PROMOTING ENERGY EFFICIENCY STUIDIES
DURING MINERAL PROCESSING PLANT DESIGN

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ABSTRACT

This paper discusses how to effectively conduct energy efficiency studies during the design of new mineral processing plants and plant expansions. Energy management studies for new plants are ideally conducted as part of the feasibility study, but can also be done at the detailed design stage prior to the purchasing of equipment. Energy management engineers work as part of the mineral processing plant design team.

Such studies usually result in energy savings of approximately 3-8% of the predicted plant's energy consumption and energy demand. Potential cost savings can be significant. A variety of mineral processing systems – crushing/grinding, pumping, materials handling, fans/blowers, compressed air, and others – are assessed within this study.

Energy Management Information System (EMIS) studies can also be performed for the new plant or plant expansion, as an independent study. EMIS can be incorporated into the electrical and controls design of the plant.

Most Canadian Utility companies fund new plant design studies and provide financial incentives based on the predicted energy savings and incremental cost of the more energy-efficient design. A new plant energy efficiency study improves the potential for energy reduction because only the incremental equipment cost is included in the project return-on-investment calculation. After the design and construction phases, energy efficiency projects must justify the entire cost of the upgrade, which is significantly higher than the incremental cost alone.

This paper outlines the major steps of a new plant/plant expansion energy efficiency study, the available utility company incentives, and the areas yielding the largest potential energy savings.

KEYWORDS

New Plant Design, Energy Efficiency, Utilities, EMIS, Energy Management Studies, Ore Sorting

INTRODUCTION

This paper discusses energy efficiency studies and energy management systems with regards to mining operations. Energy management refers to the systems of monitoring, analyzing, and optimizing energy usage within a facility. It includes energy efficiency optimization of the initial plant design as well as the implementation of an Energy Management System (EnMS) and Energy Management Information System (EMIS) for optimizing energy usage over the lifetime of the facility. An EnMS is the organizational framework and procedures for managing energy use; an EMIS is the system of monitoring, reporting, and tracking process energy use against targets.

It is important to consider energy management during the design phase of a new plant or a plant expansion; when completed during the design phase, energy optimization is more cost effective than if undertaken at a later stage. Regardless of when energy optimization efforts are implemented, there are key areas and processes that stand to benefit most – we will discuss ore sorting, process controls, and process equipment decisions in detail. For energy efficiency upgrades on both new and existing facilities, engineering and construction costs can be heavily subsidized by provincial utility programs, reducing payback periods.

For mine sites, the benefits of effective efficiency are plenty, including significant cost savings, reduced resource usage and environmental impact, and benefits to corporate reputation.

NEW PLANT DESIGN

As energy is a major expense for industrial facilities, it is important for new facilities to be designed with energy efficiency in mind. The benefits of incorporating energy efficiency considerations into new plant design are obvious; implementation is simpler and more cost effective than if undertaken at a later date.

Further, provincial utility companies have programs in place to support and fund energy efficiency studies for new plant designs. Key benefits of such programs can include funded engineering support during the design phase, subsidized construction costs (for the incremental cost of efficient equipment vs. standard less-efficient equipment), and industry recognition upon project completion. Program details will be discussed later in this paper.

By designing a facility with energy efficiency in mind, EnMS and EMIS programs can be developed in tandem and can be implemented more easily once the facility starts to operate.

Design and Equipment Selection

New plant design reviews are intended to be performed independently of regular construction activities. New plant design reviews offer a more detailed assessment of specific options. When performed in parallel to project engineering tasks, new plant design reviews are less constricted by project schedules and project resources. A new plant design review is a secondary review of the business case for design changes or alternative equipment selection.

Equipment Selection

The status quo is to only consider capital investment, reliability, schedule and convention when making equipment selection decisions. When only looking at these factors, conventional technology is chosen due to lower capital costs and better understood risks. There seems to be little incentive to delay a project schedule by completing a detailed review of a more expensive, higher risk option. Engineering consultants to mills often use mill specifications which haven't been updated for over 20 years despite advances in technology (Orser et al., 2011).

Despite these driving forces, engineers continue to innovate with new solutions that have higher energy efficiency as well as higher reliability and performance. Unfortunately, major mining equipment has such high capital cost that there is no business case for changing major equipment after start-up of a new mine. The only time to review major equipment selection is in the new plant design phase.

Some examples of energy efficient major equipment are;

- Trolley assisted mine trucks
- Gearless mill drives (Combes et al., 2014)
- Ore sorting technology
- High energy blasting
- Milling technology (HPGR, stirred mills)

The business case review of alternative major equipment requires a high level of detail. Many variables must be accounted to determine the total life-cycle cost of any piece of equipment. Energy and fuel costs will continue to rise over the foreseeable future, as will the cost to maintain and operate remote power plants. Accurate forecasting of energy costs, whether for remote diesel generation or utility transmission, requires a detailed review by experts. In addition to rising energy costs, greenhouse gas regulations will continue to become more restrictive.

There are other benefits of new plant design that require detailed definition. Many new technologies have higher reliability and/or better performance than conventional technology. If a large reduction in energy is identified, there may even be some cost savings in energy infrastructure. For example, trolley assisted mine trucks have the following additional benefits which support the business case (Mazumdar, 2011)

- Increased productivity or reduced number of trucks
- Increased accessibility to deeper parts of the mine
- Increased lifespan of engines due to reduced daily operating hours
- Reduced noise
- Reduced environmental emissions

Lastly, local utility companies can be approached for additional savings. Many progressive utilities have programs to incentivize efforts to reduce energy usage. Capital incentive funding may be enough to tip the scales, making the purchase of energy efficient major equipment feasible.

<u>Design</u>

New plant designs can also be reviewed for other energy efficiency opportunities. Typical design activities are confined to checking one design point of maximum production plus one or two worse-case scenarios (turndown capacity etc). Again, conventional designs are often used for the sake of project schedules and reducing engineering budgets.

As an example, flotation blower systems may be sized for the maximum production plus a contingency factor. In reality, the flotation blowers may operate at substantially reduced capacity. There can be a substantial variation in the part-load energy efficiency of different technologies. A new plant design review will confirm that the equipment will operate efficiently at its normal operating point (part loading). To estimate the energy consumption, the normal operating cases must be determined.

Another example of a design change is upsizing tailing pipe diameters. Conventional practice limits the pipe diameter on a capital cost basis, but large diameter pipelines have lower friction loss. When considering energy savings and utility incentives, a business case can be made for using larger diameter tailing pipe.

Procurement

Many simple energy conservation measures have been well defined by the energy efficiency industry. These upgrades can be addressed during a new plant design phase simply by including them in the purchasing specifications. Local utility companies can help identify available incentives and rebates, which makes it easy to assess financial viability of alternative equipment. Purchasing specifications can then be sent to direct contractors to purchase energy efficient equipment. Typical examples of well-defined energy efficient equipment are;

- High efficiency motors
- Lighting technology
- High efficiency boilers (HVAC)
- Synchronous and/or cogged belt transmissions
- Compressed air equipment (compressors, air dryers etc.)

Study Schedule

It is best to start a new plant design review during the feasibility study. The design and cost information from the pre-feasibility study is required as a baseline for comparison to other design alternatives. The new plant design review must be completed in advance of any purchasing requirements, but in parallel with project engineering. Both the project staff and owner's engineer will require input to the review.

If utility incentive funding is applicable, time will be required for contract negotiations with the utility prior to purchase of incentivized equipment. Six to nine months from new plant design review kick-off to finalized incentive contracts can be expected.

Utility-supported new plant design reviews typically include the following items:

- Application for new plant design engineering funding
- New plant design kick-off meeting with project team and owner's representative
- New Plant Design Review
    - Review baseline design
    - Develop energy distribution map
    - Identify energy Key Performance Indicators (KPIs)
    - Interview client and design team regarding potential targets
    - Develop preliminary business case for each target
    - Feasibility level engineering of energy efficiency projects
        - Project cost estimate
        - Energy savings calculations
- Detailed evaluation of business case for each potential project
- Technical and business reviews of new plant design report
- Application for capital incentive funding and contract negotiations

Ore Sorting

A large portion of the energy consumed in a mining operation is due to comminution which ranges from 30-70% of the total energy spent by the mine (Radziszewski, 2013). Further, the majority of the input energy for comminution is consumed by the machines or is wasted as heat. Figure 1 shows the distribution of energy consumption at various stages of the mining cycle. One of the easiest ways to reduce energy consumption is by reducing the amount of material being processed. Traditionally, the ore is crushed and ground fine before transporting to the mill. If the quantity of material undergoing crushing and grinding is reduced, the energy spent on comminution is reduced proportionally. By pre-concentrating the ore, the quantity of material to be crushed and ground decreases for the same metal yield. In an ore body, the valuable mineral is usually concentrated in a smaller weight % of the material and the rest of the material contains negligible amounts. However, this is often overlooked, and instead the entire mass is ground and sent to the mill for processing. Pre-concentration by ore sorting at early stages in the mining cycle rejects the unwanted waste from being treated retains only the ore stream carrying valuable mineral. This facilitates a significant reduction in energy consumption at the processing stage.

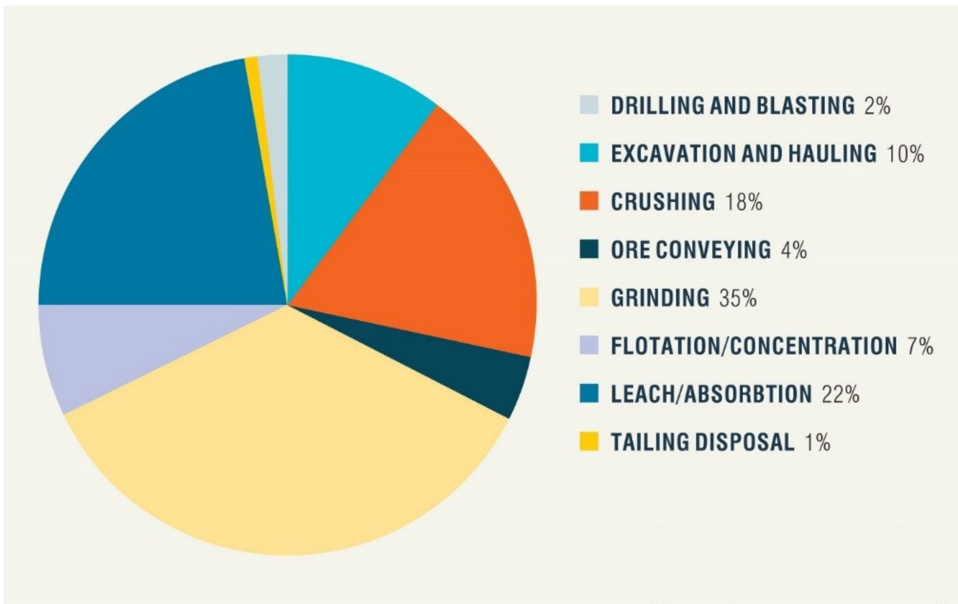

Figure 1 – Energy Consumption in an Open Pit Mine (Stadler & Boucaut, 2015)

Ore sorting has been practiced since the Bronze Age, but due to misconceptions involved such as perceived low throughput and the requirement to prepare feed, the concept it is not prevalent in today's mining industry. However, advancements in sensor-based ore sorting over the last decade are beginning to interest mining companies. Sensor-based ore sorting is a simple mechanism of separating ore and waste using a wide range of sensors such as x-ray fluorescence, x-ray transmission, high frequency electromagnetics, microwave, infrared, and laser technology. The above methods can determine the metal content in a rock or material stream and decide the path of the material being scanned; if the material is identified as ore it will be sent to the mill for further processing, otherwise it will be discarded.

Castlemaine Goldfields in Australia was able to reject 48% of its feed as gangue by pre-concentrating the ore, resulting in a 30% reduction in energy consumption. It also increased the recovery of the mill by 3.8% (Ballantyne et al., 2012).

ENERGY MANAGEMENT SYSTEMS

EnMS

An Energy Management System (EnMS) is the organizational framework and processes to manage energy use. It is made up of people and management processes, rather than capital equipment or production processes.

As such, design of an Energy Management System is not really part of a "new plant" design, but instead would be part of the design of the new Business Operating Unit. Alternatively, if the new plant is part of a plant expansion, it may be an opportunity to start putting an Energy Management System in place for whole plant.

Our paper presented last year (How to Use Energy Management to Improve Mining Operation Productivity and Reduce Downtime: Canadian Utility Company Incentive Programs) discussed the benefits of an Energy Management System, so they will not all be repeated here. However, primary benefits include the following:

- Reduced operating cost for energy
- Reduced GHG emissions and other environmental impacts
- Visible demonstration of social responsibility (especially if you issue a yearly Corporate Social Responsibility Report)
- A more engaged workforce

An Energy Management System is similar in structure to an Environmental Health and Safety (EHS) System or to a Quality Program. Like those two programs, it includes measuring performance against objectives, systems for reporting results, and an organizational accountability structure. Each of these programs has ISO standard to provide guidance. However, just as you can have a good EHS program without being certified to ISO 450001 (which is currently in progress) and you can have good Quality program without being certified to ISO 90001, you can have a good Energy Management program without being certified to ISO 50001. The resources put in the Energy Management System should be appropriate to the size of the organization and the amount spent on energy.

Most importantly, an Energy Management System is like EHS and Quality Systems in that to be successful, there must be visible management commitment.

As mentioned, people are an important part of an Energy Management System. It may be easier to implement an Energy Management System in a new operating unit because the employees are not already accustomed to doing things the old way. On the other hand, the first year or two of operation of the new plant may be focussed on just getting plant up and running. Without visible management support, Energy Management may be relegated to low priority.

A complete Energy Management System will include the following elements and activities:

- An appropriate organizational structure with clearly defined authorities and accountabilities
- Baseline energy use characterized as a function of production, ambient temperature, or other variables
- Energy Performance Indicators (EPI's) and energy use targets
- Measurement of energy performance against baselines and targets
- Energy use reporting and documentation
- Allocation of energy costs to their associated production units
- Procedures to ensure energy use is considered in procurement of all new equipment
- Employee training and communication
- A system for corrective actions

While the new operating unit is being constructed, the Energy Management Team can be assembled and parts of the Energy Management System can be planned and created:

- The overall program objectives
- An Energy Policy
- The organizational structure for Energy Management, including the reporting structure
- Energy use targets
- A plan to measure and report energy use against targets

If members of the team have limited experience with Energy Management systems, a consultant that is experienced in Energy Management Systems can help you plan and create a system that is appropriate for your organization.

EMIS

An Energy Management Information System (EMIS) is a structure for systematic measuring and reporting of energy use to track progress against targets. It consists of equipment (hardware and software), management processes, and people.

An EMIS is an essential part of an effective Energy Management System, but can be put in place without a full Energy Management System implementation. (It should be noted that without a full Energy Management System implementation, the organization will not get maximum benefit from the EMIS.)

To be effective, an EMIS should include the following:

1. Data measurement, collection, and storage
2. Energy use analysis and comparison against targets
3. A structure for reporting and accountability
4. Management systems to ensure action on results

The last two items on this list and, to some extent, the second item, have to do with management processes and people and have overlap with Energy Management Systems. They can be planned out with the new plant is being constructed.

Energy use analysis and comparison against targets need to be designed as part of the new plant design because to get a good understanding of how energy is used, it is necessary to measure where the energy is being used. Typically, overall plant energy use is broken down between various process departments, known as Energy Account Centres. A minimum breakdown would be into mine and mill. A more granular breakdown might include mining, hauling, hoisting and conveying, comminution, etc. In order to set targets, one must know what factors influence energy use (for instance, amount of ore processed, haul distance, ore grade, Bond work index) and one must have a model of energy use as a function of those factors. The model, in turn, depends on the process and the choice of equipment.

Data measurement, collection, storage have to do with hardware and software and they should be constructed as part of the new plant design. Design of the measurement system includes designing the electrical and other utility systems to facilitate metering by Energy Account Centre. Decisions must be made about what to meter (electric, gas, water, steam, cold utility, nitrogen), where to meter it, and what type of meters to use. The SCADA or other data system must be designed to collect and store the data. The scope of energy use analysis and comparison against targets must be determined early so the method can be chosen. Many software packages are available, but not all of them will satisfy the needs of the particular organization. It is also possible to do the analysis by hand or on excel. Some software packages include automatic reporting and distribution. Alternatively, it can be done by hand, depending on the particular needs of the organization.

As a note, we have seen a number of less-than-optimal EMIS implementations when metering was put in place or software was procured piecemeal without a first understanding the organization's needs and making an overall system plan.

Optimal design for energy use analysis and comparison against targets and for data measurement, collection, and storage requires specialized knowledge in diverse areas such as metrology, available EMIS software packages, utility tariff structures, energy-use modelling, and statistical process control. It can take a lot of staff time, especially if you don't already have in-house capabilities in all these areas. Bringing in an experienced consultant to help you will save time and, in the long run, money. An experienced consultant can also help with planning EMIS processes, energy account centres, and energy use targets. However, you can't turn the whole job over to the consultant. In order to arrive at an Energy Management System or an EMIS system that meets your organization's unique needs, you need to stay involved with the design. Consider the consultant to be like your Personal Trainer: they can help you exercise more effectively, but they can't do the exercise for you.

UTILITY SUPPORT AND INCENTIVES PROGRAMS

Utility incentives for new plant design energy efficiency studies are available in most Canadian provinces. New plant design programs are available for greenfield facilities or expansion of existing facilities (brownfield projects). In most cases, energy efficiency studies are 75-100% funded by utility companies. Utility companies provide major incentives (millions of dollars in some cases) to implement upgrades that are identified in the new plant design study. Financial incentives can cover as much as 75-100% of the incremental construction costs (i.e. the cost difference between the standard design and energy efficient design). This incentive can significantly reduce the payback period of the energy efficient design. Another option is available in some programs: conservation rates reduction. This option is ideal for mining companies which are looking to reduce future operating cost.

Some utility companies have implemented recognition programs to celebrate successful new plant design energy efficiency projects.

Energy Efficiency Programs in the United States

Most states offer energy incentive programs to help offset energy costs. The Federal Energy Management Program's (FEMP) provides information about the availability of energy-efficiency and renewable energy project funding. As an example, the Bonneville Power Administration (BPA) is a utility company which provides electricity to Idaho, Oregon, Washington, California, Utah, Nevada and Wyoming. BPA promotes energy efficiency projects, usage of renewable resources and new technologies.

CONCLUSION

There are many good reasons for existing and future mine sites to perform energy efficiency studies and implement energy management programs. With an understanding of the steps required to initiate such work and acquire funding, we hope owner's representatives will be more inclined to take advantage of the long lasting financial, operational and environmental benefits that await.

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