



CEEC INTERNATIONAL LTD

The CEEC Roadmap for Eco-Efficient Comminution



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Workshop 12-13 June 2012, Noosa, Queensland

Executive Summary

Introduction

The Coalition for Eco-Efficient Comminution (CEEC) was established in 2011 to encourage the implementation of eco-efficient comminution strategies through promotion of supporting data and industry benefits. In June 2012 CEEC collaborated with JKTech Pty Ltd to run a two day workshop for 37 invited senior industry experts with a brief to develop a roadmap for the industry to use when addressing this issue. The names and affiliations of the delegates are listed in Appendix 2. The aim was to define the issues relating to comminution energy efficiency, recommend strategies for addressing the problem, and suggest some mitigating actions.

Workshop process

On Day 1 workshop participants were divided into four groups based on their industry sector and asked to comment on comminution energy issues relevant to that sector. Eight short presentations were made by selected representatives of these groups during the workshop to provide background and promote discussion. The sectors represented were:

- Mining companies
- Manufacturers and vendors
- Engineering companies
- Researchers and consultants

On Day 2 participants were randomly assigned to four new groups and asked to develop draft roadmaps for eco-efficient comminution (EEC), with two groups focussing on short term aims and two on long term, based on the outcomes of Day 1. These drafts, together with other material collected during the workshop discussions, have been combined and edited to create this document.

Addressing the challenge - workshop recommendations

The roadmap aims to articulate the issues and benefits of more EEC, define the obstacles to achieving better outcomes and provide direction on how to achieve improved industry performance. The key strategic elements are:

- Measure performance and produce benchmarks that allow energy efficiency performance to be quantified and evaluated, including a 4-star energy rating.
- Adopt best practice in technology.
- Identify and implement appropriate business drivers and KPIs.
- Communicate the benefits, motivate, engage and train.

A list of specific actions designed to achieve these outcomes is provided in Appendix 1. It is important to note that energy efficiency benefits are usually cumulative; major gains are unlikely to be achieved by one-off interventions.

This roadmap and copies of the short presentations are available on the CEEC website (www.ceecthefuture.org).



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1. Problem Statement

Why comminution energy use matters

Mineral processing plants are being designed and operated at less than optimal energy efficiency. However the benefit of better performance, or the size of the prize, is not well understood in many sectors of the industry and neither is the relative ease with which some efficiency measures can be introduced. Energy efficiency is often not identified as a major factor in determining project value, partly because of the standard methods used to assess value.

The key factors contributing to poor energy efficiency in existing mineral processing operations were identified as:

- More difficult orebodies, with lower grades, more complex mineralogy, access difficulties and high infrastructure costs.
- Difficulty in attracting skilled people, leading to a poor understanding of nature of the efficiency problem and reduced ability to find solutions.
- Focus on maximising production capacity and throughput.
- Inconsistent work structures and metrics across an organisation, often organised into operational silos, and conflicting priorities between sections which make it difficult to assess process performance as a whole; lack of a systems approach.
- A general reluctance in industry to adopt new technologies, coupled with unwillingness to adopt new processes perceived as being high risk, or engage in or support risky research.
- Lack of open information exchange, often related to protection of IP.
- A lack of operational focus in many R&D activities, and lack of R&D funding.
- Project valuation practices (eg NPV) which may support CAPEX savings over OPEX. NPV does not necessarily reflect real value especially over long discount periods, though it is recognised that it is the standard method of assessing competing options.
- Energy efficient strategies lack support from senior management.

Comminution is a process which starts in the mine and ends with a product of a required size for processing, and is generally the single largest consumer of energy on a mine site. Comminution energy includes all energy directly consumed in size reduction as well as energy consumed in the manufacture of comminution consumables, especially steel grinding media and liners.

Failure to improve comminution energy efficiency will increase exposure to:

- Increasing cost of energy resulting from increasing production costs and costs associated with carbon constraints,
- Reduced security of energy supply, and
- Negative impact on the license to operate.



2. Value Proposition

Benefits of solving the problem

The benefits of increasing energy efficiency are manifold, and although the potential improvements will differ substantially from project to project and between commodities, it is estimated that improvements of up to 50% kWh/metal unit are feasible within 10 years, and more beyond that.

One-off interventions that result in an efficiency step-change are rare, and cannot be relied on to solve the problem. Substantial gains can be made by the cumulative effect of relatively small improvements.

Benefits

The benefits of improving energy efficiency in processing operations include:

- Immediate OPEX benefit through energy cost savings, leading to increased profitability.
- Enhanced ability to manage more complex, lower grade or difficult ores thereby expanding potential ore resources.
- Reduced carbon emissions, energy footprint and potential for reduced water usage.
- Better community relations from reduced energy and water footprint, enhancing the license to operate.
- Improved security of energy supply.
- Reduced generation of fine waste.
- Lower exposure to increased energy costs or reduced security of supply.

Several factors are improving the industry's ability to deal with energy efficiency and should allow it to do better. These include:

- Ore processing knowledge is constantly improving.
- New and better tools are available for ore characterisation.
- New comminution and classification technology is being developed and maturing.
- Access to cheaper automation for process control.
- More sophisticated communication is available for remote technical support.

Barriers to progress are discussed in Section 4.

Risks and Rewards

Risk/reward incentives will encourage corporate management to support energy efficient strategies.

Risks of inaction

- Risk of quantum leap by alternative technology: game changers
- Exposure to rising processing costs
- Exposure to energy shock
- Reduced security of supply
- Potential loss of licence to operate
- Environmental risk (carbon constraints)

Rewards of action

- Game changing technology leadership
- Reduction of processing costs
- Improved business leadership
- Attract the best staff
- Secure the licence to operate
- More effective utilisation of finite ore resource



3. Targets

What are we aiming to achieve?

Realistic targets for reductions in comminution energy consumption are 15-30% in the short term (eg brownfield development), 50% within 10 years, and possibly more beyond 10 years.

EEC performance targets are grouped under four main headings.

3.1. Measure Performance

The mineral processing discipline should develop clear benchmarks and standards for use by process designers, equipment manufacturers and project operators. This will allow performance to be compared with industry standards and with others operating in similar circumstances so that strategies can be devised to achieve best practice.

A key recommendation is the introduction of a 4 star energy rating system, which can be used to audit:

- Overall operational efficiency.
- Planning systems.
- Equipment efficiency.
- Maintenance systems.
- Control systems.
- Technical support systems.

Some specific suggestions about how to establish benchmarks and standards are provided in Appendix 1. An example of how an energy rating system is applied in another industry is provided in *Equations for Appliance Star Ratings, Appliance Energy Consumption in Australia*¹.

3.2. Adopt Best Practice in Technology

There is a substantial gap between current operational standards and industry best practice. Many well understood technologies are not being used. A number of actions are recommended that relate to comminution performance from the mine (intelligent blasting, mine-to-mill) right through the process (ore sorting, classification or pre-concentration, reprocessing and product recovery). A systems approach across the mining value chain would materially advance the cause. There are many readily available tools and methodologies that can be used to achieve these aims. Appendix 1 provides a list of several specific technology options for investigation.

3.3. Identify and Implement Appropriate Business Drivers and KPIs

Many of the barriers to progress that were identified by the workshop groups related to current business practices, rather than technological issues.

Industry needs to work collaboratively to develop, implement and review appropriate energy metrics. These must be universal, well understood and auditable. It is also essential to put meaningful business drivers in place if improvements in energy efficiency are to be achieved. The process could be modelled on existing standards such as health and safety regulations.

¹ <http://www.energyrating.gov.au/wp-content/uploads/2011/03/appliance-star-ratings.pdf>



3.4. Communicate the Benefits, Motivate, Engage and Train

Change can only occur when people are willing to change, so it is important to communicate the benefits of improved EEC performance to all stake-holders. This includes developing the skills necessary to understand the potential for change and to successfully implement change, and the breaking down of disciplinary silos within companies and across the industry to allow free flow of ideas throughout the value chain.

4. Barriers to Action

Why are we not doing better?

Some of the identified barriers were considered especially important at the industry level:

- The way industry deals with intellectual property is seen as a key barrier, as IP 'hoarding' directly impedes the advance of innovative practices.
- Conservative circuit design and operation, coupled with slow rate of adoption of viable emerging technologies, means that some existing mineral liberation circuits have significant short-term potential to increase the efficiency of energy usage.
- Industry is generally risk-averse. There is therefore a high cost to achieve proof of concept for new technologies. The 'first to be second' mentality is well understood, and makes it difficult for new technology to be accepted.
- Measurement of economic impact using Net Present Value (NPV) does not always reflect the real value of energy efficient technologies. Another economic measure may be required that better captures the impact of reductions in operational costs and rehabilitation costs.

Many sites are not taking advantage of current well known efficiency improvements, even where there is no obvious technical barrier. Some suggested causes:

- There is a low level of awareness of the ease of implementing changes and the magnitude of the potential benefits.
- Inappropriate metrics make it difficult to make meaningful comparisons or assessments.
- Operators are comfortable with current standards, e.g. use of tumbling mill technology.
- Energy costs are still too low and thereby not viewed as a significant component of total costs.
- Opportunities for improvement conflict with current business models, and current organisational practices (KPIs) do not encourage maximising efficiency.
- In many operations the culture supports cost minimization, not performance excellence.
- Orebodies are complex, and operators are reluctant to move away from familiar technologies in the face of ore variability.
- Data is poorly managed, and often not properly utilised.
- Declining grades lead to over-emphasis on increasing throughput in order to achieve production targets.
- FIFO workplace culture exacerbates difficulties in communication, team work and the successful conduct of longer-term optimisation projects.



- There is a gap between project owners and engineers on one side and developers of new technology on the other, so technology transfer is more difficult than it should be.
- The lifespan of technological advantage is very short, so there is little incentive to be an early adopter.

5. Actions

What should we be doing?

A detailed list of possible actions is given in Appendix 1. Not all these actions will be applicable in all situations, but they provide some options for a site-based or company-based action plan. A general approach to action, arranged according to the targets specified earlier, is as follows:

5.1. Measure Performance

- Companies or organisations should set up a cross-disciplinary study group to determine a base-line for current energy use, using a clearly articulated formal methodology. The base-line study should address performance of individual units and systems, supporting work practices, control systems and planning strategies, and relate these to energy use defined in terms of kWh/unit metal, not tonne treated.
- Use this study process to set performance targets, and conduct regular reviews and report changes in performance. When appropriate, set new performance targets.
- It is essential that this review process has clearly stated support from corporate management.
- In greenfield design situations, project teams should include projected energy efficiency in their design specifications, expressed in kWh/unit metal, and use this information when evaluating design options.

5.2. Adopt Best Practice in Technology

- Ensure that you are familiar with best practice in operation and design.
- Appendix 1 lists specific opportunities that can be investigated and implemented. Some (classified as short-term) can be investigated easily and quickly, and these should be considered first. Others (classified as long-term) will require further research and development to reduce the risk, and more time and effort to investigate and implement.

5.3. Implement Appropriate Business Drivers and KPIs

- Provide a business structure that encourages both cross-team engagement and external collaboration. To implement energy-efficient outcomes, internal interaction between mine, plant, production and maintenance teams must be maximised. Also, a better environment for innovation will be fostered by high levels of engagement between industry, R&D and consulting organisations.



- The operating strategy should be reviewed and refined to include long term planning in terms of the federal government EEO² initiatives. Ideally the EEO plan should form part of the site's sustainability plan.
- An energy efficiency metric should be developed and incorporated in the Key Performance Indicators (KPIs) of senior management. This will require a focus on systems rather than individual components.

5.4. Communicate the Benefits, Motivate, Engage and Train

- Spread the energy efficiency message through regular forums, conferences, think-tanks and professional development courses. Accumulate case studies of quantified success, to motivate the implementation of EEC.
- Raise awareness within your own organisation and ensure that people employed at all levels are aware of 'the size of the prize'.
- Review skills and establish appropriate training at all levels so that operators can monitor energy efficiency within their own areas of influence.

² Energy Efficiency Opportunities. See www.ret.gov.au/energy/efficiency/eo/pages/default.aspx



Appendix 1: List of Potential Actions

The CEEC website (<http://www.ceecthefuture.org>) has collections of relevant papers and reports that will help inform action.

Short-term actions using mature technology

Technology

1. Construct a mathematical model of the energy profile of the complete process system and evaluate performance. View comminution energy input in the context of the whole process. Use and maintain this model for process optimization.
2. Refine comminution models to include better estimates of energy consumption. Simulation and optimisation studies should include total comminution energy.
3. Know your orebody (review geometallurgical information). Characterise feed and understand variability. Ensure that performance is optimized for different feed characteristics. Ensure information feeds to the planning process. Apply flexible operation based on mineralogy: do the right thing to each type of rock.
4. Blending schedules / stockpile management strategies should be cognisant of consequences on energy efficiency.
5. Conduct a 'Mine-to-Mill' modelling study.
6. Review the use of 'Intelligent Blasting' to optimise plant feed size distribution.
7. Evaluate use of mine blasting with in-pit sorting and conveying to replace an in-pit crusher.
8. Size reduction effort should be pushed upstream (towards crushing) as far as practically possible to reduce the amount of reduction that has to be conducted by the more expensive final grinding stages.
9. Identify key pieces of equipment, and review their efficiency of unit process performance.
10. Automate circuit operation as much as possible, through the use of simple or expert control systems. Optimise use of existing control systems. Regularly tune and maintain the process control system.
11. Consider early waste rejection strategies such as coarse flotation and coarse gravity separation, low-grade pebble rejection from SAG product, and pre-concentration by screening, ore sorting or DMS.
12. Review equipment maintenance and availability against industry standards. Ensure maintenance drivers reflect energy targets.
13. Classification efficiency should be maximized to avoid wastage of energy through overgrinding.
14. Assess alternative comminution technologies. Some mature technologies that can improve performance are:
 - Autogenous grinding to replace SAG mills
 - High pressure grinding rolls to replace SAG mills
 - Stirred mills in fine grinding applications

People and planning

15. Develop and implement appropriate energy metrics. These must be universal, well understood and auditable. Review them regularly.`



16. Learn and adopt the operating and design practices of the best performing operations. Require demonstrated best comminution practice in process selection or design.
17. Examine long term planning in terms of government and EEO initiatives: Carbon Price, Efficiency Reports.
18. Align KPIs to sustainability objectives.
19. Create a site sustainability plan with a focus on energy efficiency, to ensure reduction in energy consumption is not viewed solely as a cost driving measure but also as a means to preserve a scarce resource and ensure that the mining activity is sustainable.
20. The process of developing meaningful business drivers for energy efficient performance could be modelled on existing standards such as health and safety regulations or the international cyanide code.
21. When designing a new process, address long-term operational philosophy and ensure that this information is communicated to plant operators.
22. Create a shared information bank at the design stage for operators to use, and maintain shared knowledge environment during operation.
23. Identify or create a documented operating strategy. As part of the process, check plant performance against design specifications – most plants are operating well outside of design. Revert to design parameters or provide technical justification for deviation from design.
24. Valuation methods based on Net Present Value (NPV) may encourage a focus on CAPEX reduction rather than minimizing OPEX. Another economic measure may be required that better reflects the impact of operational costs and rehabilitation costs on project value.
25. Use smart engineering to offset CAPEX.
26. Train staff in the benefits of accurate monitoring and link to personal KPIs.
27. Encourage external collaboration.
28. Encourage cross team engagement. Provide an organisational framework that allows different business groups to communicate better and allows for collaboration may provide a better environment for innovation.
29. Review interaction between key groups such as mine and plant, production and maintenance.
30. Set up a cross-disciplinary review of major site issues; identify efficiency bottlenecks.
31. Evaluate technical support requirements. Provide on and off-site technical support.
32. Instrumentation people should be well trained in understanding the purpose of various process control instruments.
33. Effective technology transfer and implementation of advanced solutions requires a high level of involvement from research and consulting organisations in addition to buy-in from mine site operators. High levels of engagement between industry and research and development must be encouraged and supported.

Longer term actions using existing technology

Technology

34. Develop and implement new operational tools, for example modelling packages which allow whole flow-sheet optimisation, multifunction/multidiscipline life cycle analysis. These will permit operators to readily address opportunities or risks.
35. Run large scale pilot plant / demonstration plants to support development programs.
36. Develop and use selective blasting.



37. Use instrumentation such as Smart Tag radio frequency identification to allow tracking of ore and selective treatment.
38. Integrate mine operation processes and sub-processes using high level supervisory control with energy efficiency focus.
39. Dedicated experts should have capability to access mine and plant data remotely. This would assist with rapid diagnosis and troubleshooting for areas that are resource constrained (limited or no on-site skills).
40. Use smart flexible circuits – able to operate on efficient frontier by switching set-points and process flow paths based on feed characteristics – with feedback to mine planning.
41. Develop advanced ore sorting systems.
42. Develop new comminution machines, such as:
 - new generation crushers
 - variations on IsaMill
 - variations on HPGR
 - grinding roller mill

Long term actions that involve some risk

Technology

43. Reverse the trend towards lower grade deposits with high grade undersea mining.
44. Enable cheap in-situ or dump leaching.
45. Develop pre-treatment separation processes that will remove 100% of free gangue ahead of surface rock breakage.
46. Pre-treat or liberate by electric pulse fragmentation, microwave or ultrasound.
47. Develop separation devices that will allow primary selection at >250 microns, reducing volume of material in breakage.
48. Develop selective breakage and liberation capability using SelFrag or similar technology, and based on specific liberation requirements.
49. Develop new sensors/markers for ore classification and sorting (learn from robotics).
50. Revert to largely dry processing leading to an order of magnitude reduction in water consumption and associated energy savings. This may involve air cycloning or other dry classification.
51. Develop and use cheaper renewable energy, for example power generation by small portable nuclear reactors at remote sites.
52. In the future no operators will enter the mine, as all equipment will be fully automated. All geological data will be gathered by remote imaging techniques and from drilling. This will drive the blast design and lead to selective mining of ore to minimise waste coming from the pit and appropriate size for downstream breakage. Only maintenance personnel will be on site in the concentrator with full sensory in field equipment feeding all data to a control centre in a major city – the mining industry will become the ‘sexy’ industry for the tech savvy graduates of the day



Appendix 2: Workshop Delegates, Speakers and Organisers

Delegates - Names and Affiliations

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