Drivers to Improving Coal Quality: Rationale, Costs, and Benefits

This paper is a companion piece to RAP's *International Best Practices Regarding Coal Quality*. The key questions and issues addressed by this paper are:

- What is the history in the United States (US) with coal quality? What drove the US to establish standards? Were there market forces or state laws driving behavior prior to the Clean Air Act?
- What type of return on a generator's investment may be possible? What net financial benefits may accrue?
- How are actual coal quality standards used in the US?
- Do market prices of coal vary according to its quality? Are there case studies of a generator which chose or switched to a higher quality coal and received an economic benefit?

1. Drivers of Coal Quality

Historical Perspective

The United States was an early adopter in establishing standards for agencies to purchase coal. George Pope's *Purchase of Coal by the Government under Specifications* (1910), describes why standards should be established, and provides a framework for such standards. Pope argues that buyers of gold, silver, and copper have long required specifications and standards for purchase of these commodities, and given the variability in coal and the then high value of coal contracts, that the customer (in this case the US Government) should demand to know what is in the product before they purchase it.[1] A customer may negotiate a purchase of coal from a certain mine, knowing that the type of coal found in that geographic area is a particular rank. However, coal properties vary substantially in a single mine, and even in a single seam within a given mine.

Boilers are designed to accommodate a range in the primary variables in coal that can affect performance and efficiency. Coal can be blended, either by the producer or at the power plant itself, to maintain the fuel properties within the required ranges. However, a boiler designed to burn a high rank bituminous coal is going to perform quite differently if lower rank subbituminous coal is introduced, and variables such as high ash or sulfur can impair not only the thermal performance of the boiler, but also associated duct work. Prior to the establishment of environmental requirements, operators of coal-fired power plants established standards and specifications for the fuel they purchased so they would be able to effectively operate the boiler, and minimize the amount of time the boiler had to be taken off line for maintenance.

[1] Pope, George S. (1910). *Purchase of Coal by the Government under Specifications: with Analyses for Coal Delivered in the Fiscal Year 1908-09.* Government Printing Office. Available at http://pubs.usgs.gov/bul/0428/report.pdf.

There is also a relationship between the quality of coal and its cost. It will require more tons of coal with a lower heating value to produce the same power output as coal with a higher heating value.

Current Drivers of Coal Quality

Two main factors influence coal quality and the steps taken to improve its quality:

- **Compliance with environmental requirements**: Each one percent increase in boiler thermal efficiency can decrease CO_2 emissions by 2 to 3 percent. Coal beneficiation can also remove mercury and sulfur, allowing the power plant owner to design a smaller emissions control device to meet applicable air pollution requirements.[2]
- **Extend the life of coal supplies:** As the thickness of the coal seam decreases, improving run of mine coal can add value and increase its marketability.[3]

In the eastern United States, where coal has been mined for more than a century, coal seams are becoming thinner, and the properties of the coal have changed. In several eastern states, the coal quality itself has declined, with higher ash and lower heating value. In response, coal boiler technologies have improved over the last several decades, and today can accommodate a broader range in the type of coal. For example, fluidized bed combustors (FBC) and stoker boilers are capable of burning a wider variety of coals, and can handle coal with high ash and sulfur content. Pulverized coal boilers require a tighter range in coal quality, and are more affected by high ash and sulfur. This difference relates to the design of the boiler itself. Fuel in FBC and stokers can be fed into the boiler without requiring fuel preparation, and the fuel sits on a bed, which has a long retention time in the combustion chamber that helps to assure more complete combustion. Pulverized coal boilers, as their name implies, require that the fuel be ground finely before it is injected into the combustion chamber. Any impurities in the fuel have a greater influence on the combustion efficiency.

Coal beneficiation (as coal washing is referred to in the industry) is most economical and beneficial when applied to fuel that will be burned in a pulverized boiler. The trend in the United States towards fluidized bed boilers has resulted in less coal washing occurring today than in the 1980s and 1990s. Another contributing factor towards lower percentages of coal washing in the US is the increased availability of coal from the Powder River Basin (PRB). PRB coal has an ash content of 5-6 percent, is lower in sulfur than Appalachian coal, and is mined almost exclusively through longwall or opentop extraction, which optimizes the amount of coal than can be removed per unit of labor.

2. Costs and Benefits of Improved Coal Quality

Several qualitative and authoritative studies discuss factors that affect the performance of coal boilers, and the direction of the particular effect (i.e., increasing or decreasing). The Electric

[2] *Ibid,* page 128.

[3] Gluskoter, H. et al. (2009). *Meeting Projected Coal Demands in the USA: Upstream Issues, Challenges and Strategies*. National Commission on Energy Policy. Available at http://bipartisanpolicy.org/library/research/meeting-projected-coal-production-demands-usa-upstream-issues-challenges-and.

Power Research Institute (EPRI) and many utilities have developed proprietary models that assess how a variable, or variables, influence a particular plant.[4] As proprietary models, interested users must purchase rights to use the model. However, agencies have conducted more general and broader studies that can be used to assess why coal quality matters, and what variables are the most important to consider.

One study assessed the costs and benefits of improving coal quality for a hypothetical 500 MW coal plant, with a heat rate of 10,000 Btu per kW, burning bituminous coal. Key findings are summarized below:

- Delivered costs increased from $41.50 per ton (for coal with a heating value of 11,900 Btu/lb) to $46.50 per ton for the washed coal (with a heating value of 13,300 Btu/lb). Annual fuel costs were forecast to increase by $200,000.
- The results reflect a heat rate improvement to 9890 Btu/kW, a 1% increase in boiler efficiency, which was estimated to save $450,000 annually.
- A 45 percent decrease in ash and more than a 50 percent decrease in sulfur is projected, which would result in reducing annual ash disposal costs by $230,000 per year. The sulfur emissions rate was estimated to decrease from 4.2 pounds per MMBtu to 1.9 pounds per MMBtu.
- Improved coal handling was estimated to also save about $230,000 per year.
- Fuel costs were forecast to decline slightly, from 17.44 mil/kW to 17.25 mil/kW.[5]
- In this case, an increased expenditure of $200,000 per year for higher quality fuel would produce annual savings of $910,000 per year, for a net savings of $710,000 per year. These savings do not include longer boiler and equipment life.

The International Energy Agency (IEA) surveyed coal boiler operators in the early 1990s to assess what variables affect boiler performance and efficiency, and the direction of each variable (beneficial or harmful).[6] Sixty power plants in 12 countries were included in the survey. IEA concluded that coal quality factors account for up to 60 percent of forced outages at power plants. Some variables were shown to have positive and negative effects. For example, high ash content in the coal could lead to plugging in the coal handling system if the ash was clay-based, or help to clean the system if the ash was shale-based. Principle variables found to impede boiler performance and efficiency were ash, sulfur, moisture content, heating value, and the grindability of the coal. These effects were described qualitatively.

IEA also published detailed results of the above mentioned survey.[7] Changes in coal quality were evaluated in general, and several specific examples are provided. The general trends in coal

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[4] N. M. Skorupska (1992). *Coal Specifications-Impact on Plant Performance: An International Perspective*. Presented at Effects of Coal Quality on Power Plants-Third International Conference. Electric Power Research Institute. Examples include: EPRI's Coal Quality Impact Model (CQIM), EBASCO performance models, heat rate models, or least cost fuel models.

[5] Waymel, Edmond and Roderick Hatt (1987). *Improving Coal Quality: An Impact on Plant Performance.* Island Creek Corporation: Lexington, Kentucky. Available at http://www.coalcombustion.com/PDF%20Files/Improving%20Coal%20Quality.pdf

[6] N. M. Skorupska, *Ibid*.

[7] N. M. Skorupska (1993). *Coal Specifications-Impact on Power Station Performance.* International Energy Agency: London. IEACR/52.

quality were evaluated for a 1,000 MW plant, with a 65 percent capacity factor, a 10,000 Btu/kWh heat rate, a coal heating value of 12,000 Btu/lb, an ash content of 10 percent, and a fuel cost of $35/ton. Changing the quality of the coal burned by increasing the ash content 10 percent, increasing moisture content by 5 percent, and decreasing heating value by 15 percent resulted in a higher heat rate, and a negative cost impact of $4.46 million/year (1986$).

Results of case studies reflect significant cost effects. A 1 percent increase in ash content at Czech power plants resulted in 10 percent higher costs in mill components and maintenance.[8] The Tennessee Valley Authority (TVA) improved coal quality at its Cumberland power plant (2 units, each at 1,300 MW) over the period from 1977 to 1986. TVA found that their operating and maintenance costs decreased on average by $15 million per year. The largest change in coal quality was decreasing the ash content from 15.2 percent to 9.2 percent.[9] Sulfur content also decreased from 3.5 to 2.8 percent, and heating value increased from 10,712 Btu/lb (24.9 MJ/kg) to 11,635 Btu/lb (27.1 MJ/kg).

The Southern Company, which operates several coal plants in the southeastern United States, also analyzed its operating and maintenance costs. Southern found that increasing the ash content from 15 to 20 percent, increased waste disposal costs, maintenance costs, and forced outages due to ash.[10]

The Asian Development Bank (ADB) conducted an extensive survey of the Indian coal industry in the 1990s. Through questionnaires, the ADB consultant assessed several variables related to coal mining, transport, and combustion at power plants. [11] The following factors summarize the performance of coal plants based on fuel beneficiation in India. For each 10 percent reduction in ash content:

- The plant use factor (PUF) (or capacity factor) can increase up to 6 percent as forced outages and maintenance issues related to tube leaks, the economizer, and associated components are reduced;
- The thermal efficiency can be improved by the same rate, of up 6 percent, with an average of 1 to 2 percent;
- CO_2 emissions decrease by 2.5 to 2.7 percent;
- Efficiency of the particulate control device (electrostatic precipitators were assessed in this study) improves from 98 to 99 percent;[12]

[8] We note that many Chinese power plants have two separate mills in order to process highly variable fuels. Improving fuel quality (or at least specifying its characteristics) could mitigate the need for this duplicative expense, and reduce both capital and operating costs for the power plant owners.
[9] N.M. Skorupska 1993, at page 75
[10] *Ibid,* at page 75.
[11] Montan-Consulting GMBH (1998). *India: Implementation of Clean Technology through Coal Beneficiation.* Asian Development Bank (ADB) Project Number 26095. Available at http://www2.adb.org/documents/reports/Consultant/IND/26095/26095-ind-tacr.pdf
[12] In effect, this is a 50 percent improvement in the particulate collection efficiency. A 98 percent efficiency means that, for each 100 tons of particulate mass in the flue gas, 2 tons would not be captured and would be emitted to the atmosphere. A 99 percent efficiency means that for each 100 tons of particulate mass in the flue gas, 1 ton would not be captured.

- Auxiliary power demand also declined by 10 percent (the report noted a range of 8-12 percent of the total power output for the plant auxiliary power requirements)
- Operation and maintenance costs decline by 20 percent.
- Capital investment in the power plant will be reduced 5 percent (note that these data specifically relate to reducing ash content from 41 percent to 34 percent).
- Land requirements for ash disposal are reduced. For a 1,000 MW coal plant, assuming a plant life of 20 years, the size of the land required is reduced from 400 hectares to 229 hectares.
- Water required to move the ash from the plant to the land disposal site is reduced by 30 percent. For a 1,000 MW plant, this translates to 11.99 million m^3 per year consumption, compared to 17.05 million m^3 per year for unbeneficiated coal.

ABD also noted that coal plants that received ash that was 10-15 units higher than the plant was designed for observed that thermal efficiency decreased by 4.5 percent.

3. Examples of Coal Quality Standards

There are several ways in which quality control requirements can be specified. Contractual arrangements between the seller of the coal and the purchaser are the primary means by which commercial quality control is established. One example of contractual standards for coal quality comes from the New York Mercantile Exchange (“NYMEX”). Under standard NYMEX rules, there are a number of coal quality specifications:

> (A) Coal delivered under this contract shall meet the following quality specifications on an as received basis, (as-received does not refer to subsections (6) and (7)):
>
> > (1) Btu: Minimum 12,000 btu/lb., gross calorific value, with an analysis tolerance of 250 btu/lb below (A.S.T.M. D1989)
> >
> > (2) Ash: Maximum 13.50%, with no analysis tolerance (A.S.T.M. D3174 or D5142)
> >
> > (3) Sulfur: Maximum 1.00%, with an analysis tolerance of 0.050% above (A.S.T.M. D4239)
> >
> > (4) Moisture: Maximum 10.00%, with no analysis tolerance (A.S.T.M. D3302 or D5142)
> >
> > (5) Volatile Matter: Minimum 30.00%, with no analysis tolerance (A.S.T.M. D5142 or D3175)
> >
> > (6) Grindability: Minimum 41 Hardgrove Index (HGI) with three-point analysis tolerance below. (A.S.T.M. D409)
> >
> > (7) Sizing: Three inches topsize, nominal, with maximum fifty five percent passing one quarter inch square wire cloth sieve to be

determined basis the primary cutter of the mechanical sampling system. (A.S.T.M. D4749)[13]

Under these kinds of contractual arrangements, quality standards are enforced by the parties to the contract, with recourse to the appropriate judicial body in cases of disputes over performance.[14] An example coal contract for Central Appalachian coal may be seen at: http://www.cmegroup.com/rulebook/NYMEX/2/260.pdf.

4. Economic Effects of Coal Quality

The heating value of coal varies with its rank. Bituminous coal has a heating value that averages 24 million Btu per ton; subbituminous averages 18 million Btu per ton; and lignite averages 13 million Btu per ton. To compare, it would require nearly two tons of lignite and about one and one-third tons of subbituminous to produce the same heat as one ton of bituminous.

Coal is priced both on a dollars per ton and a dollars per MMBtu basis. The price itself is based upon several factors, including its rank, how it is mined, and its quality. Coal mined through subsurface means is more expensive than coal mined at the surface (e.g., mountain top removal). Coal with lower sulfur and ash content is more expensive than coal with higher sulfur and ash content.

Coal prices vary considerably, so it would be inappropriate here to include coal price data without an explanation. As soon as such data were published, they would be out of date. Several agencies, such as the US Department of Energy's Energy Information Administration and the International Energy Agency, provide coal price data on a quarterly or annual basis. Commodity exchanges like NYMEX also provide coal price data for current and future contracts. A review of data on coal prices reflects that prices roughly track the rank of the coal; higher heating value means that the coal can command a higher price. The MIT study *The Future of Coal*, includes the following table, which illustrates the influence of several variables on the price of coal.[15]

[13] CME Group (2013). *Central Appalachian Coal Options*. Available at http://www.cmegroup.com/trading/energy/coal/central-appalachian-coal_contract_specifications.html.
[14] Contracts generally specify the method of resolving conflicts, as well as the adjudicatory body and jurisdiction.
[15] Katzer, J. et al. (2007). *The Future of Coal: Options for a Carbon-constrained World*. Massachusetts Institute of Technology: Cambridge, MA USA. Available at http://web.mit.edu/coal/.

Figure A-3.A.2 Coal Characteristics by Coal Type

	Higher Heating Value (kJ/kg)	Moisture Content (%wt)	Carbon Content (%wt)	Ash Content (%wt)	Sulfur Content (%wt)	Minemouth Coal Cost (2005 $/ton)
Anthracite	30,000[1] – 31,500[2]	2.1[2] –12[1]	72[1]–87[2]	6.9[2]–11[1]	0.5[2]–0.7[1]	44–87[5]
Pittsburgh # 8	30,800[3] – 31,000[4]	1.1[4]–5.13[3]	73[4]–74[3]	7.2[3]–13[4]	2.1[3]–2.3[4]	45–55[5]
Illinois #6	25,400[3]– 25,600[4]	8.0[4] –13[3]	60[4]–61[3]	11[3]–14[4]	3.3[3]–4.4[4]	32–39[5]
Chinese Coal	19,300– 25,300[6]	3.3–23[6]	48–61[6]	28–33[6]	0.4–3.7[6]	N/A
Indian Coal	13,000– 21,000[7]	4[7]–15[6]	30–50[8]	30–50[7]	0.2–0.7[7]	14–19[7]
WY Powder River Basin	19,400[3]– 19,600[4]	28[4] –30[3]	48[3]–49[4]	5.3[3]–6.3[4]	0.37[3] –0.45[4]	6–17[5]
Texas Lignite	14,500[9]– 18,300[10]	30[10]–34[9]	38[9]–44[10]	9[10]–14[9]	0.6[10]–1.5[9]	14[11]– 15[12]
ND Lignite	14,000[3]– 17,300[4]	32[4]–33[3]	35[3]–45[4]	6.6[4]–16[3]	0.54[4]–1.6[3]	9[12]

1. Eberle, J.S., Garcia-Mallol, A.J., Simmerman, A.M., "Advanced FW Arch Firing: NOXReduction in Central Power Station," WPS Power Development, Inc. & Foster Wheeler Power Group, Inc., Presented at Pittsburgh Coal Conference, Pittsburgh, PA, Sept. 2002.

2. Edward Aul & Associates, Inc., & E.H. Pechan & Associates, Inc., "Emission Factor Documentation for AP-42 Section 1.2 Anthracite Coal Combustion," U.S. EPA, Research Triangle Park, NC, 1993.

3. Integrated Environmental Control Model, Carbon Sequestration Edition, IECM-cs 5.02, Carnegie-Mellon University, 2005.

4. U.S. Department of Energy, OFE/NETL "Carbon Capture and Sequestration Systems Analysis Guidelines," Washington, D.C., April 2005.

5. U.S. Department of Energy, Energy Information Administration, "Coal News and Markets," webpage, downloaded 11/30/05 from http://www.eia.doe.gov/cneaf/coal/page/coalnews/coalmar.html

6. Oskarsson, Karin, et al., "A planner's guide for selecting clean-coal technologies for power plants," Washington, DC : The World Bank, 1997.

7. International Energy Agency, "Coal in Energy Supply of India," OECD/IEA, Paris France, 2002.

8. Ohio Supercomputer Center, "Anthropogenic Emissions from Energy Activities in India: Generation and Source Characterization" website, downloaded 11/30/05 from http://www.osc.edu/research/pcrm/emissions/coal.shtml.

9. San Filipo, John R., "U.S. Geological Survey Open-File Report 99-301," U.S. Geological Survey, Reston, VA, 1999.

10. Gray, D., et al., "Polygeneration of SNG, Hydrogen, Power, and Carbon Dioxide from Texas Lignite," NETL, Falls Church, VA, 2004.

11. U.S. Department of Energy, Energy Information Administration, "Coal Industry Annual, 2000," Washington, D.C. 2000.

12. U.S. Department of Energy, Energy Information Administration, "Average Open Market Sales Price of Coal by State and Coal Rank," 2004, webpage, downloaded 11/30/05 from http://www.eia.doe.gov/cneaf/coal/page/acr/table31.html.

Source: Katzer, J. et al. *The Future of Coal*, Appendices to Chapter 3.

Below is an example of the coal price data available from EIA. This table illustrates the price differences based on both heating value and sulfur content. Low sulfur Central Appalachian coal represents the highest price, while low Btu Powder River Basin coal is lowest.

Average weekly coal commodity spot prices (dollars per short ton)[16]

Week Ended	Central Appalachia 12,500 Btu, 1.2 SO2	Northern Appalachia 13,000 Btu, <3.0 SO2	Illinois Basin 11,800 Btu, 5.0 SO2	Powder River Basin 8,800 Btu, 0.8 SO2	Uinta Basin 11,700 Btu, 0.8 SO2
18-January-13	$68.05	$62.10	$47.90	$10.15	$35.85
25-January-13	$68.05	$62.10	$47.90	$10.15	$35.85
01-February-13	$66.50	$62.10	$47.90	$10.15	$35.85
08-February-13	$66.50	$62.10	$47.90	$10.15	$35.85
15-February-13	$66.50	$62.10	$47.90	$10.25	$35.85

Source: with permission, SNL Energy

The EIA also summarizes the prices fetched by various coal ranks. Below are data for 2011. Regardless of the mine location, bituminous coals sold for much higher prices than subbituminous and lignite. Anthracite is mined in Pennsylvania; its high heating value makes it attractive as a coking or metallurgical coal:

[16] **Note:** Coal prices shown are for a relatively high-Btu coal selected in each region, for delivery in the "prompt quarter." The prompt quarter is the quarter following the current quarter. For example, from January through March, the 2nd quarter is the prompt quarter. Starting on April 1, July through September define the prompt quarter. The historical data file of spot prices is proprietary and cannot be released by EIA; see SNL Energy.

Table 31. Average sales price of coal by State and coal rank, 2011

(dollars per short ton)

Coal-Producing State	Bituminous	Subbituminous	Lignite	Anthracite	Total
Alabama	102.69	-	-	-	102.69
Alaska	-	w	-	-	w
Arizona	w	-	-	-	w
Arkansas	w	-	-	-	w
Colorado	w	w	-	-	39.88
Illinois	50.80	-	-	-	50.80
Indiana	47.96	-	-	-	47.96
Kansas	w	-	-	-	w
Kentucky Total	63.63	-	-	-	63.63
Eastern (Kentucky)	74.70	-	-	-	74.70
Western (Kentucky)	45.89	-	-	-	45.89
Louisiana	-	-	w	-	w
Maryland	49.37	-	-	-	49.37
Mississippi	-	-	w	-	w
Missouri	w	-	-	-	w
Montana	w	15.43	w	-	16.02
New Mexico	34.22	-	-	-	34.22
North Dakota	-	-	15.72	-	15.72
Ohio	46.39	-	-	-	46.39
Oklahoma	70.39	-	-	-	70.39
Pennsylvania Total	79.61	-	-	75.70	79.47
Anthracite (Pennsylvania)	-	-	-	75.70	75.70
Bituminous (Pennsylvania)	79.61	-	-	-	79.61
Tennessee	74.24	-	-	-	74.24
Texas	-	-	19.32	-	19.32
Utah	33.80	-	-	-	33.80
Virginia	135.14	-	-	-	135.14
West Virginia Total	84.81	-	-	-	84.81
Northern (West Virginia)	61.27	-	-	-	61.27
Southern (West Virginia)	95.44	-	-	-	95.44
Wyoming	-	13.56	-	-	13.56
U.S. Total	68.50	14.07	18.77	75.70	41.01

- = No data reported.

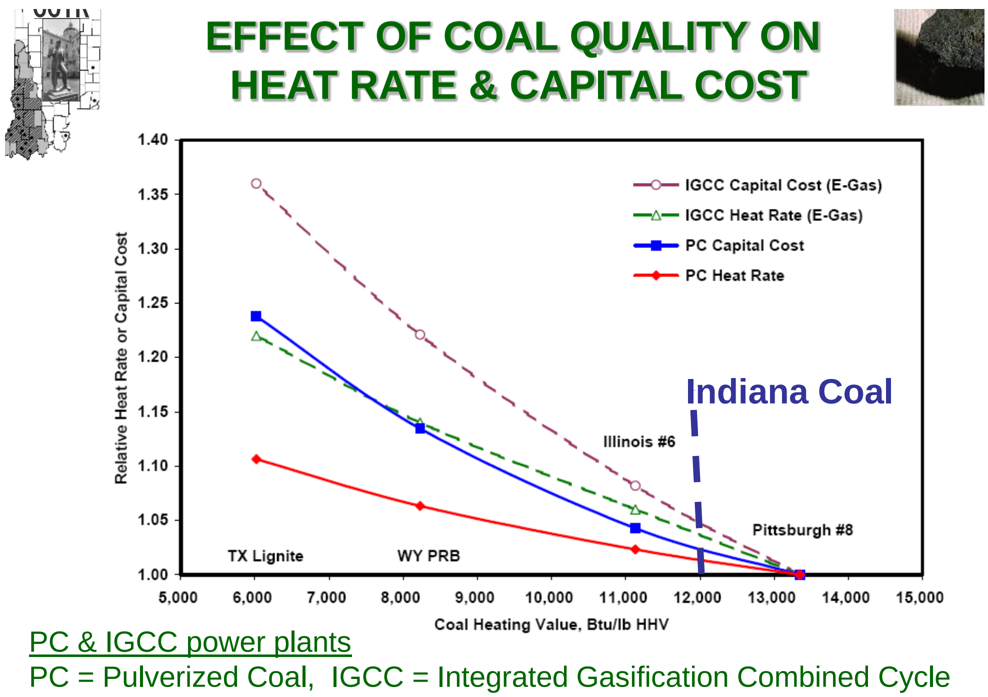
w = Data withheld to avoid disclosure.

Note: An average sales price is calculated by dividing the total free on board (f.o.b) rail/barge value of the coal sold by the total coal sold. Excludes mines producing less than 25,000 short tons, which are not required to provide data. Excludes silt, culm, refuse bank, slurry dam, and dredge operations. Totals may not equal sum of components because of independent rounding.

Source: U.S. Energy Information Administration Form EIA-7A, 'Coal Production and Preparation Report' and U.S. Department of Labor, Mine Safety and Health Administration Form 7000-2, 'Quarterly Mine Employment and Coal Production Report.'

Source: Available at: http://www.eia.gov/coal/annual/pdf/table31.pdf

The quality of the coal to be burned by a boiler affects its capital costs. Purdue University research (using data from the Electric Power Research Institute) is shown below.[17] Plant capital costs are shown to increase as the heating value decreases.



Source: "Economic Analysis of New Coal Fired Generation Options", George S. Booras et al, EPRI, Palo Alto, 2004

Section 2 above provided examples where improvements to the quality of coal burned directly benefitted the power plant owners and operators. A small price increase for better fuel quality led to more revenue for the power plant, through increased availability, and decreased operation and maintenance costs. The examples in Section 4 further increase the potential benefits from improving coal quality. Improved heating value per ton of coal burned means that a smaller boiler can be specified for the same power output, and that the mining companies themselves can benefit from higher quality coal by receiving a higher price for their product.[18]

[17] Bowen, Brian and Marty Irwin (2008). *Coal Characteristics: CCTR Basic Facts File #8.* Indiana Center for Coal Technology Research. Available at http://www.purdue.edu/discoverypark/energy/assets/pdfs/cctr/outreach/Basics8-CoalCharacteristics-Oct08.pdf

[18] Note that this argument primarily applies to the domestic US market and not to coal exports. There is evidence to support a rough link between the quality of coal and its price. Higher quality metallurgical coal generally commands a higher price than thermal coal. There is also evidence that Indonesia and Australia may be exercising market power that is independent of the quality of coal traded internationally, so the discussion above should not be treated as applying universally to a global coal market.

5. Conclusions

The United States has a long history of establishing standards and specifications for the quality of coal purchased and burned in power plants. Initially, having specifications was a means to assure the buyer that the commodity being purchased matched what the seller described and to provide a degree of consistency. Today, the following factors influence why higher coal quality is sought:

- *Extend the life of the coal seams:* Lower quality coals can be extracted and sold if their ash and sulfur is removed or reduced through beneficiation processes. This can improve profits of the coal mining companies;
- *Improve boiler performance:* Producing the same or higher power output with less fuel, reducing unscheduled maintenance and boiler down time, reducing waste disposal costs, and extending the life of the boiler, coal preparation equipment, and plant duct work can improve profits for power plant owners and operators;
- *Help to meet environmental requirements*. Each 1 percent improvement in boiler thermal efficiency by can reduce CO_2 emissions 2 to 3 percent. Coal beneficiation can also reduce sulfur by 10 to 20 percent or more, and reduce mercury by 20 percent or more. Upstream beneficiation can also reduce the size of an emissions control device, providing cost savings compared to that for a control device to be installed on power plants burning coal that has not been beneficiated.