DOE F 241.3
(2-01) p. 1 of 4

ANNOUNCEMENT

UNITED STATES DEPARTMENT OF ENERGY (DOE)
Scientific and Technical Information (STI) For Financial Assistance Recipients and Non-M&O/M&I Contractors

OMB Control No. 1910-1400

PART I: STI PRODUCT DESCRIPTION
(To be completed by Recipient/Contractor

A. STI Product Identifiers

1. REPORT/PRODUCT NUMBER(s)
none
2. DOE AWARD/CONTRACT NUMBER(s)
DE-FC36-04Go14034
3. OTHER IDENTIFYING NUMBER(s)
none

B. Recipient/Contractor
Powder River Coal Co.

C. STI Product Title
Powder River Coal Plant Wide Assessment

D. Author(s)
Glenn B. fosmo

E-mail Address(es):
gfosmo@peabodyenergy.com

E. STI Product Issue Date/Date of Publication
04/28/2006 (mm/dd/yyyy)

F. STI Product Type *(Select only one)*

☒ 1. TECHNICAL REPORT
☒ *Final* ☐ *Other (specify)*

☐ 2. CONFERENCE PAPER/PROCEEDINGS
Conference Information (title, location, dates)

☐ 3. JOURNAL ARTICLE
a. TYPE: ☐ *Announcement Citation Only* ☐ *Preprint* ☐ *Postprint*
b. JOURNAL NAME
c. VOLUME *d. ISSUE*
e. SERIAL IDENTIFIER (e.g. ISSN or CODEN)

☐ OTHER, SPECIFY

G. STI Product Reporting Period (mm/dd/yyyy)
04/20/2004 *Thru* *04/28/2006*

H. Sponsoring DOE Program Office
US DOE

I. Subject Categories *(list primary one first)*
01
Coal, lignite, and peat

J. Description/Abstract
Energy savings assessment of a coal mine

K. Intellectual Property/Distribution Limitations
(must select at least one; if uncertain contact your Contracting Officer (CO))

☒ 1. UNLIMITED ANNOUNCEMENT *(available to U.S. and non-U.S. public; the Government assumes no liability for disclosure of such data)*

☐ 2. COPYRIGHTED MATERIAL: *Are there any restrictions based on copyright?* ☐ *Yes* ☐ *No*
If yes, list the restrictions as retained in your contract

☐ 3. PATENTABLE MATERIAL: THERE IS PATENTABLE MATERIAL IN THE DOCUMENT
INVENTION DISLOSURE SUBMITTED TO DOE:
DOE Docket Number: S-
(Sections are marked as restricted distribution pursuant to 35 USC 205)

☐ 4. PROTECTED DATA: ☐ *CRADA* ☐ *Other*
If other, specify
Release date (mm/dd/yyyy)

☐ 5. SMALL BUSINESS INNOVATION RESEARCH (SBIR) DATA
Release date (Required,
(No more than 4 years from date listed in part 1.E above)

☐ 6. SMALL BUSINESS TRANSFER (STTR) DATA
Release date (Required,
No more than 4 years from date listed in part 1.E above)

☐ 7. OFFICE OF NUCLEAR ENERGY APPLIED TECHNOLOGY

L. Recipient/Contractor Point of Contact *Contact for additional information (contact or organization name to be included in published citations and who would receive any external questions about the content of the STI Product or the research contained therein)*

Name and/or Position
Glenn B. Fosmo
E-mail *Phone*
gfosmo@peabodyenergy.com
Organization Maintenance

ANNOUNCEMENT

UNITED STATES DEPARTMENT OF ENERGY (DOE)
Scientific and Technical Information (STI) For Financial Assistance Recipients and Non-M&O/M&I Contractors

OMB Control No. 1910-1400

PART II: STI PRODUCT MEDIA/FORMAT and LOCATION/TRANSMISSION

(To be completed by Recipient/Contractor)

A. Media/Format Information:

1. MEDIUM OF STI PRODUCT IS:
   ☒ Electronic Document ☐ Computer medium
   ☐ Audiovisual material ☒ Paper ☐ No full-text
2. SIZE OF STI PRODUCT 64 pages
3. SPECIFY FILE FORMAT OF ELECTRONIC DOCUMENT BEING TRANSMITTED, INDICATE:
   ☐ SGML ☐ HTML ☐ XML ☐ PDF Normal ☐ PDF Image
   ☐ WP-Indicate Version *(5.0 or greater)* ________
   Platform/operating system ________
   ☒ MS-Indicate Version *(5.0 or greater)* ________
   Platform/operating system Microsoft Windows
   ☐ Postscript ________
4. IF COMPUTER MEDIUM OR AUDIOVISUAL
   a. Quantity/type *(specify)* ________
   b. Machine compatibility *(specify)* ________
   c. Other information about product format a user needs to know: ________

B. Transmission Information:

STI PRODUCT IS BEING TRANSMITTED:
☒ 1. Electronic via Elink
☒ 2. Via mail or shipment to address indicated in award document *(Paper products, CD-ROM, diskettes, videocassettes, et.)*
____
☐ 2a. Information product file name *(of transmitted electronic format)*
NARM Plant Wide Assessment

PART III: STI PRODUCT REVIEW/RELEASE INFORMATION

(To be completed by DOE)

A. STI Product Reporting Requirement Review:

☐ 1. THIS DELIVERABLE COMPLETES ALL REQUIRED DELIVERABLES FOR THIS AWARD
☐ 2. THIS DELIVERABLE FULFILLS A TECHNICAL REPORTING REQUIREMENT, BUT SHOULD NOT BE DISSEMINATED BEYOND DOE.

B. DOE Releasing Official

☐ 1. I VERIFY THAT ALL NECESSARY REVIEWS HAVE BEEN COMPLETED AS DESCRIBED IN DOE G 241.1-1A, PART II, SECTION 3.0 AND THAT THE STI PRODUCT SHOULD BE RELEASED IN ACCORDANCE WITH THE INTELLECTUAL PROPERTY/DISTRIBUTION LIMITATION ABOVE.

Released by *(name)* ________

Date ________
(mm/dd/yyyy)

E-mail ________

Phone ________

Final Technical Report
Powder River Coal Company Plant Wide Assessment

The following report contains information pertaining to a Plant Wide Assessment done by Powder River Coal Company, through the use of a Rockwell Automation Power and Energy Management Solutions group (PEMS) and employees of North Antelope Rochelle Mine (NARM).

A scope of work was determined by NARM personnel and the Rockwell PEMS group to analyze existing systems and energy uses, along with suggestions and solutions for Energy Conservation Measures (ECM).

Scope of Work:

Description of the existing facility and operation of 3 mines
Description of the existing processes and operation of 3 mines
A summary of the data gathered during the process of 3 mines
Utility Data
kWh consumption and cost
kW demand and cost
Load Factor
Power Factor
Summary of the Energy Conservation Measures, ECM's found during the survey including:

- ♦ Estimate of the energy savings for each ECM
- ♦ Identify specific corrective actions that will address these ECM's
- ♦ Operational Changes
- ♦ Capital Projects
- ♦ Cost estimate for the recommended ECM's
- ♦ Return on investment estimate for each ECM
- ♦ An engineering design document illustrating an architecture and component system to accomplish manual demand management
- ♦ Completion of a power study on the effects of the shovels and draglines synchronizing with each other and what it does to the demand of the mine.
- ♦ Completion of a power study showing RPC inadequacies and trail cable lengths.

Upon completion of this scope of work it was hoped to achieve the following energy savings:

- ♦ Through low cost and or no cost operational changes it is intended that 603,000 KW demand out of 40.2 MW demand every month, and 232,000 KWH out of 15.5 MWH every month will be conserved.
- ♦ Through capital funded projects it is intended that 1 MW demand out of 40.2 MW demand every month and 387,000 KWH out of 15.5 MWH every month will be conserved.
- ♦ Through the assessment process for future expansion, 1% energy conservation due to new technologies and the installation of energy efficient equipment is expected.

Findings and Significant Information:

In comparing some of the differences between a large mine such as NARM, and a smaller mine such as Rawhide, is that the fixed portion of electrical energy usage is 52% of total electrical energy usage at NARM as compared to Rawhide which has a fixed component of only 9%, which in turn creates a higher electrical cost per production unit at Rawhide than at NARM.

- ♦ First, this translates into the fact that if Rawhide were to increase tonnage, the cost per production unit would decrease significantly. For NARM, if production were to drop off, a substantial increase in cost per production unit would be seen.
- ♦ Secondly, this indicates that much of the fixed electric energy can be associated with equipment that is constantly running whether systems are loaded or not. So, there must be some operational changes that could take place to relieve this equipment from usage if not being used for production such as, the turning off or slowing down of unused equipment at non productive times.
  ie… Conveyor belts, pumps, air compressors, crushers, and lighting.

-
- In the latter case, variable frequency drives (VFD) for conveyor belts pumps, and crushers seem to be a viable option. In this case the option of VFD's for the 4160v conveyors are very expensive and an engineered scheme of how coal has to flow through gates and chutes at certain speeds could be quite involved that the payback for these devices does not meet normal standards. But, when engineering new conveyor systems with the thought of VFD's for motor control and the correct design for coal flow can be resolved before construction, the idea has much merit. In fact, NARM has already used this premise to engineer a new plant and control scheme for an additional 20mty coal processing system. And VFD's have been installed on existing crusher motors to help with times when production tons are low or unexpectedly low.
- Findings associated with RPC (Reactive Power Compensation) and cable lengths used on shovels, showed minimal impact on demand and usage. The RPC components of 9 shovels would have an impact if total kVAR components were taken into account. Each machine has the ability to inject approximately 6mVARs into the power system. Each machine uses a step method of approximately 850 kVARs to accomplish this. This is very small compared to total kVAR generation throughout the mine such as what the draglines produce at any one time of approximately 9 to 10 mVARS.

  Throughout the past couple of years, an attempt to repair RPC components immediately on these machines has lessened the affect of kVAR mismanagement on the entire system.
- Findings associated with the draglines running in synchronization with each other and the affects on the overall demand of the power system has shown that a demand controller could save some power costs. Base load of the mine without the draglines shows to be approximately 15.5mW. As the draglines are in production, the demand raises to an average level of 20mw. When the draglines are in sync with other, which happens many times per day, but only about 9 times on the average per month long enough to cause the demand to rise above 25mW, there would seem to be an ample opportunity to capture this time and make some changes to either the operation of the draglines or the base load to offset the overall demand.

The attached reports on overall mine power usage were compiled by Rockwell Automation PEMS group and explain findings.
The other attached facts and figures on Shovels and Draglines were compiled by mine personnel.

Mine Energy Assessment –

Supplemental Report

Peabody Energy Company

Gillette, Wyoming

Report # DE-FG36-40GO14034

October 31, 2005

For personal assistance regarding your report contact:

Steve Nalbandian
6261 Katella Avenue, Suite 1B
Cypress, CA 90630
Phone: 714 816-6316
Email: sjnalbandian@ra.rockwell.com

Visit us at: http://www.ab.com/PEMS/ Systems/Products/Communications/Applications

Introduction

This report includes a comprehensive analysis of energy requirements and usage at the North Antelope Rochelle (NAR) mine. Electricity usage information from an existing energy metering/accounting system was available to augment, validate and support traditional analysis of electric/gas bills, production data, weather data and an equipment rating survey. This allowed a complete top-down and bottom-up analysis as described in the next section.

Models used to understand process energy requirements were validated using NAR data. This report includes those models. Benefits of this report include:

- A heightened awareness and understanding of how and where energy is used in the mining process. This should lead to additional insight and ideas for work practice changes and process design changes that will significantly reduce cost.
- Specific information on energy usage by department that demonstrates the value of continuing to use and develop the existing energy accounting system, including more reports and regular review of data. Eventually, targets should be set and report-by-exception used to manage energy and drive cost out of the process.
- A mathematical model that can be used to study the impact of proposed changes to the process and extended to other mines
- Better understanding of slot-storage energy costs per ton of coal
- Specific recommendations related to major belt drives, lighting, demand management and other aspects of energy usage at the mine
- Guidance to be considered as NAR evolves and expands, from simple lighting change-out to alternative major belt drive designs

North Antelope Rochelle Energy Analysis

The purpose of this section is to understand energy usage for present operations. This understanding form the basis for identifying and evaluating changes intended to improve energy performance (lower energy cost per ton of coal produced).

There are two (2) approaches to energy analysis; top-down and bottom-up.

1. Top-Down or *Statistical Analysis* – regression analysis of usage as a function of production and weather data

2. Bottom-up or *Load Modeling* – estimating usage based on equipment configuration, ratings and operating procedures

Energy usage is best understood by approaching the analysis from both directions and then reconciling the differences with actual recorded data. The resulting understanding and system model are very useful in predicting the impact of proposed changes.

This section of the report contains the statistical analysis and model development for North Antelope Rochelle Mine. It also includes the reconciliation based on actual data recorded in an RSEnergyMetrix database. An appendix includes a lot of the detailed supporting information.

Statistics

The period of time used for this analysis is January 1, 2003 through July 30, 2005. The following data were required and available over this time period:

- Coal production [tons]
- Electricity usage [kWh]
- Outdoor temperature [heating degree-days (HDD) and cooling degree days(CDD)]

Actual monthly data used in the analysis are given in Appendix – A. The regression analysis involves finding a best-fit straight line for electric energy usage (kWh) as a function of coal production and weather. The result was as follows:
Energy [kWh] = 7,100,000 + 910 x production [1000 tons] + 650 x heating [HDD]

This expression can be used to calculate historical electric energy usage at NAR, given production and weather data. It indicates a fixed component of 7.1 million kWh each month, independent of production level or weather. Further, it indicates that 910 kWh are added for each 1000 tons of coal produced, and 650 kWh for each heating degree day. Cooling degree days have no significant impact. The following table shows how accurate the expression is in calculating historical usage:

Line Ref. #	Error [+/-%]	Number of Months	Cumulative Number of Months	Percentage	Cumulative Percentage
1	0	5	5	16%	16%
2	1	5	10	16%	32%
3	2	7	17	23%	55%
4	3	4	21	13%	68%
5	4	4	25	13%	81%
6	5	1	26	3%	84%
7	6	4	30	13%	97%
8	7	0	30	0%	97%
9	8	0	30	0%	97%
10	9	0	30	0%	97%
11	10	1	31	3%	100%
12	Total	31			

There are a total of 31 months in the time period studied. The error table indicates the following:

- Line #1 – In 5 of the 31 months studied (16% of the sample), the expression correctly predicts energy usage with a very small error (a few tenths of a %)
- Line #2 – In another 5 of the 31 months studied (16% of the sample), the expression predicts actual energy usage within +/- 1%. Including line #1 and line #2, the expression predicts actual usage within +/- 1% 32% of the time.
- The expression predicts actual energy usage within +/-6% error in 30 of the 31 samples (97%)
- Line #11 indicates there is one statistical outlier which happens to be November 2004. In this month, the expression has an error of 10%

Annual results are as follows:

Year	Actual Energy	Predicted Energy	Error	Error %
2003	160,815 MWh	163,009 MWh	-2,194 MWh	-1%
2004	168,756	164,437	4,319	3%
2005 (Jan - July)	94,496	95,945	-1,449	-2%

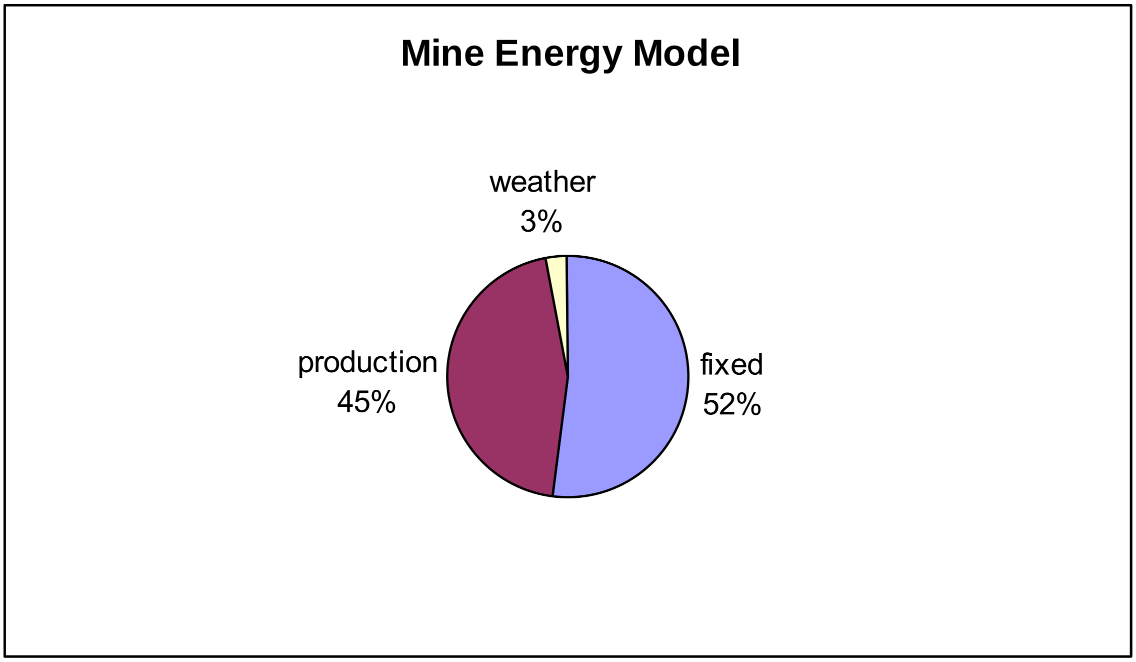
As expected, the expression becomes more accurate as the period of time is extended. When applied to November, 2004 the expression had an error of 10%. However, the error is reduced to 3% for the entire 2004 calendar year.
By definition, the average error over the entire study period (31 months) is zero. This is a fundamental characteristic of regression analysis.

If applied to individual days, the errors would be greater. However, the results are very useful in understanding energy usage and the impact of weather and production. The following are important observations:

1. The fixed portion (7,100 MWh per month) is 52% of total usage in a typical year. Energy usage in a mining operation is usually a stronger function of production. In other words, the fixed usage is relatively high. There are surely opportunities to reduce usage by looking for production equipment running unnecessarily and thus becoming part of the fixed load.

2. The high fixed usage also implies that the cost of energy per unit of production will increase at lower production. The fixed usage must be allocated to each unit of production, so lower production will mean significantly higher energy cost per unit of production.

3. High ambient temperature does not impact usage significantly. This northern location of this mine, at high altitude is not expected to have a significant cooling load.



Additional information and all the source data are given in Appendix – A.

Load Modeling

Total usage is the sum of each individual electric load in the mine. The purpose of this "bottom-up" analysis is to understand usage at different points in the process. The process is broken down into the following for analysis:

1. Pits
   a. Overburden
   b. Coal
2. Plants
   a. East
   b. West
3. Support
   a. East Administration
   b. East Shop
   c. West Administration
   d. West Shop

The goal is to develop a model that "explains" the known (metered) energy consumption in each step of the process.

Pit Model

The pit model is based on RSEnergyMetrix data and estimates based on equipment ratings and known operating procedures. Electric energy measurements for overburden and coal activities over a period of time are divided by coal production over the same period of time. Equipment ratings and hours of operation are also used for estimates.

Overburden

Overburden activity does not directly result in coal delivered to the hopper. However, over a period of several months, the energy used for overburden work is expected to correlate to production. The following equipment is classified for this study as overburden equipment.

Unit#	Equipment Description
103*	P/H 4100A Shovel
104	P/H 4100 Shovel
105	P/H 4100 Shovel
106	P/H 4100A Shovel
107	P/H 4100A Shovel
108	P/H 4100A Shovel
109	P/H 4100XPB Shovel
120	Bucyrus 2570 Dragline
154	Marion 8200 Dragline
157	Bucyrus 395

* Note that unit 103 began service in August 2004 and was used to replace unit 104 which was moved to coal service at that time.

From June 1, 2004 to May 31, 2005 NAR produced 83,660 ktons of coal. During that period of time, overburden activities used 81.2 GWh of electric energy. That translates to about 971 kWh or $ 30.10 per 1000 tons of coal. The draglines consume about 50% of the overburden energy. Cumulative net energy is used for the analysis in order to account for momentary regeneration by the draglines.

Unit#	Equipment Description	Period Energy*	Percent
103	P/H 4100A Shovel	4,589 MWh	6 %
105	P/H 4100 Shovel	5,258	6
106	P/H 4100A Shovel	5,932	7
107	P/H 4100A Shovel	5,913	7
108	P/H 4100A Shovel	5,894	7
109	P/H 4100XPB Shovel	9,446	12
120	Bucyrus 2570 Dragline	22,700	28
154	Marion 8200 Dragline	18,000	22
157	Bucyrus 395	3,493	4
Total		81,225 MWh	100 %

*Energy values in the above table are from June 1, 2004 to May 31, 2005.

Coal Operation in the Pits

Coal operation energy is required primarily by shovels engaged in coal movement, including the following equipment:

Unit#	Equipment Description
104*	P/H 4100 Shovel
152	P/H 2800 XPA Shovel
155	Bucyrus 290B Shovel
156	P/H 4100A Shovel
158	Bucyrus 295 Shovel

* Note that unit 104 was moved to coal service in August 2004 when unit 103 arrived for overburden work.

From June 1, 2004 to May 31, 2005 NAR produced 83,660 ktons of coal. During that period of time, coal activities used 25.2 GWh of electric energy. That translates to about 302 kWh or $ 9.35 per 1000 tons of coal.

Unit#	Equipment Description	Period Energy*	Percent
104	P/H 4100 Shovel	5,576 MWh	22 %
152	P/H 2800 XPA Shovel	6,566	26
155	Bucyrus 290B Shovel	3,045	12
156	P/H 4100A Shovel	7,113	28
158	Bucyrus 295 Shovel	2,940	12
Total		25,240 MWh	100 %

*Energy values in the above table are from June 1, 2004 to May 31, 2005.

East Plant Model

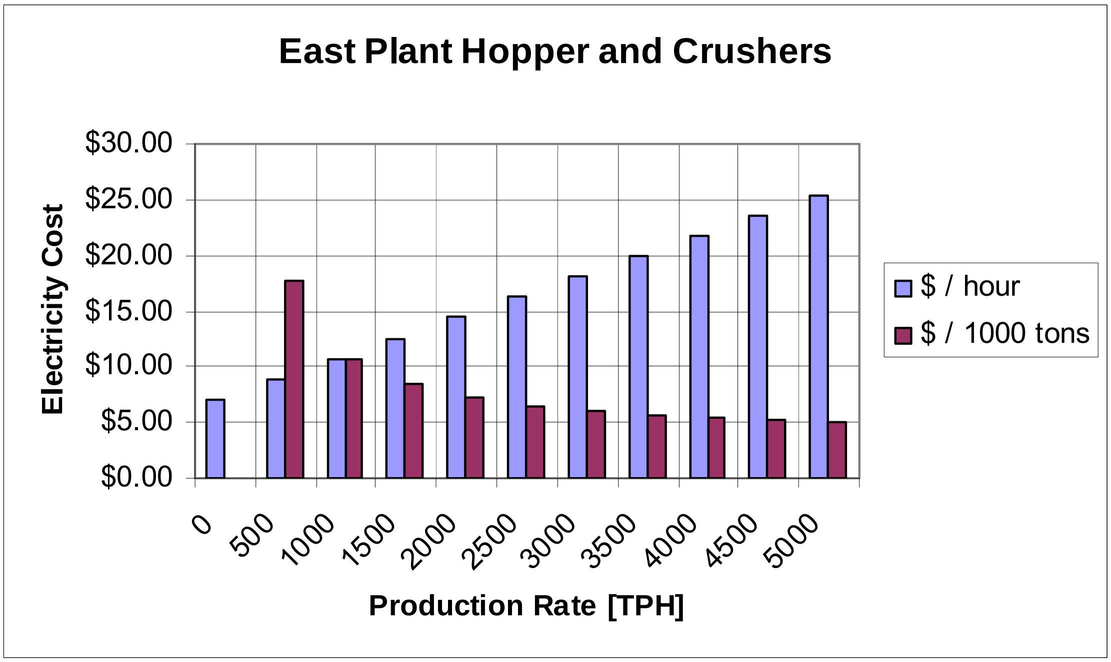
Elements of the East Plant model are:

1. Hopper feed and crusher
2. Reclaim belt (E-21)
3. Transfer building
4. Slot Storage
5. Silo feed (E-43 and E-343)
6. Silos
7. Auxiliaries

Hopper Feed and Crusher

The connected motor load is 1375 hp. This includes 1200 hp for the crusher and 175 hp for hydraulics, air compressor, wash down, sump, etc. The crusher motors are estimated to run at 72 to 78% of rated load while processing coal at 5000 TPH, and are estimated to draw 15% of rated load when no coal is being processed. Auxiliary motors are assumed to draw 72% of rated load independent of production. Based on measurements at the West Plant, these estimates may be a little high. However, based on RSEnergyMetrix data and field measurements, average motor load in the East Plant runs about 70% of rating.

With a small addition to account for lighting and miscellaneous loads, the hopper feed and crusher load at 5000 TPH is 820 kW and 212 kW when idle (spinning with no coal throughput.) The following graphs are based on this model and $ 0.031 / kWh average cost of electricity.



This model for the hopper and crusher will help form an overall model for the East Plant. The next set of important components to be modeled is the major belts.

Coal Conveyance Model – Technical Approach

The purpose of this section is to understand the energy and power requirements associated with coal conveyors. Major belts in the East Plant are included in the analysis.

Conveyor power has three (3) components:

1. *no-load conveyor friction power*: needed to overcome belt and roller friction whether or not there is coal on the belt
2. *load friction power*: needed to overcome additional friction caused by the weight of coal on the belt
3. *lift*: needed to lift the coal to a higher elevation

Total Power = no-load friction + load friction + lift

Each of the major belts were analyzed to determine power requirements for the above components. Field measurements were used from belt E-21 to check the analysis and also to determine the coefficient of friction.

Analysis

The following information is given for each major belt.

Number	Description	Capacity [TPH]	Length [ft]	Lift [ft]	Speed [fpm]
E-21	60" Hopper Reclaim	5300	2200	31	1228
E-43	48" Silo Feed	3200	2500	183	881
E-343	60" Silo Feed	5300	2500	183	1230
E-102	Slot Feed	4000	650	80	872
E-112	Slot Reclaim	3000	425	0	872
E-113/4	Steep Angle	3200	250	80	882

A variety of calculations are then performed with these given numbers.

Tons of Coal on the Belt – The total weight of coal on the belt at any point in time is needed to calculate lifting power. This determines how much power is required for lift. The weight of coal, combined with the coefficient of friction, also determines the load friction power.

No-load Friction – The belt and rollers have friction that requires power even when the belt is empty. This value was determined by field measurement of motor load with no coal on the belt.

Load Friction – As the belt is loaded, additional friction is created and more power is required to overcome it. A coefficient of friction was determined by measuring motor load with the belt loaded. Friction loss (power) is determined by the weight of coal normal to the belt, belt speed and the coefficient of friction. Friction loss (in hp) is equal to the weight normal to the belt (lbs) x belt speed [fps] x coefficient of friction.

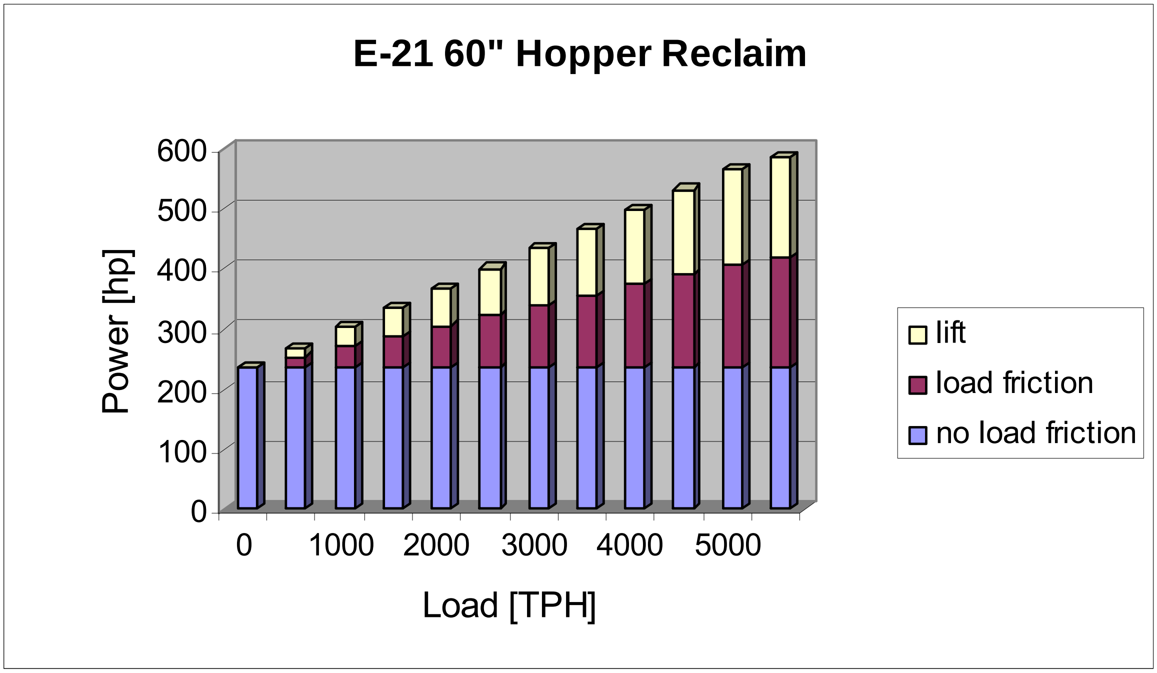
Lift Power – Lift power is determined by the speed at which the coal is lifted and the weight of the coal. One horsepower is required to lift 550 lbs of coal 1 foot in 1 second. So lift power (in hp) is equal to (lbs. of coal delivered per second) x (lift in feet) / 550.

Total Power – Coal conveyors require power to overcome friction and lift the coal if the conveyor delivery end is at a higher elevation than the supply end. Total power is equal to the sum of no-load power, load friction power, and lift power.

For each of the major belts, this analysis results in an understanding of belt power components over a range of loads (tons per hour).

E-21 60" Hopper Reclaim

This belt is relatively long (2200 feet) and has a small lift (31 feet). The analysis results are as follows.

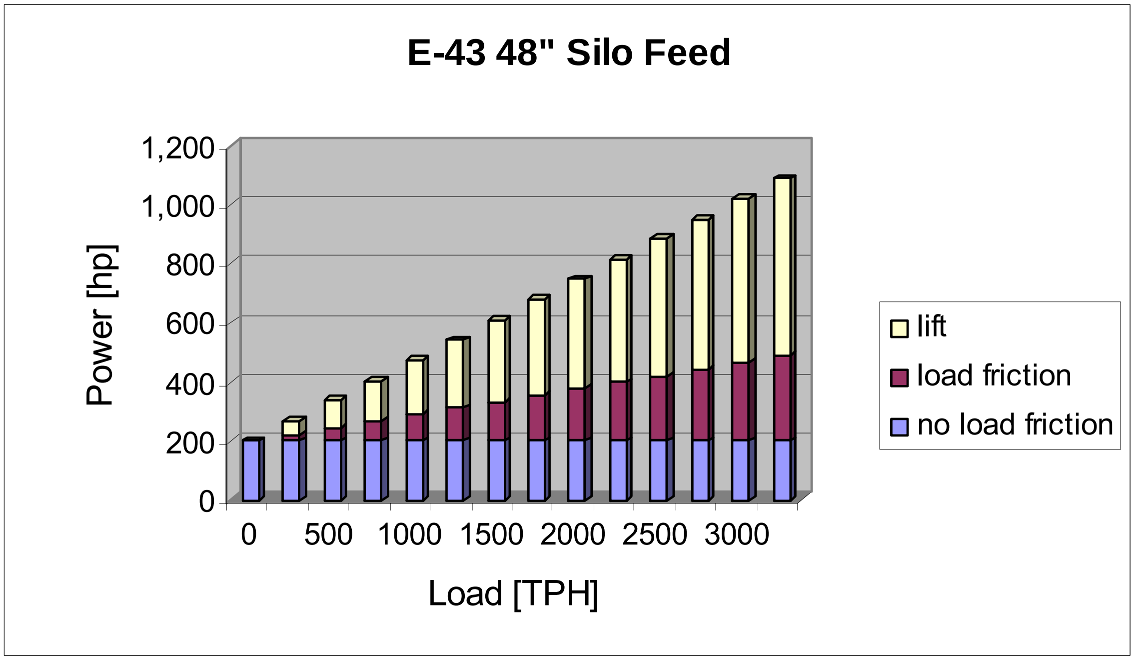


Motor power of 237 hp is required to move the belt without coal. This no-load friction result is based on actual field measurements and is considered reliable. The power to overcome additional friction caused by the coal load and power required to lift the coal are about equal. The resulting total power at rated load of 5300 TPH is 580 hp.

Based on the average cost of electricity and drive/motor efficiency, it costs $2.81 to move 1000 tons of coal across this belt. The cost of running the belt unloaded (no coal) is $6.09 / hour.

E-43 48" Silo Feed

This belt is relatively long (2500 feet) and has a large lift to the top of the silos (183 feet). The analysis results are as follows.

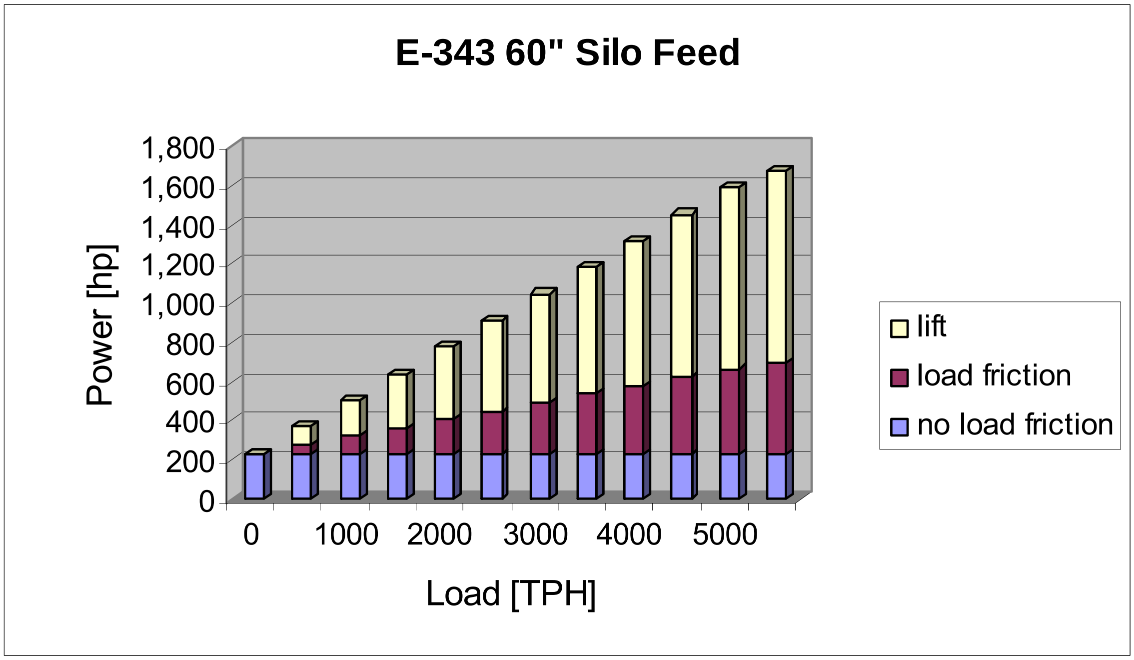


Motor power of 200 hp is required to move the belt without coal. This no-load friction result is based on actual field measurements and is considered quite reliable. The power to overcome additional friction caused by the coal is only about half the power required to lift the coal. The resulting total power at rated load of 3200 TPH is 1087 hp.

Based on the average cost of electricity and drive/motor efficiency, it costs $5.27 to move 1000 tons of coal across this belt. The cost of running the belt unloaded (no coal) is $5.14 / hour.

E-343 60" Silo Feed

This belt is relatively long (2500 feet) and has a large lift to the top of the silos (183 feet). The analysis results are as follows.

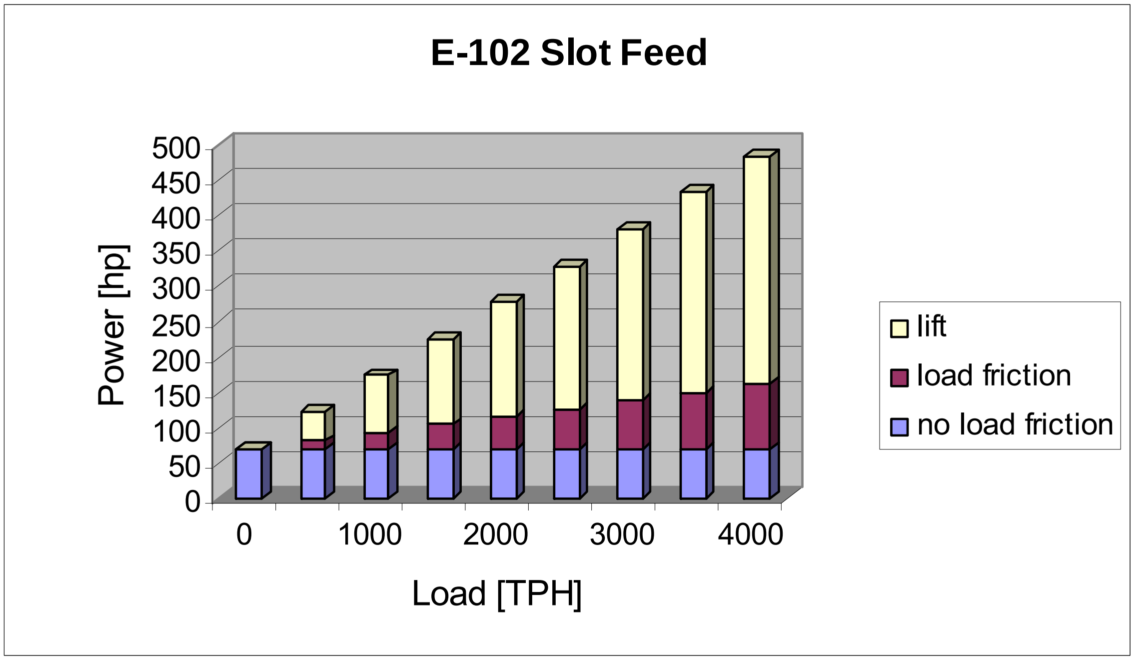


Motor power of 236 hp is required to move the belt without coal. This no-load friction result is based on actual field measurements and so regarded as quite reliable. The power to overcome additional friction is only about half what is required to lift the coal. The resulting total power at rated load of 5300 TPH is 1672 hp.

Based on the average cost of electricity and drive/motor efficiency, it costs $8.10 to move 1000 tons of coal across this belt. The cost of running the belt unloaded (no coal) is $6.09 / hour.

E-102 Slot Feed

This is a short belt (650 feet) that uses most of its power requirement to lift the coal to the top of the slot storage facility. The analysis results are as follows.

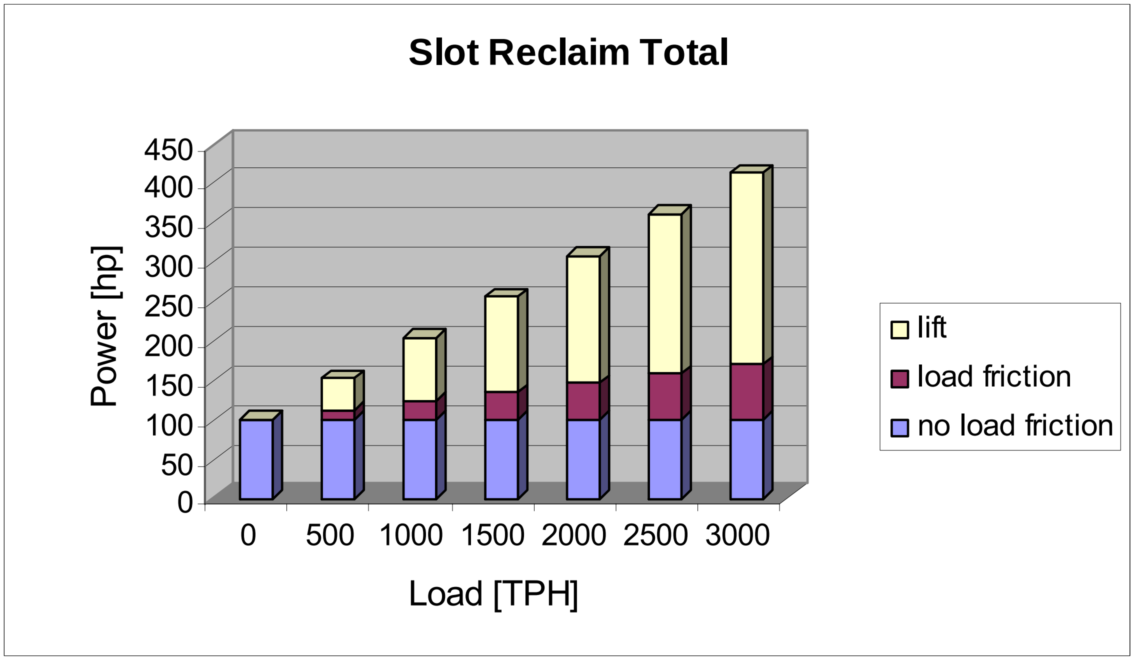


Motor power of 70 hp is required to move the belt without coal. This no-load friction result is estimated based on measurements of other belts. As expected, the power to lift coal is three (3) times the power required to overcome load friction. The resulting total power at rated load of 4000 TPH is 484 hp.

Based on the average cost of electricity and drive/motor efficiency, it costs $3.11 to put 1000 tons of coal in the slot on this belt. There are other electric loads in the slot storage area. See the analysis section on page 17 for complete information on the cost of slot storage. The cost of running this belt unloaded (no coal) is $1.80 / hour.

Slot Reclaim

Slot reclaim includes three (3) belts (E-112, 113 and 114). This analysis is based on the combination of all three (3) belts. The lift is 80 feet on the steep-angle belts. As expected, lift power is a significant component in the total.



Motor power of 100 hp is required to move the belts without coal. The power to lift the coal is more than double the friction load. The resulting total power at rated load of 3000 TPH is 413 hp.

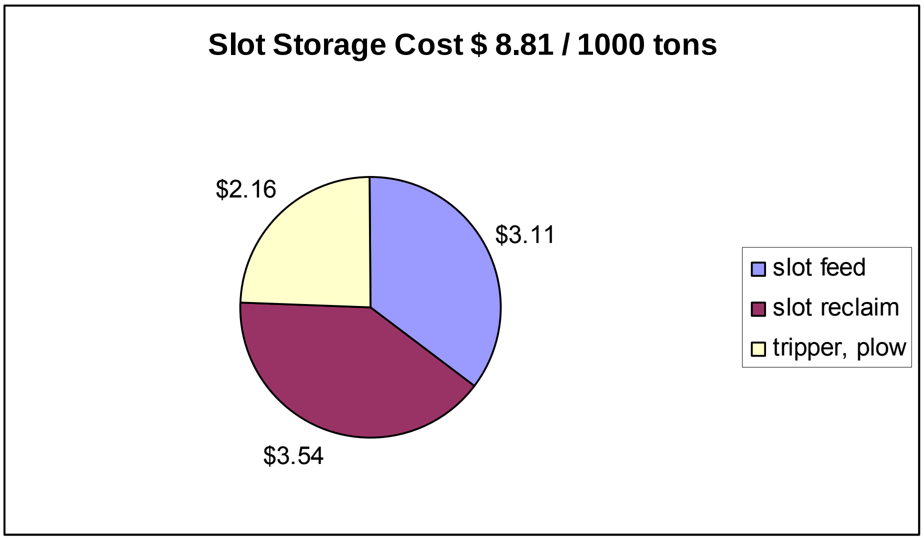
Based on the average cost of electricity and drive/motor efficiency, it costs $3.54 to reclaim 1000 tons of coal from the slot. This does not include other significant slot electric loads. See the analysis on page 17 for a complete discussion on slot storage. The cost of running the belts unloaded (no coal) is $2.57 / hour.

Slot Storage and Reclaim

In addition to belt energy moving coal in and out of slot storage, the facility itself has equipment with significant loads (tripper, rotary plows, etc.) In order to model the "round trip" cost of slot storage, this section includes the belt energy and also the additional loads.

Consider the cost of running 1000 tons of coal in and out of slot storage. The slot feed belt will run for about 15 minutes and use electricity costing $3.11 The reclaim belts will run for about 20 minutes getting the 1000 tons of coal out of storage and will cost $3.54 Miscellaneous and support equipment (tripper, rotary plows, etc) will also run during this time and cost $ 2.16

Therefore, a round trip through the slot costs $ 8.81 per 1000 tons.



Silos

The silos have a variety of hydraulic equipment, a shuttle belt and air compressor. The total connected load is about 310 hp, plus miscellaneous lighting and space conditioning (ac and heat in the control room) load. Although some variation in energy usage is expected from when a train is being loaded versus when no trains are being loaded. This model is based on the assumption of constant load.

Based on the connected load and average motor utilization in the silos of 78%, the silo load is 220 kW or about $ 6.20 / hour based on the average cost of electricity.

Transfer Building and Auxiliaries

The final piece to the East Plant model must account for transfer belts and auxiliary equipment including water pumps, wash down and the sampling systems.

Equipment	Connected Load [hp]
Sample System 1	10
Sample System 1	30
Sample System 1	40
Sample System 2	10
Wash down	40
Wash down	25
Wash down	25
Wash down	25
Deep well #1	100
Deep well #2	290
Mine #1 water	100
Mine #2 water	100
Potable water #1	7.5
Potable water #2	7.5
Transfer Shuttle	125
Transfer Shuttle	100
Total	1035 hp

This table details the miscellaneous equipment. Duty cycles established from RSEnergyMetrix data indicate this equipment represents an idle load of about 370 kW. Using the average cost of electricity, this is a fixed cost of $11.45 per hour.

If the transfer belts are running, the cost increases to $ 15.50. The transfer shuttle belts are not major loads. So, for this model, an average cost is used without attempting to account for idle and production periods separately.

This completes the component analysis for the East Plant. It is now possible to construct a complete picture of electricity usage and cost as a function of plant production.

Complete East Plant Model

The East Plant model is the sum of the components as follows.

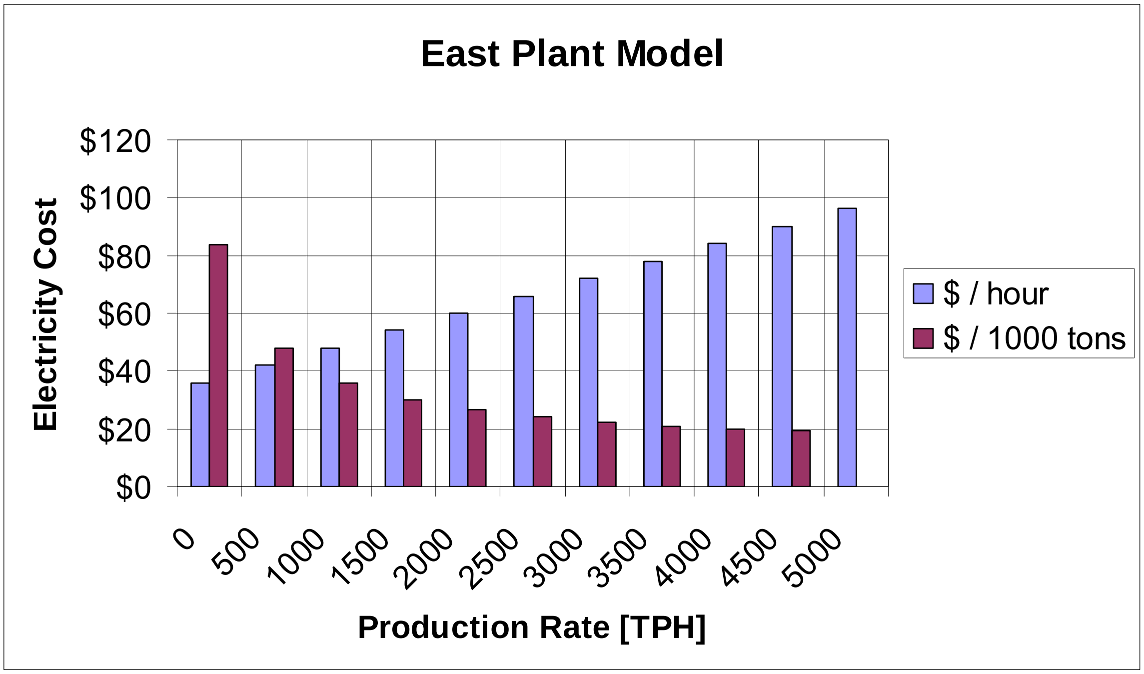
Component	Fixed Load	Variable Load
Hopper feed and crusher	212	122
Reclaim belt E-21	186	51
Transfer and auxiliaries	370	0
Silo feed E-43 and E-343	171	215
Silo	220	0
Total	1159	388

By definition, the fixed load is present whether or not coal is being processed. The variable load coefficient times the load [in 1000 tons per hour] gives the additional electric load directly associated with moving coal. From this table, it is established that average electric load for the East Plant can be estimated by the following expression:

Average electric load [kW] = 1,159 + 388 x Production [1000 tons / hour]

Based on the average cost of electricity, this translates into the following cost per hour:

East plant electric cost [$/hour] = $35.93 + $12.03 x Production [1000 tons / hour]



Because of the large fixed component, East Plant energy usage [kWh per 1000 tons] will vary depending on the production rate. An analysis of 2004 production data on a 15-minute basis reveals the following summary statistics.

Average (mean) production rate	4020 tons per hour
Standard deviation	1642

At the average production rate of 4020 TPH, the East Plant uses 676 kWh / 1000 tons. The following table summarizes how the East Plant model is derived.

Production Rate	Tons / Hour	Energy Usage
Average	4020	676 kWh / 1000 tons
+ 1 Std Deviation	5662	593
– 1 Std Deviation	2378	875
Used for Model		**705**

This model does not include a trip through slot storage. Recall from the previous analysis (on page 17) that the cost of such a trip is $ 8.81 per 1000 tons. As an example, consider the cost of moving 1000 tons of coal at the rate of 4000 TPH.

Itinerary	Cost per 1000 tons
East Plant hopper to silos	$ 21.01
Round trip through slot storage	$ 8.81
Hopper through slot to silos	$ 29.82
Slot excursion premium	42%

From this table, it can be concluded that an excursion through slot storage increases the cost by $ 8.81 per 1000 tons for additional electricity. This represents a 42%-increase in electricity cost within the East Plant.

West Plant Model

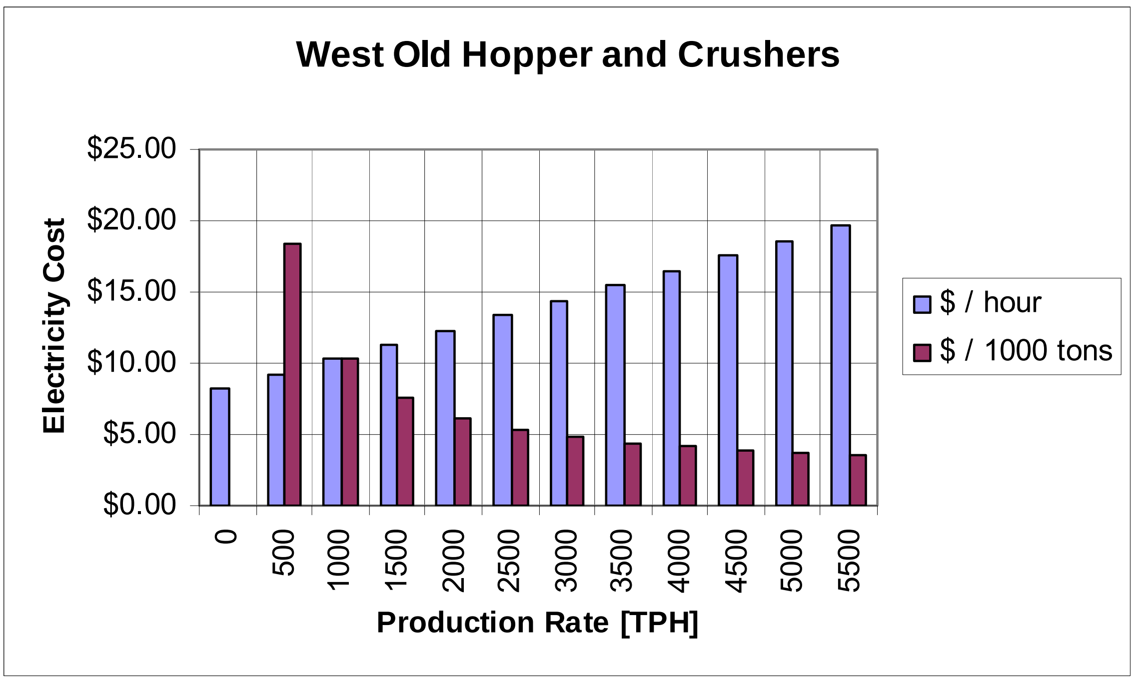
Elements of the West Plant model are:

1. Old and OLC hopper feeds and crushers
2. Belt E-680
3. Belt E-801
4. Silos, including trippers
5. Auxiliaries

Old Hopper Feed and Crusher

The connected motor load is 1757 hp. This includes 1600 hp for the crushers and 157 hp for hydraulics, air compressor, wash down, sump, etc. Four (4) 200-hp crusher motors averaged 133 hp each while processing coal at 3200 TPH (field measurement), and are estimated to draw 15% of rated load when no coal is being processed. Auxiliary motors are assumed to draw 72% of rated load independent of production.

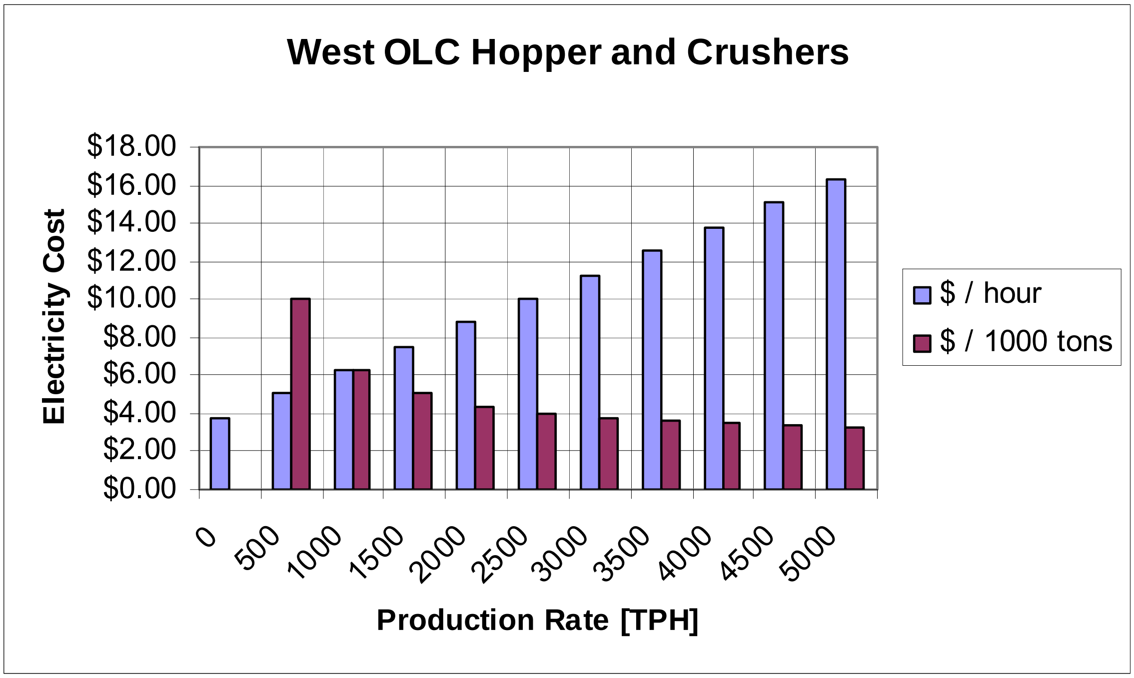
The following graph is based on this model, assuming all eight (8) motors are equally loaded and $ 0.031 / kWh average cost of electricity.



OLC Hopper Feed and Crusher

The connected motor load is 780 hp. This includes 700 hp for the crusher and 80 hp for auxiliaries. Based on field measurements, these crusher motors draw 331 kW while processing coal at 4100 TPH. They are estimated to draw 15% of rated load when no coal is being processed. Auxiliary motors are assumed to draw 72% of rated load independent of production.

The following graph is based on this model and $ 0.031 / kWh average cost of electricity.



While crushing loads are based on field measurements, the allocation of auxiliary loads associated with the crushers are estimates. This includes hydraulics, air compressor, wash down, sump, etc. The purpose is to understand hopper/crusher loads as compared to conveyors, silos, etc.

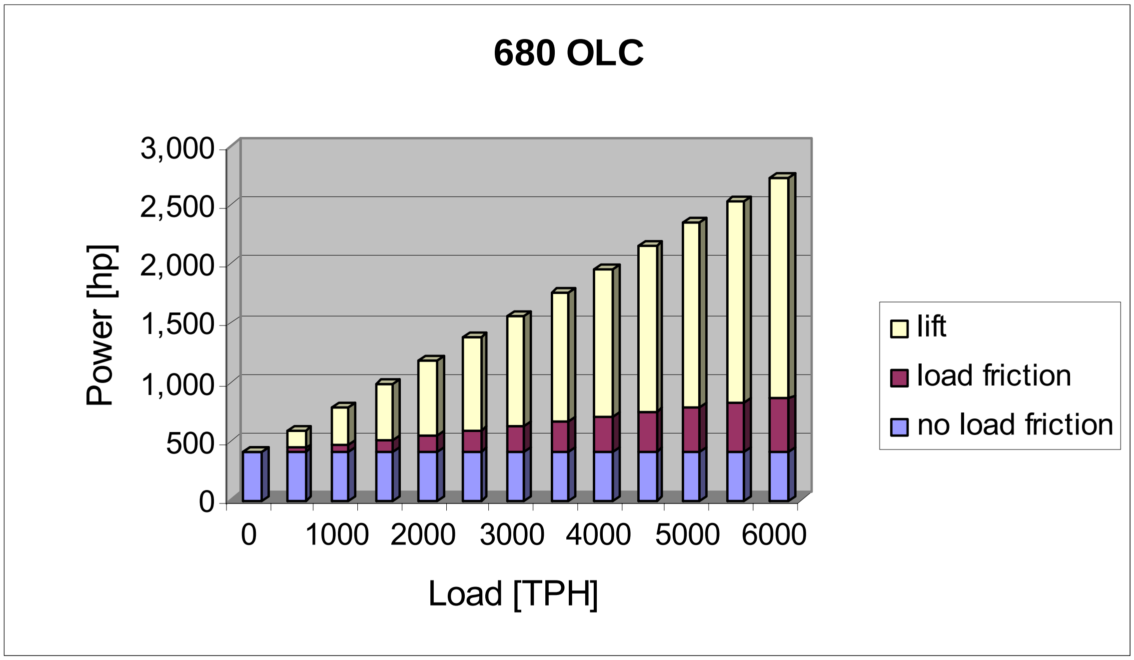
Coal Conveyance Model

The following information is given for each major belt.

Number	Description	Capacity [TPH]	Length [ft]	Lift [ft]	Speed [fpm]
E-680	Overland Coal (OLC)	5500	5250	310	1230
E-801	Old Silo Feed	4000	1300	323	872

W-680 OLC Belt

This is the longest belt at the mine (5250 feet) and has a large lift to the top of the silos (310 feet). The high lift power is evident in the graph below. The analysis results are as follows.

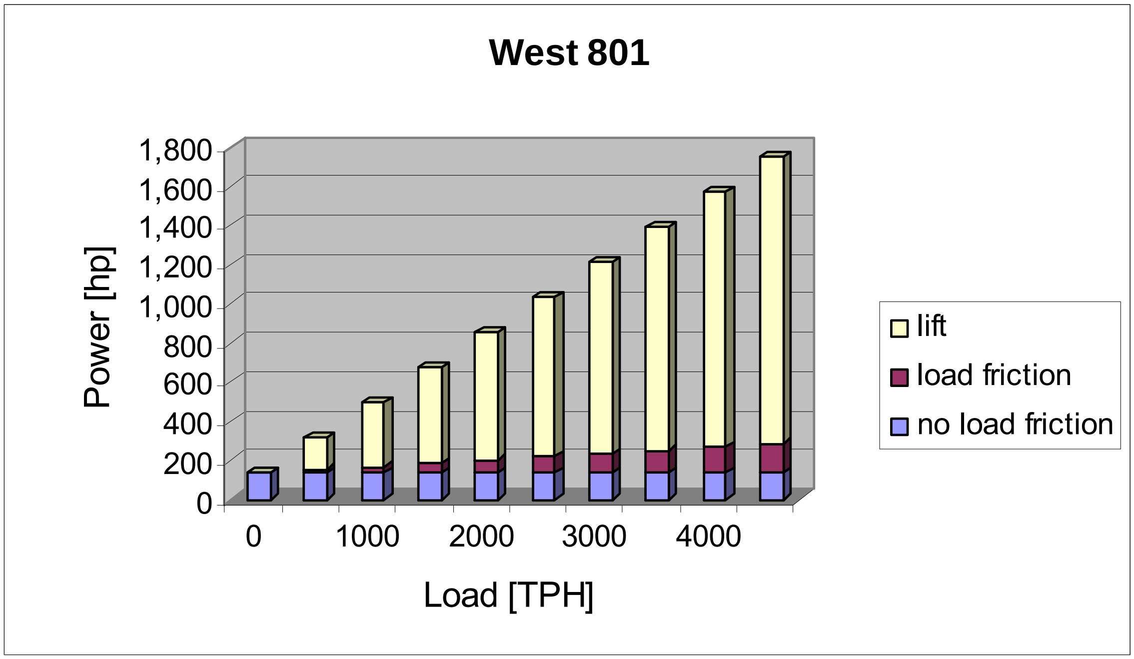


Motor power of about 400 hp is required to move the belt without coal. When loaded with coal, the power to overcome additional friction is only about 25% of what is required to lift the coal. The resulting total power at rated load of 5500 TPH is 2540 hp.

Based on the average cost of electricity and drive/motor efficiency, it costs $11.87 to move 1000 tons of coal across this belt at rated load. The cost of running the belt unloaded (no coal) is $10.28 / hour.

W-801 Old Silo Feed Belt

This is a relatively short belt (1300 feet) but it has the highest lift at the mine (323 feet). The high lift power as compared to friction power is evident in the graph below. The analysis results are as follows.



Motor power of about 135 hp is required to move the belt without coal. The power to overcome additional friction is only about 33% of what is required to lift the coal. The resulting total power at rated load of 4000 TPH is 1571 hp.

Based on the average cost of electricity and drive/motor efficiency, it costs $10.09 to move 1000 tons of coal across this belt at rated load. The cost of running the belt unloaded (no coal) is $3.47 / hour.

Silos and Trippers

The silos have hydraulic equipment, tripper belts, etc. The auxiliary connected load is about 320 hp plus 700 hp for the tripper belts. Miscellaneous load includes lighting and space conditioning (ac and heat in the control room). Although some variation in energy usage is expected based on whether or not a train is being loaded. For this model, it is assumed the load is constant. Alternatively, the tripper belt loads could be included in the silo feed belt loads. However, for this model, they are included as part of the silo load.

Based on the connected load, and average motor utilization in the silos of 78%, the silo load is 380 kW or about $ 11.78 / hour based on the average cost of electricity.

Auxiliaries

The final piece to the West Plant model must account for auxiliary equipment including water pumps, wash down and the sampling systems.

Equipment	Connected Load [hp]
OLC TD water	25
OLC DH water	25
OLC air comp.	25
Old air compressor	25
OLC samples	30
Old sample	40
OLC sump	40
Water	100
Well	100
Pond	100
Deep well	100
Total	610 hp

This table details the miscellaneous equipment. Duty cycles established from RSEnergyMetrix data indicate this equipment represents a load of about 220 kW. Using the average cost of electricity, this is a fixed cost of $6.82 per hour.

This completes the component analysis for the West Plant. It is now possible to construct a complete picture of electricity usage and cost as a function of plant production.

Complete West Plant Model

The West Plant model is the sum of the components as follows.

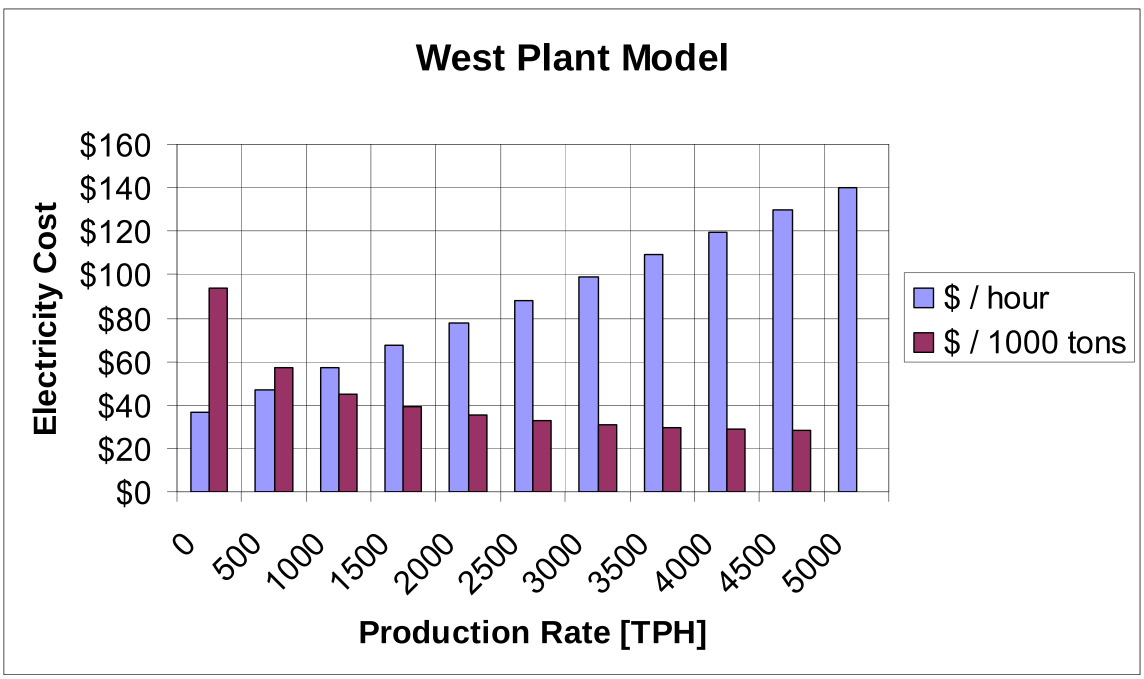
Component	Fixed Load	Variable Load
Hopper feed and crushers	160	80
OLC W-680	314	306
W-801	106	282
Silo	380	0
Auxiliaries	220	0
Total	1180	668

By definition, the fixed load is present whether or not coal is being processed. The variable load coefficient times the load [in 1000 tons per hour] gives the additional electric load directly associated with moving coal. From this table, it is established that average electric load for the West Plant can be estimated by the following expression:

Average electric load [kW] = 1,180 + 668 x Production [1000 tons / hour]

Based on the average cost of electricity, this translates into the following cost per hour:

East plant electric cost [$/hour] = $36.58 + $20.71 x Production [1000 tons / hour



Similar to the East Plant, the West Plant energy usage [kWh per 1000 tons] will vary depending on the production rate. An analysis of 2004 production data on a 15-minute basis reveals the following summary statistics.

Average (mean) production rate	5350 tons per hour
Standard deviation	2215

At the average production rate of 5350 TPH, the West Plant uses 889 kWh / 1000 tons. The following table summarizes how the West Plant model is derived.

Production Rate	Tons / Hour	Energy Usage
Average	5350	889 kWh / 1000 tons
+ 1 Std Deviation	7565	824
– 1 Std Deviation	3135	1044
Used for Model		**910 kWh / 1000 tons**

It is more expensive to process coal through the West Plant compared to the East Plant. While the fixed cost is essentially the same, the variable cost is much higher in the west. This is due primarily to the length of the OLC belt and higher lifts.

The West Plant also operates more often at less than rated capacity, because of the fixed energy component; this causes the usage per unit of production to be higher.

East and West Support Facilities

There are a number of facilities such as shop, maintenance and administration buildings that support the mining operation. They require energy for lighting, heating, cooling and miscellaneous loads such as small tools and computers. Clearly, these loads are not correlated directly to coal production. They are mostly fixed loads. However, the heating and cooling portion is expected to correlate to outside weather conditions.

HVAC Loads

The following table summarizes the HVAC energy analysis based on building size, type of construction and uses. Energy for heat is primarily provided by natural gas, and cooling is an electric load. One exception is the building that houses the fire truck which has electric heat.

Building Description	Floor Area [sq ft]	Design Load		Annual Energy	
		Heating [kBtu/hr/F]	Cooling [tons/F]	Heating [MBtu]	Cooling [kWh]
Business Unit	10,000	7.5	0.50	1,260	10,080
RC Admin / Miners Changing	14,400	10.8	0.72	1,814	14,515
East Truck Shop	55,300	207.4	2.77	34,839	
East M&E	6,900	7.8	0.35	1,304	1,739
North Shop	9,600	10.8	0.48	1,814	
NA Administration	11,200	10.9	0.56	1,835	11,290
West Change House	22,500	16.9	1.13	2,835	22,680
Fire Truck	2,500	3.8	0.13	630	
First Aid	2,400	2.9	0.12	484	2,419
West M&E	7,200	8.1	0.36	1,361	1,814
Central Warehouse	10,000	16.5	0.50	2,772	1,008
West Shop	24,600	92.3	1.23	15,498	3,720
Caterpillar Shop	32,000	144.0	1.60	24,192	323
Total				90,638	69,588

The Fire Truck building has electric heat, so the total annual electric usage is the entire cooling load plus the Fire Truck building heat load. (70,218 kWh per year)
Information is also available from RSEnergyMetrix to help model the total facility load.

Natural Gas Usage

Most of this report is focused on electric energy. However, here is an opportunity to examine natural gas usage. Gas is used for space heating and hot water. Based on recent billing, the mine uses about 94,600 MCF each year. Using an average heating value of 1025 Btu / ft^3, and 92% boiler efficiency, that represents 89,200 MBtu per year. Based on the HVAC model, facilities require 90,638 MBtu for heat. This is a satisfactory reconciliation of actual gas usage and calculated facilities heating load.

Based on an average cost per MCF of $4.00, the following table gives estimated heating cost by facility.

Building Description	Floor Area [sq ft]	Annual Heating Energy	
		Energy [MBtu]	Cost
Business Unit	10,000	1,260	$5,040
RC Admin / Miners Changing	14,400	1,814	$7,256
East Truck Shop	55,300	34,839	$139,356
East M&E	6,900	1,304	$5,216
North Shop	9,600	1,814	$7,256
NA Administration	11,200	1,835	$7,340
West Change House	22,500	2,835	$11,340
Fire Truck	2,500	630	$2,520
First Aid	2,400	484	$1,936
West M&E	7,200	1,361	$5,444
Central Warehouse	10,000	2,772	$11,088
West Shop	24,600	15,498	$61,992
Caterpillar Shop	32,000	24,192	$96,768
Total		90,638	$362,552

Lighting

Lighting data is repeated here from the original survey done at various support facilities. The estimated lighting load will be subtracted from total facility load along with HVAC energy to provide an estimate of the miscellaneous loads.

Building Description	Lighting Power [kW]
Business Unit	12.5
RC Admin / Miners Changing	18
East Truck Shop	84.5
East M&E	7.4
North Shop	8.3
NA Administration	14
West Change House	28
Fire Truck	3.2
First Aid	2.9
West M&E	13.3
Central Warehouse	16.6
West Shop	69.5
Caterpillar Shop	36.8
Total	315 kW

Miscellaneous Loads

Miscellaneous loads such as tools and computers can be estimated from RSEnergyMetrix data, the model, and other considerations. Now all the components are available to assemble the complete mine model.

Complete Mine Model

All of the model components are now assembled into the complete model as follows.

Component	Usage [kWh / 1000 tons]
Overburden	971
Coal – Pit	302
East Plant	705
West Plant	950
Administration	54

The final step is to use production, weather and total mine usage data to check the bottom-up model. For reference, the top-down model results are also given in the following table.

Year	Coal Production			Weather	
	East	West	Total	Heating [HDD]	Cooling [CDD}
2003	35,308	45,144	80,452	7074	750
2004	35,370	46,860	82,230	6781	385
2005*	20,189	19,919	40,108	4197	390

* The present year of 2005 is a partial year with results through July 31, 2005.

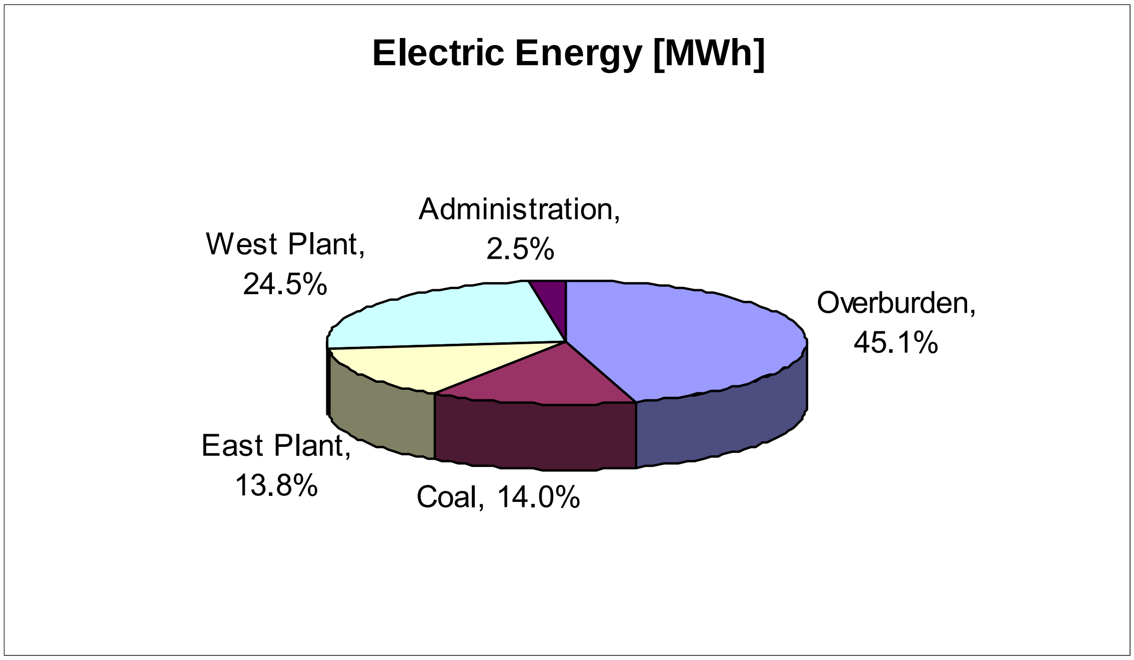
Comparison of Top-Down and Bottom-Up Results

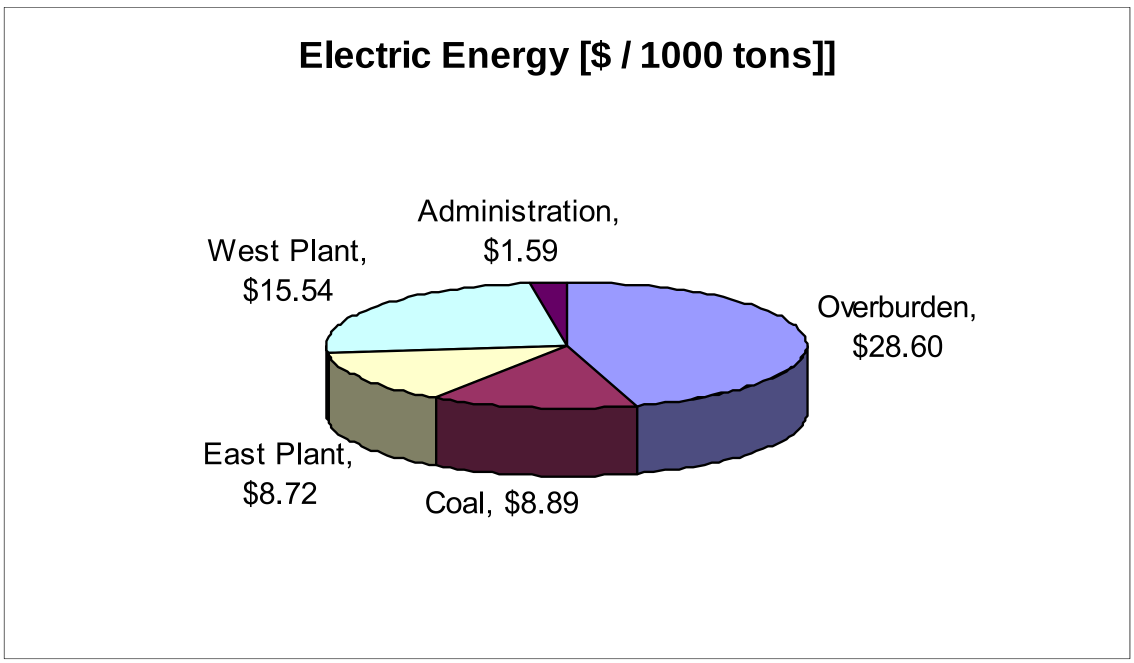
Year	Actual [MWh]	Bottom-up Model		Top-down Model	
		Result	Error	Result	Error
2003	160,815	174,540	9%	163,010	1 %
2004	168,757	178,570	6%	164,436	-3 %
2005	94,496	86,380	-9%	95,945	2 %

Having modeled energy usage from the top-down (statistical) and from the bottom-up (load modeling), agreement this close indicates the models are sufficient for use as energy conservation measure (ECM) evaluation.

The following is a graphical representation of overall mine energy usage in a typical year with total production of 82,000,000 tons of coal, 58% processed by the West Plant, and 42% processed by the East Plant. No slot storage activity is included.

The first figure indicates the percentage of electric energy used in each department. The second figure gives electricity cost for each department per 1000 tons of coal produced.





Analysis by Area and Department

For a typical year, real and reactive electric energy can be allocated to departments based on the model and using RSEnergyMetrix data for validation as follows.

Area	Department	Real Energy [MWh]	Real Energy %	Average Power Factor
Main Electric Supply		167,550	100 %	98%
Pits	Overburden	75,640	45 %	87% (lead)
	Coal	23,530	14 %	95%
Plants	East	23,070	14 %	84%
	West	15,210	9 %	82%
	OLC	25,900	15 %	88%
Support	Admin and Shops	4,200	3 %	85%

Remember that the estimates can have several percentage point errors based on the model and available data for validation.

Discussion

There are a number of topics for which additional information was requested. This section provides that additional information and discussion on the topics assigned to this supplemental report.

Major Belt Motors and Operating Practices

The energy model quantifies requirements associated with fixed friction, load friction and (coal) lift. Belt performance is an integral part of mine operations. Any proposed energy-saving action must not compromise belt performance.

Three (3) areas are considered for belt energy savings; no-load operating practices, power factor correction, and control under load conditions. The first refers to times when the belt is presently operated with no coal on the belt, such as during shift changes. The second is aimed at correcting power factor at each motor as currently installed. The third is where drives are often mentioned as a possibility. First, consider no-load operating practices.

No-Load Operating Practices

There are significant amounts of time when the belts are running but not transporting coal. There are also operating constraints that may prohibit belt shutdown during some periods of time. There do appear to be times, such as during shift changes, when the belts could be shut down. The energy model and the original study report quantify the expected savings. Changes in work practices to include staggering operations are recommended as a means of reducing empty belt time and energy expense.

Power Factor Correction

These large motors require reactive power. The overall mine power factor as seen from the utility meter is near unity. So reactive power requirements are presently supplied elsewhere in the mine by capacitor banks or controlled synchronous loads.

Correcting the power factor at the motor load will not reduce the price paid for electricity because the reactive power comes from within the mine; there is no power factor penalty. The only savings would be associated with reduced distribution losses. A small amount of real energy is required to get the reactive power from the source to the motor load.

There is an opportunity to add power factor correction capacitor banks at each of the existing motors. This option would correct poor power factor caused by induction motors. However, the savings earned by this option would be minimal.

Variable Frequency Drives for Major Belts

Major belts are run continuously at constant supply frequency (no drives). There would appear to be an opportunity for energy savings associated with motor speed control (variable frequency drives). This section makes use of actual belt load measurements and motor drive performance data to examine the installation of drives.

Belt	Rated Load [tons/hr]	Horsepower			
		@ rated load	@ average load	@ no load	Connected
E-21	5,300	580	500	237	1250
E-43	3,200	1087	801	200	2 x 450
E-343	5,300	1672	1374	236	2 x 1250
W-680	4,000	2540	1653	400	3 x 900
W-801	5,500	1571	894	135	2 x 1500

The load model and field measurements indicate that several of the major belt drive motors are typically under-loaded. However, this is a conveyor application where variable speed is likely to interfere with performance. For example, these belts move coal, and running them at 50% speed to save energy is just not practical

The brake horsepower delivered to the conveyor drive shaft is a function of rotational speed and torque. There is presently a mismatch between the conveyor requirements and the motor capability.

Conveyor Requirements – The conveyor power requirement is a function of lift, coal load and friction. Since lift and coal load cannot be changed, the opportunity for reduced requirement is friction. The model quantifies the friction load and allows for estimates of potential savings from low-friction bearings, etc.

Motor Capability – Each motor has a speed-torque characteristic and efficiency associated with various operating points. As the motor is unloaded, the power factor and efficiency decrease. Power factor decreases because reactive current requirements decrease by a small amount while real current is proportional to mechanical load and decreases significantly.

The application of drives or other motor changes will not impact brake horsepower requirements at a given delivery [TPH]. The only savings would result from the motor being able to supply the conveyor requirement more efficiently.

In theory, a transmission between the motor and conveyor could be used to allow the motor to run at reduced speed while maintaining belt speed. While technically feasible, this is not considered a viable option. The cost could rival that of replacing the motor. There are also benefits to the larger motors. The extra power could be needed from time to time under extreme conditions to get the belt moving, or when one of several motors is out of service.

Therefore, savings associated with changes to the motor/drive assets must come from increased motor efficiency and/or reduced reactive power requirements (power factor closer to unity.) The available savings is relatively small.

Another consideration is the possibility of reducing the number of motors in operation. In some cases, there are several motors and the belt requirements could be met without all motors in operation. A detailed analysis would be required over a period of time to verify belt requirements and the practicality of this option.

Belt Power Requirements

One challenge in sizing major belt motors is the trade off between operating efficiency and the occasional need for extra power. Factors such as static friction, load momentum (accelerating coal), icing, etc. can require extraordinary torque and power. Unfortunately, that extra motor capacity then remains on-line for the vast majority of the time when operations are normal. In future designs, consideration should be given to this issue. Other methods of providing temporary, extra torque/power should be considered.

Variable Frequency Drives for Deep Water Wells

There are number of large motors at the mine that operate well pumps or otherwise move water as follows. An additional deep well was being installed at the time of this report.

Description	Serving	Connected Load [hp]
Deep well #1	East	100
Deep well #2	East	290
Mine #1 water	East	100
Mine #2 water	East	100
Potable water #1	East	7.5
Potable water #2	East	7.5
Water	West	100
Well	West	100
Pond	West	100
Deep well	West	100

Factors that affect the efficiency of pumping include matching the pump and motor characteristics (speed – torque). This allows both pieces of equipment to operate in their most efficient range. Impellor selection/trim is important.

Unless the flow rate and/or hydraulic head are significantly different than anticipated during the design process, the motor-pump match is probably correct.

Other factors that impact efficiency include pump maintenance, specifically impeller condition, and water distribution piping and valves. A partially-closed value in the distribution network being used to throttle water flow is a source of inefficiency. It is better to slow the pump with a variable-speed drive than to operate at full speed and throttle the flow (essentially increase the head) with partially-closed valves.

Variable speed control comes with a price, and it is unlikely the investment could be justified for these pumps. Any significant mismatch between pump and motor should first be addressed by considering impeller trim or changing the motor.

Compressed Air

Obvious measures to be taken include a leak repair program and a periodic review of work practices and the necessity to use compressed air as an energy supply. The cost and magnitude of leakage is commonly underestimated. It is interesting to evaluate compressed air usage during idle times to quantify the leakage problem.

Compressed air is a very expensive energy source. Less than 10% of the electric energy used to drive the air compressor actually arrives at the end-use device and does useful work. A variety of alternatives are available and often cost effective. This includes the use of small electric motors and air amplifiers (venture devices) for blow-off.

Air compressors, like water pumps, have a speed-torque characteristic. Efficiency is lost as load is reduced. Given a certain air requirement, it is desirable to have all compressors operating in an efficient range.

More specifically, all air compressors should be operated at the same incremental cost of air. In other words, the cost (in additional kW) to output one additional increment of air flow (scfm) should be equal for all machines on-line. Centrifugal and screw compressors will have different operating characteristics.

This economic dispatch algorithm is typically used for industrial air supplies with four (4) or more large (>1000 cfm) compressors. Usually, the large centrifugal units are base-loaded and one or more screw units modulate pressure.

The usefulness of economic dispatch at NAR is limited (probably not cost-effective). The air requirements are modest and dispersed around the mine. After the obvious leak program and use review, the recommendation is to evaluate each significant compressor to be sure it is operating in an efficient range.

As a benchmark, Industrial compressed air supplies should average over 4 scfm delivered per drive motor horsepower.

Lighting

The model estimates total annual lighting cost of about $70,000. Knowing that number helps put potential savings estimates in perspective. Savings would result from more diligent lighting control (turned off when not needed) and upgrading to high-efficiency lighting. For the purpose of estimating savings, it is not correct to use the average cost of electric energy ($ 0.031 kWh) because changes may not reduce demand. In particular, lighting control usually does not impact demand. So estimates must use only the energy charge component ($ 0.019 / kWh) for savings calculations.

Lights in the West Shop, East Shop, North Shop, Caterpillar Shop and Slot Storage burn all the time and represent about 575,000 kWh per year of potential energy savings. The annual savings associated with this control is about $ 11,000.

High efficiency lighting should also be considered. The following table summarizes the potential savings. The savings are based on the assumption that lighting control is implemented. In other words, there is no double counting of savings that results when the analyst fails to consider that a high-efficiency lamp uses no less energy than a low-efficiency lamp when turned off.

Existing Fixtures	Replacement	Number of Fixtures	Energy Savings	Value of Savings	Installed Cost
1000-Watt	468-Watt	208	827 MWh	$ 15,700	$ 92,000
400-Watt	242-Watt	170	222 MWh	$ 4,200	$ 58,250
Totals				$ 19,900	$ 150,250

The above figures are based on a ballast factor of 1.15, energy cost of $0.019 per kWh and estimated 6500 hours of operation per year. Installed cost is based on $400 per fixture ($300 for the smaller ones) plus 32 minutes of installation time with a crew-hour priced at $ 80.00. However, the above costs are driven primarily by the cost of the fixtures (they represent about 90% of the cost.)

Also, consideration should be given to adjusting the number of fixtures to meet specific illumination requirements. It may be possible to eliminate some fixtures entirely.

The Bottom Line on Lighting

Peabody Energy could invest about $150,000 in lighting upgrades to save an estimated $20,000 per year. The simple payback is 7.5 years. The decision whether or not to make this investment should be based on the cost of capital and other investment opportunities. Even without additional information or analysis, this does not appear to be a very attractive investment. However, consideration should be given to a change-out program that is implemented as fixtures and lamps require maintenance or replacements.

Electric Demand Control

Electricity prices have two (2) major components; energy and demand. Most of the analysis is based on the average cost of $0.031 per kWh. Inherent is the assumption that all loads contribute equally to the overall demand, and therefore, demand will be reduced proportional to energy. In the case of lighting control, only the energy component ($ 0.019 per kWh) was used. It is known that demand will not be significantly affected by lighting control. Using the lower cost figure yields a conservative estimate.

The mine load factor averages 75%. It ranges from 66% to 84% in any given month. The following table summarizes the estimated contribution of each department to overall billing demand.

Area	Department	Peak Demand [kW]	Peak Demand %
Main Electric Supply		24,500	100
Pits	Overburden	15,000	61
	Coal	4,400	18
Plants	East	2,300	10
	West / OLC	2,500	10
Support	Administration	300	1

It would appear that opportunities for demand management are presented by the draglines and shovels. It is estimated that pit operations account for 79% of the billing demand. However, nine (9) shovels offer significant diversity just due to random variations in operation. It is unlikely that demand management would make a significant difference in shovel contribution to billing demand.

Two (2) draglines do not have the same statistical advantage. In other words, random variation between two (2) draglines does not yield much demand reduction from diversity. So coordinated dragline control might be worth consideration. The original draft of this report questioned the practicality of such control. This was based on a concern for maintaining smooth operations. However, electrical engineers from Peabody Energy report success with similar control at Kayenta/Black Mesa. So there is direct evidence that demand control can be acceptable to operations and result in significant savings.

Billing demand is determined by the highest interval usage for the billing period. Draglines could be coordinated for 29 days of the month and then negate all savings with one uncoordinated interval if it occurs during peak demand at the mine. So the demand controller must be properly designed and implemented. Peabody Energy has reported success at another mine and this analysis does not uncover any technical reason why the result would not transfer to NAR as well.

Appendix A – Monthly Data for Statistical Analysis

		Production [1000 tons]			Degree Days	
	Energy [kWh]	East	West	Total	Heating	Cooling
January	14,280,000	2896	3724	6620	1108	0
February	12,411,000	2601	3266	5867	1187	0
March	12,348,000	2422	3513	5935	993	0
April	12,957,000	2840	3541	6381	493	0
May	13,251,000	3071	3990	7061	403	19
June	12,978,000	3109	3575	6684	185	30
July	13,629,000	3136	3829	6965	0	307
August	13,398,000	3254	3646	6900	17	351
September	13,524,000	3079	3834	6913	275	38
October	13,899,305	3032	3971	7003	440	5
November	13,566,000	2798	3939	6737	872	0
December	14,574,000	3070	4316	7386	1101	0
Total 2003	**160,815,305**	**35,308**	**45,144**	**80,452**	**7,074**	**750**
January	14,952,000	2845	4224	7069	1233	0
February	13,377,000	2727	3637	6364	1007	0
March	13,209,000	2898	3791	6689	746	0
April	13,608,000	3073	2799	5872	560	0
May	13,881,000	2681	4103	6784	362	3
June	13,986,000	2990	3962	6952	155	40
July	14,238,000	3106	4165	7271	23	205
August	14,357,712	3150	4369	7519	70	91
September	13,832,000	3143	4238	7381	210	46
October	14,224,000	2931	4341	7272	506	0
November	14,756,000	2879	3310	6189	866	0
December	14,336,000	2947	3921	6868	1043	0
Total 2004	**168,756,712**	**35,370**	**46,860**	**82,230**	**6,781**	**385**
January	14,336,000	2827		2827	1221	0
February	13,552,000	2893		2893	919	0
March	14,588,000	3103	4523	7626	846	0
April	13,104,000	3035	4054	7089	600	0
May	13,188,000	2813	3247	6060	448	1
June	12,376,000	2644	3359	6003	151	105
July	13,352,260	2874	4736	7610	12	284
Total 2005	**94,496,260**	**20,189**	**19,919**	**40,108**	**4,197**	**390**

Weather data was taken from a National Weather Service weather station at the Gillette Campbell County Airport (GCC) in Gillette, Wyoming.

Month	Energy [kWh]		Error		Production	Degree Days
	Actual	Predicted	[kWh]	[%]	Total	Heating

January	14,280,000	13,844,400	435,600	3%	6620	1108
February	12,411,000	13,210,520	-799,520	-6%	5867	1187
March	12,348,000	13,146,300	-798,300	-6%	5935	993
April	12,957,000	13,227,160	-270,160	-2%	6381	493
May	13,251,000	13,787,460	-536,460	-4%	7061	403
June	12,978,000	13,302,690	-324,690	-3%	6684	185
July	13,629,000	13,438,150	190,850	1%	6965	0
August	13,398,000	13,390,050	7,950	0%	6900	17
September	13,524,000	13,569,580	-45,580	0%	6913	275
October	13,899,305	13,758,730	140,575	1%	7003	440
November	13,566,000	13,797,470	-231,470	-2%	6737	872
December	14,574,000	14,536,910	37,090	0%	7386	1101
Total 2003	**160,815,305**	**163,009,420**	**-2,194,115**	**-1%**	**80,452**	**7,074**
January	14,952,000	14,334,240	617,760	4%	7069	1233
February	13,377,000	13,545,790	-168,790	-1%	6364	1007
March	13,209,000	13,671,890	-462,890	-4%	6689	746
April	13,608,000	12,807,520	800,480	6%	5872	560
May	13,881,000	13,508,740	372,260	3%	6784	362
June	13,986,000	13,527,070	458,930	3%	6952	155
July	14,238,000	13,731,560	506,440	4%	7271	23
August	14,357,712	13,987,790	369,922	3%	7519	70
September	13,832,000	13,953,210	-121,210	-1%	7381	210
October	14,224,000	14,046,420	177,580	1%	7272	506
November	14,756,000	13,294,890	1,461,110	10%	6189	866
December	14,336,000	14,027,830	308,170	2%	6868	1043
Total 2004	**168,756,712**	**164,436,950**	**4,319,762**	**3%**	**82,230**	**6,781**
January	14,336,000	14,326,440	9,560	0%	7069	1221
February	13,552,000	13,488,590	63,410	0%	6364	919
March	14,588,000	14,589,560	-1,560	0%	7626	846
April	13,104,000	13,940,990	-836,990	-6%	7089	600
May	13,188,000	12,905,800	282,200	2%	6060	448
June	12,376,000	12,660,880	-284,880	-2%	6003	151
July	13,352,260	14,032,900	-680,640	-5%	7610	12
Total 2005	**94,496,260**	**95,945,160**	**-1,448,900**	**-2%**	**40,108**	**4,197**

Rawhide Report

Peabody Energy Company

Gillette, Wyoming

Report # DE-FG36-40GO14034

March 13, 2006

For personal assistance regarding your report contact:

Steve Nalbandian
6261 Katella Avenue, Suite 1B
Cypress, CA 90630
Phone: 714 816-6316
Email: sjnalbandian@ra.rockwell.com

Rockwell Automation
POWER & ENERGY
Management Solutions
Hardware • Software • Communications & Value Added Services

Visit us at: http://www.ab.com/PEMS/
Systems/Products/Communications/Applications

Table of Contents

Introduction

The Powder River Coal Company (a Peabody Energy company) has engaged Rockwell Automation – Power & Energy Management Solutions (PEMS) to provide an energy assessment at two (2) surface coal mines in the Southern Powder River Basin. The mines are all located within 65 miles of Gillette, Wyoming.

- North Antelope – Rochelle Mine
- Rawhide Mine

North Antelope Rochelle ships about 85 million tons of coal each year. The other mine are growing, and collectively ship about 30 million tons per year. The most significant operating costs are diesel fuel, blasting materials/services, and electricity. The annual cost of electricity for all three mines is over $7,000,000.

This is a report for the Rawhide Mine. It includes a statistical (top-down) analysis of electric energy consumption as a function of production and outdoor temperature, and a generalized discussion based on information and observations from all the mines.

Rawhide Typical Electricity Requirements

Peak Demand	6,700	kW
Annual Energy	14,500	MWh
Monthly Cost	$830,000	
Unit Cost	$ 0.057	per kWh
Demand Charge	$ 6.79	per kW per month
Energy Charge	$ 0.018	per kWh
Load Factor	25	%
Cost per Production	$ 0.33	per ton

Comparison

It is interesting to compare the electrical energy requirements of the various mines. Consider the following summary:

Metric	Mine			Units
	NAR	Rawhide		
Peak Demand	24,700	6,700		kW
Annual Energy	162,500	14,500		MWh
Monthly Cost	$ 5,100k	$ 830k		
Unit Cost	$ 0.031	$ 0.057		per kWh
Demand Charge	$ 6.79	$ 6.79		per kW per month
Energy Charge	$ 0.019	$ 0.018		per kWh
Load Factor	75	25		%
Annual Production	85	3		million tons
Cost per Production	$ 0.06	$ 0.33		per ton

Rawhide has higher electricity cost per ton, and also per kWh, because of low load factor. Also, Rawhide has significantly lower total production. This also contributes to higher cost per ton because of the fixed load and also economy of scale.

The load factor at Rawhide is much lower because there is only one work shift. Load factor is based on 8,760 hours per year. With only one work shift, there is little opportunity to level the load.

This comparison will change dramatically if Rawhide goes to 24-hour operation. In that case, load factor will increase to perhaps 50% or more. The price paid per kWh could decrease by as much as 50%. The mine can be expected to use additional energy in proportion to production, however energy cost per ton will drop significantly because of the lower price paid per kWh.

Background

Facility Overview

The Rawhide operation consists of two (2) shovels and eight (8) trucks delivering coal from one pit to one plant at an average rate of 20,000 tons per hour. The initial entry point for the coal is a doublewide hopper located near the pit. It contains a set of primary crushers that feed coal to hydraulically-driven drag belts that meter coal at a set rate onto the main belt (DC915). These hydraulic pick lines feed the coal onto the overland conveyor (OLC) using a hydraulic pump system as the prime mover.

The distance between the feed hopper and plant is about 1.5 miles which requires an OLC with three large motors (1750 hp, 4160 V). This conveyor delivers coal into an 11,000-ton surge hopper at a maximum rate of 6,500 TPH. This surge hopper in turn feeds into what is known as the ‘Old Plant’.

The Old Plant starts with a hopper including a secondary set of crushers and apron feeder which deposits coal onto a reclaim belt (CV201). This acts as a metering control for deliveries to the Old Plant. The maximum throughput is 4,200 TPH.

CV-201 transfers coal through a sampling system and then to four of the six silos via belts CV301, CV302, and CV401. The filling of the four 11,000 ton silos is done with a tripper conveyor. The other two 13,000-ton silos receive coal via transfer belt CV450 and reversing belt CV451. A small feeder conveyor attached to the bottom of each silo delivers coal to two topper silos. This is used during the train loading process where an initial ‘bulk’ load is delivered to the car via a pneumatic controlled batching system attached to the silos. The required balance of the load is delivered via the hydraulically controlled ‘topper’ silos.

General Layout

RAWHIDE MINE: 2.5MILLION TONS '03	EXTRACTION CHARACTERISTICS: COAL AND OVERBURDEN	NOTES:
SINGLE PIT	SHOVEL / TRUCK	COAL QUALITY (8250-8300 BTU)
FACILITY SEPERATED INTO PLANT / PIT Total Plant / Pit Output: 15-20K tons/hr	PLANT: HOPPERS - BELTS - SILOS - LOADING	PIT: SHOVELS AND LOADERS TO TRUCKS
	HOPPERS (2): OLC AND OLD PLANT	DRAG LINES (0):
	SILO 250' TALL 15k TON CAPACITY (6) TOPPERS (2)	SHOVELS (2): ELECTRIC
	BELTS: (6) MAIN & COAL LIFT (12) TRANSFER AND TOPPER	TRUCKS (8): CAT797 400TON (8)
MINING EQUIPMENT:	HP , VOLTAGE, KW	NOTES:
COAL SHOVELS: **(2)**		
BUSYRUS 295	800HP, 4160V, 1.0 MW AVE.	
P/H 4100 Shovel	800HP, 4160V, 1.0 MW AVE.	
ELECTRICAL DISTRIBUTION:	(1) UTILITY FEED AT 69kV 4 FIXED SUBSTATIONS PRIMARY SUBSTATION UNIT 1/6.2MVA PRIMARY SUBSTATION UNIT 2 /6.2MVA SUBSTATION 10 CRUSH AREA 5MVA SUBSTATION 11 MAIN DRIVE 7.5MVA	CONTROLS: RSVIEW32, RSPOWER32, CLOGIX, SLC500

Lighting

Building Lighting	Location	Usage Type	Equip Type	Total # of fixtures	Watts per Fixture	Watts per location	Ballast Factor	Input watts per location	Total kWc	Location Total kWc
Maintenance		HPS	High Bay	98	1000	98,000	1.15	112,700	112.7	**113**
Old Plant	Apron Feeders	HPS	Bay	21	250	5,250	1.15	6,038	6.0375	
	to CV 201	Incandescent		27	150	4,050	1.00	4,050	4.05	**10**
Sample Building		Incandescent		85	150	12,750	1.00	12,750	12.75	**13**
Silos		Incandescent		66	150	9,900	1.00	9,900	9.9	
	Silo Connection Belt	HPS		20	400	8,000	1.15	9,200	9.2	**19**
Topper Silos		HPS		8	94	752	1.15	865	0.8648	**1**

Major Electric Processes	HP or Tons	kWc	% Diversity	kWd	Hrs/day	Run days per wk	Wks/yr	hrs/yr	kWh/year	Process Total kWh	Process Total kW
Lighting					10						
Maintenance		113	100%	113	10	7.00	52	3640	410,228		
Old Plant		10	100%	10	10	7.00	52	3640	36,719		
Sample Building		13	100%	13	10	7.00	52	3640	46,410		
Silos		19	100%	19	10	7.00	52	3640	69,524		
Topper Silos		1	100%	1	10	7.00	52	3640	3,148	**566,028**	**156**

Electric Distribution

ELECTRICAL DISTRIBUTION:	**1 UTILITY FEED AT 69kV SUBSTATIONS from 69Kv to 4160V**		
Name	***Type***	***Voltage***	***kVA***
PRIMARY SUBSTATION UNIT 1	Fixed	69kV-4160V	6250
PRIMARY SUBSTATION UNIT 2	Fixed	69kV-4160V	6250
SUBSTATION 10 CRUSH AREA	Fixed	69kV-4160V	5000
SUBSTATION 11 MAIN DRIVE	Fixed	69kV-4160V	7500

Mining Process Equipment

Pits

Major Electric Processes	HP or Tons	kWc	% Diversity	kWd	Hrs/day	Run days per wk	Wks/yr	hrs/yr	kWh/year	Process Total kWh	Process Total kW
Coal Shovels			70%		6						
Bucyrus 295	800	597	70%	418	6	7.00	52	2184	912,388		
P/H 4100	800	597	70%	418	6	7.00	52	2184	912,388	**1,824,776**	**836**

Plant

Major Electric Processes	HP or Tons	kWc	% Diversity	kWd	Hrs/day	Run days per wk	Wks/yr	hrs/yr	kWh/year	Process Total kWh	Process Total kW
Plant			67%		6						
PRIMARY CRUSHER 1A	250	187	67%	125	6	7.00	52	2184	272,902		
PRIMARY CRUSHER 2A	250	187	67%	125	6	7.00	52	2184	272,902		
PRIMARY CRUSHER 1B	250	187	67%	125	6	7.00	52	2184	272,902		
PRIMARY CRUSHER 2B	250	187	67%	125	6	7.00	52	2184	272,902		
Primary Crusher										1,091,607	500
PICK LINE HYD PMP1	125	93	67%	62	6	7.00	52	2184	136,451		
PICK LINE HYD PMP2	125	93	67%	62	6	7.00	52	2184	136,451		
PICK LINE HYD PMP3	125	93	67%	62	6	7.00	52	2184	136,451		
PICK LINE HYD PMP4	125	93	67%	62	6	7.00	52	2184	136,451		
FOGGER AIR COMP.	50	37	67%	25	6	7.00	52	2184	54,580		
Pick Line										600,384	275
WELL PUMP	60	45	67%	30	6	7.00	52	2184	65,496		
DEEP WELL PUMP	125	93	67%	62	6	7.00	52	2184	136,451		
Water Pumping										201,947	92
OLC MOTOR1	1750	1,306	67%	875	6	7.00	52	2184	1,910,312		
OLC MOTOR2	1750	1,306	67%	875	6	7.00	52	2184	1,910,312		
OLC MOTOR3	1750	1,306	67%	875	6	7.00	52	2184	1,910,312		
OLC Motors										5,730,936	2,624
RECLAIM CONV	200	149	67%	100	6	7.00	52	2184	218,321		
APRON FEEDER A	40	30	67%	20	6	7.00	52	2184	43,664		
APRON FEEDER B	40	30	67%	20	6	7.00	52	2184	43,664		
FEED CRUSHER A1	250	187	67%	125	6	7.00	52	2184	272,902		
FEED CRUSHER A2	250	187	67%	125	6	7.00	52	2184	272,902		
FEED CRUSHER B1	250	187	67%	125	6	7.00	52	2184	272,902		
FEED CRUSHER B2	250	187	67%	125	6	7.00	52	2184	272,902		
CV201 A	500	373	67%	250	6	7.00	52	2184	545,803		
CV201 B	500	373	67%	250	6	7.00	52	2184	545,803		
CV301	250	187	67%	125	6	7.00	52	2184	272,902		
CV302 A	500	373	67%	250	6	7.00	52	2184	545,803		
CV302 B	500	373	67%	250	6	7.00	52	2184	545,803		
CV450	250	187	67%	125	6	7.00	52	2184	272,902		
CV451	100	75	67%	50	6	7.00	52	2184	109,161		
Feed Crusher										4,235,435	1,939
SILO AIR COMPRESSOR	150	112	67%	75	6	7.00	52	2184	163,741		
SILO TOPPER FEED1	10	7	67%	5	6	7.00	52	2184	10,916		
SILO TOPPER FEED2	10	7	67%	5	6	7.00	52	2184	10,916		
SILO TOPPER FEED3	10	7	67%	5	6	7.00	52	2184	10,916		
SILO TOPPER FEED4	10	7	67%	5	6	7.00	52	2184	10,916		
SILO TOPPER FEED5	10	7	67%	5	6	7.00	52	2184	10,916		
SILO TOPPER FEED6	10	7	67%	5	6	7.00	52	2184	10,916		
TOPPER MAIN FEED 1	75	56	67%	37	6	7.00	52	2184	81,871		
TOPPER MAIN FEED 2	125	93	67%	62	6	7.00	52	2184	136,451		
HYDRAULIC PUMP T1	40	30	67%	20	6	7.00	52	2184	43,664		
HYDRAULIC PUMP T2	40	30	67%	20	6	7.00	52	2184	43,664		
Silo Toppers										534,887	245
Plant										12,395,196	5,675

Electricity

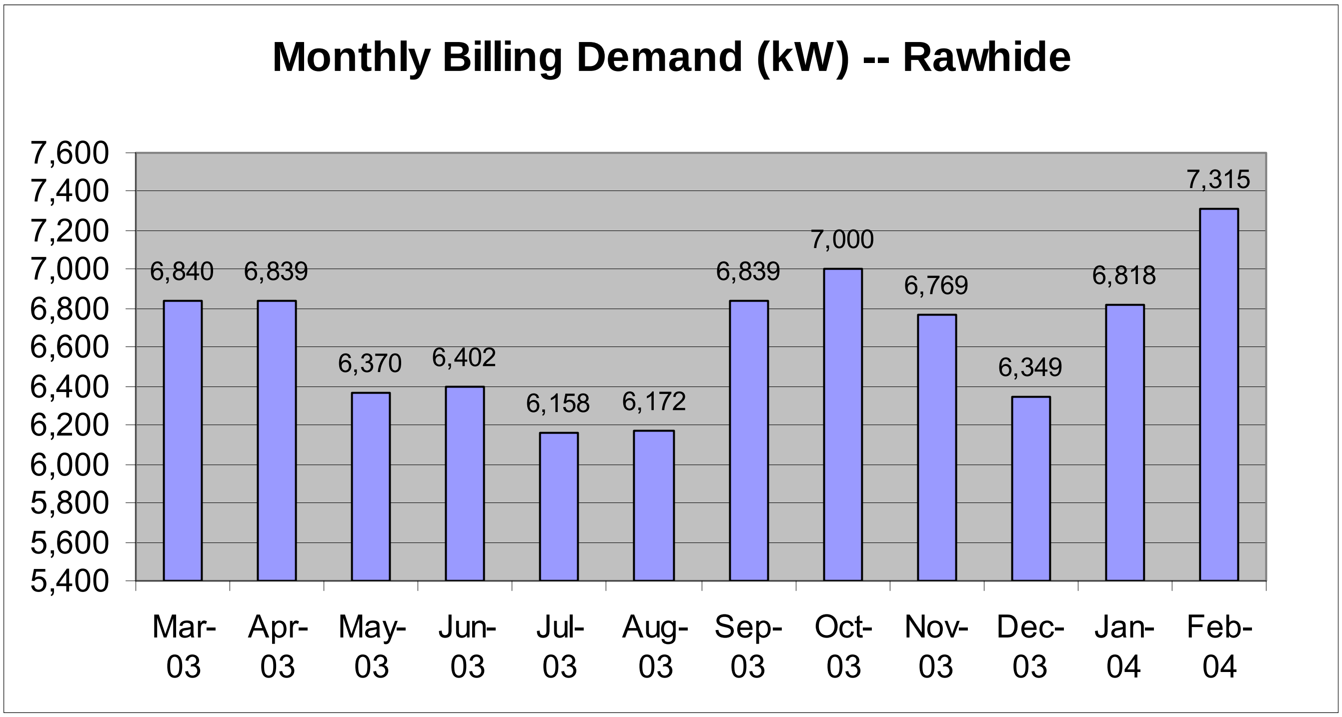
The Powder River Energy Corporation supplies electricity on the Large Power Transmission Level (LPT) Rate Schedule. The cost of electricity for the 12 months ending February 2004 was $832,637. The monthly billing demand averaged 6,656 kW --- ranging from a low of 6,158 kW in July of 2003 to a high of 7,315 kW in February of 2004.

The overall average price $0.057 per kWh. The demand component of the electric bill was $553,506 and averaged $6.79 per kW per month and the energy component of the bill was

$282,925 and averaged $0.018 per kWh. The hours use of demand for the year was 2,176 representing an average electric load factor of 25%.

Historical purchases of electricity are summarized from invoices in the following table.

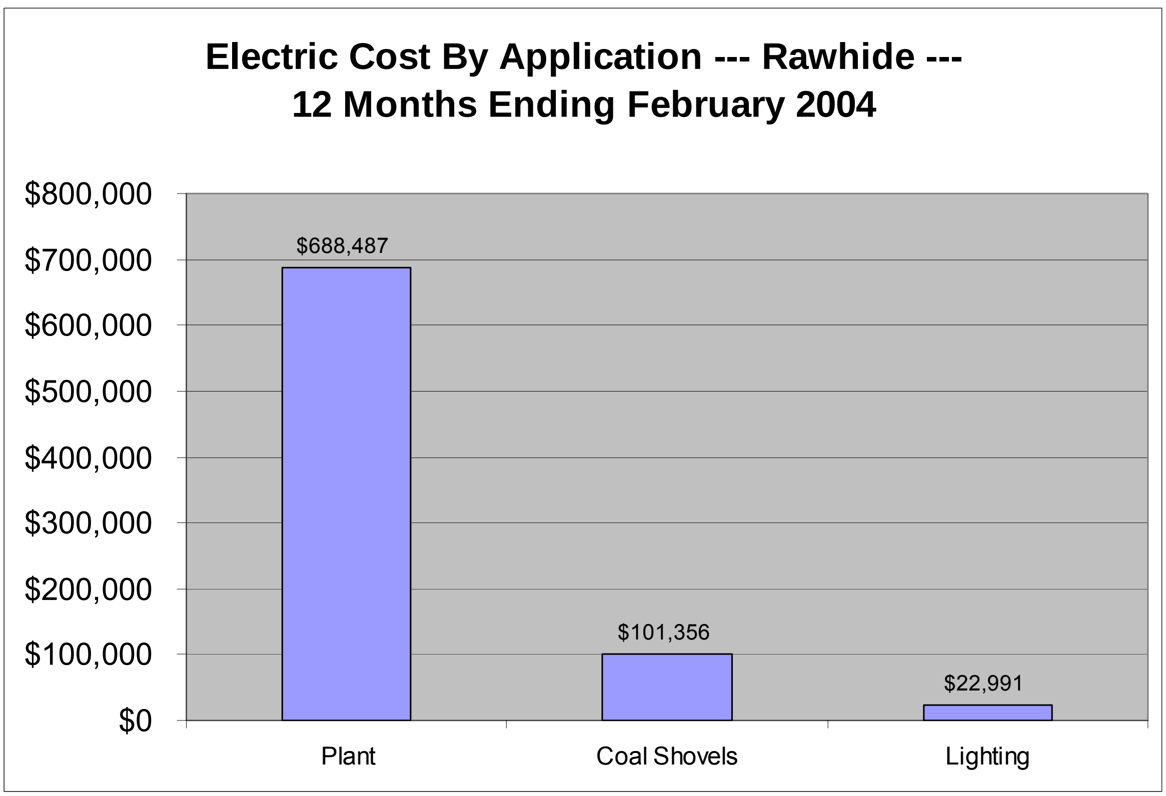
Rawhide													
Large Power Transmission (LPT)	**Mar-03**	**Apr-03**	**May-03**	**Jun-03**	**Jul-03**	**Aug-03**	**Sep-03**	**Oct-03**	**Nov-03**	**Dec-03**	**Jan-04**	**Feb-04**	**12-Month Total/Ave**
Demand Charge	Winter	Winter	Winter	Summer	Summer	Summer	Summer	Winter	Winter	Winter	Winter	Winter	
Transmission, per kw	$1.05	$1.05	$1.05	$1.05	$1.05	$1.05	$1.05	$1.05	$1.05	$1.05	$1.05	$1.05	
Generation, per kw	$5.88	$5.88	$5.88	$5.88	$5.88	$5.88	$5.88	$5.88	$5.88	$5.88	$5.88	$5.88	
Total Demand Charge	$6.93	$6.93	$6.93	$6.93	$6.93	$6.93	$6.93	$6.93	$6.93	$6.93	$6.93	$6.93	
Energy Charge													
Generation, per kWh	$0.01954	$0.01954	$0.01954	$0.01954	$0.01954	$0.01954	$0.01954	$0.01954	$0.01954	$0.01954	$0.01954	$0.01954	
Billing Demand (kW)	6,840	6,839	6,370	6,402	6,158	6,172	6,839	7,000	6,769	6,349	6,818	7,315	6,656
Actual kWh	1,197,000	1,197,000	1,022,000	994,000	1,008,000	994,000	1,085,000	1,330,000	1,456,000	1,239,000	1,442,000	1,519,000	14,483,000
Demand Charge	$47,401	$47,394	$44,144	$44,366	$42,675	$42,772	$47,394	$48,510	$46,909	$43,999	$47,249	$50,693	$553,506
Energy Charge	$23,383	$23,383	$19,965	$19,418	$19,691	$19,418	$21,195	$25,982	$28,443	$24,204	$28,169	$29,674	$282,925
Basic Charge	$600	$600	$600	$600	$600	$600	$600	$600	$600	$600	$600	$600	$7,200
Power Cost Adjustment	($857)	($840)	($717)	($698)	($708)	($698)	($762)	($901)	($1,022)	($870)	($1,423)	($1,499)	-$10,995
Total Monthly Charge	**$70,528**	**$70,538**	**$63,992**	**$63,686**	**$62,258**	**$62,092**	**$68,428**	**$74,190**	**$74,930**	**$67,932**	**$74,595**	**$79,468**	$832,637
Averages													
Demand ($/kW) --- w/adj.	$6.86	$6.86	$6.86	$6.86	$6.86	$6.86	$6.86	$6.86	$6.86	$6.86	$6.86	$6.86	$6.79
Energy ($/kWh) --- w/ adj.	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018
Ave Cost per kWh	**$0.059**	**$0.059**	**$0.063**	**$0.064**	**$0.062**	**$0.062**	**$0.063**	**$0.056**	**$0.051**	**$0.055**	**$0.052**	**$0.052**	**$0.057**
Hours use of Demand	175	175	160	155	164	161	159	190	215	195	211	208	2,176


Monthly Billing Demand (kW) -- Rawhide
7,600
7,400
7,200
7,000
6,800
6,600
6,400
6,200
6,000
5,800
5,600
5,400
6,840
6,839
6,370
6,402
6,158
6,172
6,839
7,000
6,769
6,349
6,818
7,315
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04

Usage Analysis

Electricity Consumption Estimate by Application -- 12 Months Ending February 2004
Rawhide

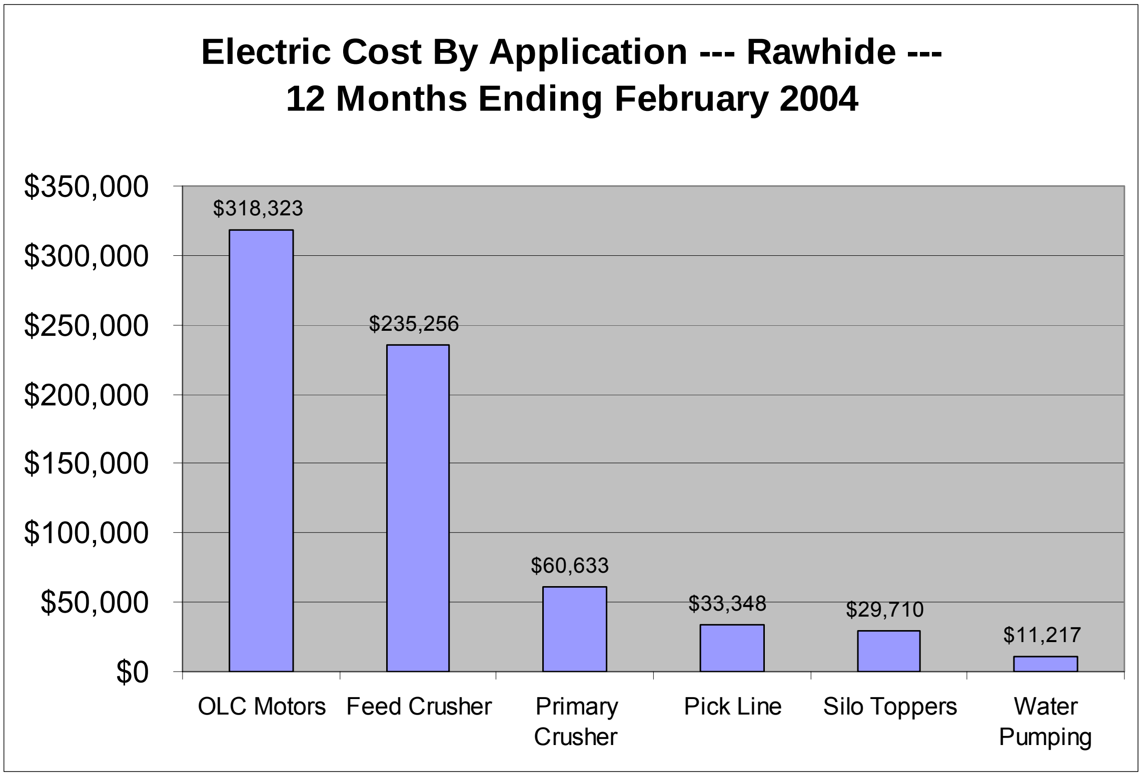
Process	Contribution To Billing Demand (kW)		Annual kWh	Annual Demand Cost @ $6.79 per kW per Month	Annual Energy Cost @ $0.018 per kWh	Total Annual Cost
Plant	5,675		12,395,196	$462,532	$225,955	$688,487
Coal Shovels	836		1,824,776	$68,092	$33,264	$101,356
Lighting	156		566,028	$12,673	$10,318	$22,991
Total (Estimate)	**6,666**		**14,786,000**	**$543,297**	**$269,538**	**$812,834**
Total Actual	**6,656**		**14,483,000**	**$553,506**	**$282,925**	**$832,637**



Plant

Electricity Consumption Estimate by Application -- 12 Months Ending February 2004
Rawhide Plant

Process	Contribution To Billing Demand (kW)		Annual kWh	Annual Demand Cost @ $6.79 per kW per Month	Annual Energy Cost @ $0.018 per kWh	Total Annual Cost
OLC Motors	2,624		5,730,936	$213,852	$104,471	$318,323
Feed Crusher	1,939		4,235,435	$158,047	$77,209	$235,256
Primary Crusher	500		1,091,607	$40,734	$19,899	$60,633
Pick Line	275		600,384	$22,404	$10,945	$33,348
Silo Toppers	245		534,887	$19,960	$9,751	$29,710
Water Pumping	92		201,947	$7,536	$3,681	$11,217
Total (Estimate)	**5,675**		**12,395,196**	**$462,532**	**$225,955**	**$688,487**



Energy Analysis
This section includes a top-down analysis of electrical usage at the Rawhide mine. The purpose of the analysis is to understand energy usage for present operations.

This is a "top-down" or *Statistical Analysis* which is a regression analysis of usage as a function of production and weather data at the Rawhide mine.

Statistics

The period of time used for this analysis is April 1, 2004 through December 31, 2005. The following data were required and available over this time period:

- Coal production [tons]
- Electricity usage [kWh]
- Outdoor temperature [heating degree-days (HDD) and cooling degree days(CDD)]

Actual monthly data used in the analysis are given in Appendix – A. The regression analysis involves finding a best-fit straight line for electric energy usage (kWh) as a function of coal production and weather. The result was as follows:

Energy [kWh] = 156,700 + 1,903 x production [1000 tons] + 163 x heating [HDD]

This expression can be used to calculate historical electric energy usage at Rawhide, given production and weather data. It indicates a fixed component of about 156,700 kWh each month, independent of production level or weather. Further, it indicates that 1,910 kWh are added for each 1000 tons of coal produced, and 163 kWh for each heating degree day. Cooling degree days have no significant impact on Rawhide energy usage.

The following table shows how accurate the expression is in calculating historical usage:

Error [+/-%]	Number of Months	Cumulative Number of Months	Cumulative Percentage
0	3	3	14%
1	2	5	24%
3	1	6	29%
4	1	7	33%
5	1	8	38%
6	2	10	48%
7	1	11	52%
20	7	18	95%

There are a total of 21 months in the time period studied. The error table indicates the following:

- In 6 of the 21 months studied (29% of the sample), the expression correctly predicts energy usage within +/- 3%
- In another 5 of the 21 months studied (24% of the sample), the expression predicts actual energy usage within +/- 7%. Including line #1 and line #2, the expression predicts actual usage within +/-7% 52% of the time.
- There are 3 statistical outliers in 2004 (August, September and December). In these month, the expression has an error of greater than 20%

Detailed results are given in the Appendix. Note that 2005 follows the model much better than 2004. Compared to other studies of this type, the model has higher errors than normal. This could be a result of some data collection errors, or other operational factors that affect energy side from coal production and weather.

Annual results are as follows:

Year	Actual Energy	Predicted Energy	Error	Error %
2004 (Apr–Dec)	12,278,327	12,726,081	447,754	- 4%
2005	27,058,723	26,621,022	437,700	2%

As expected, the expression becomes more accurate as the period of time is extended. When applied to September 2004 the expression had an error of 25%. However, the error is reduced to 4% for the last 9 months of 2004. By definition, the average error over the entire study period (21 months) is zero. This is a fundamental characteristic of regression analysis. Rounding errors result in a non-zero total of 2%.

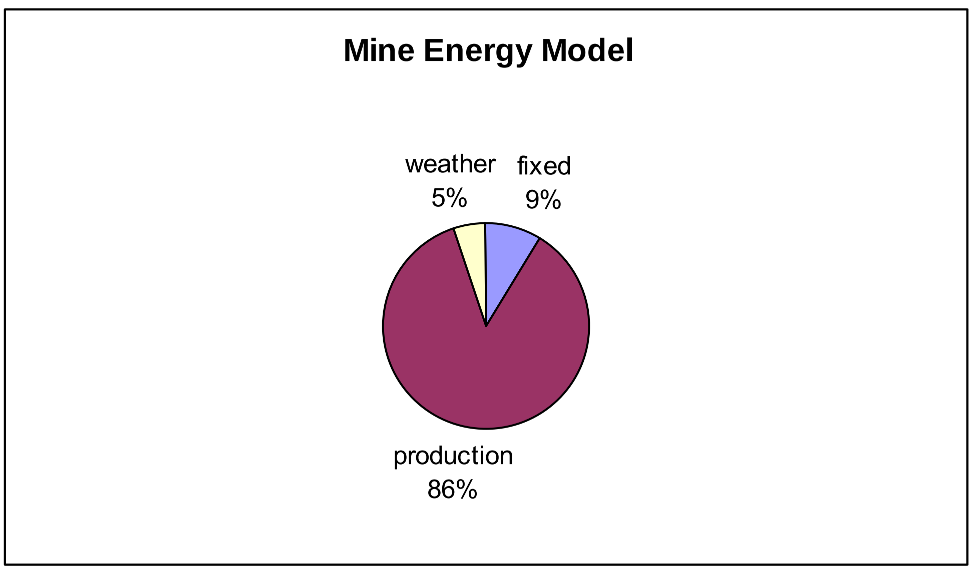
If applied to individual days, the errors would be greater. However, the results are somewhat useful in understanding energy usage and the impact of weather and production. The following are important observations:

4. Energy usage in a mining operation should be a strong function of production, as is the case at Rawhide. Note that the fixed portion (156,700 kWh per month) is only 9% of total energy usage in a typical year. Compare this to NAR which has a fixed component of 52%.

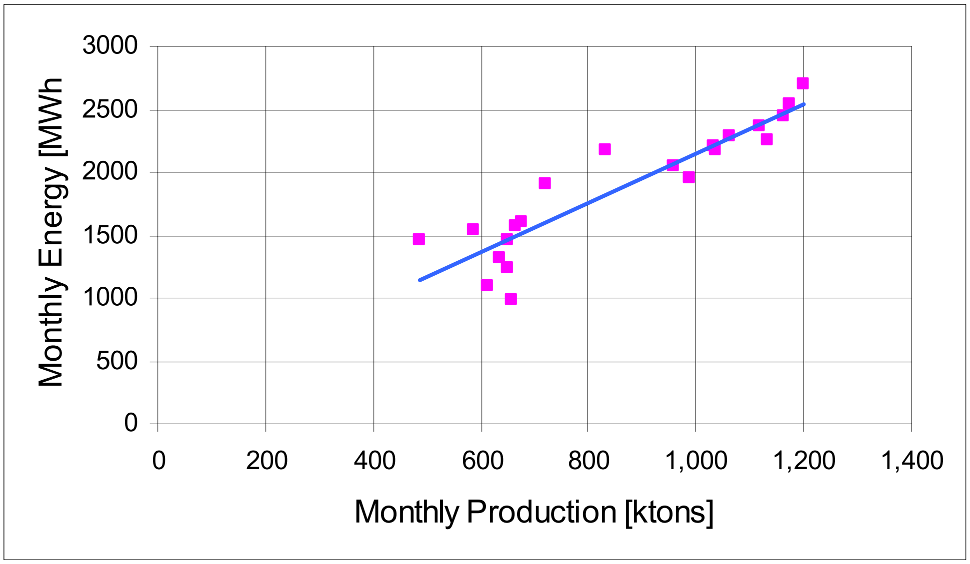
5. The fixed portion is quite small at Rawhide; most energy usage is a function of production. For this reason, energy cost per unit of production is expected to change only a small amount as production is increased or decreased. Energy cost per ton will increase slightly at lower production and decrease slightly at higher production; *provided that single-shift operation is maintained*.

6. An additional work shift at Rawhide (24-hour operation) will dramatically change the equation and reduce energy cost per ton. Load factor will increase from 25% to perhaps 50% or more. This could reduce the price paid for electricity (per kWh) by as much as 50%.

7. High ambient temperature does not impact usage significantly. The northern location of this mine, at high altitude is not expected to have a significant cooling load.



Additional information and all the source data are given in Appendix – A. A graphical depiction of the regression analysis (production against energy) showing the strong correlation is given on the next page.


3000
2500
2000
1500
1000
500
0
Monthly Energy [MWh
0
200
400
600
800
1,000
1,200
1,400
Monthly Production [ktons]

Discussion

OLC Belt Motors and Operating Practices

Three (3) areas should be considered for belt energy savings; no-load operating practices, power factor correction, and control under load conditions. The first refers to times when the belt is presently operated with no coal on the belt, such as before and after the work shift. The second is aimed at correcting power factor at each motor as currently installed. The third is where drives are often mentioned as a possibility.

This one-shift operation does not have the same issue as other mines with equipment running unloaded during shift changes. However, it was noted that approximately one (1) hour of unloaded operation each day could possibly be eliminated by changing start-up and shutdown procedures. The resulting annual savings is estimated at $35,000. This assumes less run time for the OLC as well as related coal transport equipment.

Variable Frequency Drives for Major Belts

The OLC belt is run continuously at constant supply frequency (no drives). There would appear to be an opportunity for energy savings associated with motor speed control (variable frequency drives). Based on the detailed analysis at NAR, the following loads are estimated for the OLC belt.

Belt	Rated Load [tons/hr]	Horsepower			
		@ rated load	@ average load	@ no load	Connected
OLC	6,500	2,500 – 3,000	1,500	135	3 x 1,750

The load model and field measurements from NAR indicate that major belt drive motors are typically under-loaded. However, this is a conveyor application where variable speed is likely to interferer with performance. For example, these belts move coal, and running them at 50% speed to save energy is just not practical

The brake horsepower delivered to the conveyor drive shaft is a function of rotational speed and torque. There is presently a mismatch between the conveyor requirements and the motor capability.

Conveyor Requirements – The conveyor power requirement is a function of lift, coal load and friction. Since lift and coal load cannot be changed, the opportunity for reduced requirement is friction. The NAR model quantifies the friction load and allows for estimates of potential savings from low-friction bearings, etc.

Motor Capability – Each motor has a speed-torque characteristic and efficiency associated with various operating points. As the motor is unloaded, the power factor and efficiency decrease. Power factor decreases because reactive current requirements decrease by a small amount while real current is proportional to mechanical load and decreases significantly.

The application of drives or other motor changes will not impact brake horsepower requirements at a given delivery [TPH]. The only savings would result from the motor being able to supply the conveyor requirement more efficiently.

In theory, a transmission between the motor and conveyor could be used to allow the motor to run at reduced speed while maintaining belt speed. While technically feasible, this is not considered a viable option. The cost could rival that of replacing the motor. There are also benefits to the larger motors. The extra power could be needed from time to time under extreme conditions to get the belt moving, or when one of several motors is out of service.

Therefore, savings associated with changes to the motor/drive assets must come from increased motor efficiency and/or reduced reactive power requirements (power factor closer to unity.) The available savings is relatively small.

Another consideration is the possibility of reducing the number of motors in operation. In the case of OLC, there are three (3) motors and the belt requirements could be met without all motors in operation. A detailed analysis would be required over a period of time to verify belt requirements and the practicality of this option.

Belt Power Requirements

One challenge in sizing major belt motors is the tradeoff between operating efficiency and the occasional need for extra power. Factors such as static friction, load momentum (accelerating coal), icing, etc. can require extraordinary torque and power. Unfortunately, that extra motor capacity then remains on-line for the vast majority of the time when operations are normal. In future designs, consideration should be given to this issue. Other methods of providing temporary, extra torque/power should be considered.

Variable Frequency Drives for Deep Water Wells

There are number of large motors at the mine that operate well pumps. Factors that affect the efficiency of pumping include matching the pump and motor characteristics (speed – torque). This allows both pieces of equipment to operate in their most efficient range. Impellor selection/trim is important.

Unless the flow rate and/or hydraulic head are significantly different than anticipated during the design process, the motor-pump match is probably correct.

Other factors that impact efficiency include pump maintenance, specifically impeller condition, and water distribution piping and valves. A partially-closed value in the distribution network being used to throttle water flow is a source of inefficiency. It is better to slow the pump with a variable-speed drive than to operate at full speed and throttle the flow (essentially increase the head) with partially-closed valves.

Variable speed control comes with a price, and it is unlikely the investment could be justified for these pumps. Any significant mismatch between pump and motor should first be addressed by considering impeller trim or changing the motor.

Lighting

The study estimates total annual lighting cost of about $ 26,000. Knowing that number helps put potential savings estimates in perspective. Savings would result from more diligent lighting control (turned off when not needed) and upgrading to high-efficiency lighting. For the purpose of estimating savings, it is not correct to use the average cost of electric energy ($ 0.057 kWh) because changes may not reduce demand. In particular, lighting control usually does not impact demand. So estimates must use only the energy charge component ($ 0.018 / kWh) for savings calculations.

The annual savings associated with lighting control is about $ 2,000. A small automatic control system (timers) or simple work practice changes (turn them on/off manually as needed) are recommended for consideration.

High efficiency lighting could also be considered. The recommendation is to install high-efficiency fixtures as the opportunity arises during normal maintenance. A wholesale replacement of fixtures is unlikely to have an acceptable return on the investment. This is based on findings at other mines such as NAR.

Electric Demand Control

Electricity prices have two (2) major components; energy and demand. Analysis is usually based on the average cost of $0.057 per kWh. There is an assumption that all loads contribute equally to the overall demand, and therefore, demand will be reduced proportional to energy. In the case of lighting control, only the energy component ($ 0.018 per kWh) was used. It is known that demand will not be significantly affected by lighting control. Using the lower cost figure yields a conservative estimate.

The mine load factor averages 25% which is low considering that other mines average 65 to 80%. However, this mine is operated with one work shift. Since load factor includes all 8,760 hours in a year, a low load factor is expected.

Appendix A – Monthly Data for Statistical Analysis

Month	Energy [kWh]	Production Total [ktons]	Heating DD	Cooling DD
April	1,460,361	485	560	0
May	1,610,292	678	362	3
June	1,542,411	587	155	40
July	1,579,144	665	23	205
August	990,561	657	70	91
September	1,088,397	614	210	46
October	1,316,522	633	506	0
November	1,457,295	651	866	0
December	1,233,345	651	1043	0
Total 2004	**12,278,327**	**5,620**	**3,795**	**385**
January	2,175,336	831	1221	0
February	1,906,971	720	919	0
March	2,543,795	1,173	846	0
April	2,279,424	1,063	600	0
May	2,358,437	1,117	448	1
June	1,951,586	987	151	105
July	2,054,244	956	12	285
August	2,201,995	1,032	56	140
September	2,179,036	1,035	162	57
October	2,448,187	1,161	496	9
November	2,704,819	1,199	807	0
December	2,254,893	1,131	1197	0
Total 2005	**27,058,723**	**12,407**	**6,915**	**597**

Weather data was taken from a National Weather Service weather station at the Gillette Campbell County Airport (GCC) in Gillette, Wyoming.

Month	**Energy [kWh]**		**Error**		**Production**	**Degree Days**
	Actual	**Predicted**	**[kWh]**	**[%]**	**Total**	**Heating**
April	1,460,361	1,171,235	289,126	20%	485	560
May	1,610,292	1,505,331	104,961	7%	678	362
June	1,542,411	1,298,665	243,746	16%	587	155
July	1,579,144	1,425,392	153,752	10%	665	23
August	990,561	1,419,269	-428,708	-43%	657	70
September	1,088,397	1,358,721	-270,323	-25%	614	210
October	1,316,522	1,444,648	-128,126	-10%	633	506
November	1,457,295	1,537,582	-80,287	-6%	651	866
December	1,233,345	1,565,239	-331,894	-27%	651	1,043
Total 2004	**12,278,327**	**12,726,081**	**447,754**	**- 4%**	**5,620**	**6,781**
January	2,175,336	1,938,359	236,978	11%	831	1,221
February	1,906,971	1,676,221	230,751	12%	720	919
March	2,543,795	2,527,407	16,388	1%	1,173	846
April	2,279,424	2,278,129	1,295	0%	1,063	600
May	2,358,437	2,356,315	2,122	0%	1,117	448
June	1,951,586	2,059,996	-108,410	-6%	987	151
July	2,054,244	1,978,743	75,501	4%	956	12
August	2,201,995	2,130,467	71,528	3%	1,032	56
September	2,179,036	2,153,392	25,644	1%	1,035	162
October	2,448,187	2,446,863	1,324	0%	1,161	496
November	2,704,819	2,570,612	134,207	5%	1,199	807
December	2,254,893	2,504,520	-249,627	-11%	1,131	1,197
Total 2005	**27,058,723**	**26,621,022**	**437,700**	**2%**	**12,407**	**6,915**

Appendix B – Miscellaneous Lighting Data

Building	***Location***	***Type***	***No.***	***Power (W)***	***Ballast Factor***	***Total kW***	***Hour Usage / Yr***	***Demand Cost***	***Energy Cost / Yr***
Maintenance		HPS	98	1000	1.15	112.7	8760	$662.68	$19,285.97
Old Plant	Apron Feeders	HPS	21	250	1.15	6.0	8760	$35.50	$1,033.18
	to CV 201	Incandescent	27	150	1	4.1	8760	$23.81	$693.06
Sample Building		Incandescent	85	150	1	12.8	8760	$74.97	$2,181.86
Silos		Incandescent	66	150	1	9.9	8760	$58.21	$1,694.15
	Silo Connection Belt	HPS	20	400	1.15	9.2	8760	$54.10	$1,574.36
							Totals	$909.27	$26,462.59

Appendix C – Findings

As part of the effort, an energy auditor has provided the following suggestions, included here for the record.

Lighting Control

The following table identifies lights that are presently on 24/7 that can be turned off at least 12 hours per day. Turning these lights off will not reduce the billing demand, however annual energy consumption will be reduced by 125,651 kWh for a savings of $2,279 at $0.018 per kWh.

Turn Select Lights Off When Not Needed	kW	off hours per year	kWh Savings	Energy Savings
	29	4,380	125,651	**$2,279**

Building Lighting	Location	Usage Type	Equip Type	Total # of fixtures	Watts per Fixture	Watts per location	Ballast Factor	Input watts per location	Total kWc	
Old Plant	Apron Feeders	HPS	Bay	21	250	5,250	1.15	6,038	6.0375	lights not needed 24/7
Sample Building		Incandescent		85	150	12,750	1.00	12,750	12.75	lights not needed 24/7
Silos		Incandescent		66	150	9,900	1.00	9,900	9.9	lights not needed 24/7

Reduce Running Time of Select Equipment By 1 Hour per Day

Rawhide operates one work shift. The following table identifies motor load that is running unnecessarily during the shift start-up and shut-down. It is estimated that the following motor load totaling 5,338 kW can be shut down for at least 1 hour each day. As with lighting, the demand charge is not affected, however energy will be reduced by 1,948,398 kWh annually for a savings of $35,518 at $0.018 per kW

Reduce Running Time of Select Equipment By 1 Hour per Day -- Plant

Plant	kWd	
Primary Crusher	500	
Pick Line	275	
OLC Motors	2624	
Feed Crusher	1939	
Total	5,338	kWd
Shut Down	1	hours per day
	365	days per year
	365	hours per year
	1,948,398	kWh per year
	$0.018	Energy cost per kWh
Annual Savings	**$35,518**	