Ghada Ahmed *is a Senior Research Analyst with the Center on Globalization, Governance & Competitiveness (CGGC) and lecturer at the Sanford School of Public Policy Center DCID at Duke University. Her research applies the global value chains framework to analyze countries, industries, and firms to address economic, social, and environmental growth challenges. She holds an M.A. in International Development Policy from Duke University and a B.A. in Business Administration from American University in Cairo. Ms. Ahmed can be contacted at ghada.ahmed@duke.edu.*

Ajmal Abdulsamd *is a Research Analyst with the Center on Globalization, Governance & Competitiveness (CGGC) at Duke University. He received his M.A. in International Development Policy from the Sanford School of Public Policy at Duke University. He has over 12 years of international development experience working for various international development organizations and the United Nations. His current research at the CGGC focuses on the value chains of energy in the U.S. and food security in the Middle East and North Africa.*

Gary Gereffi *is Professor of Sociology and Director of the Center on Globalization, Governance & Competitiveness at Duke University. He received his B.A. degree from the University of Notre Dame and his M.Phil. and Ph.D. degrees from Yale University. Dr. Gereffi's books include* Free Trade and Uneven Development: The New Offshoring of Jobs and Global Development *(International Institute of Labor Studies, 2006);* Manufacturing Climate Solutions: Carbon-Reducing Technologies and U.S. Jobs *(Center on Globalization, Governance & Competitiveness, Duke University, 2008); and* Global Value Chains in a Postcrisis World: A Development Perspective *(The World Bank, 2010). His research interests deal with the competitive strategies of global firms, the governance of global value chains, economic and social upgrading, and the emerging global knowledge economy.*

Jack Daly *is a Research Associate with the Center on Globalization, Governance & Competitiveness (CGGC) at Duke University. He is a 2012 graduate of N.C. State's Masters of International Studies program. His current research at the CGGC focuses on the value chains of energy in the U.S., the role of various industries in North Carolina in the global economy, and food security and energy in the Middle East and North Africa.*

What Role Can Coal Play in the United States' Energy Future?

A wider collaboration framework among the various value chain actors may provide a technology advancement pathway. However, for this collaboration to occur, lead coal companies need to expand their business model beyond coal mining into the downstream coal conversion business to include higher-value coal products and by-products.

Ghada Ahmed, Ajmal Abdulsamad, Gary Gereffi and Jack Daly

I. Introduction

Coal is a key fuel in power generation in the United States and in Asia and Africa, where it continues to power developing economies (Keith & Bhattaharya, 2011). Its popularity depends on a number of factors: the relative cost and availability of alternative fuels; environmental regulations; rate of economic growth; and the power generation technologies already in use (Coal Industry Advisory Board, 2006). The fuel draws considerable criticism, particularly for its contribution to soil erosion, loss of biodiversity and high carbon dioxide emissions across the value chain.[1] Nevertheless, improvements in technology in coal mining and coal use can significantly lower its negative environmental effects.

In the U.S., the coal industry is coping with declining demand as the nation burns less coal to generate electricity (**Figure 1**). Electric power is the largest single source of coal consumption, accounting for 90 percent of overall use, but increasing production costs and the availability of cheap natural gas is hurting coal's competitiveness. Leading companies are hoping to compensate for sluggish U.S. demand by sending more coal to

 1040-6190/$–see front matter http://dx.doi.org/10.1016/j.tej.2014.03.008

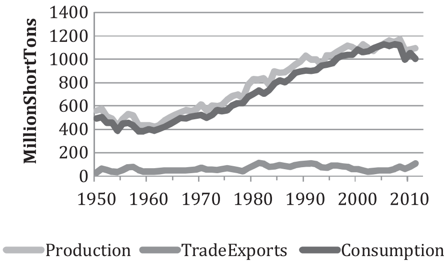


Figure 1: Coal Production, Consumption and Exports, 1950–2011

Asia; however, only 10 percent of U.S. production is currently exported overseas, and the capacity of U.S. ports is limited. These trends are driving new trading patterns, fuel switching, technology development, and price shifts that coal buyers and suppliers must consider.

The decreasing share of coal in power generation implies that the future of coal depends on technologies that change the way we manage and use coal. In particular, advances such as carbon capture and utilization, coal gasification, and coal liquefaction technologies hold promise. Clean energy technologies (or ''clean tech'') grew in recent years because of private innovation, entrepreneurship and critical public sector support in the form of tax credits, grants, and loan guarantees (Jenkins et al., 2012). However, nearly all clean technologies in the U.S. remain reliant on subsidies or other supportive policies to expand their foothold in energy markets. Many of these incentives are poised to expire, with total federal clean technology spending in the U.S. projected to fall from $44.9 billion in 2009 to $11 billion in 2014.

II. Overview of the U.S. Coal Industry

A. U.S. coal production and consumption

The United States holds the world's largest estimated recoverable reserves and is the second-largest producer and consumer of coal after China (EIA, 2011a,b,c,d). In 2011, total revenues for the U.S. coal market reached $57.7 billion (MarketLine, 2012). Historically, coal was the largest and least expensive source of electric power generation in the U.S. for more than 60 years; however, in April 2012, coal's share of electric power generation dropped to 32 percent, putting it level with natural gas as the most popular source of electric power generation.

B. Coal supply regions

There are three primary coal regions in the U.S.: the Appalachian region, the Interior region, and the Western region, with several subregions located within each (Gluskoter et al., 2009). Coal regions may differ in the types and quality of coal and mines (EIA, 2011a,b,c,d). For example, Northern Appalachia coal, rated at 13,000 Btu per pound, is the highest quality, while Powder River Basin coal (from Wyoming and other Rocky Mountain states) is the lowest quality, with a rating of just 8,800 Btu per pound.

Over the last couple of decades, much of the country's coal production has shifted from underground mining in the Appalachian region to surface mining in Western states. There are a number of reasons behind this move, including rising underground mining costs, thinning coals seams in Appalachia, as well as the boom in shale gas in the region. As a result of these changes, the Western region is now the single largest source of inexpensive coal in the U.S., accounting for more than half of total supply. Buoyed by the mammoth Powder River Basin (PRB), Wyoming is the largest single coal-producing state in the nation. Back east, coal remains an important part of the Appalachian economy—more than one-third of U.S. coal still comes from the region. Coal mined in Appalachia is primarily used for steam generation to produce electricity, metal production and exports.

III. Coal Value Chain

A. Value chain overview

The value chain (VC) framework maps industry and firm-level activities and supply networks that bring a product

 1040-6190/$–see front matter http://dx.doi.org/10.1016/j.tej.2014.03.008

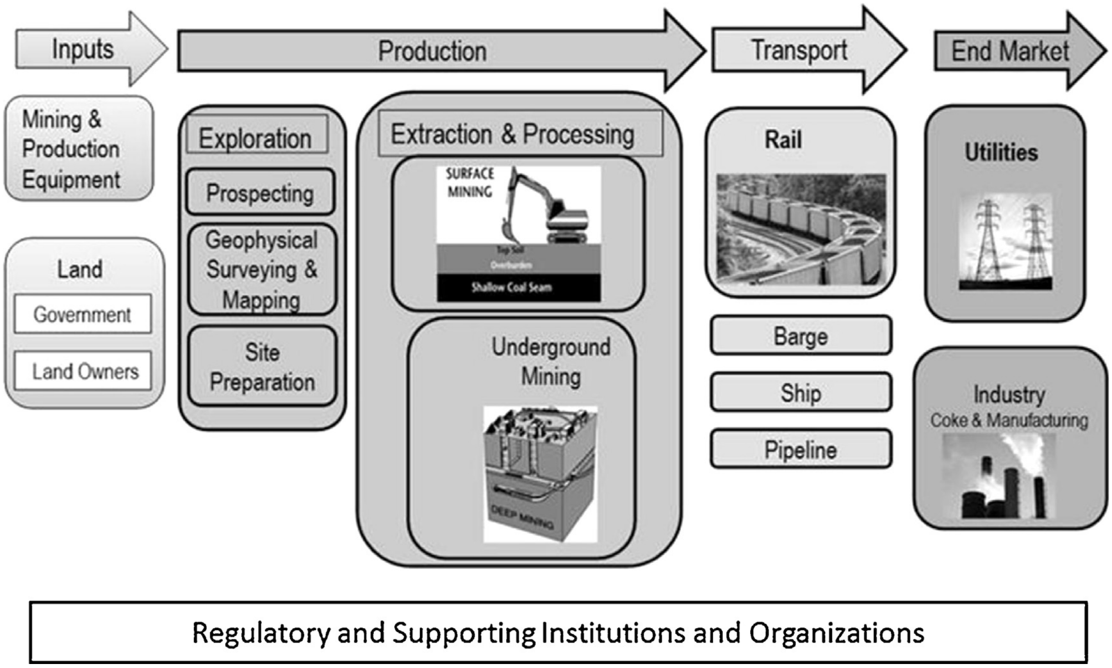


Figure 2: The Coal Industry Value Chain
Source: Authors.

from conception to its end market. The coal value chain segments in Figure 2 (from left to right) are coal production, transportation and coal utilization markets.

B. Coal production

The coal production segment of the chain is fairly consolidated with the top five companies accounting for 55.4 percent of U.S. coal production in 2010 (EIA, 2011a,b,c,d). The lead firms are Peabody Energy, Arch Coal, Cloud Peak Energy, Alpha Natural Resources, and CONSOL Energy. The individual companies differ in their production costs, delivery costs to key markets, regional footprints, and the quality of coal produced. Companies in the chain engage in strategic acquisitions, joint ventures and investments to expand their global footprint.

The lead firms maintain a transaction-based relationship with their suppliers and buyers in the chain. Suppliers to coal producers offer highly specialized services and equipment that account for about one-third of revenues (Mining Journal, 2012).

Additionally, the five lead firms are characterized by high capital and operations costs. Primary expenses include labor, repair and maintenance, royalties, freight and handling costs, and taxes. Firms use different mining techniques to extract coal, including long-wall mining (underground) and high-wall mining (surface). Companies are regulated on a number of policies, from mine safety and land reclamation guidelines to environmental laws. The firms focus on the production and selling of thermal coal to power generators and metallurgical coal to steel manufacturing, but not on transforming coal into higher-value-added products. This contrasts with other fossil fuel suppliers, which are vertically integrated and invest in refining and higher value products.

C. Transport

About 71 percent of coal is transported to market by rail (Association of American Railroads, 2011). Coal accounts for approximately 45 percent of railroad carloads and 25 percent of the annual revenues of freight rail Class I companies (Association of American Railroads, 2011). Lead firms in Class 1 rail are Burlington Northern Santa Fe (BNSF), CSX Transportation, Union Pacific Railroad, and Norfolk Southern.

 1040-6190/$–see front matter http://dx.doi.org/10.1016/j.tej.2014.03.008

Trucks are often the quickest and easiest way to move coal. They are used in shorter hauling, moving smaller quantities, and can access loading points or nearby electric and industrial plants. Barges only move coal from mines that have access to the rivers. They are slower but more cost-effective and fuel-efficient.[2] About 20 percent of the coal used in U.S. electricity generation travels by inland waterways. Many coal companies use a multimodal delivery system that includes rail (short and long haul), trucks, railcars and barges. Coal transportation cost, especially in the west, can exceed mining cost (EIA, 2012a,b).

Firms in the transport segment, particularly the Eastern railroads, CSX and Norfolk Southern, have lost substantial share of their coal market due to declining coal demand by utilities. CSX's domestic and export coal volumes were down about 25 percent and 5 percent, respectively, year-on-year in the fourth quarter of 2012.

D. End market

Demand for coal depends on an array of factors, from whether a country is experiencing economic growth (higher economic growth implies higher energy consumption, which usually increases demand for coal) to the cost of competing energy sources to the presence of environmental policies governing emissions and hazardous waste.[3] The U.S. power sector is the single largest consumer of coal (EIA, 2011a,b,c,d) while natural gas, nuclear, oil, and renewables are the largest competitors (PWC, 2009). Electric utilities are composed of investor-owned utilities (37 percent), public utilities (10 percent), federal utilities (6 percent), cooperatives (5 percent) and non-utility generators (41 percent), all of which operate in regulated and/or competitive electricity markets (APPA, 2012).

The recent drop in natural gas prices resulted in an unprecedented coal-gas fuel substitution in power generation.

Since the 1990s, increasing deregulation has been transforming utilities from vertically integrated monopolies to functionally unbundled entities with a competitive market for power generation (Energy Information Administration, 2002). In 2010, the top five firms in the chain accounted for about 17 percent of approximately 4,125 million MWh of total net generation (EIA, 2011a,b,c,d). The lead electric power firms are Duke Energy Corporation, Southern Company, American Electric Power, Exelon Corp., and NextEra Energy Inc. Those firms differ in their coal-fired capacity, which can range from as low as 3 percent to about 67 percent.

Since the 1990s, power generators have slowed their demand for new conventional and/or advanced coal-fired technologies (RAND, 2011) while also expanding the number of natural gas and more efficient combined-cycle units (EIA, 2011a,b,c,d). The recent drop in natural gas prices hastened the deployment of natural gas units, resulting in an unprecedented coal-gas fuel substitution in power generation (EIA, 2000, 2011a,b,c,d, 2012a,b). At the same time, many utilities are facing the imperative of replacing their aging infrastructure, which suffers from decades of underinvestment (Flaherty et al., 2012). Many firms are opting to retire their older and inefficient coal units rather than retrofit them with environmental controls (Credit Suisse, 2010; NERC, 2011; The Brattle Group, 2012).

Beyond utility companies, the steel industry is the second largest user of coal and coal by-products to make steel for automobiles, bridges, and buildings (Spiegel, 2006). Nearly 70 percent of global steel production depends on coal (Ernst & Young, 2011). Other coal users include concrete, cement, aluminum, paper, chemical, wood, and roofing companies. Coal gas by-products such as methanol and ethylene are used to make products such as plastics, medicines, fertilizers and tar.

 1040-6190/$–see front matter http://dx.doi.org/10.1016/j.tej.2014.03.008

E. Value chain dynamics

Coal mining and burning in the U.S. are regulated at the federal and state levels to improve mine safety and reduce the environmental hazards associated with production. Regulations, market dynamics, and labor issues have all influenced the value chain over the last three decades (Gluskoter et al., 2009)—more stringent mine safety and reclamation laws forced many small mines out of operation in the 1970s; falling coal prices caused inefficient producers to close in the 1980s; and pressure to reduce costs motivated producers to seek economies of scale by forming larger companies and shift production from Appalachia to PRB beginning in the 1990s (McNerney et al., 1998).

Long-term competitive contracts of at least one year govern interactions in the chain between producers and buyers. The terms of these contracts vary by customer, including differing price adjustments, coal quality, and quantity requirements, compliance with regulatory changes and termination procedures (Alpha Natural Resources Inc., 2012; Arch Coal Inc., 2012; Cloud Peak Energy Inc., 2012; Consol Energy Inc., 2012; Peabody Energy, 2012). The cost of coal-burning technology, transportation, public policy, monopolistic behavior of buyers, and monopolistic behavior of suppliers are factors that influence the price of coal and terms of contract. Higher use of natural gas in power generation reduced the share of long-term contract trading from over 90 percent in 2011 to less than 40 percent in 2013; as a result, most coal is now traded on shorter-term contracts (six months to one year) and spot contracts (one- or two-month transactions) (IEA, 2013).

Coal's main competitive advantages compared to other fossil fuels are that it is cheap and available (Grubert, 2012). In the past, increased demand for coal brought new investors to the coal industry and promoted the development of new mines. These factors resulted in added production capacity throughout the industry, which led to increased competition and lower coal prices (Grubert, 2012). However, technological advances in the gas industry have made natural gas less expensive and more readily available (Grubert, 2012).

Winners and losers in the chain vary according to their degree of dependence on coal, geographic focus, and ability to address market and regulatory changes. Competition from natural gas and fuel diversification in electric power generation changed power in the chain from supplier-driven to buyer-driven. Coal producers are highly dependent on their sales to electric power generators, with about 30 to 40 percent of their revenues coming from their top five to 10 customers (Alpha Natural Resources Inc., 2012; Arch Coal Inc., 2012; Cloud Peak Energy Inc., 2012; Consol Energy Inc., 2012; Peabody Energy, 2012). The future of coal hinges on clean-tech developments that reduce emissions and expand utilization via advanced technologies such as carbon capture utilization and storage, coal to gas, coal to liquids and coal to chemicals. **Figure 3** summarizes the coal VC dynamics.

Value Chain Dynamic	Influence on the Chain
Increasing costs in Appalachian coal mining	Regional shift from Appalachia to lower cost, low sulfur content PRB coal
Falling domestic consumption & rising global demand for coal	U.S. coal suppliers are increasing their global footprint through exports and acquisitions
Deregulation & restructuring of electric power market	Lead power generators focus on cost competitiveness and contract flexibility
Low natural gas prices & shale gas discoveries	An unprecedented shift to natural gas in electric power generation
Coal fired power plant retirement	Power generators retiring inefficient and older coal plants
Future of increased coal use in the U.S. is bleak	Commercialization of advanced coal technology can diversify coal utilization requires higher collaboration and investments from coal companies & other stakeholders

Figure 3: Summary of VC Dynamics for Coal
Source: Authors.

IV. Future of Coal Use

In September 2012, a difficult U.S. coal market forced lead firms such as Alpha Natural Resources to make production cuts, close mines, and eliminate a large

 1040-6190/$–see front matter http://dx.doi.org/10.1016/j.tej.2014.03.008

Please cite this article in press as: Ahmed G, et al. What Role Can Coal Play in the United States' Energy Future?, Electr. J. (2014), http://dx.doi.org/10.1016/j.tej.2014.03.008

number of jobs (Associated Press, 2012).[4] Market pressures suggest that long-term coal use hinges on technology investment and strategic collaborations to make burning coal cleaner. The availability of advanced coal technologies is a function of how well industry actors can develop and commercialize the technology to reduce emissions footprints by 2050 (Schwartz, 2012).

A. Advanced coal technology

Advanced coal technology refers to the new generation of coal-based processes and technologies that reduce emissions and/or transform coal to expand its use beyond electric power generation. There are many government-sponsored programs between research institutions and companies that are working to improve existing coal technologies (Spiegel, 2006). These technologies focus on carbon capture, use and storage, coal gasification, coal liquefaction, combustion (including oxy-combustion and advanced supercritical combustion), and the use of coal by-products and carbonization for advanced material.

The U.S. has the largest number of carbon capture and storage projects in the world (Global CCS Institute), followed by Europe and China. However, the business case for many of these projects has been hurt by reduced technology investments, the absence of a comprehensive regulatory framework with incentives for CCS development, and the declines in natural gas prices (Global CCS Institute, 2012).

Coal gasification and liquefaction technologies have been known for some time. Their products can range from transportation fuels and gases to valuable chemicals that can be used in the industrial gas, fertilizer, plastics, rubber, and other industries (Spiegel, 2006).

Market pressures suggest that long-term coal use hinges on technology investment and strategic collaborations to make burning coal cleaner.

Private industry and the U.S. Department of Energy (DOE/NETL) identified coal as a potential source of replacement for olefins (ethylene, propylene, butadiene) and for aromatics (benzene, toluene, xylenes) (Bajura, 2012). However, investment in coal conversion technologies will remain contingent on its competitiveness against petroleum-based processes.

B. Lead firms in advanced coal

Firms in the gasification and coal-to-liquids technologies value chain are typically large and diversified global actors. Their core business is mostly in the chemicals, oil, and gas industries. These firms also maintain proprietary licenses over the technology modules for coal gasification and liquefaction plants. In the U.S., the leading firms include Basin Electric Cooperative, Eastman Chemical Company, Koppers Inc., and Rentech (Spiegel, 2006).

Chemical manufacturing firms, or industrial gas producers, such as Air Products and Chemicals, Inc., Praxair, Inc., and The Linde Group, are major players in the design and manufacturing of air separation units, gas processing, hydrogen recovery and purification. These firms also serve global customers in chemical and petrochemical manufacturing, oil and gas recovery, processing and coal gasification, and liquefaction industries. These companies are predominantly disengaged from downstream applications of synthetic gas.

Oil companies have long been involved in gasification technology development to meet the hydrogen needs of their refineries. Royal Dutch Shell is a major supplier of gasification technologies worldwide. In 2010, Shell gasifiers were installed in approximately 42 plants across 15 countries; they now account for 30 percent of total installed gasification capacity worldwide (NETL, 2012). In addition, Sasol Ltd., Exxon Mobil Corporation,

 1040-6190/$–see front matter , http://dx.doi.org/10.1016/j.tej.2014.03.008

and Rentech Inc. are major synthetic gas and oil producers. Unlike the industrial gas producers, these firms are engaged in the downstream industrial applications of synthetic gas, including refinery, production, and distribution of petrochemical products.

C. Strategic collaboration

Relationships between firms in the coal value chain are complex. Strategic collaboration among actors is limited and insufficient to address technology requirements that would mitigate environmental and market challenges. Coal companies focus on digging and processing the fossil fuel and selling the product to utilities. Their growth strategy has been to focus on expanding exports to burgeoning Asian markets while also investing in technologies that reduce operating costs. Investments in advanced coal use have been limited to a few firms and are not sufficient to meet increasing environmental pressures.

The long-term sustenance of the coal industry depends on addressing technology constraints in coal use and diversification into higher-value products. Industries in the coal value chain need to develop adaptive measures in ways that can contribute to the U.S. economy and local economic development in key supply regions. State-industry partnerships may also be feasible and offer potential pathways in regions where local economies are reliant on coal. This will involve operating through collaborative and integrated industrial networks while also expanding growth strategies to include non-traditional uses of coal. Collaboration in research and demonstration projects and technology transfer are important components of product stewardship by coal producers

and users that can enhance performance along the value chain (Coal Industry Advisory Board, 2006).

The type of collaboration that promotes advanced technology development requires a paradigm shift among the coal value chain actors, especially individual firms. Technology leadership among coal producers is more likely to occur among the lead players, making the future existence of smaller coal competitors uncertain.[5]

While lead coal players have limited downstream investments beyond mining in advanced coal technology, there are some examples that could provide a blueprint for a more sustainable coal future—for example Peabody recently formed a joint venture with ConocoPhillips to advance the development of a coal-to-gas facility in Kentucky. The facility is projected to produce 1.6 trillion cubic feet of gas over its first 30 years of operation and will be fueled by 2.5 million tons of coal annually (Peabody Energy, 2012). And the Chinese Shenhua Group is partnering with other public and private organizations to advance coal to gas, coal to chemical and coal-to-carbon utilization and management.

V. Conclusion

The coal industry is facing unprecedented challenges that range from high production costs to more stringent environmental regulations to the availability of cheap natural gas. In order for coal to remain part of a diversified energy portfolio, advanced coal technology must be developed and commercialized. Federal support for the technology is limited, which means that value chain actors will need to identify pathways to collaborate and invest in technology development and commercialization. Progress can be made by collaborating on technologies that improve efficiency, reduce emissions and contribute to the development of a more diverse and secure energy future.

Existing partnerships are limited and inadequate for long-term sustainable coal use. Companies will need to expand beyond traditional strategies and become dynamic and proactive players in advanced coal technology. Moreover, expanding and building partnerships with other industries such as the chemical and oil and gas sectors is also necessary to expand coal use beyond electric power. These activities can eventually lead to the successful commercialization of advanced coal technology and a more diversified coal market.

References

Alpha Natural Resources Inc., 2012. Form 10-K, Annual Report for the Fiscal Year Ended December 31, 2011. Alpha Natural Resources, Inc.

APPA, 2012. Electric Power Statistics. American Public Power Association.

Arch Coal Inc., 2012. Form 10-K, Annual Report For the Fiscal Year Ended Dec. 31, 2011. Arch Coal Inc.

Associated Press, 2012. Alpha Closing 8 Coal Mines, Cutting 1, 200 Jobs. USA Today.

Association of American Railroads, 2011. Class I Railroad Statistics. Statistics and Publications. Association of American Railroads (AAR), Washington, DC 2012.

Bajura, R.A., 2012. Harnessing Coal's Carbon Content to Advance the Economy, Environment and Energy Security. National Coal Council.

Cloud Peak Energy Inc., 2012. Form 10-K, Annual Report For the Fiscal Year Ended December 31, 2011. Cloud Peak Energy Inc.

Coal Industry Advisory Board, 2006. Case Studies in Sustainable Development in the Coal Industry. International Energy Agency.

Consol Energy Inc., 2012. Form 10-K, Annual Report For the Fiscal Year Ended December 31, 2011. Consol Energy Inc.

Credit Suisse, 2010. Growth from Subtraction: Impact of EPA Rules on Power Markets. Credit Suisse.

DOE/NETL, 2011. DOE/NETL Advanced Carbon Dioxide Capture R&D Program: Technology Update. National Energy Technology Laboratory, U.S. Department of Energy.

EIA, 2000. The Changing Structure of the Electric Power Industry 2000: An Update. Energy Information Administration, U.S. Department of Energy.

EIA, 2011a. Annual Coal Report. Energy Information Administration, U.S. Department of Energy.

EIA, 2011b. Average Utilization of the Nation's Natural Gas Combined-Cycle Power Plant Fleet is Rising.

U.S. Energy Information Agency, U.S. Department of Energy. Retrieved from: http://www.eia.gov/todayinenergy/detail.cfm?id=1730 (October 2012).

EIA, 2011c. Electric Power Annual Report 2010. Energy Information Administration, U.S. Department of Energy.

EIA, 2011d. Most Electric Generating Capacity Additions in the Last Decade were National Gas-Fired. Energy Information Administration, U.S. Department of Energy. Retrieved from: http://www.eia.gov/todayinenergy/detail.cfm?id=2070 (October 2011).

EIA, 2012a. Coal Mining and Transporation. Coal Explained. Retrieved from: http://www.eia.gov/energyexplained/index.cfm?page=coal_mining (28.09.12).

EIA, 2012b. Factors Affecting Natural Gas Consumption in the Electric Power Sector. Energy Information Administration, U.S. Department of Energy. Retrieved from: http://www.eia.gov/todayinenergy/detail.cfm?id=6290 (June 2012).

Energy Information Administration, 2002. Electric Power Annual 2000, vol. II. Energy Information Administration, U.S. Department of Energy, Washington, DC.

Ernst & Young, 2011. Global Steel – 2011 Trends, 2012 Outlook. Ernst & Young.

Flaherty, T.J., et al., 2012. 2012 Utilities Industry Perspective. Booz & Company.

Global CCS Institute, 2012. Global Status of Large-scale Integrated CCS Projects. Global CCS Institute.

Gluskoter, H.J., et al., 2009. Meeting Projected Coal Production Demands in the USA: Upstream Issues, Challenges, and Strategies. Virginia Polytechnic Institute and State University.

Grubert, E., 2012. Reserve reporting in the United States coal industry. Energy Policy 44, 174–184.

IEA, 2013. Coal Medium-term Market Report 2013. OECD/IEA. International Eenergy Agency (IEA).

Jenkins, J., et al., 2012. Beyond Boom and Bust. Putting Clean Tech on a Path of Subsidy Independence. The Brooking Institution.

Keith, Burnard, Bhattaharya, Sankar, 2011. Power Generation from Coal: Ongoing Developments and Outlook. Paris: International Energy Agency. http://www.iea.org/publications/freepublications/publication/name,4009,en.html.

MarketLine, 2012. Coal in the United States. MarketLine Industry Profile, MarketLine.

McNerney, R., et al., 1998. Challenges of Electric Power Industry: Restructuring for Fuel Suppliers. Energy Information Administration, Washington, DC.

Mining Journal, 2012. Mining 101. Retrieved from: http://www.mining-journal.com/knowledge/Mining-101-Marketplace (28.08.2012).

NERC, 2011. Potential Impacts of Future Environmental Regulations. North American Electric Reliability Corporation.

NETL, 2012. 2010 Worldwide Gasification Database. Gasification Systems, National Energy Technology

  http://dx.doi.org/10.1016/j.tej.2014.03.008

Please cite this article in press as: Ahmed G, et al. What Role Can Coal Play in the United States' Energy Future?, Electr. J. (2014), http://dx.doi.org/10.1016/j.tej.2014.03.008

Laboratory, U.S. Department of Energy. Retrieved from: http://www.netl.doe.gov/technologies/coalpower/gasification/worlddatabase/summary.html (September 2012).

Peabody Energy, 2012. Form 10-K, Annual Report For the Fiscal Year Ended December 31, 2011. Peabody Energy Corporation.

PWC, 2009. Monetisation of Coal Assets. PricewaterhouseCoopers LLP (PWC).

RAND, C., 2011. Characterizing the U.S. Industrial Base for Coal-powered Electricity. RAND Corporation.

Schwartz, A., 2012. Duke Energy CEO Jim Rogers on the Future of Coal, Nuclear, and the Energy Industry. Retrieved from: http://www.fastcompany.com/1766582/duke-energy-ceo-jim-rogers-future-coal-nuclear-and-energy-industry (28.09.2012).

Spiegel, C., 2006. Opportunities for Coal-based Products: Clean Coal and Coal Processing Technologies. BCC Research, BCC Research.

The Brattle Group, 2012. Potential Coal Plant Retirements: 2012 Update. The Brattle Group.

Endnotes:

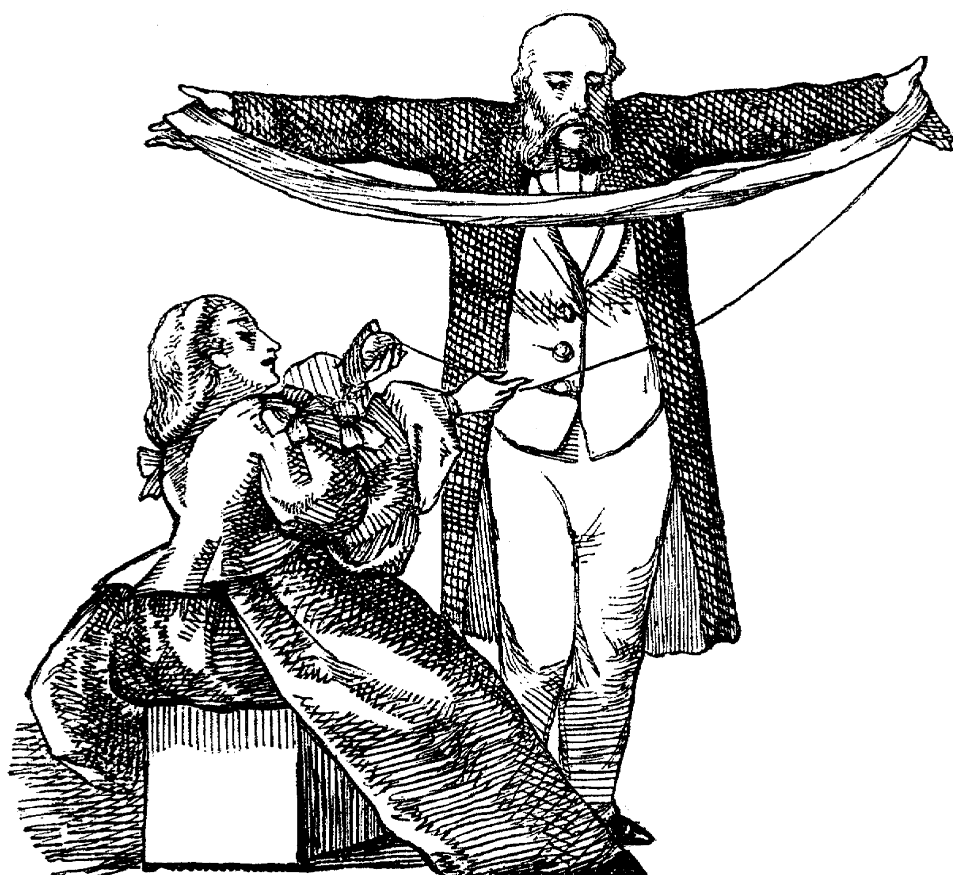
1. Carbon dioxide (CO_2) from coal-fired power plants is at the center of global warming discussions—burning coal releases 9–12 billion tons of carbon dioxide into the atmosphere each year. Estimates indicate that power generation is responsible for one-third of the more than 28 billion tons of global CO_2 emissions each year WNA (2012, August 2012). ''''Clean Coal'' Technolgies, Carbon Capture & Sequestration.'' *World Nuclear Association (WNA)*. Retrieved October 8, 2012, from http://www.world-nuclear.org/info/inf83.html.

2. Hauling one ton of cargo 576 miles per gallon of fuel.

3. Nitrogen oxide, sulfur dioxide and mercury are regulated by the federal government Carbon dioxide is also a major emission, but it is not regulated.

4. It is cutting production by 16 million tons and eliminating 1,200 jobs, including 400 with the immediate closing of eight mines in Virginia, West Virginia and Pennsylvania Associated Press (2012). Alpha Closing 8 Coal Mines, Cutting 1,200 Jobs. *USA Today*.

5. These firms are struggling to make the necessary long-term adjustments amidst changes in coal demand and rising production costs.



Relationships between firms in the coal value chain are complex.