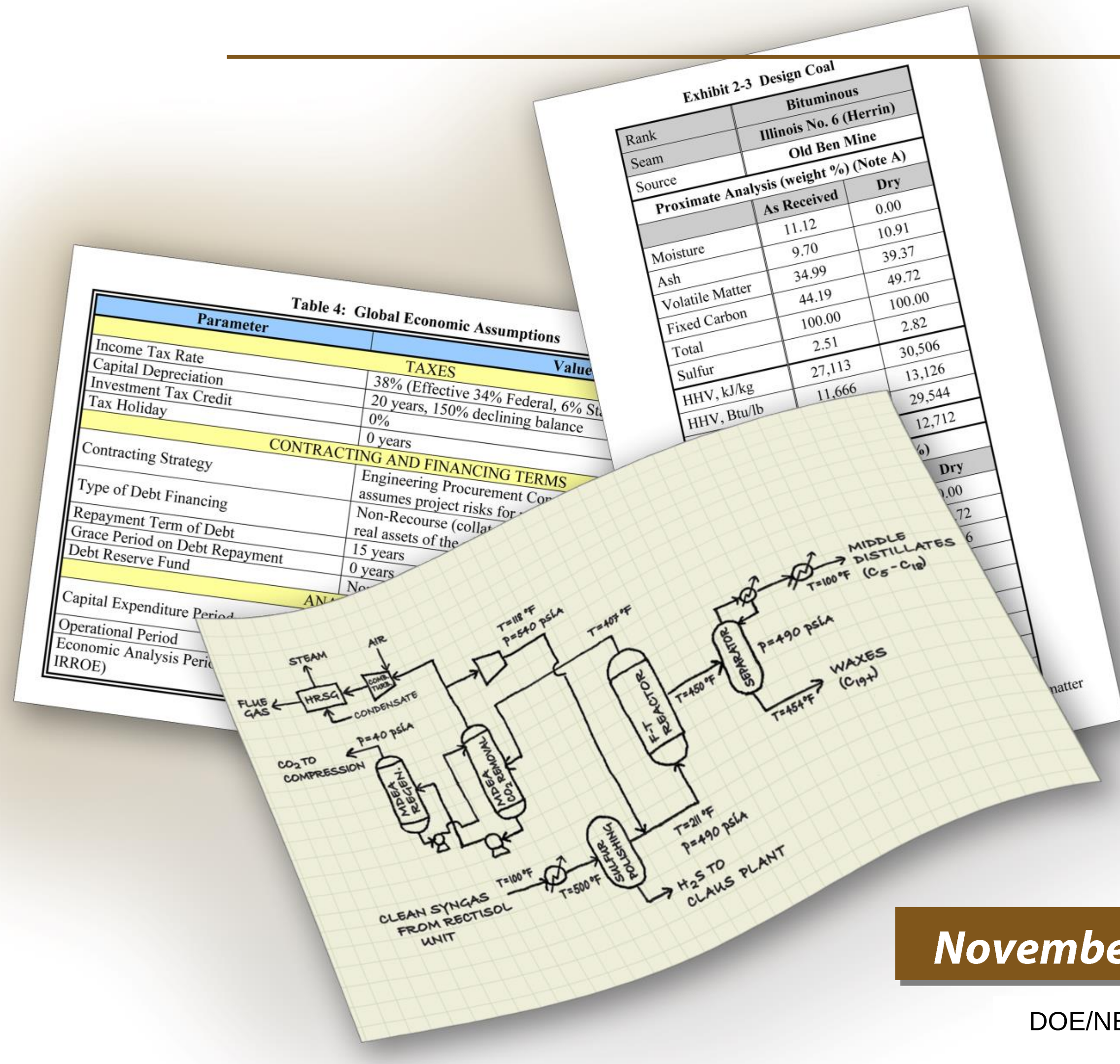
the ENERGY lab

QUALITY GUIDELINES FOR ENERGY SYSTEM STUDIES

Fuel Prices for Selected Feedstocks in NETL Studies



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Final Report

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List of Exhibits

Acronyms and Abbreviations

CAIR	Clean Air Interstate Rule
CO_2	Carbon dioxide
DOE	Department of Energy
EIA	Energy Information Agency
EV	Energy Velocity
FGD	Flue gas desulfurization
HHV	Higher heating value
MMBtu	Million British thermal units
NETL	National Energy Technology Laboratory
NPRB	Northern Powder River Basin
O&M	Operation and maintenance
PRB	Powder River Basin
U.S.	United States

Executive Summary

The fuel/feedstock price values to be used in systems studies sponsored by the National Energy Technology Laboratory (NETL) are summarized in Exhibit ES-1. The basis for these values is discussed below.

Exhibit ES-1 Fuel Prices for use in NETL systems studies

Plant Location	Fuel / Feedstock	Delivered Price for Systems Studies (2011$)
Midwest	Illinois Basin Coal	$68.54/ton ($2.9376/MMBtu)
	Powder River Basin Coal	$36.57/ton ($2.1351/MMBtu)
	Natural Gas	$6.13/MMBtu
Texas	Texas Lignite	$23.38/ton ($1.7836/MMBtu)
	Natural Gas	$4.56/MMBtu
North Dakota	North Dakota Lignite	$18.19/ton ($1.3745/MMBtu)
	Natural Gas	$5.17/MMBtu
Montana	Powder River Basin Coal	$19.63/ton ($1.1461/MMBtu)
	Natural Gas	$5.17/MMBtu

Source: NETL

1 Objective

The purpose of this guideline is to estimate the market price, delivered to specific end-use areas, of four coals that are commonly used as feedstock in the energy systems studies sponsored by the National Energy Technology Laboratory (NETL). The coals and their market areas are:

- Illinois Basin (delivered to Illinois/Missouri/Iowa region)
- North Dakota lignite (minemouth)
- Texas lignite (minemouth)
- Montana Rosebud Powder River Basin (PRB) (delivered to central Montana region)

In addition to these four coals, for comparison purposes, the market price was estimated for Southern PRB coal delivered to Midwest power plants, and for natural gas delivered to the Midwest (Iowa/Illinois/Missouri/Wisconsin), the Texas Gulf, and the Mountain West (Wyoming/ Nebraska/Colorado) regions.

2 Approach

Power plants are required to report to the Energy Information Agency (EIA) details on the cost and quality of fossil fuels delivered to both regulated and unregulated electric generating facilities in the United States (U.S.). These details include fuel source, quality, transportation options, and delivered costs. This information is reported on a monthly basis on form EIA-923 (formerly the FERC 423 and EIA 423 forms).

These data are easily gathered and filtered using Ventyx Corporation's Energy Velocity (EV) Suite, a compilation of energy industry and market databases. [1] For each of the four coals into each specified delivery area, the fuel prices, transportation costs, higher heating value (HHV), sulfur content, and ash content were retrieved from the EV database for 2009, 2010, and 2011 (through May, the last month that data were available when this analysis was performed) and averaged (weighted based on tonnage) for each year. Deliveries to plants located in the target market areas were used when possible with the exception of Montana Rosebud coal, which required transportation costs to be added to the minemouth cost since there were no deliveries of this coal to the target area. The average free-on-board (FOB) mine prices were determined by subtracting the average transportation costs from the average delivered prices. All prices in this guideline are expressed in nominal dollars.

The coals used in the NETL studies were not necessarily the same quality as the coals that were delivered in the three years mentioned above; this can affect the market price. Thus, it is necessary to adjust the actual delivered prices to account for the quality differences. The three quality parameters (and their units) used by the coal industry for price adjustments are energy content (Btu/lb), sulfur content (lb SO_2/MMBtu), and ash content (wt. %). The adjustments are:

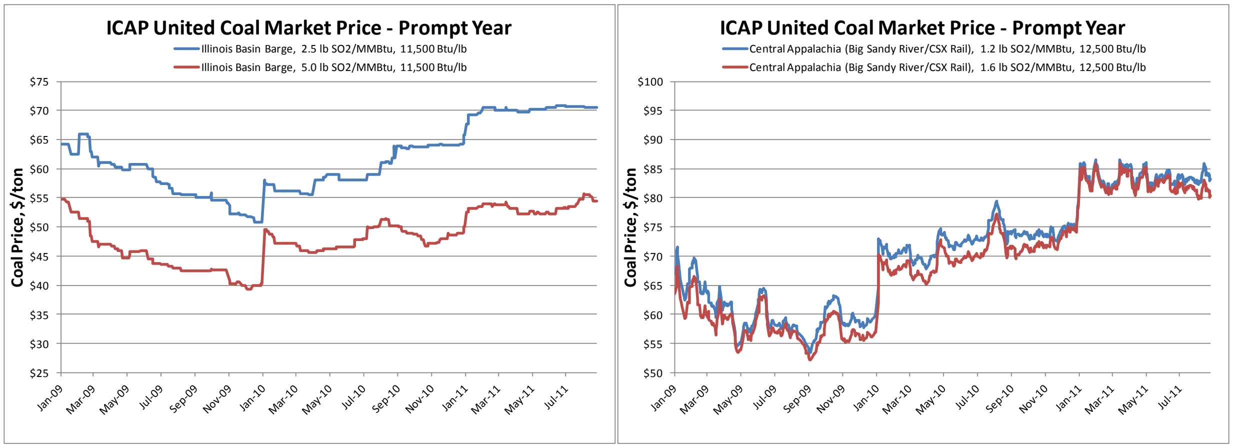
Btu Adjustment: In reality, power plants are buying energy, so the per-ton price must be adjusted to keep a consistent per-Btu price. The adjustment is a straightforward ratio of coal Btu contents.

Coal Ash Adjustment: The differences in the ash contents will affect the cost of ash disposal, which must be taken into consideration. The typical adjustment is 15 cents per ton times the difference in the coal ash contents, expressed in weight percent. This adjustment factor has been the same for at least a decade; in the future it could increase if environmental regulations make ash disposal more expensive for many power plants.

Coal Sulfur Adjustment (aka Sulfur Penalty): During combustion, the sulfur in the coal is converted to sulfur dioxide (SO_2), the emissions of which are regulated by federal and state laws. Because of this, the cost of complying with these laws will vary for coals with different sulfur contents, and the price must be adjusted accordingly. This adjustment is a combination of many factors and can change as these factors change. These include the cost of flue gas desulfurization (FGD), percent of the coal market that has installed FGD, emissions limits in the coal market area, and market demand. Two examples of the effect of sulfur content on coal price are illustrated in the figure below, which shows the prices from 2009 through 2011 for Illinois coal in the left graph, and Central Appalachian coal in the right graph. The two Illinois coals have the same 11,500 Btu/lb heat content; the only difference between them is the sulfur content, 2.5 vs. 5.0 lb SO_2/MMBtu. The price difference between the two coals is \$8.00 to \$18.25/ton coal; this translates into sulfur penalties of \$278 to \$635/ton SO_2. Likewise, the two Central Appalachian coals have the same 12,500 Btu/lb heat content; their sulfur contents are 1.2 and 1.6 lb

SO_2/MMBtu. The price difference between these two coals is \$0.64 to \$4.00/ton coal, which translates into sulfur penalties of \$128 to \$800/ton SO_2.

Exhibit 2-1 Market prices of Illinois and Central Appalachian coals, 2009-2011 [2]



The sulfur penalty in markets with many FGD-equipped units, such as the market for Illinois coal, theoretically should be close to the marginal cost of scrubbing, typically around \$150-250/ton SO_2. When the Clean Air Interstate Rule (CAIR) was in force, SO_2 emissions allowances were traded over the counter, making the coal sulfur content fungible. As a result, the sulfur penalty was close to the marginal cost of scrubbing. But, in 2008, the courts vacated CAIR; thus, utilities had fewer options for SO_2 emissions compliance. This made the sulfur penalty much less dependent on the cost of scrubbing and more dependent on other market forces. For the purpose of this study, the sulfur penalty into a scrubbed market was estimated to be \$550/ton of SO_2, based on the high sulfur/low sulfur difference in over-the-counter coal prices [2] for Illinois Basin barge coal and Central Appalachian rail coal on August 26, 2011.

The coal quality used in NETL studies was reported in the *Quality Guidelines for Energy Systems Studies (QGESS- Specifications for Selected Feedstocks.)* [3] For the four coals in this guideline, the qualities were:

Illinois Basin coal: 11,666 Btu/lb, 4.30 lb SO_2/MMBtu, 9.70 wt% ash

North Dakota lignite: 6,617 Btu/lb, 1.90 lb SO_2/MMBtu, 9.86 wt% ash

Texas lignite: 6,554 Btu/lb, 2.75 lb SO_2/MMBtu, 15.0 wt% ash

Montana Rosebud coal: 8,564 Btu/lb, 1.70 lb SO_2/MMBtu, 8.19 wt% ash

The FOB mine prices were adjusted for differences in coal quality in the following manner:

Btu:	Ratio of HHVs of the as-received coals
Ash:	\$0.15/ton times the absolute % difference in coal ash content
Sulfur:	Difference in Btu-adjusted sulfur content (lb SO_2/MMBtu) times sulfur penalty of \$550/ton of SO_2

Thus, the general equation for coal quality adjustment is:

$$P_{adj} = P_{orig} \times \left(\frac{Btu_{adj}}{Btu_{orig}}\right) - \$0.15 \times [A_{adj} - A_{orig}] - \$550 \times \frac{[Btu_{adj} * S_{adj} - Btu_{orig} * S_{orig}]}{10^6}$$

Where: P is the coal price (\$/ton)
Subscript *adj* represents the coal to which the price is being adjusted
Subscript *orig* represents the original coal
Btu is the higher heating value of the coal (Btu/lb as received)
A is the coal ash content (wt % as received)
S is the sulfur content of the coal (lb SO_2/MMBtu)

Natural gas prices need no quality adjustment, because the prices are already reported on a \$/MMBtu basis (thus, no Btu adjustment is needed), and pipeline quality gas contains no sulfur or ash.

3 Results

3.1 Illinois Basin Coal (delivered to IL/MO/IA region)

Only one plant in this region, Duck Creek, took deliveries of Illinois basin coal in 2010 and 2011 (the others burned Southern PRB coal). Two plants (Duck Creek and Fair Station) took deliveries in 2009.

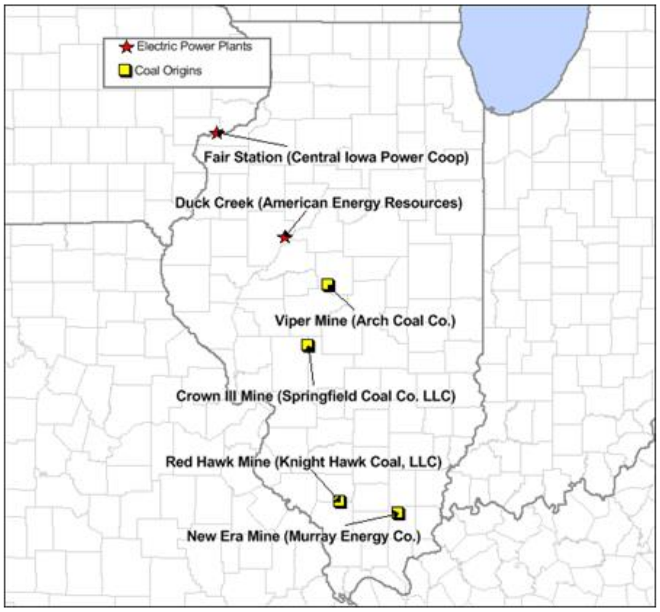
	2009	2010	2011 (through May)
Average delivered coal price, \$/MMBtu	2.01 ± 0.13	2.35 ± 0.05	2.59 ± 0.05
Average delivered coal price, \$/ton	43.38 ± 2.83	49.28 ± 0.89	54.59 ± 1.08
Average transportation cost, \$/ton	5.72 ± 1.29	5.77 ± 0.03	5.82 ± 0.01
Average coal price, FOB mine, \$/ton	37.66 ± 3.46	43.50 ± 0.92	48.77 ± 1.07
Average HHV, Btu/lb	10,781	10,484	10,524
Average Ash Content, wt. %	9.21	9.30	9.08
Average S Content, lb SO_2/MMBtu	5.48	6.26	6.28
Prices adjusted to 11,666 Btu/lb, 4.30 lb SO_2/MMBtu, 9.70 % ash			
Quality adjusted coal price, FOB mine, \$/ton	45.59	56.87	62.72
Quality adjusted coal price, delivered, \$/ton	51.33	62.53	68.54
Quality adjusted coal price, delivered, \$/MMBtu	2.20	2.68	2.94[1]

(± represents 1 standard deviation)

[1] A coal cost of \$2.9376/MMBtu is used in COE calculations to more closely match the \$/ton value results.

The map below shows the active mines and the power plants in this region. [1]

Exhibit 3-1 Location of Illinois basin coal mines and coal-fired power plants



Source: NETL

3.2 North Dakota Lignite (Minemouth)

There are four minemouth lignite mines in North Dakota: Freedom Mine (serving Antelope Valley power plant via belt), Falkirk Mine (serving Coal Creek power plant via belt), Beulah Mine (serving Coyote power plant via belt), and Center Mine (serving Milton R. Young power plant via short-haul truck). Truck cost averaged $0.04/ton higher than belt cost.

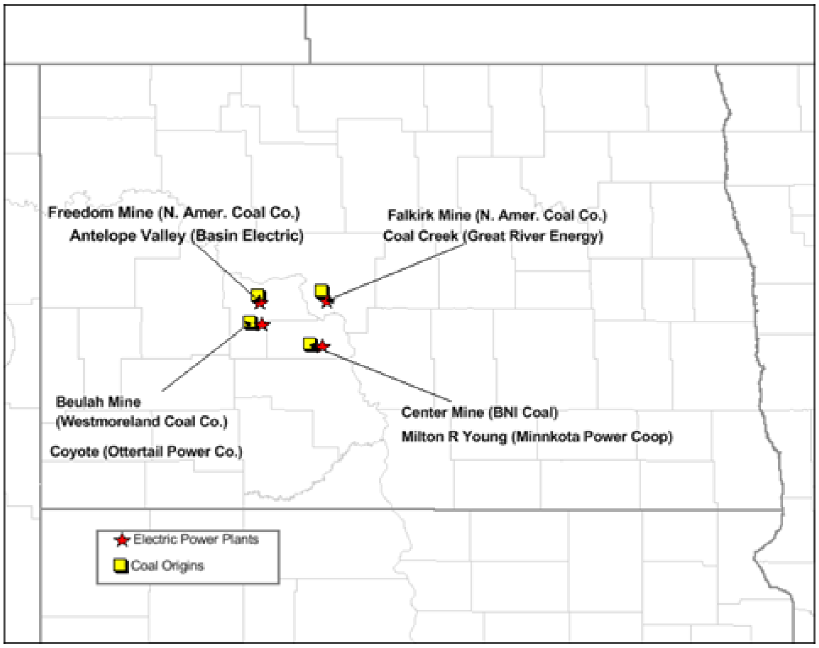
	2009	2010	2011 (through May)
Average delivered coal price, \$/MMBtu	1.08 ± 0.24	1.19 ± 0.42	1.27 ± 0.37
Average delivered coal price, \$/ton	14.24 ± 3.01	15.68 ± 5.43	16.79 ± 4.42
Average belt/truck transportation cost, \$/ton	0.30 ± 0.02	0.31 ± 0.02	0.32 ± 0.02
Average coal price, FOB mine, \$/ton	13.93 ± 3.02	15.37 ± 5.43	16.47 ± 0.43
Average HHV, Btu/lb	6,628	6,598	6,634
Average Ash Content, wt. %	9.23	9.09	9.05
Average S Content, lb SO_2/MMBtu	2.32	2.32	2.32
Prices adjusted to 6,617 Btu/lb, 1.90 lb SO_2/MMBtu, 9.86 % ash			
Quality adjusted coal price, FOB mine, \$/ton	15.35	16.80	17.87
Quality adjusted coal price, delivered, \$/ton	15.62	17.07	18.19
Quality adjusted coal price, delivered, \$/MMBtu	1.18	1.29	1.37[1]

(± represents 1 standard deviation)

[1] A coal cost of $1.3745/MMBtu is used in COE calculations to more closely match the $/ton value results.

The map below shows the active mines and the power plants in this region. [1]

Exhibit 3-2 Location of North Dakota lignite coal mines and coal-fired power plants



Source: NETL

3.3 Texas Lignite (Minemouth)

There are 12 lignite mines in Texas serving 9 power plants via belt, truck, or short-line rail (see map below).

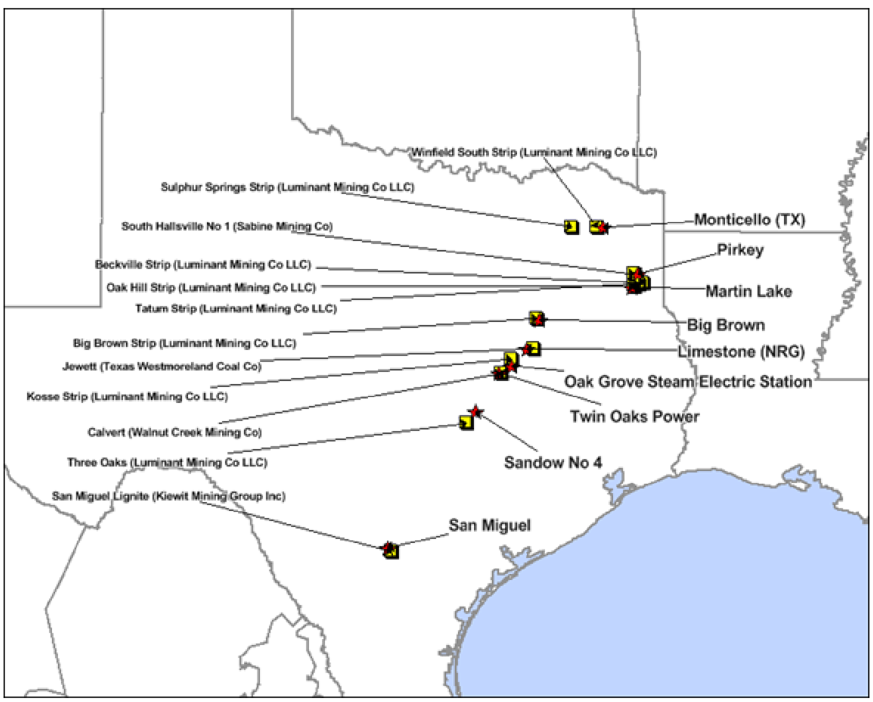
	2009	2010	2011 (through May)
Average delivered coal price, \$/MMBtu	1.69 ± 0.63	1.61 ± 0.42	1.66 ± 0.48
Average delivered coal price, \$/ton	22.10 ± 7.91	21.28 ± 5.26	21.85 ± 5.62
Average transportation cost, \$/ton	0.86 ± 0.71	0.87 ± 0.70	0.87 ± 0.71
Average coal price, FOB mine, \$/ton	21.24 ± 8.22	20.41 ± 5.59	20.98 ± 5.98
Average HHV, Btu/lb	6,643	6,646	6,646
Average Ash Content, wt. %	17.0	16.7	16.9
Average S Content, lb SO_2/MMBtu	3.40	3.24	3.13
Prices adjusted to 6,554 Btu/lb, 2.75 lb SO_2/MMBtu, 15.0 % ash			
Quality adjusted coal price, FOB mine, \$/ton	23.84	22.33	22.51
Quality adjusted coal price, delivered, \$/ton	24.64	23.20	23.38
Quality adjusted coal price, delivered, \$/MMBtu	1.88	1.77	1.78[1]

(± represents 1 standard deviation)

[1] A coal cost of \$1.7836/MMBtu is used in COE calculations to more closely match the \$/ton value results.

The map below shows the active mines and the power plants in this region. [1]

Exhibit 3-3 Location of Texas lignite coal mines and coal-fired power plants



Source: NETL

3.4 Montana Rosebud PRB Coal (Delivered to Central MT)

Montana Rosebud is a Northern Powder River Basin (NPRB) coal; NPRB coal represents around 10 percent of the total PRB production. The Rosebud mine is essentially committed to a minemouth power plant (over 80 percent of the Rosebud mine's annual production is delivered by belt to the Colstrip power plant); therefore, to get a proper estimate of the cost of NPRB coal delivered to the central MT region, other NPRB coals should be included. The approach taken was to use EV's estimated rail cost for NPRB coals (in mills/ton-mile) multiplied by 150 miles (the approximate distance to the central MT region). This transportation cost was added to the average FOB mine prices estimated by EV for the Absaloka, Decker, Rosebud, and Spring Creek mines. The results are in the following table.

	2009	2010	2011 (through May)
Average transportation cost, mills/ton-mile	15.64 ± 5.23	17.51 ± 4.93	19.26 ± 4.17
Average transportation cost, $/ton	2.35 ± 0.78	2.63 ± 0.74	2.89 ± 0.63
Average coal price, FOB Mine, $/ton	14.45 ± 3.26	15.33 ± 2.79	18.21 ± 2.85
Average delivered coal price, $/ton	16.79 ± 3.35	17.96 ± 2.89	21.10 ± 2.92
Average delivered coal price, $/MMBtu	0.93 ± 0.19	1.03 ± 0.17	1.22 ± 0.17
Average HHV, Btu/lb	8,984	8,710	8,663
Average Ash Content, wt. %	7.32	8.64	8.49
Average S Content, lb SO_2/MMBtu	1.19	1.40	1.41[1]
Prices adjusted to 8,564 Btu/lb, 1.70 lb SO_2/MMBtu, 8.19 % ash			
Quality adjusted coal price, FOB mine, $/ton	11.52	13.84	16.74
Quality adjusted coal price, delivered, $/ton	13.86	16.47	19.63
Quality adjusted coal price, delivered, $/MMBtu	0.81	0.96	1.15

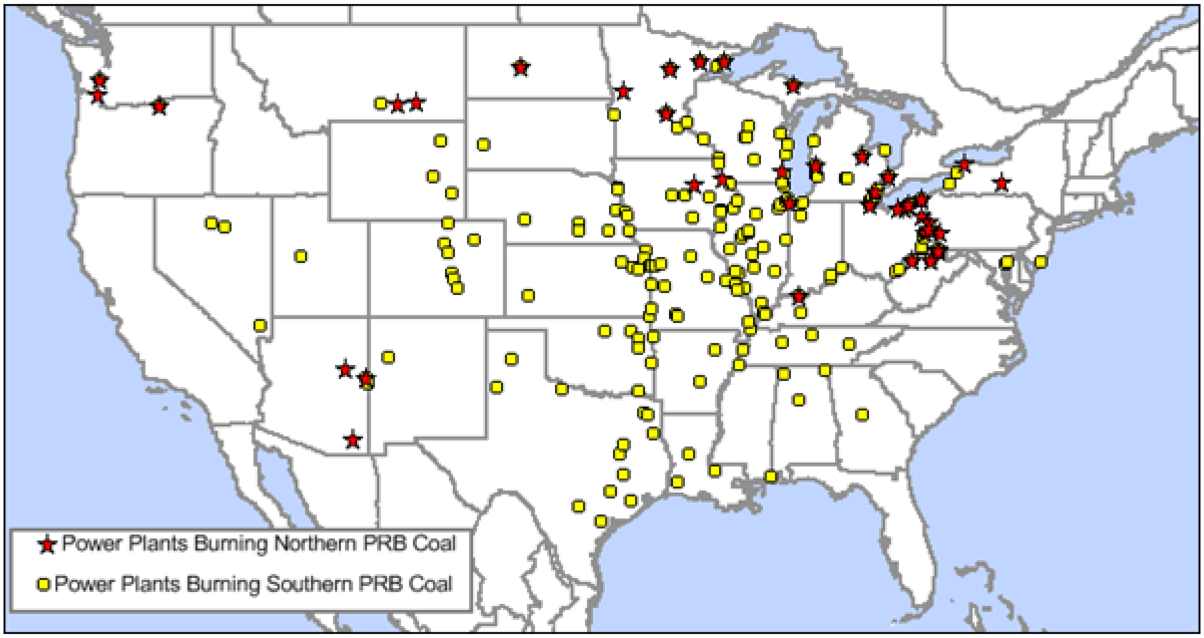
(± represents 1 standard deviation)

[1] A coal cost of $1.1461/MMBtu is used in COE calculations to more closely match the $/ton value results.

3.5 Montana Rosebud PRB Coal (Delivered to the Midwest)

Montana Rosebud is a Northern Powder River Basin (NPRB) coal. The Rosebud mine is essentially committed to a minemouth power plant (over 80 percent of the Rosebud mine's annual production is delivered by belt to the Colstrip power plant). To get a proper estimate of the cost of NPRB coal delivered to the Midwest region, other NPRB coals should be included. In addition, only a small amount of NPRB coal is delivered to the Midwest, because its high sodium content cannot be tolerated by many coal-fired boilers. A map showing PRB power plant deliveries in 2009-2011 is shown in Exhibit 3-4. [1]

Exhibit 3-4 Map of PRB power plant coal deliveries



Source: NETL

However, about half of the 400 million tons of Southern Powder River Basin (SPRB) coal is delivered to power plants in the Midwest census region. Therefore, the approach taken for this guideline was to use EV's average rail cost for delivery of SPRB coals to the Midwest. This transportation cost was added to the average FOB mine prices estimated by EV for the Absaloka, Decker, Rosebud, and Spring Creek mines. The results are in the following table.

	2009	2010	2011 (through May)
Average NPRB coal price, FOB Mine, \$/ton	14.45 ± 3.26	15.33 ± 2.79	18.21 ± 2.85
Average NPRB HHV, Btu/lb	8,984	8,710	8,663
Average NPRB Ash Content, wt. %	7.32	8.64	8.49
Average NPRB S Content, lb SO_2/MMBtu	1.19	1.40	1.41
Average rail cost (SPRB to Midwest), \$/ton	16.10 ± 6.53	16.81 ± 6.63	19.81 ± 7.36
Prices adjusted to 8,564 Btu/lb, 1.70 lb SO_2/MMBtu, 8.19 % ash			
Quality adjusted coal price, FOB mine, \$/ton	11.52	13.84	16.76
Quality adjusted coal price, delivered, \$/ton	27.62	30.65	36.57
Quality adjusted coal price, delivered, \$/MMBtu	1.61	1.79	2.14[1]

(± represents 1 standard deviation)

[1] A coal cost of \$2.1351/MMBtu is used in COE calculations to more closely match the \$/ton value results.

3.6 Average Natural Gas Prices, Delivered to Electric Power Plants

The natural gas prices (reported as $/MMBtu) delivered to power plants in the Midwest, Mountain West and Texas Gulf are in the following table.

	2009	2010	2011 (through May)
Iowa/Illinois/Missouri/Wisconsin area	5.19 ± 1.75	5.45 ± 1.38	6.30 ± 1.20
Wyoming/Nebraska/Colorado area	5.71 ± 1.83	5.17 ± 0.88	6.30 ± 1.29
Texas Gulf area	4.09 ± 0.90	4.58 ± 0.82	4.56 ± 0.73

(± represents 1 standard deviation)

The natural gas prices in the table above are for deliveries to all gas-burning plants in the listed areas, including relatively small peaking plants that purchase gas on an intermittent basis. For comparison with coal prices, it is more appropriate to examine the price of gas delivered to large (450 to 600 MW capacity) gas turbine and combined cycle gas-fired power plants that operate on a more frequent basis. Since there are no gas-fired power plants in this size range in North Dakota, the Mountain West price is used as a surrogate. These prices are in the following table.

	2009	2010	2011 (through May)
Iowa/Illinois/Missouri/Wisconsin area	4.66 ± 1.04	5.36 ± 3.02	6.13 ± 1.43
Wyoming/Nebraska/Colorado area	(no deliveries)	(no deliveries)	5.17 ± 0.22
Texas Gulf area	4.02 ± 0.88	4.38 ± 0.82	4.56 ± 1.29

(± represents 1 standard deviation)

4 Discussion of Coal Price Forecasting

The price estimates in this guideline are only valid for the time periods from which the data were taken. It is important to understand that they do not represent, nor reliably predict, future prices. Coal prices can vary substantially with time due to variations in supply and demand in the coal market. For example, the market price of 2.5 lb SO_2/MMBtu Illinois Basin coal went from \$44.50/ton in mid-2007 to well over \$90.00/ton a year later, but by mid-2009 the price came down to \$57.50/ton; such behavior was observed across the entire U.S. coal market. The 2008 price spike has its roots in the global nature of the coal market. Temporary reductions in 2008 coal production in Australia and South Africa pulled several million tons more U.S. coal into the international market than normal. This reduced the volume of coal available to domestic customers, leading to the equivalent of a bidding war for the remaining supply and subsequent price escalation. In 2009, supply increased as U.S. coal miners increased production to meet the demand, and some of the lost Australian and South African production returned to the international market. Prices dropped as a result.

The FOB mine price for coal is based mainly on what the market will bear, and only weakly based on mining and production costs. In fact, mining and production costs do not even set a floor for the price. When low demand keeps the prices very low (as occurred in 2007), producers switch to "high-grading" production where they only mine the lowest-cost coal, leaving the higher-cost coal unrecovered. The result is a temporary reduction in operating costs in exchange for the unrecovered resources. When high demand drives the coal prices up (as occurred in 2008), producers try to capture additional profits by restarting expensive mines that had been idle due to high costs. The result is a temporary increase in the overall average mining cost.

Although market conditions are a large factor in the price of coal, other factors will contribute to coal price variations, including:

- Coal quality
- Mode of delivery (river barge, rail, truck, belt, ocean vessel)
- Market area where it is delivered
- Competition in the market area
- Cost of electricity generation from non-coal sources
- Contract vs. spot market (including contract length)
- Transportation cost

Some of these conditions (such as coal quality) are easier to account for than others (such as competition). Like the coal price, the transportation cost can vary with time due to market conditions. Less coal is shipped during periods of low coal demand, and shippers will reduce their prices to retain business. When coal demand is high, shippers raise their prices to capture some of the economic rent from the coal producers. Also, transportation costs will vary with the price of oil; coal shippers generally add fuel surcharges to their contracts so that, if the price of diesel fuel goes up, the cost increase is passed on either to the coal producer or to the power plant customer.

Forecasting the delivered price of any coal to any market is very difficult. Nevertheless, effective planning requires some type of forecast, and coal pricing is no exception. The approach most forecasters take is to assume long-term balancing of supply and demand while acknowledging that short-term fluctuations will inevitably occur. Provided that fluctuations are taken into consideration, a reasonable coal price forecast can be constructed for planning purposes.

5 Revision Control

Exhibit 5-1 Revision table

Revision Number	Revision Date	Description of Change	Comments
1	January 9, 2014	Summary added	
		Document formatted	

6 References

1 Ventyx: An ABB Company. (n.d.). *Energy Market Data*. Available from http://www.ventyx.com/velocity/energy-market-data.asp

2 Ventyx: An ABB Company. (n.d.). *Energy Market Data: ICAP United coal prices as listed in the Energy Velocity data base*. Available from http://www.ventyx.com/velocity/energy-market-data.asp

3 National Energy Technology Laboratory (NETL). (2011). *Quality Guidelines for Energy Systesm Studies: Specification for Selected Feedstocks*. Pittsburgh, Pennsylvania.