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Characterizing the U.S. Industrial Base for Coal-Powered Electricity

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Summary

Coal-fired generating units provide approximately 46 percent of the electricity generated in the United States, yet most of the existing coal-fired electricity-generating fleet is 25–45 years old (Energy Information Administration [EIA], 2011c; Ventyx, 2011). Deploying new coal-fired electricity-generating units (EGUs) and maintenance of the existing fleet requires an industrial capacity to provide equipment, skilled labor, and project management expertise. However, in the near term, the domestic industrial base to provide the capacity for future coal-based EGUs faces several challenges. These include low demand for new conventional and advanced coal units in the next several years, regulatory uncertainty regarding emission standards for conventional pollutants and greenhouse gases, competition from other electricity-generation fuels, and an aging workforce.

To better understand these challenges, NETL asked RAND to describe the current state of the domestic industrial base for coal-based electricity generation. RAND was asked to focus on coal-fired EGU design and construction, technology development, and equipment manufacturing.

This monograph addresses the concern about whether the industrial base for the U.S. domestic coal-based electricity-generation industry can maintain the capability to design, construct, operate, and maintain coal-fired EGUs within reasonable cost, schedule, performance, environmental, and quality expectations. By first describing the capability that is inherent in the existing coal-fired fleet, this monograph takes a first step toward addressing the larger policy ques-

tions of how to develop, deploy, and maintain an advanced, low-carbon electricity-generation industry capability into the future.

We framed this research in terms of capability: What resources are required to sustain the capabilities of a financially and technically viable coal-based electricity-generation industry? Maintaining such a capability requires a combination of the following:

- enough firms that can design and manufacture the required unit components and subsystems, including those components unique to coal
- enough engineering, procurement, and construction (EPC) firms capable of designing and managing the construction of a coal-fired generating unit
- enough demand for services to enable EPC and component-manufacturing firms to remain financially viable
- enough skilled labor
- enough annual engineering, operation and maintenance (O&M), and construction market–sector activities to sustain the required level of experience in the skilled workforce.

To investigate these dimensions of the domestic industrial base, we reviewed existing reports and databases, conducted interviews with a variety of stakeholders, and collected and analyzed data describing key elements of industry capability and validation or verification of concerns.

Key Findings

Some Capabilities Are Maintained Through Active Operation and Maintenance and Pollution-Control Markets, but New Construction Is Required to Maintain Complete Capabilities

The coal-based electricity-generation equipment industry can be divided into three interconnected market sectors, distinguished by the type and scope of activities: new-unit construction, O&M, and pollution control.

The new-unit construction sector includes the design and construction of new coal EGUs, either on existing sites or on new sites, and the design, development, and production of the major subsystems and components of a coal-fired EGU (pulverizer, boiler, steam-turbine generators, pollution control, and cooling towers). After a coal-fired generating unit is constructed, the O&M sector performs maintenance activities that range from simple repair or routine maintenance of plant subsystems to replacement or refurbishment of major components or subsystems.

The existing coal-fired fleet contains a mix of units with and without advanced pollution-control equipment. The installation and upgrading of pollution controls in response to regulations creates the market for pollution-control equipment manufacturing and installation. The O&M and pollution-control markets appear to be fairly robust, while the new-construction sector activity is sporadic and relatively small. These O&M and pollution-control sectors utilize some, but not all, subsectors of the U.S. industrial base. For example, although manufacturing coal-unique equipment occurs largely outside the United States, engineering design and manufacturing of pollution-control equipment remains largely within the United States.

Globally, more than 800 gigawatts (GW) of total new coal capacity is forecast from 2015 to 2035, with 600 GW of this installed in China, a rate of 30 GW per year (EIA, 2010a). In contrast, EIA's *Annual Energy Outlook 2011* reference case forecasts only 2 GW of new U.S. coal-fired capacity additions from 2012 through 2035 (EIA, 2011a). The global marketplace still offers enough business for U.S. firms to exercise some critical capabilities. Yet, the dearth of new U.S. coal-based generating-unit construction results in a lack of continued development in the integrated design, specialized project management, scheduling, procurement, and labor skills associated with constructing a new conventional or advanced coal-fired generating unit.

Additionally, U.S. firms participating in predominantly foreign coal EGU construction will not fully develop the critical experience in cutting-edge combustion technology for advanced coal-based generation systems, such as ultrasupercritical, integrated gasification combined-cycle (IGCC) and oxy-combustion, which will be critical

if the industry transitions to advanced coal EGUs with carbon capture and sequestration (CCS). Experience gained using local coals in China and other countries deploying these technologies will provide some experience, but additional expertise on the design implications of using various U.S. coals with these advanced combustion systems will be needed. These remain critical areas in research and development (R&D) for advanced coal-based power generation.

Coal Boilers Are Critical to the Coal Power Industrial Base, but the Equipment Market Is Global

Several components of coal-fired power generating units are utilized in other types of power plants or in other industries; the largest and most important coal-unique system is the boiler. It consists of components that are exposed to the ash and other combustion products of coal and need to contain steam at high pressures and temperatures. These components are called *pressure parts* or *pressure components*. They include seamless tubing, carbon-steel plates, forgings, and castings and are assembled into the economizer, interior furnace tubing, steam separators, headers, walls, superheaters, and reheaters that characterize the boiler system. Fabrication of pressure parts requires facilities capable of forging and applying heat-treatment techniques to the large components, as well as the use of advanced and highly skilled welding. Large components of the boiler system are fabricated in sections in factories and then assembled at the construction site.

The market for coal-based electricity-generation equipment and construction is global, and the United States no longer dominates in terms of demand for equipment or power plant construction. Most new construction activity occurs outside the United States, especially in China. Since 1990, coal power plant installation activity in China has consistently been more than 10 GW annually, with a peak of more than 80 GW in 2006 (EIA, 2010a). This compares with a high of 6 GW in 2010 in the United States, which is the highest annual demand in the past two decades. Our interviewees concurred that nearly all pressure-component manufacturing currently occurs outside of the United States, mostly in Asia, with some facilities in eastern Europe. However, several firms maintain a core engineering design and technology devel-

opment capability within the United States. These firms include a few U.S.-headquartered firms that have manufacturing activities overseas.

The influence of overseas markets on both supply and demand is extraordinarily important to U.S.-based firms. This influence reflects shifts in market signals and changes in the business environment. Several reasons were given by interviewees for the shift to international pressure parts manufacturing, including the following:

- desire to colocate manufacturing supply with local coal-fired power plant demand
- reductions in labor costs and productivity gains achieved in international locations
- lack of available manufacturing facilities in the United States with steel heat-treatment capabilities suitable for very large coal power unit components
- a need for U.S. EPC firms to globally source major equipment in order to remain competitive in the U.S. market.

Some of these factors were also mentioned during our interviews on why many components of coal-powered EGUs besides pressure parts were also manufactured in Asia. Because delivery times to the construction site are established early in the project development process, sufficient time exists for custom fabrication and shipment from an international supplier. Thus, interviewees stated, barring large increases in logistics costs (or risks), market forces affecting domestic demand and manufacturing costs do not support major investments in domestic manufacturing capabilities to support new unit construction.

Workforce Challenges Are Not Unique to Coal but Would Raise Costs During High-Demand Periods

A 2009 industry survey found that roughly half the current workforce in several relevant job classifications will be eligible for retirement between 2009 and 2015, including 46 percent of pipefitters, pipelayers, and welders; 51 percent of technicians; and 51 percent of engineers

(Center for Energy Workforce Development [CEWD], 2009).[1] Perhaps more significantly, utilities responding to the survey reported having trouble filling openings in skilled-labor positions: "between 30 [and] 50 percent of applicants (those [who] met the minimum requirements for a position) were not able to pass the pre-employment aptitude test" (CEWD, 2009). Interviewees also supported this concern.

Although these results are not specific to coal, they do indicate that the utility industry perceives a current shortage of skilled labor in the workforce and anticipates that the shortage will grow worse in the near future. Bureau of Labor Statistics data, which show decreasing labor associated with fossil-fuel power plants, are consistent with the concern that the workforce is declining and new workers are not being hired at a one-for-one rate of replacement, but they do not explain the causes of this decrease in the workforce.

In interviews, individuals expressed concern that, should there be an increase in construction of coal EGUs, there would likely be shortages of skilled labor that would increase labor costs and slow the construction of coal-fired generating units. Of particular concern to interviewees were the supply, productivity, and costs of skilled welders critical to construction of coal-fired generating units. However, interviewees were confident that the industry could respond to correct labor shortages if a period of sustained demand were to arise. There are several reasons that they believed this to be the case:

- With a global marketplace for coal-fired generating units, the technical knowledge of knowing how to build a power plant will not be permanently lost with retirements.
- The markets for O&M and installation of pollution-control equipment, as well as construction of other electricity-generation technologies, such as natural gas–fired power plants, provide some level of relevant training for workers.
- If a sustained surge in demand occurred, firms might need to invest in training programs to increase the size and capabilities

[1] The survey covered 31 companies accounting for 44 percent of U.S. electricity and natural gas utilities. See CEWD, 2009.

of the workforce, and the supply of workers could be increased to meet a sustained demand within a few years.

In general, we found that the workforce responds to market forces in a way similar to the way it does in equipment manufacturing. Stakeholders share responsibility for the hiring and training of new workers, and the organization of existing workers, including utilities; trade unions; equipment manufacturers; architecture, engineering, and construction (AEC) and EPC firms; and community colleges and trade schools. In the face of a sustained increase in demand, according to their experience and interview discussions, these stakeholders are well-suited to collaborate to eventually generate the level of skilled labor needed. However, this adjustment phase is likely to be accompanied by increases in the cost of labor, albeit temporary, and a period of longer-than-normal construction times until efforts to increase the pool of skilled labor are implemented or demand subsides. One potential strategy for mitigating shortages of skilled labor is an increased emphasis on programs that increase awareness of career opportunities and provide training and apprenticeship opportunities, and several interviewees said that their organizations had active programs in these areas. There is potentially a role for federal support for these kinds of programs and partnership with the organizations that run them.

Interviewees also expressed concern that the near-term demand and short compliance timelines involved with installing equipment to meet proposed U.S. Environmental Protection Agency (EPA) pollution-control regulations will substantially increase construction costs and schedules for pollution-control retrofits and, in tandem, for new-unit construction. After the installation of pollution-control retrofits to existing units is complete, this market will be limited to pollution controls for new coal unit construction. Hence, interviewees noted that incentives for pollution-control firms to add capacity during the compliance period will be limited. This is an area that should continue to be examined for potential bottlenecks and strategies to alleviate workforce, cost, and schedule pressures.

Construction Costs and Schedules Have Increased for Recently Built Coal-Fired Power Plants

As with all aspects of construction, cost and schedule increases have been and will continue to be experienced during periods of high demand. Cost growth and schedule slip are common in large, complex projects (see Merrow, McDonnell, and Arguden, 1988; Merrow, 1989). Additionally, new coal-fired unit designs and resurgence of deployment will experience cost growth. If there is a resurgence of demand and it includes advanced coal technologies, then higher costs are expected until experience is gained with deploying these systems (Merrow, Phillips, and Myers, 1981). Many factors drive undesirable cost and schedule outcomes, from technical difficulty to poor management. In the limited coal-fired electricity-generating unit examples we were able to identify, increased cost and schedule are due at least in part to rising prices of materials and labor. In turn, these price increases are due in part to increasing global demand for materials and shortages of skilled labor required for construction. The IHS CERA Power Capital Costs Index and IHS CERA European Power Capital Costs Index show a near doubling of power plant costs in the past decade (IHS, undated). These data include coal, gas, and wind projects but exclude nuclear power. IHS stated that the slight rise in prices in 2010 was due to increased steel costs but was tempered by declines in major coal-equipment costs due to lack of orders and interest (IHS, 2010). EIA's updated capital cost report shows an increase in the capital costs for coal but not for natural gas, which, the report hypothesizes, could be due to the higher cost of financing for larger projects or to the lack of firms with experience constructing large megaprojects (EIA, 2010c).

Locally sourced labor for construction, engineering, and construction management services comprises about one-third of capital costs for coal power plants (Gerdes et al., 2010). In contrast, globally sourced procured equipment, which is highly sensitive to material input costs and market demand, represents nearly half of the capital costs for coal power plants. The cost pressures of the recent past are driven more by demand in China and elsewhere, which accounts for the vast majority of the market, than they are by increased U.S. demand. The role of potential shortages of skilled labor in the United States is more difficult

to ascertain in terms of cost pressures. However, the decline in costs in 2010 and high unemployment in construction trades show that these pressures have largely eased.

Potential Future Challenges Could Increase Costs and Schedules

Some industry interviewees were concerned about the effect that a prolonged drought of a decade or more without new construction of coal-fired generating units would have on domestic labor (especially in project management and engineering) when coupled with large-scale workforce retirements. Others raised questions of how the effects of these trends, or even the short-term price oscillations associated with the current market, would affect the competitiveness of coal-fired power generation and thus have implications for the long-term costs of electricity generation in the United States.

From a policy perspective, the market for coal-fired generating units might be too narrow when examining potential problems. There is a robust market for electricity-generation technologies, and owners will choose the cheapest option (subject to regulations, fuel prices, local conditions, and labor costs). Most interviewees stated that the electricity sector has historically experienced large surges in power plant construction demand followed by periods of low activity and that, after a period of initial higher prices, the industry has generally adapted to the changing conditions of the market. It is unclear how quickly markets will adapt and whether prices will stabilize in future periods of high demand. Interviewees also noted that other electricity-generation technologies, such as natural gas, nuclear, and renewables, compete with coal for some of the labor, material, and equipment required for plant construction, and a large power-sector reinvestment that involves several technologies deployed simultaneously would initially result in cost and schedule pressures for these resources across all technologies.

If the industry transitions to advanced coal EGUs with CCS, additional cost and schedule challenges are anticipated, as with all first-of-a-kind technologies. We examined the state public utility commission testimony of one utility executive discussing the sources of cost growth for a specific recent IGCC power plant that is the first of its kind at this size (586 MW) (Haviland, 2011), which would facili-

tate the future inclusion of CCS. Unforeseen engineering challenges and changes, larger-than-expected requirements for material quantities, and delays increased costs for this project considerably. In his testimony, the official mentioned poor labor productivity as the project progressed, especially regarding specialized welding services. However, he attributes low labor productivity largely to the unanticipated quantities required and poor project and resource planning that resulted. Thus, workers often did not have the materials needed on-site for construction, which further affected productivity and costs. He also stated in his testimony that the unplanned increase in quantities substantially increased the number of welders needed and that the use of specialty alloys in the project caused welding difficulties (Haviland, 2011). Therefore, the project under consideration at the hearing at which he testified points to several potential causes for increased costs, but they are not clearly separable from first-of-a-kind-at-this-size learning issues. The industry should examine the experiences at this IGCC plant to improve designs, schedules, and workforce planning for future advanced coal power plants.

The preponderance of evidence examined for this monograph indicates that, despite the recent recession, the industry base to supply equipment for coal-based electricity generation remains capable of responding to potential demands in the near term. Ultimately, the interest in the capabilities of the coal-based power generation industry base is driven by questions of whether the industry will be able to respond to future demand. However, demand is highly uncertain and depends on forecasts of economic growth, coal power's competitiveness relative to other generation technologies, the success of technological development efforts to improve the efficiencies of and reduce the pollution associated with coal-fired and other power generation, and the path that future pollution and greenhouse gas regulations take.

Costs and project schedules are likely to increase when new coal power projects are initiated after a long period of low demand and during high-demand periods caused by short regulatory compliance timelines or market forces. Resource and workforce competition from constructing other electricity-generation technologies will likely contribute to these increases. Hence, this monograph is a first step in

understanding the implications of a large-scale power-sector reinvestment and transition to advanced technologies for the U.S. industrial base. Although this and other studies have examined workforce and equipment needs for specific generation technologies, a holistic analysis, including multiple technologies deployed across a range of technology, demand, and construction scenarios, is needed to anticipate gaps in skills and resources and to determine robust strategies to alleviate barriers to a large power-sector reinvestment.