprise that China’s 2006 Energy Development Report concluded that coal is “irreplaceable.”

**Policy makers view coal as the core of China’s energy supply and security**

“China will adhere to the principle of reliance on domestic energy supply and will consider coal as its major energy resource. This is the foundation for China’s energy security.” —China’s Academy of Social Sciences, 2006

There can be little question that Chinese leaders view coal as the primary energy source to move their society forward. Chinese leaders recognize that coal is abundant, reliable, secure, affordable, increasingly clean and highly versatile. In regard to this last point, coal is seen as meeting a variety of energy needs. When asked how China could ever meet burgeoning demand for electricity, liquid fuels and NG, Du Minghua, Director of the Beijing Research Institute of Coal Chemistry replied, “Coal is the solution to all three.”

Armed with the conviction that coal can help across the board, China’s 2006 Energy Development Report concluded:

“Coal consumption still has a great potential…the coal liquefaction and gasification technologies help create…conditions for transforming coal into a clean energy….clean coal technology is beneficial to the sustainable and healthy development of the national economy….and to help improve the environment.”

In July, 2006, CASS (see Box A) published what is currently the definitive analysis of the developing energy situation in the context of China’s eleventh Five Year Plan (2006-2010) and beyond to 2020. This extensive 500-plus page analysis provides valuable insight into how the Chinese view their energy situation, rather than how it is interpreted by Westerners. And, in this context, it is abundantly clear that Chinese energy analysts see their economic and energy destiny inextricably linked to coal:
“…coal plays an irreplaceable role in economic development…ensuring people’s livelihood.”

“In a foreseeable future, coal will continue to be China’s leading energy and its important strategic goal. This position is irreplaceable.”

“Coal, as China’s basic energy, has an irreplaceable and important position in the country’s energy industry and national economy. The fast development of downstream products will lead to brisk and huge demands for coal, and China’s coal industry will maintain a growing and stable trend.”

“Coal will continue to be a pillar industry in China’s energy sector, and this is decided by China’s basic national conditions.”

In order to meet steady demand growth, China has implemented a series of policy steps to enhance utilization of coal including: (1) Reorganization of the coal industry under the motto “doing big and doing strong,” (2) Expanding and upgrading railways, barges and seaports to improve coal transportation, (3) new mine construction, (4) “coal by wire” projects to transmit electricity from mine-mouth generating plants in the north central provinces to eastern and southern load centers, (5) coal exploration projects to expand available resources, (6) construction of a strategic coal reserve and (7) constraints on coal exports—especially coke. In addition, virtually all of the coal-producing provinces have implemented plans to expand the use of coal.

As part of a focus on clean coal, China has: (1) Continued to invest heavily in developing over 200 coal washing facilities as well as undertake many other environmental technology improvements, (2) Moved toward implementation of advanced combustion power generation technology developed by the U.S. to increase efficiency and significantly reduce emissions and (3) Initiated the GreenGen Program—a near zero emissions power plant.

**China will continue to use increasing amounts of energy**

China’s ever rising demand for energy in general and electricity in particular, is driven by four key factors:

(1) **Population growth**

While China’s fertility rate has declined 65 percent since 1990, the sheer magnitude of China’s fecund adult population insures steady population growth over the next several decades.
Figure 2.7
The Momentum of Population Growth in China

<table>
<thead>
<tr>
<th>Year</th>
<th>Population (Millions)</th>
<th>Number of People Added over 5 years (millions)</th>
<th>Number Europe OECD will add in 5 years intervals (Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>1,312</td>
<td>37</td>
<td>10</td>
</tr>
<tr>
<td>2010</td>
<td>1,355</td>
<td>43</td>
<td>10</td>
</tr>
<tr>
<td>2015</td>
<td>1,393</td>
<td>38</td>
<td>7</td>
</tr>
<tr>
<td>2020</td>
<td>1,424</td>
<td>31</td>
<td>5</td>
</tr>
<tr>
<td>2025</td>
<td>1,441</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>166</td>
<td>36</td>
</tr>
</tbody>
</table>

Source: EIA, 2007

As the data in Figure 2.8 indicate, China will be adding an average of about nine million people each year for the next two decades. This growth rate is far below that which characterized the previous generation but the incremental total in two decades will still exceed the total population of Russia.

(2) **Economic growth**

The story of China’s booming economy is well known:

Figure 2.9

Dramatic Economic Growth in China

*GDP Expressed in purchasing power parity
Source: EIA, 2007
Since 1990, China’s GDP has increased 270 percent and is projected to be the world’s largest economy in terms of GDP by 2010.

**Figure 2.10**

*China’s Economy Relative to Other Parts of the World*

<table>
<thead>
<tr>
<th>Year</th>
<th>GDP in Billions, 2000 dollars</th>
<th>China</th>
<th>U.S.</th>
<th>Europe (OECD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>8,400</td>
<td>11,120</td>
<td>11,483</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>17,912</td>
<td>14,698</td>
<td>14,428</td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td>31,023</td>
<td>19,666</td>
<td>17,902</td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>39,594</td>
<td>22,494</td>
<td>19,913</td>
<td></td>
</tr>
</tbody>
</table>

Source: EIA, 2007. (Note: There is evidence that China’s GDP may be growing even more rapidly than predicted. The above data are expressed in standard Purchasing Power Parity terms, but if Market Exchange rates are used, China’s 2007 GDP of $3.4 trillion is already beyond the EIA forecast of $2.9 trillion for 2010)

(3) **Urbanization**

The growth of China’s cities began to surge in the 1980’s as (a) Deng Xiaoping’s agricultural reforms were put into place (b) rural migration to the cities was stimulated by the One Child Policy limiting natural population growth in the cities and (c) globalization of the coastal cities greatly enhanced employment opportunities.

**Figure 2.11**

*Growth of Urban Population*

<table>
<thead>
<tr>
<th>Year</th>
<th>Urban Residents (millions)</th>
<th>Urban Residents as % of Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>297</td>
<td>26</td>
</tr>
<tr>
<td>2000</td>
<td>524</td>
<td>40</td>
</tr>
<tr>
<td>2005</td>
<td>679</td>
<td>49</td>
</tr>
<tr>
<td>2025</td>
<td>874</td>
<td>60</td>
</tr>
</tbody>
</table>

Source: IEA, 2007

In China, urbanization has emerged as an explicit component of government policy. In a 2005 presentation to the Central Committee, Chinese President Hu Jintao stated:

“Urbanization is the ultimate trend for economic and social development, as well as an important symbol for industrialization and modernization.”

At least 10 million rural residents migrate to Chinese cities each year. Projections indicate **300 million rural migrants will move to cities by 2025**. The Chinese Academy of Science (CAS) projects that by 2050, **1.1 billion Chinese will live in cities**—75 percent of the population.
(4) **Modernization and rising expectations**

In 1848, the political philosopher Alexis de Tocqueville noted that once a population experiences improvement in the quality of life, the mindset begins to shift to the future in anticipation of continued and expanded improvements—especially as people became aware of other groups already experiencing the sought after lifestyle. There is probably no nation on earth that represents the principle of rising expectations more clearly than China. No longer caught in the backwater of poverty and the stagnation of the Cultural Revolution, China has literally burst on to the modern scene.

The relative prosperity of recent years has created an increasingly sophisticated and educated populace. In her book *The Consumer Revolution Urban China*, Davis (2000) describes this phenomenon:

> “After decades of equalitarian, restricted consumption, residents of China’s cities are surrounded by a level of material comfort unrecognizable just ten years ago … [allowing] ordinary citizens to nurture dreams and social networks that challenge official discourse and conventions.”

Indeed, Marquard, writing in *The Christian Science Monitor* (2006), posited that “the hopes of ordinary Chinese have never percolated so strongly” as dreams of material possessions suddenly seem within the grasp of the common person, prompting one businessman in Beijing to comment:

> “Things have gone from all ideology and no materialism to all materialism and no ideology.”

But most Chinese are very pleased with all this progress. A Pew Global Attitudes survey found that 81 percent of Chinese citizens were satisfied with the state of the nation—one of the highest rates of satisfaction in the world.

Two of the most clear indicators of modernization regarding energy consumption relate to ownership of (a) electric appliances and (b) motor vehicles. Both dimensions have, and will continue to see, substantial growth in China over the next generation.

(a) **Appliance ownership** in China has rapidly escalated through a combination of rising incomes and declining unit pieces. This pattern is especially prevalent in the largest cities but there is considerable room to grow ownership in the rural areas where color televisions prevail but other appliances still lag.
In fact, as Figure 2.12 demonstrates there is still a large gap before China reaches a saturation point on the major appliances similar to the United States. These four major appliances—color television, washing machines, refrigerators and air conditioners use about 21 percent of residential electricity. Yet, as the IEA has warned, as incomes continue to rise in China:

“more households start to own electric equipment such as home theatre systems which consume more electricity than a refrigerator.” —IEA, 2007

(b) Motor vehicle ownership increases in China have been equally dramatic, as the four-wheel vehicle stock in China has increased almost seven times since 1990—from 5.5 million vehicles to almost 37 million (IEA, 2007). China has an additional 60 million motorized two wheelers. Figures 2.13 and 2.14 show the sheer size of China’s move into the worlds of four-wheel, motorized vehicles.
The scale of China’s surging auto sales is shown by the fact that the above 2007 EIA estimate of 6.7 million in 2010 is far below the actual sales of 8.9 million in 2007—underlining the difficulty in estimating and forecasting the massive change in China.
Coal consumption in China will continue to increase along three lines

China’s energy consumption will increase 85 percent over the next 25 years. With the confluence of availability, affordability, need, supply and political support, there can be little doubt that coal’s central role in China’s energy system will increase even further. The EIA forecasts indicate the continuing role of coal:

**Figure 2.15**

**Fuel Share of Primary Energy Demand in China, 1990-2030**

<table>
<thead>
<tr>
<th>Year</th>
<th>Coal</th>
<th>Biomass</th>
<th>Oil</th>
<th>NG</th>
<th>Hydro</th>
<th>Nuclear</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>61</td>
<td>23</td>
<td>14</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2005</td>
<td>63</td>
<td>13</td>
<td>19</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>2015</td>
<td>66</td>
<td>8</td>
<td>19</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>2030</td>
<td>63</td>
<td>6</td>
<td>21</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: IEA, 2007
This reliance on coal will manifest itself along three key dimensions:

(1) **Electricity** in China will continue to mean electricity from coal. The IEA projects that by 2030, over 78 percent of China’s electric power will be coal based. Coal will generate over 6,500 Terawatt hours of electricity—more than double what the European Union uses today.

(2) **Manufacturing** coal is widely used in many manufacturing sectors of China’s economy. Natural gas is costly and often not available and coal is affordable and plentiful. The steel, chemicals, nonmetallic minerals, petroleum refining and coking sectors consume more than 80 percent of the 640 million tons consumed in manufacturing. Coal use in these sectors will more than triple as China continues to ride a building wave, unprecedented in human history, that is unlikely to crest for at least another decade. In 2006 alone, China will consume 300 million tons of steel. The enormous volume of such building materials—including concrete, aluminum, nonferrous metals, glass, and plastics—will require significant amounts of energy. These energy units will be supplied by coal.

(3) **Coal Conversion** technology is being developed. China is leading a renaissance of coal conversion technology founded on a broad based effort to convert coal into a range of chemicals typically produced from natural gas and petroleum.

> “Coal to chemicals is an opportunity that is literally exploding [in China] right now.”—T. Vail, WSJ, 2007

This approach could provide China with a significant competitive advantage in the development and commercialization of Btu conversion technologies and produce relatively low-cost fuel and raw materials for the manufacturing sector. Such products will benefit a broad swatch of the Chinese economy: ammonia used for fertilizers, methanol used to produce olefins for plastics and other petrochemicals and acetic acid used in synthetic fibers and plastics. China’s coal companies are also commercializing cutting-edge technologies to convert coal into liquid fuels.

> “The People’s Republic is striving to use its vast coal reserves to displace as much as 12 percent of its petroleum consumption by 2020.”—J. Brock, CERA, 2007

China will clearly need more liquid fuels given the rise of four-wheel, motorized vehicles documented in Figures 2.13 and 2.14.
Finally, China is the world’s leader in producing a promising new fuel called dimethyl ether (DME) — a substitute for diesel fuel and liquid propane gas that can be made safely and affordably from coal.

The escalation of this demand for energy will translate into even more coal consumption in China.
Figure 2.17
Projected Coal Consumption in China by Sector

Works Consulted


Chapter Three
China Use of Coal-Based Electricity to Alleviate
Poverty and Improve the Human Condition

“Electricity use and gross national product [are] strongly correlated. The relationship … is so important that it should be considered in developing … energy and economic policies [to] promote the implementation of electrotechnologies [and] to lower the real cost of electricity supply.”
—National Academy of Science, 1984

China as an example for the rest of the world.
In less than 15 years, China expanded electricity service to over 450 million people—one and a half times the population of the United States. In fact, without China’s achievement, the world’s population without access to electricity would have increased over the same period.

“Electrification in China is a remarkable success story…the electrification goal [is] part of its poverty alleviation campaign…the most important lesson for other developing countries [is] that electrified countries reap great benefits, both in terms of economic growth and human welfare…China stands as an example.” —IEA, 2007

Coal drove the electrification of China and has served as a stable source of the concomitant benefits—longer lives, better food, improved health care, higher education, increased gender equality and expanded awareness of the outside world. Coal’s role in leading hundreds of millions of Chinese out of poverty is one of the major stories of our age.

Electricity is the pathway to a better life all around the world.
In 1999, the U.S. Academy of Engineering identified electrification as the most important engineering achievement of the last century. The unique attributes of electricity hold continuing promise for societal progress:

- The high quality of electricity makes it convertible to virtually any energy service—light, motion, heat, electronics and chemical potential
- Permits previously unattainable precision, control and speed
- Provides temperatures far greater than those attainable from standard fuels
- Yields instantaneous access and 100 percent convertible to work
Unlike standard fuels, electricity has no waste product at the point of use. At the point of electricity generation, carbon capture and near zero criteria pollutant emission controls will allow the world’s nations to utilize our most reliable and affordable fuel—coal.

Given these contributions and continuing potential, it is not surprising that reliable electricity has become the lifeblood of modern society, powering machines, providing illumination, enhancing and protecting our food supply, propelling the manufacturing process and cleaning the environment. Modern life could not exist without electric power. Electricity is essential to increases in the quality of life, economic well being and a clean environment. As the National Academy of Sciences contends, societies seeking human progress should facilitate the development of additional electric generation capacity to provide affordable and reliable electricity. The experience of the U.S. is displayed in Figure 3.1.

**Figure 3.1**

![Net Generation Versus GDP](image)

As other nations seek to emulate the United States the global quest for electricity is clear:

- By 2030, consumption of electric power will increase 85 percent at the global level
- Developed nations seek more electricity to enhance productivity, comfort and communication
- Developing nations seek electricity to give billions of people a better life
- In a world of over 6 billion people, environmental quality utterly depends upon reliable electricity
In the developing world, electricity is literally the key to life itself through cleaner air and water, access to medical treatment and expanded food supplies. Yet, as Figure 3.2 indicates, hundreds of millions of people across the globe have no or minimal access to electricity.

**Figure 3.1**

![The Global Inequality of Access to Electricity](image)

Both the quantity and quality of life are closely associated with access to electricity. On key human development measures, countries that are “electricity deprived” (i.e. use less than 500 kwh per capita per year) compare very unfavorably to countries with significant access to electricity (e.g. 6,000 kwh/capita). For instance, the electricity deprived nations:

- Have an improved sanitation rate of only 28 percent
- Have an infant mortality rate reaching 1 in 10 live births
- Have female illiteracy rates reaching 80 percent

Perhaps most telling of all, people in the electricity deprived nations die, on average, 28 years before their counterparts in more electrified nations. Women and children bear the greatest burden from the travails of gathering and using non-electric sources of energy:

- In Africa, many women carry 20 kilograms of fuel wood an average of five kilometers every day (IEA, 2007)
- Over 2.5 million women and young children die prematurely each year from fumes emitted from biomass stoves burning wood and dung (World Health Organization, 2007)
- Millions of women and children carry water for miles as they do not have access to electric pumps or wells
- Women and children spend so much time meeting basic energy needs they have no time for education, especially given the lack of illumination in the evening

“Every single one of the United Nations Millennium Development Goals requires access to electricity as a necessary prerequisite.” —Global Energy Institute, 2008

The escape from poverty requires clean water, sanitation, health services, education, communication, leisure time for self improvement and an endless list of similar opportunities the modern world takes for granted.

**Figure 3.3**

![Access to Electricity and Progress on the U.N. Human Development Index, (H03) 2005](image)

At the present time as many as three billion people lack adequate access to electricity that would enable the UN Millennium Development goals to be met.
TO THE CHILDREN OF THE WORLD IT IS A SIMPLE EQUATION
No Electricity + Dirty Water = Diarrhea + Death

Figure 3.4
Access to Improved Sanitation

Diarrhea Prevalence Among Children Under 5

Deaths Per 1000 Children Under 5
The Rise of Electrification in China

China has dominated the global expansion of electricity access. From 1990 to 2005, a net amount of about 400 million people gained access to electricity. China alone contributed over 450 million to the accessed population. China’s rapid growth in access, interacting with steadily rising incomes, stimulated an ever-increasing drumbeat of electricity demand. As Figure 3.2 demonstrates, for more than a decade, almost one-third all new electricity has been generated in China.

Figure 3.5

China has desperately needed this additional generation due to escalating demand. As Figure 3.3 shows, from 2000 to 2005 alone, China’s consumption of electricity increased over 1,000 Terawatt hours—more than the annual consumption of Japan.

Figure 3.6
Coal drives Electricity Growth in China

The staggering electricity consumption increases in China would be impossible without coal. While coal has long been a core fuel in China’s power system, it has rapidly become the sine qua non of China’s efforts to meet demand and grow the economy. China’s NG and oil endowment is relatively modest, nuclear is capital intensive, hydro is inherently limited and land is needed to grow food for 1.3 billion people, not biomass.

As Figure 3.7 shows, since 1990, coal has accounted for over four-fifths of electricity supply increases.

Figure 3.7

Electricity generated by coal increased more than 1,500 Terawatt hours in 15 years. To put this increase in perspective, the European Union’s increase for all fuels over the same period was only 700 Terawatt hours.

The Drama is Just Beginning

Despite the massive growth in generation and per capita consumption, China remains more or less in the backwater of electricity use (see Figure 3.8).
The 17th National Congress of the Communist Party, held in October, 2007, set a quadrupling of GDP over 2000-2020 as a major goal. Electricity from coal is expected to power that economic expansion. Figure 3.5 displays the projected increase in electricity generation through 2030. Specifically, consumption is expected to more than triple over the next 25 years. In fact, if these IEA forecasts come to pass, the Chinese will consume about one fourth, (24 percent) of the world’s electrical power.
Figure 3.10 gives a relative perspective of the sheer scale of China’s emerging pattern of electricity consumption. By 2030, for example, China will consume more electricity than the world’s other major economies combined.

**Figure 3.10**

![The Scale of China's Demand for Electricity](source)

Coal will be the core of future electricity generation.

“The basic framework of future China’s power structure is to take coal-fired generation as the foundation...China has rich coal resources...It’s our inevitable choice to vigorously develop clean coal generation with high efficiency.” —National Development and Reform Commission, 2004

Thus, it is clear government policy that coal will bear the load to meet these increases in electricity consumption. As Figure 3.7 shows, in 2005, coal accounted for 78 percent of generation and by 2030 it will continue to account for 78 percent.

**Figure 3.11**

![China Will Increasingly Rely Upon Coal for Electricity Generation](source)
Even more importantly, however, 77 percent of the incremental electricity consumption over the 25-year period will be met by coal. By 2030, coal-based generation in China will approach one fifth (19 percent) of all electricity generated in the world, regardless of fuel.

**Figure 3.12**
China’s Projected Increase in Coal-Based Generation Compared to Total Generation Increases in Other Regions

<table>
<thead>
<tr>
<th>Region</th>
<th>Increase in Total Generation 2005-2030</th>
<th>China’s Increase in Coal Based Generation 2005-2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>499</td>
<td>4,590</td>
</tr>
<tr>
<td>Middle East</td>
<td>882</td>
<td></td>
</tr>
<tr>
<td>Latin America</td>
<td>1,152</td>
<td></td>
</tr>
<tr>
<td>OECD Europe</td>
<td>1,330</td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>1,479</td>
<td></td>
</tr>
</tbody>
</table>

Source: IEA (2007)

The Inevitability of Coal: If China did not use Coal to Meet Incremental Demand for Electricity, the following sources would be needed by 2030:

- **Natural gas**—39 TCF, more than combined production of Russia, Canada and the entire Middle East
- **Nuclear**—over 600 nuclear power plants and the uranium to fuel them
- **Wind**—almost quadruple what the entire world is projected to produce by 2030
- **Solar**—28 times more than the entire world is projected to produce by 2030
- **Hydro**—the equivalent of 1,150 Hoover Dams

Clearly, both China’s economic and energy destiny is inextricably linked to coal as the means to what the national government calls a “moderately well off” society.

**Coal-Based Electricity is Lifting Hundreds of Millions out of Poverty in China**

Observers from the Western World, typically accustomed to adequate and reliable electricity, may find it difficult to believe the dramatic lifestyle improvements electricity from coal has brought to China.
In 1990, China generated 471 Terawatt hours from coal and the GDP was about $2 trillion. Only 56 percent of the population (644 million people) had electricity.

By 2005, China generated 1,996 Terawatt hours from coal (an increase of 320 percent) and:

- Had a GDP of $8.4 trillion—a 320 percent improved increase
- An electrification rate of 99 percent—over 1,300 billion people

As the GDP increased, the quality of life has been dramatically enhanced throughout China and millions have benefited. Figure 3.13 shows the scale of massive uplifting of the population.

**Figure 3.13**

![A Sea of Change in the Quality of Life for Hundreds of Millions](image)

(1) Reduction of extreme poverty and hunger

In 2000, the United Nations adopted the Millennium Declaration in order to promote a comprehensive approach to solving the major problems of human society. The Declaration proposed that by 2015 the world would achieve eight goals regarding poverty, hunger, disease, illiteracy, environmental degradation and discrimination against women.

The first two goals were explicit:

(a) Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar per day. China’s progress along these lines is clear:
Figure 3.14 shows the dramatic reduction of extreme poverty in China. From 1990 to 2005, at least 275 million people were removed from the “one dollar a day” category the World Bank uses as a measure of extreme poverty.

(b) Halve, between 1990 and 2015, the proportion who suffer from hunger. Once again, the accomplishments of China speak for themselves:

Figure 3.15

By 2005, China’s rate of infants with low birth weight was below that of the United States.
There can be little question that since 1990 China has increased coal-based electricity over 300 percent and the nation has made greater progress toward reduction of poverty and hunger than any nation in the world.

(2) Longer, higher quality lives for China’s women and children

Four of the top 10 United Nations Millennium Development goals deal specifically with women and children:

- Reduce child mortality
- Improve maternal health
- Promote gender equality and empowerment
- Achieve universal primary education for females

As Figure 3.16 demonstrates, the health and educational levels of the most vulnerable segments of Chinese society have greatly increased. This progress has global significance because women and children account for 70 percent of the world’s poor.

**Figure 3.16**

![Coal Based Electricity is Improving the Life of Women and Children in China](image)

There is absolutely no question that the coal-based electrification of China’s countryside, towns and cities has enhanced the Human Development profile of women and children throughout the nation.
A Chinese population better prepared to meet the modern world

Education and the ability to communicate thoughts, data and images with a larger demographic, geographical, and socioeconomic setting are crucial components of modernity. As Figure 3.17 shows, the dramatic increase in electricity access in China is correlated with striking steps forward in education and communication.

Figure 3.17

Better Education, Improved Communication

Coal-based generation increased over 300% and:

Telephone availability increased 44-fold
Internal telephone increased 14-fold
Youth literacy increased 15%
Adult literacy increased 17%

(4) Overall improvement in human development

The U.N. Millennium Goals are based upon improvements in the Human Development Index (HDI)—a composite measure of a nation’s socioeconomic progress.

Figure 3.18

Electricity and the Human Condition in China
Electric Power Consumption in the Economic Sectors of China

Electric power consumption in China has been growing faster than its overall economy. From 2002 to 2006, growth in electricity use has averaged 14 percent per annum. As a result, total electricity use increased 40 percent over this period, rising from 1,633 billion kilowatt hours (kwhr) to more than 2,800 billion kwhr (see Figure 1). By way of comparison, total consumption of electricity in the United States is slightly over 3,800 billion kwhr. Assuming an average power plant of 800 Megawatts (MW) and an 80 percent capacity utilization rate, China’s growth in electric power use required new 219 power plants each year.

Figure 3.19
Total Electric Power Consumption in China, 2002-2006

More than half of China’s electricity use occurs in manufacturing (see Figure 3.20). The next largest category is the utility sector, which includes electric, gas, and water utilities.

Figure 3.20
Composition of China’s Electricity Use in 2006
Most of the power use in this sector occurs within the electric power sector itself for parasitic power applications, such as lighting, fans and other equipment. The next largest category is household consumption followed by mining and the remaining 14 percent is spread over services, construction, agriculture, and other sectors of the economy.

A breakdown of electricity use in the manufacturing sector appears in Figure 3.21. What is significant is that 58 percent of total electricity consumption in manufacturing occurs in four sectors in order of importance: ferrous metals, chemicals, non-ferrous metals, and non-metallic minerals. The build-out of the Chinese economy will likely continue and, therefore, continue pushing the demand for electric power.

**Figure 3.21**
Composition of China’s Manufacturing Electricity Use, 2006

The pattern of recent growth in electricity use by sector, which is detailed in Table 1 below, reveals that growth is broad based but led by strong growth in electricity use by the largest four manufacturing sectors mentioned above: metals, chemicals, and non-metallic minerals. Even the lowest growth is 5 percent. These data clearly indicate that China’s economy is well on its way to becoming significantly electrified. This expanded
use of electricity will lead to productivity advances, greater wealth and income accumulation, and still greater demand for energy and basic minerals and materials.

The sheer scale of the increase, which is equivalent to one-third of the power grid of the United States in just four years, simply could not have been achieved without the low-cost abundant coal supplies within China’s borders. As China continues down this new frontier of economic expansion, a key factor will be the availability of resources to fuel this growth. This is perhaps where China will need to focus in securing additional coal resources from abroad, such as the United States, Australia, and other lands around the world.

**Figure 3.22**
**Chinese Electricity Consumption & Compound Growth Rates by Sector, 2002-2006**

<table>
<thead>
<tr>
<th>Sector</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>Compound Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture &amp; Forestry</td>
<td>77.6</td>
<td>77.3</td>
<td>80.9</td>
<td>87.6</td>
<td>94.7</td>
<td>5.0%</td>
</tr>
<tr>
<td>Construction</td>
<td>16.4</td>
<td>19.0</td>
<td>22.2</td>
<td>23.4</td>
<td>27.1</td>
<td>12.5%</td>
</tr>
<tr>
<td>Transport, Storage and Post</td>
<td>33.8</td>
<td>39.7</td>
<td>45.0</td>
<td>43.0</td>
<td>46.7</td>
<td>8.1%</td>
</tr>
<tr>
<td>Services</td>
<td>50.0</td>
<td>62.3</td>
<td>73.5</td>
<td>75.2</td>
<td>84.7</td>
<td>13.2%</td>
</tr>
<tr>
<td>Others</td>
<td>75.9</td>
<td>91.1</td>
<td>103.7</td>
<td>134.1</td>
<td>155.6</td>
<td>18.0%</td>
</tr>
<tr>
<td>Household Consumption</td>
<td>200.1</td>
<td>223.8</td>
<td>246.4</td>
<td>282.5</td>
<td>325.2</td>
<td>12.1%</td>
</tr>
<tr>
<td>Mining</td>
<td>112.8</td>
<td>125.0</td>
<td>137.1</td>
<td>147.8</td>
<td>147.8</td>
<td>6.8%</td>
</tr>
<tr>
<td>Utilities</td>
<td>265.4</td>
<td>313.3</td>
<td>358.0</td>
<td>391.0</td>
<td>439.8</td>
<td>12.6%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>801.2</td>
<td>951.7</td>
<td>1,130.3</td>
<td>1,309.5</td>
<td>1,537.2</td>
<td>16.3%</td>
</tr>
<tr>
<td>Textiles</td>
<td>45.4</td>
<td>54.5</td>
<td>71.9</td>
<td>82.2</td>
<td>103.1</td>
<td>20.5%</td>
</tr>
<tr>
<td>Chemicals</td>
<td>135.6</td>
<td>163.0</td>
<td>184.9</td>
<td>212.5</td>
<td>243.7</td>
<td>14.7%</td>
</tr>
<tr>
<td>Non-Metallic Minerals</td>
<td>88.0</td>
<td>103.1</td>
<td>120.9</td>
<td>141.6</td>
<td>167.4</td>
<td>16.1%</td>
</tr>
<tr>
<td>Ferrous Metals</td>
<td>132.3</td>
<td>164.8</td>
<td>206.4</td>
<td>254.4</td>
<td>303.6</td>
<td>20.8%</td>
</tr>
<tr>
<td>Non-Ferrous Metals</td>
<td>82.4</td>
<td>107.2</td>
<td>125.8</td>
<td>147.0</td>
<td>182.8</td>
<td>19.9%</td>
</tr>
<tr>
<td>Metal Products</td>
<td>28.2</td>
<td>35.6</td>
<td>43.3</td>
<td>50.6</td>
<td>60.5</td>
<td>19.1%</td>
</tr>
<tr>
<td>Communications Equip.</td>
<td>15.0</td>
<td>21.7</td>
<td>27.7</td>
<td>32.7</td>
<td>40.2</td>
<td>24.6%</td>
</tr>
<tr>
<td>Paper Products</td>
<td>28.5</td>
<td>31.2</td>
<td>35.9</td>
<td>40.7</td>
<td>44.7</td>
<td>11.3%</td>
</tr>
<tr>
<td>Machinery</td>
<td>36.1</td>
<td>40.3</td>
<td>51.0</td>
<td>48.2</td>
<td>55.2</td>
<td>10.6%</td>
</tr>
<tr>
<td>Petroleum &amp; Coking</td>
<td>33.1</td>
<td>33.6</td>
<td>41.3</td>
<td>31.3</td>
<td>35.7</td>
<td>1.9%</td>
</tr>
<tr>
<td>Plastics</td>
<td>10.9</td>
<td>12.8</td>
<td>14.9</td>
<td>20.9</td>
<td>23.7</td>
<td>19.4%</td>
</tr>
<tr>
<td>Other</td>
<td>165.7</td>
<td>184.1</td>
<td>206.2</td>
<td>247.4</td>
<td>276.6</td>
<td>12.8%</td>
</tr>
<tr>
<td>Total Consumption</td>
<td>1,633.1</td>
<td>1,903.2</td>
<td>2,197.1</td>
<td>2,494.0</td>
<td>2,858.8</td>
<td>14.0%</td>
</tr>
</tbody>
</table>
Works Consulted


Chapter Four

China’s Industrial Revolution Fueled by Coal

One of the key elements behind China’s remarkable economic growth since 1980 has been the utilization of locally abundant coal supplies. The scale of industrial growth in China is unmatched in human history. China is now the world’s leading producer of steel, non-ferrous metals, cement and other materials, which are contributing to the construction of a modern manufacturing base and associated technology, communication and service industry infrastructure. As a result, China is largest consumer of food and raw materials in the world. While China generates most of its electricity from coal like other nations with large coal endowments, the industrial use of coal is much more expansive in China. This coal-based industrial development is a direct result of an explicit national development strategy that takes advantage of China’s coal resource endowment.

In 1978, Hua Guofeng, Chairman of the Chinese Communist Party announced a plan that would take China from late feudalism to industrial modernity over the next twenty years. The plan was important because it laid out specific production targets for three key items: food, steel and coal. Higher grain production enables better nutrition. Steel furnishes the basic building material for modern industry. And finally coal provides the energy requirements for this dash for economic growth. This simple three-pronged strategy underlies China’s economic development over the past quarter century.

In recent years, coal continues to underpin China’s industrial development. Indeed, China could not have achieved what is has accomplished over the past 20 years without coal. For example, coal provides more than 83 percent of the energy used in the non-metallic minerals and metals sectors of the Chinese economy. Coal is even widely used as a raw material in the petrochemical industry in China, which competes successfully with firms in the Middle East using natural gas. Finally, several Chinese coal and industrial consortiums are building coal-to-liquids plants to produce chemicals, transportation fuels, and household fuels, such as dimethyl ether, which is similar to liquid propane gas and could serve cooking and heating applications.

The following section will explain the role of basic industry in the Chinese economy, comparing it to current and past experience in the United States and describing the widespread use of coal to produce basic materials, machines and structures. The next three sections focus on sectors of the Chinese industrial economy where coal plays a vital role: iron and steel, cement and non-metallic minerals and chemicals. The use of coal in these sectors has allowed an increase in the scale of production that simply would not be possible without cheap and abundant steam and metallurgical grade coal. The chapter concludes with an analysis of China’s investment in coal energy conversion facilities to produce a range of industrial chemicals and liquid fuels to substitute for oil and natural gas. Like the metals sector, coal is providing China with a competitive edge as the world economy struggles under the burden of high oil and natural gas prices. Moreover,
Chinese policy makers recognize the growing energy needs of its society, especially for liquid transportation fuels.

**Coal and Industrial Development in China**

Economies go through various growth stages. Once a society makes the transition from an agrarian to an industrialized society, the composition of economic activity begins to shift. The role of primary sectors of the economy, such as agriculture and forestry, while still growing are overshadowed by heavy industry producing steel, concrete, and other materials for building, bridges, highways, and other infrastructure. China is currently passing through the build-out phase, just as the United States did during the late 19th and early 20th centuries.

One important difference between these two development episodes, however, is that the scale of China’s development is several orders of magnitude larger. It is as if four or five United States economies were developing. Given the magnitude of the development required, Chinese economic development will likely continue through much of this century. This continued acceleration is reflected in the composition of gross domestic product in China, which is displayed below in Figure 4.1. The industrial sector, which includes mining, manufacturing, utilities and construction, remains the largest sector of the Chinese economy, expanding on average 10 percent per annum from 1978 to 2006. The service sector expanded at an even faster pace of nearly 12 percent per annum but continues to generate about 20 percent less gross output than basic industry.

**Figure 4.1:**
Real Gross Domestic Product in China by Sector, 1978-2006
The relative importance of heavy industry in the Chinese economy is evident when comparing the share of industry in gross domestic product in China with the United States. As Figures 4.2 illustrates, more than half of gross domestic product in China is generated by basic industry. In contrast, industry in the United States generates less than 20 percent of gross domestic product. This comparison is clear evidence that China is experiencing the build-out phase of economic development.

**Figure 4.2:**
Comparison of GDP Composition: China vs. USA, 1991-2006

This economic activity in the industrial sector has been growing at a brisk pace over the past two decades. As Figure 4.3 reveals, there has been a deceleration in the growth of industrial sector GDP from the over 9 percent range during the early 1990s to the 5-6 percent range in recent years. Service sector growth has accelerated from the 2-3 percent range to more than 4 percent since 2000. The balanced nature of industry and service sector growth rates suggests that the foundations for Chinese economic growth are sound, which implies that China will need a steady supply of energy to maintain this growth.

**Figure 4.3:**
Decomposition of GDP Growth in China, 1990-2006
An overview of fuel consumption by sector in the Chinese economy appears in Table 4.1 below. Every sector uses of China’s economy uses coal. In contrast, natural gas is not used in four sectors and in much smaller quantities. The only sizeable natural gas consumption occurs in the chemical industry but that is dwarfed by coal and coke consumption, which is more than four times larger. The three most energy intensive sectors are utilities, petroleum and coking, and ferrous metals.

Table 4.1:  
Fuel Consumption by Sector in China Quadrillion BTU, 2006

<table>
<thead>
<tr>
<th>Sector</th>
<th>Total</th>
<th>Coal</th>
<th>Coke</th>
<th>Crude</th>
<th>Petroleum Products</th>
<th>Natural Gas</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture &amp; Forestry</td>
<td>1.79</td>
<td>0.51</td>
<td>0.02</td>
<td>0.93</td>
<td>0.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mining</td>
<td>4.99</td>
<td>3.43</td>
<td>0.04</td>
<td>0.50</td>
<td>0.20</td>
<td>0.32</td>
<td>0.50</td>
</tr>
<tr>
<td>Food, Beverages, Tobacco</td>
<td>0.89</td>
<td>0.62</td>
<td>0.02</td>
<td>0.07</td>
<td>0.01</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>Textile, Apparel, Leather</td>
<td>1.07</td>
<td>0.58</td>
<td>0.02</td>
<td>0.08</td>
<td></td>
<td>0.41</td>
<td></td>
</tr>
<tr>
<td>Wood Products</td>
<td>1.14</td>
<td>0.84</td>
<td>0.02</td>
<td>0.06</td>
<td>0.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petroleum &amp; Coking</td>
<td>17.70</td>
<td>5.05</td>
<td>0.02</td>
<td>12.21</td>
<td>0.22</td>
<td>0.08</td>
<td>0.12</td>
</tr>
<tr>
<td>Chemicals &amp; Medicines</td>
<td>6.23</td>
<td>2.89</td>
<td>0.46</td>
<td>0.92</td>
<td>0.29</td>
<td>0.71</td>
<td>0.97</td>
</tr>
<tr>
<td>Rubber &amp; Plastics</td>
<td>0.38</td>
<td>0.13</td>
<td>0.02</td>
<td>0.06</td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Metallic Minerals</td>
<td>4.87</td>
<td>3.74</td>
<td>0.05</td>
<td>0.01</td>
<td>0.40</td>
<td>0.09</td>
<td>0.57</td>
</tr>
<tr>
<td>Ferrous Metals</td>
<td>11.14</td>
<td>4.71</td>
<td>5.22</td>
<td>0.13</td>
<td>0.04</td>
<td>1.04</td>
<td></td>
</tr>
<tr>
<td>Non-Ferrous Metals</td>
<td>1.34</td>
<td>0.54</td>
<td>0.09</td>
<td>0.07</td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machinery &amp; Equipment</td>
<td>1.96</td>
<td>0.58</td>
<td>0.18</td>
<td>0.25</td>
<td>0.07</td>
<td>0.88</td>
<td></td>
</tr>
<tr>
<td>Utilities</td>
<td>29.34</td>
<td>27.08</td>
<td>0.01</td>
<td>0.61</td>
<td>0.14</td>
<td>1.50</td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>0.49</td>
<td>0.13</td>
<td>0.26</td>
<td>0.01</td>
<td>0.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>4.95</td>
<td>0.16</td>
<td>0.07</td>
<td>4.50</td>
<td>0.06</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>Wholesale &amp; Retail Trade</td>
<td>0.91</td>
<td>0.20</td>
<td>0.01</td>
<td>0.36</td>
<td>0.05</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1.59</td>
<td>0.17</td>
<td>0.84</td>
<td>0.05</td>
<td>0.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Households</td>
<td>3.58</td>
<td>1.87</td>
<td>0.02</td>
<td>0.21</td>
<td>0.37</td>
<td>1.11</td>
<td></td>
</tr>
</tbody>
</table>

The shares of coal in supplying the energy needs of various sectors are displayed below in Figure 4.4. Notice that the ferrous metals sector, which is predominantly the iron and steel industry, 89 percent of total energy consumption comes from coal. If the inputs of crude oil in the petroleum and coking sector are removed, coal provides more than 73 percent of the total requirements of industry in China. So clearly, coal underpins industrial growth, which contributes more than 60 percent of the growth in the Chinese economy as demonstrated in Figure 4.3.

Restricting coal use or making it more expensive would reduce economic growth in China. There is no doubt Chinese economic policy makers recognize this linkage and,
therefore, would be unwilling to switch to less carbon intensive fuels because such a switch would substantially drive up world energy prices and limit Chinese economic growth. For example, replacing industrial coal use in China outside the electric utility sector would require 26 quadrillion British Thermal Units (BTUs), which is equivalent to 12.3 million barrels of oil. Even half of this amount, 6 million barrels per day, would place an unsupportable burden on the world oil complex.

**Figure 4.4:**
*Energy Consumption Supplied by Coal and Coke by Sector, 2006*

With growing transportation requirements, such a switch from coal to reduce carbon emissions, is simply impossible, particularly since the industrial sector will likely continue to grow as the vast interior of the country develops, building infrastructure and the industrial base. The next few sections take a closer look at the industries that will support this effort: iron and steel, concrete and non-metallic minerals, and chemicals and plastic materials.

**Energy for Materials Production in China**

Materials are the building blocks of economic development and even for knowledge-based economies, they remain important. Advances in computers and the widespread adoption of information technology have spurred productivity growth, which has generated significant income gains and wealth accumulation over the past decade. Another source of overall productivity growth has been efficiency improvements in basic manufacturing industries, such as steel. Productivity growth has enabled producers to
expand their stocks of plant and equipment and consumers their stocks of housing, automobiles, and other household equipment. These tangible goods are made from materials. The resurgence of the North American economy since the early 1990s demonstrates that the linkage between economic growth and material use remains strong.

There are several classes of materials essential for economic development. These include biological materials, such as wood and fiber used to produce packaging, furniture and paper products. Metals including non-ferrous, such as aluminum, copper, brass, and bronze products and ferrous metals, including iron and steel are the next major class. Another major category of materials includes chemicals and plastics produced in most areas of the world from petrochemical feed stocks, such as ethylene. Manufactures use these materials to fabricate a huge array of durable and non-durable products. Finally, non-metallic minerals, such as cement for concrete production, sand and gravel for building and road materials, and soda ash for glass manufacturing represent the fourth major class of materials generally embodied in fixed structures or durable equipment.

The business of converting these raw materials into more refined states for fabrication into products, buildings, or other infrastructure is at the core of industrial economies around the world. These production processes involve breaking the chemical bonds of natural resources and rearranging the resulting matter into forms useful to mankind. To accomplish this transformation requires mechanical, chemical, and kinetic energy. Materials are the most energy intensive sectors of the economy. Building a modern society requires labor supplied by well-fed workers, materials to build machines and structures and energy for both. Chinese policy makers more than a quarter century ago identified the means—food, steel, and coal—to meet these ends. The next sub-sections focus on three key materials—steel, concrete and chemicals.

**Coal & the Rise of Iron and Steel in China**

Steel is the most prevalent industrial material in the world used in a wide array of manufactured goods, including automobiles, bridges, buildings, containers and thousands of other durable goods. This success reflects the low cost of steel in providing those attributes manufacturers demand. Steel is synonymous with strength, providing the backbone of infrastructure, such as skyscrapers and bridges. It is very versatile because it is easy to shape into many different forms.

The growth in steel production in China over the past decade has been explosive. During the late 1990s China began to consistently exceed 100 million tons in raw steel production, slightly ahead of total US steel production. During 2006, they produce four-times that amount, nearly 420 million tons, more than a third of world output of 1.24 billion tons (see Figure 4.5).

Steel production is energy intensive. There are two methods of producing steel—integrated steel making and scrap-based steel production using electric arc furnaces. The first uses raw iron ore in blast furnaces to produce pig iron, which is then subsequently smelted or converted. A key input to this process is a unique material called coke, which
is a nearly pure carbonaceous material produced from slowly burning or coking metallurgical grade coal in the absence of oxygen. The resulting coke provides fuel but most importantly serves as a chemical reductant and facilitates the physical balance of materials in the blast furnaces; options for substituting for coke are limited. Moreover, in scrap poor regions, such as China, integrated steel making is the only option. During 2006, China used over 230 million tons of coke in steel production and another 210 million tons as fuel in steel production. Plentiful supplies of steam and metallurgical grade coal enabled the quadrupling of steel output in China since the late 1990s.

**Figure 4.5:**
**Raw Steel production in China, 1978-2006 in millions of tons**

A breakdown of total energy used by the ferrous metals industries in China appears in Figure 4.6. As the chart vividly illustrates a very substantial share is supplied by coal and coke, accounting collectively for more than 87.5 percent of total energy used in this sector during 2006. Coke use alone is huge at over 235 million tons. Only 20-30 percent of this coke use could be replaced via injection of blast furnaces with pulverized steam coal or natural gas.

**Figure 4.6:**
**Energy Use in Chinese Steelmaking**
The industry also consumes another 200 million tons of coal for steam and power production. If this coal were not available, more than 2.2 million barrels of oil per day or 4.6 trillion cubic feet per year of natural gas would be required. Importing such large quantities of fuel would significantly boost world prices and dramatically increase the cost of steel production in China, which would raise material costs throughout the economy and contribute to lower productivity and economic growth. Electricity supplies over 11.4 percent with the remaining 1.1 percent coming from petroleum products.

China has been making significant progress improving the energy efficiency of steel production. For example, in 1999 Chinese steel producers used more than 1.3 tons of standard coal equivalent (SCE) energy to produce a ton of steel. In 2006, only 1.02 tons of SCE was used to produce one ton (see Figure 4.7). Despite these gains, the IEA sees that overall demand for steel will offset these efficiency gains and contribute to another doubling of energy use in steel production in China before it levels off by 2030.

This enormous surge in steel production will have long-run effects on China’s economy. At some point in the future, the steel currently put into use will come out in the form of recycled steel. As these iron and steel scrap resources become available, electric arc furnace based production will take root and expand, which will stimulate the demand for electricity and reduce direct coal consumption in coke and steel production.

If the United States experience can be any guide, this process can take upwards of 50-75 years to unfold. The important point is at some point in the future, the demand for electricity will surge for electric arc furnace based steel production. In the interim, China’s huge building boom will likely contribute to continued strong growth in steel
production. Coal will likely remain the fuel of choice, especially for coking but also as an inexpensive source for process heat and steam.

Non-Metallic Industries

The second largest consumer of energy from the industrial sector is non-metallic metals industries, producing cement, soda ash and other building materials. Soda ash is the raw material used to make glass. Like the iron and steel sector, coal provides a majority of the energy used in non-metallic minerals, comprising 77 percent of total energy use in this sector. The 3.8 quadrillion BTU of coal in this sector alone is equivalent to 1.8 million barrels of crude oil per day, which is roughly the oil output of Iraq, or 3.9 trillion cubic feet of natural gas, which is slightly more than Canadian natural gas exports to the United States. The next largest fuel is electricity at about 15 percent market share for this sector. Oil constitutes the remaining 8 percent of total energy use in this sector (Figure 4.8). Natural gas use is negligible in this sector.

Figure 4.8:

The main industry within non-metallic industries group is cement. Much of the growth in energy consumption in this sector is tied to the enormous building boom going on China, which is consuming vast quantities of cement, soda ash and other products (Figure 4.9).
Chemical Industries

The third most energy intensive industrial sector is the chemical industry. The broad use of a wide array of chemical products is the hallmark of an advancing economy. These products are used in thousands of consumer and producer products. In particular, one of the largest components is fertilizer products made from anhydrous ammonia. In the United States and Europe nearly all ammonia is synthesized from methane derived from natural gas.

In contrast, coal gasification is prevalent in China with more than 4,000 fixed-bed water gas systems built upon designs from the 1950s. These plants generate synthetic gas to produce a variety of chemicals. Most of these gasifiers are small and are located in rural areas to produce fertilizers for local agricultural production. Indeed, this is yet another result of Guofeng’s three-pronged strategy built around food, steel and coal. In this case, coal directly contributes to higher food production by using it to produce large quantities of inexpensive fertilizers. Once again, coal plays an important role in the doubling of fertilizer production in China since the mid-1990s. China is currently adopting modern gasification technologies to eventually replace these small facilities with larger more efficient plants.
China is leading a renaissance of coal-based chemical production. Prior to the advent of the modern petrochemical industry in the mid 20th century, coal was the main feedstock for chemical production in the world from 1850 to 1950. While petroleum offers a relatively pure feedstock for chemical production, the recent high cost of oil and technological advances in coal gasification are contributing to a resurgence of coal-based chemical production. These gasification technologies produce a synthesis gas (syngas) that can be treated with water to increase its hydrogen content. The resulting syngas can then be converted to ammonia, which is used to produce fertilizers, or to methanol that can be used to produce olefins, propylene and acetic acid, which are the basic building blocks for producing plastics and synthetic materials. As Figure 4.11 illustrates ethylene production has expanded nearly four-fold over the past decade, and this has been accomplished with virtually no natural gas.

Figure 4.10:
Sulfuric Acid and Fertilizer and Pesticide Production in China, 1978-2006

Figure 4.11:
Ethylene and Caustic Soda Production in China, 1978-2006
Instead, to meet this higher demand for chemical feed stocks, China has turned to coal. As Figure 4.12 illustrates, most of the increase in energy use by the chemical industry in China has been supplied with coal with consumption rising from slightly less than 2 quadrillion BTU in 2002 to over 3 quads in 2006, a 50 percent increase in just four years.

**Figure 4.12:**
Energy Use by Chemical Industries in China, 1999-2006

This expansion in the use of coal for chemical production in China will continue. As the Table 4.12 below indicates, coal-based ammonia production will more than double in coming years. These planned facilities alone will require more than 20 million tons of additional coal per year. This use of coal to produce chemical fertilizers will help insulate China from cost-push inflation of raw material costs that is currently weighing heavily on North American and European manufacturers of these products, which is contributing to a migration of these industries to access natural gas reserves in the Middle East.
Table 4.2:
Existing and Planned Coal-Based Ammonia Plants in China

<table>
<thead>
<tr>
<th>Owner</th>
<th>Plant Name</th>
<th>Process</th>
<th>Start</th>
<th>Capacity (MWt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lu Nan Chemical Industry (Group) Co./CNTIC</td>
<td>Lu Nan Ammonia Plant</td>
<td>GE</td>
<td>1993</td>
<td>71.8</td>
</tr>
<tr>
<td>Weihe Fertilizer Co.</td>
<td>Shaanxi Ammonia Plant</td>
<td>GE</td>
<td>1996</td>
<td>278.9</td>
</tr>
<tr>
<td>Henan</td>
<td>Puyang Ammonia Plant</td>
<td>Sasol Lurgi</td>
<td>2000</td>
<td>312.0</td>
</tr>
<tr>
<td>China National Technology Import Co. (CNTIC)</td>
<td>Shaanxi Ammonia Plant</td>
<td>Sasol Lurgi</td>
<td>1987</td>
<td>312.0</td>
</tr>
<tr>
<td>Huainan General Chemical Works</td>
<td>Hefei City Ammonia Plant</td>
<td>GE</td>
<td>2000</td>
<td>191.4</td>
</tr>
<tr>
<td>Haolianghe Ammonia Plant</td>
<td>Haolianghe Ammonia Plant</td>
<td>GE</td>
<td>2004</td>
<td>201.6</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>1367.7</td>
</tr>
</tbody>
</table>

Planned Facilities

<table>
<thead>
<tr>
<th>Owner</th>
<th>Plant Name</th>
<th>Process</th>
<th>Start</th>
<th>Capacity (MWt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinopec/Shell</td>
<td>Dong Ting Ammonia Plant</td>
<td>Shell</td>
<td>2005</td>
<td>466.2</td>
</tr>
<tr>
<td>Sinopec/Shell</td>
<td>Hubei Ammonia Plant</td>
<td>Shell</td>
<td>2005</td>
<td>466.2</td>
</tr>
<tr>
<td>Liuzhou Chemicals</td>
<td></td>
<td>Shell</td>
<td>2005</td>
<td>232.0</td>
</tr>
<tr>
<td>Shuanghuan Chemicals</td>
<td></td>
<td>Shell</td>
<td>2005</td>
<td>191.0</td>
</tr>
<tr>
<td>Anqing Sinopec</td>
<td></td>
<td>Shell</td>
<td>2005</td>
<td>465.0</td>
</tr>
<tr>
<td>Yuntianhua Chemicals</td>
<td></td>
<td>Shell</td>
<td>2006</td>
<td>465.0</td>
</tr>
<tr>
<td>Yunzhanhua Chemicals</td>
<td></td>
<td>Shell</td>
<td>2006</td>
<td>465.0</td>
</tr>
<tr>
<td>Jinling</td>
<td></td>
<td>GE</td>
<td>2005</td>
<td>287.1</td>
</tr>
<tr>
<td>China 4</td>
<td>China 4</td>
<td>GE</td>
<td>2005</td>
<td>287.1</td>
</tr>
<tr>
<td>China 3</td>
<td>China 3</td>
<td>GE</td>
<td>2005</td>
<td>287.1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>3611.7</td>
</tr>
</tbody>
</table>

Source: National Energy Technology Laboratory (2005)

Another key intermediate product that can be produced from coal via gasification is methanol, which can be purified easily by distillation and converted into so-called olefins — ethylene and propylene — acetic acid, and various other chemicals. These later feedstocks are used to produce plastic materials for durable and non-durable goods. As China becomes a consumer driven society using more packaged foods and other consumer products, the demand for plastics will continue its explosive growth and with it spurring the demand for ethylene and other plastic chemical feed stocks. Total planned capacity of coal-to-methanol plants in China is more than 8.1 million tons of methanol output per year. These plants will require almost 70 million tons of coal per year.

Major increases are also underway in coal-based acetic acid production. Acetic acid is used in the production of polyethylene terephthalate mainly in soft drink bottles; cellulose acetate, mainly for photographic film; and polyvinyl acetate for wood, as well as many synthetic fibres and fabrics. Currently China has about 850,000 tons of coal-based acetic acid production. This capacity will rise to almost 5.8 million tons over the next decade and will require more than 50 million tons of coal per year (Table 4.4).
### Table 4.3:
Planned Coal-Based Methanol-to-Olefins Plants in China

<table>
<thead>
<tr>
<th>Owner</th>
<th>Location</th>
<th>Capacity (tpa)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaanxi Xinxing Chemical</td>
<td>Yulin, Shaanxi</td>
<td>10,000</td>
<td>Test Unit</td>
</tr>
<tr>
<td>Shenhua Group</td>
<td>Baotou, Nei Mongol</td>
<td>600,000</td>
<td>Under construction</td>
</tr>
<tr>
<td>Shenhua Group</td>
<td>Yulin, Shaanxi</td>
<td>1,000,000</td>
<td>Feasibility Study</td>
</tr>
<tr>
<td>Shenhua Group</td>
<td>Ningdong, Ningxia</td>
<td>520,000</td>
<td>Start-Up 2009</td>
</tr>
<tr>
<td>Zhongyi Group</td>
<td>Erdos, Nei Mongol</td>
<td>600,000</td>
<td>Construction Start 2007</td>
</tr>
<tr>
<td>Ningxia Coal Industry Group</td>
<td>Yinchuan, Ningxia</td>
<td>550,000</td>
<td>Start-Up 2009</td>
</tr>
<tr>
<td>Ningxia Baota Petrochemical</td>
<td>Ningdong, Ningxia</td>
<td>600,000</td>
<td>Feasibility Study</td>
</tr>
<tr>
<td>Datang International Power Generation</td>
<td>Nei Mongol</td>
<td>460,000</td>
<td>Feasibility Study</td>
</tr>
<tr>
<td>Gail/Shaanxi Huashan Chemical Industry</td>
<td>Shaanxi</td>
<td>600,000</td>
<td>Feasibility Study</td>
</tr>
<tr>
<td>Huating Coal Group</td>
<td>Gansu</td>
<td>600,000</td>
<td>Feasibility Study</td>
</tr>
<tr>
<td>Henan Rongxing Industrial</td>
<td>Henan</td>
<td>1,500,000</td>
<td>Start-Up 2008</td>
</tr>
<tr>
<td>Shaanxi Investment Group</td>
<td>Xianyang, Shaanxi</td>
<td>520,000</td>
<td>Feasibility Study</td>
</tr>
<tr>
<td>Zhonghua Yiye Energy Investment Co.</td>
<td>Yulin, Shaanxi</td>
<td>500,000</td>
<td>Feasibility Study</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>8,060,000</td>
<td></td>
</tr>
</tbody>
</table>

Source: Technon OrbiChem (2005) and various press releases

### Table 4.4:
Planned Coal-Based Acetic Acid Plants in China

<table>
<thead>
<tr>
<th>Owner</th>
<th>Location</th>
<th>Start</th>
<th>Capacity (MWth)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jiangsu Sopo</td>
<td>Zhenjiang, Jiangsu</td>
<td>2008</td>
<td>800,000</td>
</tr>
<tr>
<td>Shanghai Wujing</td>
<td>Wujing, Shanghai</td>
<td>2008</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Yankuang Cathay</td>
<td>Tengzhou, Shandong</td>
<td>2015</td>
<td>400,000</td>
</tr>
<tr>
<td>BP YPC Acetyl</td>
<td>Nanjing, Jiangsu</td>
<td>2008</td>
<td>500,000</td>
</tr>
<tr>
<td>Henan Yongmei</td>
<td>Henan</td>
<td>2006</td>
<td>300,000</td>
</tr>
<tr>
<td>JV – Zhengbang Group</td>
<td>Henan</td>
<td>2007</td>
<td>200,000</td>
</tr>
<tr>
<td>Celanese</td>
<td>Nanjing, Jiangsu</td>
<td>2007</td>
<td>600,000</td>
</tr>
<tr>
<td>Guizhou Crystal</td>
<td>Guiyang, Guizhou</td>
<td>2007</td>
<td>36,000</td>
</tr>
<tr>
<td>Shenyang Coal Industry group</td>
<td>Shenyang, Liaoning</td>
<td>2009</td>
<td>300,000</td>
</tr>
<tr>
<td>JV – Zhengbang Group</td>
<td>Henan</td>
<td>2010</td>
<td>200,000</td>
</tr>
<tr>
<td>Arhui Huaihua</td>
<td>Huainan, Anhui</td>
<td>&gt; 2010</td>
<td>200,000</td>
</tr>
<tr>
<td>Yongcheng Coal &amp; Electricity</td>
<td>Shangqui, Henan</td>
<td>Planned</td>
<td>400,000</td>
</tr>
<tr>
<td>Shandong Hengtong</td>
<td>Linyi, Shandong</td>
<td>Planned</td>
<td>200,000</td>
</tr>
<tr>
<td>Tianqiao Huabohei</td>
<td>Yulin, Shaanxi</td>
<td>Planned</td>
<td>150,000</td>
</tr>
<tr>
<td>Zhongyuan Dahua</td>
<td>Henan</td>
<td>Planned</td>
<td>300,000</td>
</tr>
<tr>
<td>Shandong Hualu Hengsheng</td>
<td>Linyi, Shandong</td>
<td>Planned</td>
<td>10,000</td>
</tr>
<tr>
<td>Shanxi Jiaohua</td>
<td>Taiyuan, Shanxi</td>
<td>Planned</td>
<td>150,000</td>
</tr>
<tr>
<td>Henan Authorities</td>
<td>Henan</td>
<td>Planned</td>
<td>5,756,000</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>5,756,000</td>
</tr>
</tbody>
</table>
Virtually all of these coal-based chemical plants will generate excess electricity for sales to the grid. The total amount of these power sales depends upon many plant and site-specific considerations. Whatever this amount, these poly-generation facilities will prove critical in alleviating the critical power shortages that afflicted many regions in China over the past several years. Coal based chemical production will also reduce the need for imported natural gas (3 TCF) and petroleum (1.4 mmbd). In summary, coal-based chemical production in China will expand significantly over the next decade consuming at least an additional 140 million tons of coal per year.

The Next Logical Step: Chemical Fuel Production in China

This expertise in coal gasification proven over the past 30 years is providing a basis for China to expand into coal-based chemical fuel production. China’s first forays into the direct coal liquefaction processes began in the 1970’s with research at the China Coal Research Institute. A test facility used four Chinese coals to produce liquid fuels. Based upon these tests, the Institute collaborated with coal research groups in Germany, Japan and the United States. With the knowledge learned in these collaborations, the Central Government authorized Shenhua Group Corporation to implement the first coal liquefaction commercial prototype demonstration (IEA, 2004). Subsequently, Shenhua and other groups (e.g. Taixi) have moved steadily toward the design and construction of an increasing number of CTL plants. Further, Shenhua and several other companies have established a research facility in Tianjin to study new ways of liquefying coal.

Shenhua’s first commercial plant has a daily handling capacity of 6,000 tons, but will be expanded to 3 million tons per annum in a second stage expansion. This facility is unique because it is the world’s first direct coal liquefaction plants that uses solvents to liquefy coal into a range of liquids, including diesel fuel, gasoline or jet fuel. While there are many coal-to-fuels plants in the planning stage, there are four at this time that are either under construction or in the advanced stages of engineering feasibility evaluation. These plants are reported below in the following table. These four plants would produce more than 14 million tons of oil equivalent per year or more than 270,000 barrels per day and consume roughly 60 million tons of coal per year. In principle, these plants will have the same carbon dioxide emissions as a conventional petroleum refinery because direct liquefaction process is thermally more efficient than indirect coal liquefaction.

China is also pioneering the production of dimethyl ether (DME) synthesized from methanol produced from coal. DME is an excellent substitute for diesel fuel oil and liquid propane gas (LPG). The energy infrastructure requirements for DME are very similar to LPG. The extensive LPG network in China will likely facilitate widespread adoption of DME. As the Table below illustrates, there are several very significant DME projects planned in China. These planned projects could produce more than 7 million tons of DME per year. The associated coal requirements would approach 30 million tons per year. Collectively the capacity of these combined plants are shown below in Figure 4.13.
This supportive policy environment and favorable economic conditions imply a robust future for coal conversion to fuels and chemicals in China. Based upon the estimates reported above, China will most likely consume over 230 million tons of coal in these activities. If Shenhua’s expansion strategy is adopted by many other large coal producers, this market could expand to almost 700 million tons by 2020 and roughly 1.4 billion tons in 2030 (see Figure 4.14).

Figure 4.14:
Potential Coal use for Coal to Chemicals and Transportation Fuels in China, 2012-203
Works Consulted


