Striking Gold: How Innovations and Productivity Improvements in the Mining Industry Leverage Energy Efficiency Technologies

Karen McGinley, DNV GL
Paul Geary, DNV GL
James Dodenhoff, DNV GL

ABSTRACT

The drive to increase productivity in a cost-effective manner is critical for mining operations. Industry leaders are beginning to realize that energy efficiency measures are valuable tools for mining projects as they enhance productivity, improve quality, and reduce operating costs. Such measures can be creative, complex, and highly impactful to mining operations and the bottom line. They also deliver considerable benefits through their contributions to state energy efficiency performance standards and, ultimately, to utility customers with relatively high cost-effectiveness.

This paper provides an overview of mining projects in Arizona and Nevada where the facilities participated in utility energy efficiency incentive programs between 2012 and 2014. It also presents a closer look at some unique and innovative projects at a variety of mine sites, which provides insight into the creative ways in which energy efficiency can be bundled into mining capital-improvement packages. Specific project parameters are highlighted which include percentage of energy savings, cost effectiveness, incentive contribution, project timing, and project elements.

The authors highlight technology trends and innovations to consider for future mining projects, with a focus on metal and mineral mining projects and discrete mining processes. Recommendations from this paper are intended to support mining facility managers to help make compelling business cases for energy efficiency investments.

Study Objectives & Methodology

The innovative energy efficiency mining projects in Arizona and Nevada presented in this paper received ratepayer funded incentives under the NV Energy Sure Bet program in Nevada and the Tucson Electric Power (TEP) Easy Save Plus Large Business program in Arizona. The NV Energy Sure Bet program began in 2003 and the TEP Easy Save Plus program began in 2009. DNV GL provides energy efficiency implementation services under contract to NV Energy and TEP. These services include engineering support, technical review, and site surveys of utility business customers' energy efficiency project applications.

The authors identified and compared key findings from a sample set of energy efficiency projects with secondary research from available studies and literature and then refined our observations and findings to capture best practices in energy efficiency mining projects. The paper focuses exclusively on metal and mineral mining projects and excludes coal mining and oil and gas extraction projects.

Overview of the Mining Industry, Energy Usage, and Greenhouse Gas (GHG) Emissions

Mining is the extraction of valuable minerals or other geological materials from the earth from an ore body, lode, vein, seam, or reef. Ores recovered by mining include metals, coal, oil shale, gemstones, limestone, dimension stone, rock salt, potash, gravel, and clay. Mining techniques fall into two common excavation types: surface mining and sub-surface (underground) mining. The typical mining process includes ore extraction, crushing, grinding, mineral/metal separation (mechanical/chemical or both), and ore concentrate processing (as required). In the past 10 years, metal prices have been highly volatile and increased dramatically after an extended period of commodity price stability dating back to 1990.

Mining and metals production is an energy-intensive process, with a significant proportion of energy consumption coming from purchased electricity. A metal mining company's energy expenditures can consume between 20% and 40% of its total production costs.(Southwest Energy Efficiency Alliance 2014) Mining operations create GHG emissions directly through on-site fuel combustion and indirectly through electricity purchases from the grid. In 2011, total US emissions from this industry were 115 million metric tons of carbon dioxide equivalent (CO_2-e),[29] or 10.7% of all reported emissions, excluding power plants. (Sustainability Accounting Standards Board 2014)

Trends in Mining Industry Participation in NV Energy and TEP Energy Efficiency Programs

The NV Energy Sure Bet program, which started in 2003, is a very mature utility-administered energy efficiency program. In its early years, mining company participation in this program was minimal. The TEP program, which started in 2008, also had slow adoption from the mining sector.

For an industry with such a high profile, large size, and energy-use intensity, there is relatively little secondary literature or studies on mining industry energy efficiency projects. A previous study of industrial process energy efficiency projects implemented by Southern California Edison (SCE) identified less than five mining projects from more than 600 projects implemented between 2010 and 2012. Total estimated energy savings for these projects was less than 1 GWh. The participation level by mining companies in the SCE EE programs is less than the proportional share of mining industry energy consumption in SCE's service territory. (Dodenhoff/Hoda 2013). This is further evidence of an industry which has been slower to implement energy efficiency projects.

NV Energy senior account executives historically have been assigned to manage mining company electric service needs given these customers high consumption and demand and importance to NV Energy's business. Even with focused account management, mining company participation in the NV Energy Sure Bet program only began increasing over the past three years. This recent increased adoption of energy efficiency projects is attributable to a number of factors including:

- NV Energy and DNV GL energy engineers have familiarized themselves with capital expenditure cycles and capital expenditure decision-making process.

- Energy engineers comprehend the complexity of mining operations to better identify energy efficiency opportunities within larger capital projects
- Trust and confidence have been developed between mining facility managers and energy engineers; both realize that the time and effort spent researching and adopting energy efficiency technologies creates value..
- Professional networks have been created resulting in spillover effects, so that one successful project within a single mining operation can breed many additional projects or the adoption of similar technology at another mine, even when the mining companies are different.
- The general perception by mining customers that energy efficiency incentives are primarily for lighting projects and office buildings in cities is changing. There is now a realization that mining companies can also participate in utility incentive programs...
- Agency barriers due to project managers' lack of awareness of energy use and savings for mining capital projects are disappearing.
- Energy usage, demand, and energy cost savings estimates are more refined for very large capital improvement projects.
- Senior management buy-in is improving. Between 2004 and 2014, senior management at many mining companies embraced sustainability initiatives including energy efficiency.

Survey of Innovative Projects

Coeur Rochester – Silver Mine: Pump Retrofit and New Pump Installation

Table 1. Energy efficiency project summary

Project	Annual Energy Savings	Demand Reduction	Percentage Savings vs Baseline	Estimated Annual Energy Cost Savings	Incentive
Pump Retrofit	1,026,505 kWh	74 kW	27%	$71,855	$59,167
New Pump Installation	2,712,600 kWh	134 kW	40%	$189,900	$139,900

In 2012, DNV GL assisted an operator of Coeur Rochester mine to develop an energy efficiency retrofit project relating to the leaching process for extracting silver from ore. The mine produced in excess of 2.5 million ounces of silver in 2013 with expected production of more than 4 million ounces of silver in 2014.

Ore is mined at the site, crushed, and deposited to leach pads. The facility uses a series of tanks, pumps, and pipes to convey liquid solutions throughout the ore processing operation. As a part of this leaching process, an existing 700 horsepower (hp) pump was retrofitted with a variable speed drive (VSD). Two new 1,250 hp VSD pumps were also added to the operation.

Before the retrofit, the mining facility used a throttling valve to slow and modulate flow. While a throttling valve does slow the flow of fluid, the effect on the speed of the pump is relatively insignificant. For a high horsepower pump, even a small decrease in speed can result in large savings due to the affinity laws governing energy use for pumps and fans. The installation of VSDs on high horsepower pumps was a relatively simple enhancement that brought very significant energy and cost savings. This is especially true when pump or fan speed can be decreased or varied. These savings were derived from better matching pump operation and speed to liquid solution flow.

The annual energy savings for both measures combined in this retrofit project were 3,739,105 kWh.

Freeport McMoRan Sierrita Copper and Molybdenum Mine: Flotation Cell Process Enhancement

Table 2. Energy efficiency project summary

Project	Annual Energy Savings	Demand Reduction	Percentage Savings vs Baseline	Estimated Annual Energy Cost Savings	Incentive
Flotation Cell Improvement	14,977,598 kWh	1,783 kW	39%	$915,000	$1,497,759

Freeport McMoRan Inc. (FMI) Sierrita Mine is an open pit copper/molybdenum mine in the TEP service area south of Tucson. The Sierrita operation includes a 102,000 metric-ton-per-day concentrator that produces copper and molybdenum concentrates, a run-of-mine oxide-leaching system, and a copper sulfate crystal plant.

Many copper-mining operations, including the Sierrita Mine, include a “froth flotation” process that takes advantage of the physical and chemical properties of small copper ore particles. FMI replaced an existing rougher flotation cell process train with a new flotation cell train, resulting in increased metal recovery rates and reduced energy usage. The original process consisted of 379 flotation cells with impellers driven by 247 electric motors ranging in size from 15 hp to 75 hp. Many motors served more than one cell. The original process also relied on four 400 hp/4160V aeration blowers; three operating and one on standby during normal operation.

Figure 1. New flotation cells

The new flotation cell process has four trains or cell packs consisting of five large cells each. Each new flotation cell has a dedicated 150 hp impeller motor and every cell pack has a dedicated 125 hp multistage blower to provide aeration for the process. The new flotation cell plant design has the ultimate capacity to process up to 130,000 metric tons per day of ore.

Metered data was the basis for the energy savings analysis on this project. For the original process, customer-measured motor amperages, circa 2005, were taken for the cell trains and used as the basis for the pre-existing energy usage. The new process uses metered amperage data from the Motor Control Center MCC panel resident meters. A process runtime of 24/7 with a conservative estimate of two weeks for maintenance/downtime was used for both the pre- and post-measure energy calculations. Energy savings realized from a significantly optimized froth flotation process was the key driver to this successful energy efficiency project. By consolidating the equipment from over 300 small cells to 20 large cells, and optimizing the agitator and aeration systems, this retrofit created a large reduction in total motor horsepower for this froth flotation process, while maintaining production throughput and increasing metal recovery. The result was an overall reduction in energy use intensity.

The annual energy savings for this project was 14,977,598 kWh.

Freeport McMoRan Sierrita Copper and Molybdenum Mine: Overland Conveyor Upgrade

Table 3. Energy efficiency project summary

Project	Annual Energy Savings	Demand Reduction	Percentage Savings vs Baseline	Estimated Annual Energy Cost Savings	Incentive
Overland Conveyor Upgrade	1,778,578 kWh	219 kW	16%	$108,500	$177,858

This project, which occurred at the same site as the previous case study, retrofit existing conveyor drives with new drives for a portion of the overland conveyor system. The conveyors, which run parallel to each other, were driven by maintenance-intensive, inefficient, high torque, 600 hp wound-rotor AC motors and direct gear drives. The facility installed replacement drives based on high-efficiency 600 hp AC motors as well as new hydraulic couplings/drives that eliminated the need for the wound rotor motor's high startup torque capability. The project was part of an effort to standardize drives across the site.

Figure 2 shows the retrofitted overland conveyors (A3, B3, and B4 conveyors); the motive power is supplied by drives A3 North, A3 South, B3 North, B3 South, and B4.

Figure 2. Image of overland conveyors.

. Typically, the overland conveyors run concurrently, but loading can vary on each at any point in time depending on haul truck dumping schedules and primary crushing station output. The facility staggers scheduled maintenance to maintain production; periodic scheduled maintenance downtime occurs for eight hours every two weeks. Energy savings were based on pre- and post-metered data collected through the customer's supervisory control and data acquisition (SCADA) system. The measurement period occurred over several months to establish a baseline on the pre-retrofit configuration and over several weeks after project completion. Tonnage conveyance rates were consistent for both pre- and post-retrofit operation. The energy savings realized by this project is primarily from one for one replacement of five relatively low efficiency 600HP motors with high efficiency 600HP motors on overland conveyors along with new drive components that complimented the new motor startup characteristics.

Hycroft Gold Mine: Interior/Exterior LED Retrofit for Crushing Operations

Table 4. Energy efficiency project summary

Project	Annual Energy Savings	Demand Reduction	Percentage Savings vs Baseline	Estimated Annual Energy Cost Savings	Incentive
LED Retrofit	708,910 kWh	135 kW	72%	$49,600	$47,414

The Hycroft mine in Nevada encompasses approximately 72,000 acres. While in production under previous owners, Hycroft produced more than one million ounces of gold using an open pit heap leaching process. Allied Nevada restarted the mine in 2008, increasing gold production four-fold and silver production ten-fold through 2013.

Hycroft operates 24/7. Currently, the facility conducts open pit mining of heap leach mineralization by simple drill, blast, and truck haulage of ore to the north heap leach pad complex. It places lower-grade ore on the heap leach pads as run-of-mine, and crushes higher-grade ore using a large three-stage crushing system.[1]

As a part of a renovation and expansion of the site, the customer built new leach fields and processing facilities, which included a Merrill Crowe facility (a separation technique for removing gold and silver from a cyanide solution) and a new crusher facility. The site also uses a new technology of gold extraction utilizing a flash-freezing process.

The facility installed 80 Watt interior and exterior light-emitting diode (LED) lighting at the new facilities, rather than the 250 Watt metal halide lighting seen at most mine sites. LED lighting was chosen for both interior and exterior crushing operations due to its superior energy efficiency, significant quality improvement, greater durability in the harsh environment, and longer useful life. The ability to be able to install a type of lighting that lasts years instead of months when operated 4,000 to 8,760 hours a day and to not worry about broken elements due to the everyday hits, bumps and grinds of the industry is a huge advantage over typical metal halide lighting. This customer chose to install LED lighting a part of the construction when a lot of sites are going back and retrofitting lighting. This shows a new trend in the industry of spending additional dollars up front for long term annual cost savings.

Annual energy savings from this project were 708,910 kWh.

---

[1] http://www.alliednevada.com/properties/hycroft-mine/

Figure 3. Left to right: external LEDs at crushing facility, internal LEDs at crushing reclaim tunnel.

Diatomaceous Earth Plant: VSDs on Fans

Table 5. Energy efficiency project summary

Project	Annual Energy Savings	Demand Reduction	Percentage Savings vs Baseline	Estimated Annual Energy Cost Savings	Incentive
VSD Installation	1,835,617 kWh	210 kW	69%	$119,300	$103,325

Diatomaceous earth (DE) deposits are located in central Nevada and were created five to 20 million years ago when the state was covered by a prehistoric sea. One of the world's largest DE plants resides in the state.

As part of an upgrade to process DE and perlite products more efficiently, the facility installed VSDs on three 250 hp fans used for pneumatic conveyance of the product as it is dried by three large kilns at the site. The baseline fan size was a 200 hp fan and new 250 hp fans were installed at the same time. One fan was operating with no damper at 100% and two had dampers for control. Being able to slow down the process allows more drying earlier in the process rather than later. This reduces dependence on the second furnace to dry so much of the product. Adding the VSDs allowed the company to increase production rates because not as much product will need to go through the second furnace. Pre- and post-data logging of the fans showed that the plant was able to reduce fan speeds and obtained substantial reductions in energy use Annual energy savings from this project were 1,875,615 kWh per year.

Denton-Rawhide Gold Mine: VSDs on Cone Crushers and Feeder Motors

Table 6. Energy efficiency project summary

Project	Annual Energy Savings	Demand Reduction	Percentage Savings vs Baseline	Estimated Annual Energy Cost Savings	Incentive
VSD Installation	652,334 kWh	59 kW	48%	$45,663	$43,367

Rawhide Mining LLC operates the Denton-Rawhide Mine in in the historic Regent Mining district located outside of Fallon, Nevada. Recently, the company invested in expansion of the plant and its ore crushing capabilities; including the purchase of a primary jaw crusher, a secondary cone crusher and two new 400 HP cone crushers with VSDs and a feeder conveyor with VSDs on the motors.

Installing a VSD on the cone crusher allows the speed of the machine to change as the size and amount of the ore entering changes. In being able to better match the motor speed to the size of the ore (larger ore equates to slower speed) and the speed of the feeder system, the energy use of the cone crusher changes and overall energy was reduced. As the amount of crushed ore exiting the crusher changes, the speed of the conveyor or feeder system should also increase or reduce speed. To accommodate this need, the facility installed VSDs to one 20 HP and four 10 HP motors and was able to again show a decrease in overall expected energy use. This equipment operates approximately 20 hours per day, 7 days per week.

Total estimated annual savings were 652,334 kWh.

Figure 4. Photos left to right: feeder conveyor, cone crusher, and close-up of cone crusher.

Key Findings and Observations

This survey of mining projects identified various methods of reducing operating energy usage and costs, which derive efficiencies by better matching equipment usage with process flow. The key to the success of these projects is to unpack the often unique and complex underlying industrial processes throughout the extraction-processing-treatment-final production cycle. Interestingly, the implementation of VSDs seems prevalent across virtually all of the core mining processes with the possible exception of initial ore extraction. We identified VSD use in ore crushing activities, mechanical conveyance of crushed ore, pumping of process solutions for leaching, and agitation of process solutions to effect mineral separation.

For lighting projects, most mines are only beginning to retrofit with LEDs, but the uptake is growing. Given current market conditions, most mines operate 24/7 over a large geographic footprint in sometimes harsh and exposed environments. These situations require significant exterior and interior lighting with long lasting, highly durable, and easily maintained lighting fixtures. In many cases, LED lighting technology is a superior solution.

Our study findings align with the US Department of Energy (DOE) manufacturing and mining energy analysis study (DOE 2004). In that study, DOE explored and compared major industrial market verticals and energy use by major process systems. The study noted that the mining industry was ranked as the third-highest energy user of motor driven systems among 10 major industry verticals, higher than such verticals as the refining, cement, and computer and electronics industries. Conversely, mining was ranked very low relative to other industrial market verticals in its use of steam-based process systems. The mining industry ranked in the middle of the group for use of combustion-based process systems. These findings are corroborated by DNV GL's work in the mining industry for energy efficiency projects and opportunities.

Another crosscutting finding from the authors' work is that an enormous amount of material is extracted and liquids processed to produce a relatively small amount of metals and minerals. This, of course, drives energy use and energy efficiency opportunities. Today's open pit gold mines generally have concentrations of gold in the 1-4 gram per ton range, but most of Nevada's gold mines have concentrations less than 1 gram per ton (Toovey 2010). Silver concentrations are generally in the 15-20 grams of silver per metric ton of rock in order for a deposit to be considered marginally economic (Lechler 2010). Copper concentrations are higher. For example, the copper concentration in ore is 2600 grams per metric ton at the FMI Sierrita Copper Mine in Arizona.(U.S. Department of the Interior 2006) It is only through technology and energy efficiency enhancements that precious metal and mineral extractions remain economic in the face of lower quality ore.

Conclusions and Future Trends

We conclude through our direct experience in Nevada and Arizona that while the mining industry is one of the highest energy users, they have not traditionally participated in energy conservation. However, in the last several years due to perseverance, education of key mining decision makers, and energy efficiency "agent" interaction with mining customers, this industry is beginning to embrace energy efficiency as a means of increasing productivity and managing its environmental footprint.

We believe significant opportunities for new energy efficiency projects in both simple end uses (e.g., LED lighting) and more complicated process technologies remain. Continuing to raise awareness of energy savings and incentive opportunities created from new energy efficiency projects will help create increased levels of project adoption that have been experienced in recent years.

Our research also found that there is a growing consensus within the mining industry around the adoption of sustainability principles. The Nevada Mining Association speaks of "reducing greenhouse gas emissions by exploring opportunities to save electricity and fuel" and "continuous improvement in water management by striving for greater efficiency in water use, protection of existing water quality, and balancing the needs of various water users." (Nevada Mining Association, 2010). There is also forming the Green Mining Initiative in Canada whose goal it is to position Canada's mining sector at the forefront of competitiveness, sustainability, and innovation. (Chevalier 2014).

The proper valuing of resource impacts with business principles in the mining industry will be key to its continued success and long term sustainability and can contribute to state and national environmental and energy policy objectives.

References

Chevalier, P. 2014. *Canada's Green Mining Initiative, Workshop on Best Practices on Mining Policies and Technologies, Brussels, Belgium, Natural Resources Canada*

Department of the Interior, 2006, Minerals Yearbook, V.2. Area Reports, Domestic, p 5-2

Dodenhoff, J. and M. Hoda, 2013. *Technology Drivers of Improved Energy Productivity in Manufacturing Process Enhancement Projects*. Rosemead, CA: Southern California Edison.

DOE (Department of Energy), December 2004. *Energy Use, Loss, and Opportunity Analysis, US Manufacturing and Mining*. https://www1.eere.energy.gov/manufacturing/intensiveprocesses/pdfs/energy_use_loss_opportunities_analysis.pdf.

DNV KEMA Energy and Sustainability. 2014. *Northwest Energy Efficiency Alliance Industrial Initiatives Market Progress Evaluation Report #8*. http://neea.org/docs/default-source/reports/neea-industrial-initiatives--market-progress-evaluation-report-8.pdf?sfvrsn=8.

Lechler, P., M. Desilets, J. Price, A. Coyner, and D. Gaskin. 2010. *Geochemical Sampling of Selected Playas in Nevada: Alkali Lake (Esmeralda County), Columbus Salt Marsh (Esmeralda County), Rhodes Salt Marsh (Mineral County), and Winnemucca Dry Lake (Washoe County)*. Reno, NV: Nevada Bureau of Mines and Geology.

Nevada Mining Association. 2010. *Issues and Policy Outlook* http://www.nevadamining.org/issues_policy/outlook.php

Southwest Energy Efficiency Alliance, 2014 *Colorado Efficiency Guide* http://www.coloradoefficiencyguide.com/recommendations/mining.htm

Sustainability Accounting Standards Board, June 2014, *Sustainable Industry Classification System™ (SICS™) #NR0302 Metals and Mining Research Briefing*

Toovey, L. "Nevada: Where Low-Grade Gold Deposits Can Still be World Class." *Gold Investing News*, July 13, 2010, http://goldinvestingnews.com/5488/nevada-where-low-grade-gold-deposits-can-still-be-world-class.html.