Australian Government

ENERGY MANAGEMENT IN MINING

Leading Practice Sustainable Development Program for the Mining Industry

September 2016

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Leading Practice Sustainable Development Program for the Mining Industry.

This publication has been developed by a working group of experts, industry, and government and non-government representatives. The effort of the members of the Working Group is gratefully acknowledged.

The views and opinions expressed in this publication do not necessarily reflect those of the Australian Government or the Minister for Foreign Affairs, the Minister for Trade and Investment and the Minister for Resources and Northern Australia.

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Support for the LPSDP was provided by the Australian aid program administered by the Department of Foreign Affairs and Trade due to the reports' value in providing practical guidance and case studies for use and application in developing countries.

Cover image: Dragline stockpiling overburden in an open-cut coalmine.

September 2016.

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FOREWORD

The *Leading Practice Sustainable Development Program for the Mining Industry* series of handbooks has been produced to share Australia's world-leading experience and expertise in mine management and planning. The handbooks provide practical guidance on environmental, economic and social aspects through all phases of mineral extraction, from exploration to mine construction, operation and closure.

Australia is a world leader in mining, and our national expertise has been used to ensure that these handbooks provide contemporary and useful guidance on leading practice.

Australia's Department of Industry, Innovation and Science has provided technical management and coordination for the handbooks in cooperation with private industry and state government partners. Australia's overseas aid program, managed by the Department of Foreign Affairs and Trade, has co-funded the updating of the handbooks in recognition of the central role of the mining sector in driving economic growth and reducing poverty.

Mining is a global industry, and Australian companies are active investors and explorers in nearly all mining provinces around the world. The Australian Government recognises that a better mining industry means more growth, jobs, investment and trade, and that these benefits should flow through to higher living standards for all.

A strong commitment to leading practice in sustainable development is critical for mining excellence. Applying leading practice enables companies to deliver enduring value, maintain their reputation for quality in a competitive investment climate, and ensure the strong support of host communities and governments. Understanding leading practice is also essential to manage risks and ensure that the mining industry delivers its full potential.

These handbooks are designed to provide mine operators, communities and regulators with essential information. They contain case studies to assist all sectors of the mining industry, within and beyond the requirements set by legislation.

We recommend these *leading practice* handbooks to you and hope that you will find them of practical use.

Senator the Hon Matt Canavan

Minister for Resources and Northern Australia

The Hon Julie Bishop MP

Minister for Foreign Affairs

1.0 INTRODUCTION

Cost-effective and reliable energy sources are essential to discover, extract, process and transport mineral resources from mine site to customer. However, despite the fundamental importance of energy, the day-to-day focus on meeting operational targets at a mine often means that energy is not used efficiently. This creates a number of significant costs. Most obvious is the cost of the wasted energy. But inefficient energy use can also be a symptom of ineffective operational practices that, in turn, affect productivity, maintenance, safety and environmental performance. Inefficiencies may also be locked in through mine planning and design. To maximise energy performance—that is, to use the minimum amount of energy necessary to meet business objectives—a structured approach to energy management is essential.

Over the past decade, there has been a growing focus on energy management in the mining industry. This has been a response to rising energy costs on mine sites, together with legislative and community pressure to reduce greenhouse gas emissions from fossil fuel use.

These business drivers have had an influence on the motivation, skills and knowledge of managers across the mining sector. Energy management practices have evolved in leading companies from a conventional focus on conducting occasional, outsourced energy audits towards a more integrated and continuous approach to energy management. Some of the key shifts in energy management practices are shown in Table 1. They include changes to the way the benefits of energy efficiency are promoted, increasing accountability for energy performance and the development of new approaches to identifying energy-efficiency improvement opportunities.

Table 1: Comparing standard and leading practice energy management

APPROACH TO ...	STANDARD PRACTICE	LEADING PRACTICE
Promoting the benefits of energy efficiency	Primarily energy cost savings	Energy cost savings + other business benefits such as productivity, safety and risk management
Accountability	Individual manager (environment, sustainability or other manager)	Individual manager + responsibility for energy management written into role descriptions of site management and other relevant personnel
Identifying energy-efficiency improvement options	Energy audits conducted once every few years by external consultants, without buy-in from internal staff Use available data Focus on efficiency of ancillary equipment Operational phase	Continuous review of energy performance combined with periodic detailed examination of particular processes and related equipment Apply the updated 2014 energy audit standards for industrial activities (AS/3598.2) or transport (AS/3598.3), which consider business needs and are compatible with international energy management standards Combine internal and external expertise as required Have a plan for improving energy data to progressively build and understand potential improvement opportunities and performance over time Focus on core business operations first to identify opportunities to reduce demand before exploring opportunities to optimise operating systems and purchase more efficient equipment Considered in mine design (new and expansion projects) as well as operational phases

APPROACH TO …	STANDARD PRACTICE	LEADING PRACTICE
Presenting business case proposals to management	Written case with a focus on energy cost savings	Strategic approach that involves informing, educating and influencing internal stakeholders of multiple business benefits prior to presentation of formal business case proposal to management
Measurement and verification (M&V)	Typically not undertaken unless needed to obtain external funding	Budget for M&V when seeking project funds Evaluate project with regard to energy performance as well as other business benefits (e.g. productivity)

Source: Adapted from P Crittenden, 'New perspectives on institutional change: the case of changing energy management practices in Australia', PhD thesis, University of Technology, Sydney, 2014, http://www.climatechangestrategy.com/#!phd-thesis/c1odg.

Scope

The aim of this handbook is to provide operational managers with a guide to leading practice energy management. 'Leading practice' describes how specific operational and strategic issues are addressed in the most effective manner at a particular point in time. In this publication, leading practice energy management is defined as the best way to improve the energy performance of a given site in a way that best contributes to its business objectives.

This guide is structured in three parts.

Part 1 is focused on developing and communicating the business case for energy management. Establishing the benefits and tailoring messages to motivate key stakeholders is essential. It helps to motivate and engage management and staff so that they actively support energy management initiatives.

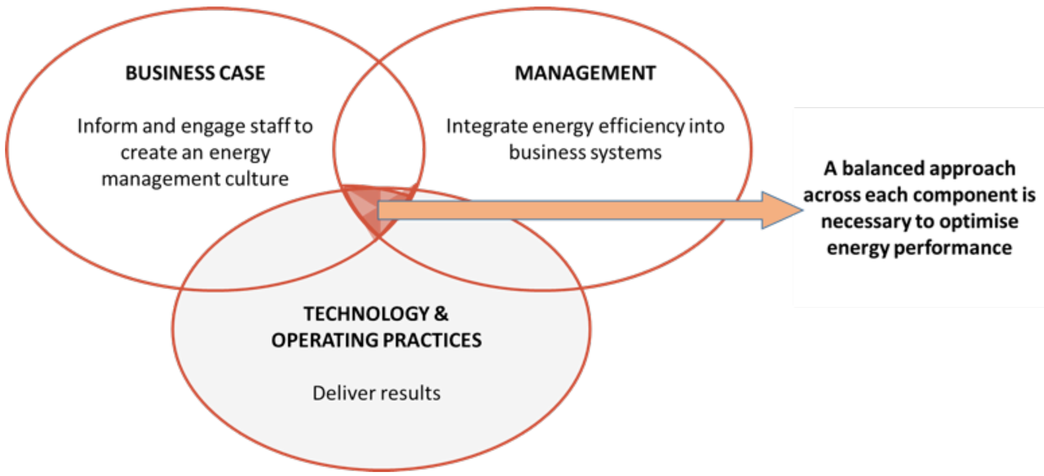
Part 2 is about integrating energy management into management systems. This is required to ensure that there is an ongoing and structured focus on energy management. It includes establishing a policy and plan, developing an effective energy information system and regularly tracking and reporting energy performance.

Part 3 is focused on technology and operating practices. Ultimately, it is through the implementation of projects and changes in practices that energy performance improves.

These essential components of leading practice—the business case, management systems, technology and operating practices—work in combination to deliver ongoing improvement in energy performance (Figure 1).

This handbook is aligned with and supports relevant Australian and international standards, including ISO 50001 *Energy management systems—requirements with guidance for use* and the AS/NZS 3598:2014 series for conducting energy audits.

Figure 1: Three essential components of leading practice energy management

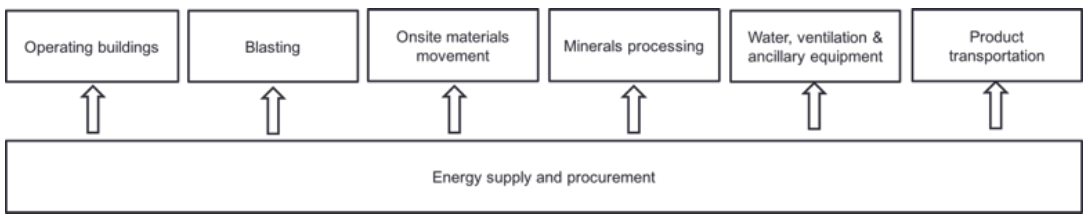


Energy consumption across the mining value chain

The mining value chain involves the extraction and processing of minerals from mine site to customer. The level of influence and interest that mining organisations have at each stage of the value chain depends on their corporate structure and business strategy. For example, a mine may be owned and operated by a single entity. Alternatively, various activities may be contracted out to other organisations.

In this handbook, opportunities to improve the management of energy are considered across seven different activities, as shown in Figure 2.

Figure 2: Mining activities that present opportunities for improved energy management



This provides a useful typology for describing improvement opportunities. At the same time, however, it is important to adopt a holistic perspective, since an increase in energy use at one stage of the process may lead to a decrease at subsequent stages. While the focus throughout the handbook is on collaboration within an organisation, achieving optimal outcomes may require collaboration with other organisations as well. For example, where subcontractors are responsible for particular activities—such as onsite materials movement—they may have direct influence over the way in which energy is used (operational control). Contracts between owners and subcontractors also highlight who will pay for the energy that is consumed (financial control).

As well as technical changes to a mine, various other factors influence the level of attention and effort that is dedicated to energy management. For example, changes in energy prices or legislation can either increase or decrease the level of attention placed on energy management. This presents a challenge for managers to ensure that when changes in consumption patterns or equipment occur energy efficiency is considered in an integrated and continuous manner. This requires a dynamic and performance-based approach to energy management, as outlined in this handbook.

PART 1: THE BUSINESS CASE—INFORM AND ENGAGE KEY STAKEHOLDERS

Key points:

- Decisions that influence the energy performance of a mining operation are made at many different management levels and across functional areas. Leading practice energy management relies upon effective engagement and alignment across a mining operation.
- There are compelling business drivers and benefits associated with improved energy management. It is essential that managers and staff understand the business case and how improved energy management can benefit the business, their teams and their individual activities.
- As projects are implemented, it is important to promote the business benefits achieved. They include productivity and other business outcomes as well as reductions in energy costs and greenhouse gas emissions.

When you consider the commercial and operational realities of the mining industry, such as fluctuations in commodity prices and the need to focus on production, safety and other business priorities, it is not surprising that managers and staff may be resistant to the introduction of new initiatives. Therefore, it is essential to establish a clear and compelling business case for energy management. The case should outline why energy management is important for the operation, including the problems that it will help to solve and the benefits that will be delivered as outcomes.

Energy management is a collective responsibility across the operation. While accountability can be assigned, it is important to consider how to motivate management and staff to be proactive. This requires the benefits of energy management to be refined so that the reasons for action are clear and tangible to the individuals and functional areas that need to improve their focus on energy management.

Ultimately, the aim is to create a 'culture' of energy management that is embedded in the operation. Culture can be roughly translated as 'the way we do things around here'. It is useful to consider the way in which the culture of safety has evolved over time in the mining industry. From an outlying issue, it has today become an essential part of the day-to-day way in which mines are operated. Energy management presents the same challenge of taking a relatively new initiative that may be of low priority and creating a culture of energy management that is embedded into the daily management and operational practices of management and staff.

This section begins with an overview of the strategic and operational business drivers for energy management. It then considers the particular interests of key stakeholders and how key messages about the reasons for and benefits of energy management can be refined. Finally, it presents a range of communication initiatives that can be used to engage with staff and build their support.

1.1 The business case

Traditionally, energy management has been approached in a reactive way. For example, new legislation or a change in energy prices has motivated short-term action. While this has led to some improvements, energy management is most effective when it is approached in a sustained and integrated way. To justify ongoing resourcing of energy management initiatives, however, the business case must be clearly articulated and updated regularly to reflect market and legislative changes.

There are clear economic, environmental and social reasons for improved energy management. However, the case for energy management will vary from one site to the next. To present a compelling case, it is important to understand the full range of business drivers as well as the benefits that an improved approach to energy management can deliver.

Strategic drivers
A number of broad business drivers highlight the importance of improved energy management in mining operations. They include:

- the decline of energy productivity in the mining industry
- fluctuating energy prices
- changes in government legislation and programs
- social expectations, including the 'social licence to operate'.

Energy productivity in the mining sector is declining

The mining industry has contributed the largest annual increases in net energy consumption of any industry in Australia over the past 10 years. The average annual growth rate of 5.7% over the 10 years to 2012–13[1] is not surprising, given the significant increase in production that occurred over that time. However, over the same period, (the energy needed to produce each unit of output) has declined.

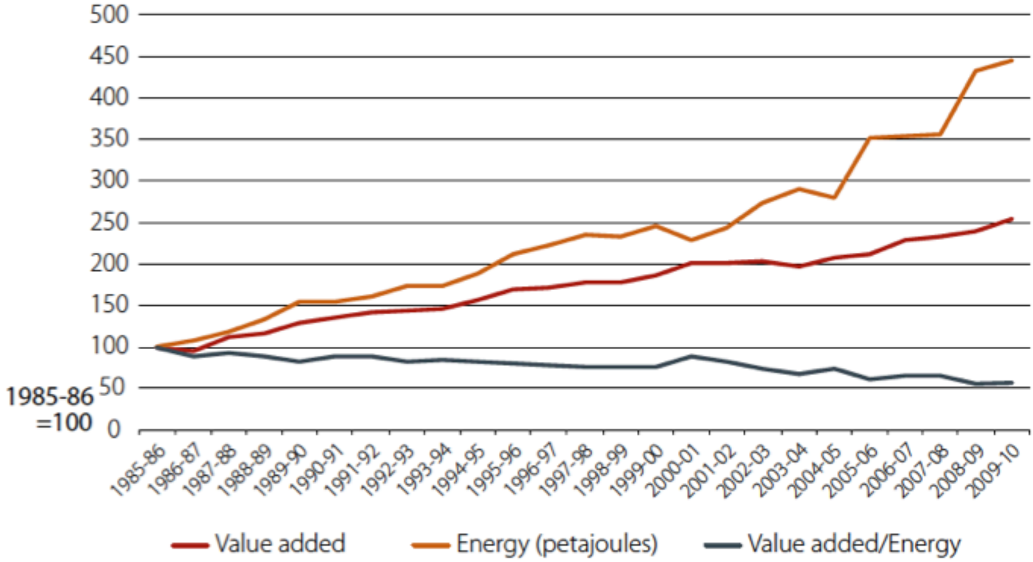
There are a number of important reasons for this decline in energy productivity. Specifically:

- the quality of ore bodies is decreasing, which means that more energy is required for processing
- ore bodies are becoming less accessible as pits get deeper, and more energy is required to access them.

Figure 3 illustrates the extent to which the physical amount of energy per unit of mining output has constantly increased over the past decade. Declining energy productivity means that most mining operations will need to increase their energy consumption per unit of product. Improved energy management can help minimise the decline in energy productivity.

1 Bureau of Resources and Energy Economics (BREE), *2014 Australian energy update,* BREE, Canberra, July, http://www.industry.gov.au/industry/Office-of-the-Chief-Economist/Publications/Documents/aes/2014-australian-energy-statistics.pdf.

Figure 3: Index of mining value added, energy use and energy productivity, 1986 to 2010



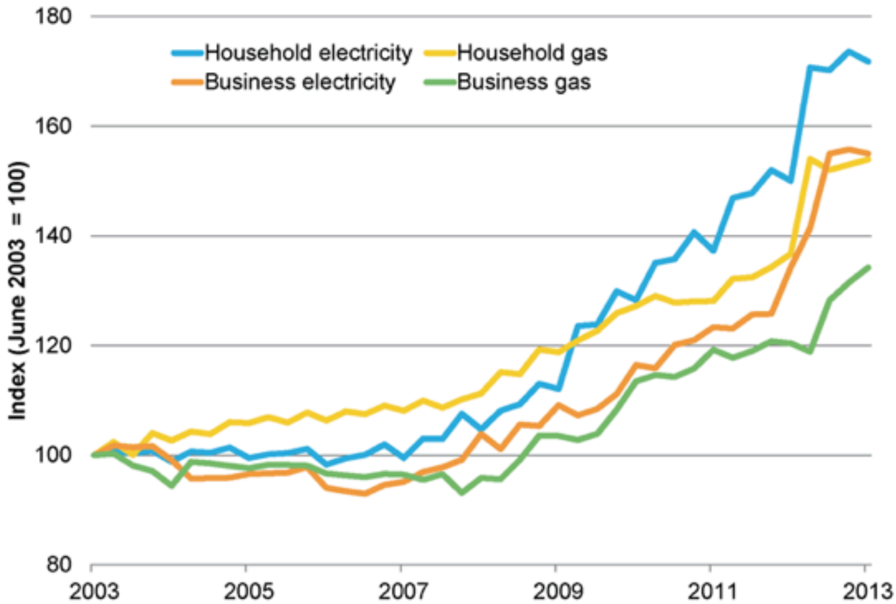
Source: A Syed, Q Grafton, K Kalirajan, *Productivity in the Australian mining sector,* BREE, Canberra, 2013, p. 34, www.industry.gov.au/…/australian-mining-productivity-paper.docx.

Fluctuations in energy prices

Energy prices have fluctuated considerably over the past 10 years. Real electricity prices increased by about 60% between 2003 and 2016 (Figure 4). Gas prices are projected to increase significantly on the eastern seaboard of Australia as it is exposed to the international market. Oil prices have fluctuated significantly, from a peak of US$147 a barrel in July 2008 to much lower prices today.

Predicting the price of energy is complex. However, it is clear that improved energy management can minimise the impact of price fluctuations on mining operations.

Figure 4: Real electricity and gas increases, 2003 to 2013



Source: Australian Bureau of Statistics, in Kai Swoboda, *Energy prices—the story behind rising costs,* Australian Parliament House, Canberra, n.d., http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BriefingBook44p/EnergyPrices.

Changes in government legislation and programs

The Australian legislative environment relating to energy management has seen a number of changes at state and national levels over the past decade. The policy objectives vary from one jurisdiction to another. Policy priorities related to energy consumption in the mining sector can include:

- improving industrial productivity
- reducing pressure on existing energy infrastructure by reducing demand through energy efficiency
- reducing greenhouse gas emissions
- improving the extent to which communities and investors can assess the energy and greenhouse gas performance of companies.

The mechanisms have varied from mandatory energy audits through to providing funding for energy-efficiency projects that can demonstrate reductions in greenhouse gas emissions.

Legislation should not just act as a driver for businesses as it is introduced. Rather, by establishing a rigorous approach to energy management, businesses can reduce their costs of compliance with existing and potential future legislation. Mining businesses may also be able to access funding to support the implementation of energy-efficiency projects. It is advisable to assess the full range of opportunities to improve energy performance before seeking government funding. As eligibility criteria may be restrictive, projects that are eligible for funding support might not offer the best financial returns, or might not align with business improvement or asset management strategies.

Social expectations and social licence to operate

Environmental responsibility can protect and enhance a company's reputation and social licence to operate. Within the mining sector, a poor reputation can make it more difficult for companies to gain approval for new mines or expansions. It can also attract more attention from regulators. In some cases, greenhouse gas and energy-efficiency projections and proposed reduction initiatives may be required as part of the project approval process.

Stakeholders within government, local communities and investors are increasingly looking for information on environmental performance. Public reporting on greenhouse gas emissions and energy efficiency is increasing through company sustainability reports and investor reports such as CDP (formerly known as the Carbon Disclosure Project[2]). The actions taken by a company to reduce greenhouse gas emissions can also be of interest to employees and can affect a company's ability to attract and retain staff.

Energy efficiency is only one of the factors that influence stakeholders' perceptions of mining companies. However, it can support a company's reputation by providing a very visible and practical example of the company's commitment to reducing greenhouse gas emissions. In doing so, it can help mining businesses to demonstrate commitments to international benchmarks such as the Equator Principles.[3]

Operational benefits

The most obvious operational benefit from improved energy management is a reduction in energy costs. However, effective energy management can deliver a range of other business benefits.

Reducing energy costs

A number of different factors influence energy prices. Energy efficiency reduces energy costs by achieving more production output with a lower energy input.

Improving productivity

Often, energy waste is a sign of other problems, so energy-efficiency improvements can reduce maintenance costs, increase plant output, improve product quality, or any combination of such benefits. It can also improve working conditions for staff, for example by reducing heat from processes or reducing noise.

Avoiding or deferring capital investment

Energy efficiency can reduce capital expenditure on plant by improving the efficiency of existing equipment or by reducing capacity requirements.

Energy contracts and pricing

Energy efficiency can significantly reduce costs if opportunities are examined with a good understanding of energy contracts and the way that energy is billed. For example, contracts may include penalties for reducing energy demand, or annual pricing linked to periods of peak demand. Additionally, more frequent and careful reviews of invoices may reveal errors that have led to overpayments.

Work health and safety

Looking at the way that energy is used can highlight work health and safety risks in the workplace related to factors such as temperature and steam.

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2 CDP: *driving sustainable economies,* https://www.cdp.net/en-US/Pages/HomePage.aspx.

3 *The Equator Principles,* June 2013, http://www.equator-principles.com/resources/equator_principles_III.pdf.

Employee involvement and motivation

Involving staff in programs to identify energy-efficiency opportunities can make them feel more involved in decision-making and contribute to improved levels of job satisfaction.

Improving profit margin

Profits are usually a small proportion of total turnover or input costs, so the cost reductions from energy efficiency may look small relative to turnover. Since they are often a significant proportion of the profit margin, however, the results can be more visible to managers when presented in this way.

Achievement of greenhouse gas reduction objectives

Where energy-efficiency improvements avoid the use of fossil fuels or electricity generated from fossil fuels, they may contribute directly to a firm's greenhouse gas reduction performance.

Reducing maintenance costs

Achieving greater production output with less energy can also reduce maintenance costs (for example, running one pump and pipeline system instead of two systems).

Contributing to a culture of continuous improvement

The environmental benefits of energy efficiency may provide additional motivation for employees to identify and implement business improvement initiatives. The thinking and collaboration applied to energy-efficiency improvements can flow over to other continuous improvement initiatives.

Examples of the multiple benefits that energy efficiency projects can deliver are described through the project examples presented in boxes in Part 3 of this handbook.

1.2 Getting key stakeholders on board

The business drivers and benefits of energy management vary from one mine site to another. Business drivers, such as energy prices and government legislation, also change over time. In order to establish the support of site management and staff (referred to as 'site stakeholders' throughout this handbook), it is important to establish the business drivers and benefits that are particularly relevant to an operation and then to refine the communication of messages to match their particular interests. It is also important to understand what energy management activities have been undertaken in the past.

To establish how best to communicate the business case to engage site stakeholders, consider the following questions:

- What business drivers and issues are currently site management's priority?
- How has the site performed from an energy productivity perspective (the ratio of energy input to tonnes of output) and what are the projections for future performance?
- How have energy prices changed over the past few years and what are future price projections?
- What impact will energy prices have on future site profitability?
- What energy-efficiency or greenhouse gas regulations are relevant to the site?
- Are there opportunities to access government funding for energy-efficiency or greenhouse gas reduction projects?

- What energy-efficiency projects have been successfully introduced and what benefits have those projects delivered?

Once the site-specific business drivers and benefits are established, it is useful to consider the range of site stakeholders who can influence energy performance on the site. Each will have particular interests. To gain their support for energy management, it is important to consider the drivers and benefits that are most relevant to particular stakeholders and to modify communications with them to reflect this. Consider the following strategies that can be used to engage particular internal stakeholders:

- The **mine manager** is the most senior executive at the site and has overall responsibility for mining and processing operations. Their main concerns are likely to be safety and meeting production and expenditure targets for the site. To obtain their support, it can be useful to relate energy management to production, safety and cost-reduction targets. Use positive examples from other sites to explain the major benefits and the risks that have been managed at those sites.
- The **mine superintendent, process superintendent** or a similar supervisor has an executive role with responsibility for mining or processing operations. Their main concerns are likely to be safety and meeting performance and expenditure targets for the site's operations. It is important to get to know their priorities and to identify any energy issues that are currently having an impact on operations. Explore with them how energy-efficiency projects will enhance the reliability of production, increase output, reduce site operational costs, reduce or defer future capital costs, or achieve any combination of those aims.
- **Finance managers** have an executive role with responsibility for managing site expenditure. Therefore, their main concern relates to cost control. Get to understand their current investment priorities and challenges and describe how energy management can address them. You may also be able to highlight opportunities for R&D tax concessions or other government funding.
- **Environmental officers** have responsibility for environmental planning and technical standards. They are concerned about environmental compliance and demonstrating environmental and energy-efficiency outcomes. To get their support, identify links between energy management and environmental issues on site (such as greenhouse gas emissions, water and waste). A focus on energy management may also help improve the data needed to meet compliance requirements.
- **Business improvement managers** can play an important role in energy management because they typically have responsibility for identifying and implementing business improvement projects across the site. It can be useful to find out about their current priorities and projects, as there can be a strong alignment between energy management and the outcomes they are trying to achieve through business improvement and asset management planning.
- **Corporate affairs managers** are responsible for creating and communicating the public image of the organisation. They can have good connections to external stakeholders, including government personnel, communities in general and the media. Corporate affairs managers will be interested in understanding both the risks and the opportunities associated with energy management. They can help to promote the positive outcomes achieved through energy projects, which can create greater interest and support for improvement both within and outside the organisation.

While this is not a complete list of site stakeholders, it does provide an indication of key stakeholders and the importance of understanding their perspectives and communicating the value of energy management in ways that align closely with their own priorities and projects.

In this way, support for energy management can be built up over time—helping to build the number of people who have an eye out for energy-efficiency opportunities. They are far more likely to support implementation when there is alignment with their own goals.

Communicate clearly and regularly

The importance of energy management can be communicated in many different ways:

- Establish regular opportunities to brief the site management team on energy management. Briefings may correspond with particular activities, such as the development or review of an annual energy management plan or the pending release of reporting data.
- As you develop and integrate key performance indicators and targets for energy management, that information can be presented and reviewed at regular production meetings.
- Involve staff in energy management teams and site assessment processes (as described in Part 2).
- Use existing forms of communication, such as site or company newsletters, intranets, noticeboards and public reports.
- Ensure that information on energy management is incorporated into site induction training.

A senior environmental officer at New Hope Coal has described the approach they took to getting management support for energy efficiency projects (Box 1).

Box 1: A considered approach to obtaining management support for energy efficiency

'In planning our energy efficiency assessments we recognised the importance of involving senior site managers but knew that we had to do that in a way that didn't draw too much on their time. First we conducted workshops that were aligned with our Lean Business Improvement Program in which we identified both energy efficiency and business improvement projects. Following those workshops we brought together the site General Manager with the Mining, Technical Services, Coal Preparation and Maintenance Superintendents.

'By having the key decision-makers together in one room for three hours we were able to quickly review and prioritise the projects that had been identified and identify new ones. Following the workshop formal capital expenditure proposals were developed for the prioritised projects. By involving senior site management early in the decision-making process, rather than waiting until after the business case is developed, there was greater awareness, buy-in and support from senior site management.

'One example of a successful project is an increase of the tray size and payload on the 785 dump truck fleet at New Acland Coal Mine which is located to the north-west of Oakey in Queensland. This has led to an energy saving of approximately 3.685 TJ and $4.9 million per annum.'

—Senior environmental officer at New Hope Coal

Source: Department of Industry (2010), *Driving energy efficiency in the mining sector,* Canberra, 2010. p. 12.

Summary

Embedding energy management into the culture of a mining business is an ongoing process. It requires regular review of the strategic business context and operational benefits of energy efficiency, understanding the interests of and benefits for key stakeholders and ongoing communication of key achievements and initiatives to keep energy management 'on the agenda'. This can help ensure that changes in the business context, such as new developments, procurement, mine expansions or business improvement projects, can be used to improve energy performance.

PART 2: MANAGEMENT—INTEGRATE ENERGY EFFICIENCY INTO BUSINESS SYSTEMS

Key points:

- Leading practice is achieved by embedding energy management into management systems to ensure that opportunities for improvement are exploited whenever key planning, procurement and operational decisions are made.
- Both corporate and site-specific energy management plans are essential to ensure that opportunities are captured across mining operations.
- Formalised management systems such as the ISO 50001 Energy management systems series may be pursued in some mining operations. However, it is important to ensure that there is a focus on performance as well as compliance.

Traditionally, energy management has focused on energy audits that are undertaken every few years. The main output from an energy audit is a report in which the estimated costs and benefits of potential energy-efficiency projects are outlined. While traditional energy audits are useful, there are some important limitations to this approach from an energy performance perspective. For example:

- Decisions made in mine design, planning and procurement activities that potentially embed energy inefficiency into equipment are not typically captured by energy audits.
- Ore quality changes, production schedules get modified, new equipment may be procured and there can be a high level of staff turnover. If energy audits are only undertaken 'every few years', opportunities to improve energy efficiency as things change will be lost.
- A lack of clear action and tangible outcomes from an energy audit can create cynicism about the value of energy management and management's commitment to improving energy performance.

Energy management systems address many of the limitations of an 'energy audit only' approach. This chapter outlines the essential components of energy management systems that are needed to deliver ongoing and effective improvement in energy performance, which are:

- policies that establish management commitment
- plans that are regularly updated and set out the actions, priorities and targets for energy management
- an energy information system that supports the identification of opportunities and helps track and report on performance
- management and staff accountability for energy management, including the use of energy management teams
- assessment of opportunities in the design, planning and operational phases of mining operations.

The 2014 AS/NZS 3598 series of energy audit standards has been designed to consider the business context of the site and to contribute to improved energy management. Detailed industrial or transport fleet audits have detailed requirements that define the data collection, analysis and evaluation requirements of an audit to provide practical recommendations that facilitate project implementation. This includes external or internal auditors providing a draft list of opportunities to the mine site staff to agree on which opportunities are suitable for detailed investigation, and consideration of whether current design and configuration are appropriate to meet system needs. Financial analysis is undertaken as agreed with the mine site, and can be tailored to the company's financial approval process for investments at a given level.

The energy audit standards have also been developed to be compatible with international energy management standards, and can augment the energy review process under ISO 50001. For multinationals, the AS/NZS 3598:2014 series may provide a more robust and consistent basis for mine site or transport fleet audits than equivalent international standards.

2.1 Develop an energy management policy and plan

Energy policy

An energy policy provides the foundation for successful energy management. It formalises senior management's support for ongoing energy management and articulates the organisation's commitment to energy efficiency for employees, shareholders, the community and other stakeholders.

It is not just the policy itself that is important—it is also the way the policy is developed, which can help to raise awareness and build support for energy management:

- Use the policy development process as an engagement and education opportunity by involving key people.
- Ensure that the language used in the policy is clear and relevant to staff as well as external stakeholders.
- Use the launch (or re-launch) of the policy to raise the profile of energy management, for example by involving senior management.
- Follow up the development of the policy with a communications program to ensure that all management and staff understand the importance of energy management and are encouraged to get involved.

An energy management policy can clarify what the energy management objectives of the organisation are and the timeframes within which they are expected to be achieved. Policies are typically clear and concise documents so that they can be easily communicated across the organisation and to external stakeholders. Energy policies are often incorporated into an environmental, greenhouse gas or climate change policy, as is demonstrated by the Centennial Coal Environment and Community Policy (Box 2). Centennial Coal has a number of coalmining operations in NSW.

Box 2: Energy efficiency incorporated into the Centennial Coal Climate Change Policy

Centennial Coal

Climate Change Policy

Vision

To be a long term and diversified energy supplier by being appropriately responsive to climate change imperatives.

Beliefs

- Climate Change response is an important aspect of our business that presents both challenges and opportunities.
- Our greenhouse gas emissions can be reduced, mitigated and offset.
- Coal will remain a significant energy source in a carbon constrained future and as such low emission technologies are essential.

Guiding Principles

1. Climate change actions are integrated into our business.
2. Measurement and reporting of emissions is accurate, reliable, robust and transparent.
3. The direct and indirect impacts of a carbon price are known.
4. Our carbon liability is managed.
5. Emissions abatement opportunities and innovations are identified, evaluated and implemented, if appropriate.
6. Energy efficiency is continually improved.
7. Accounting for greenhouse and energy is undertaken.
8. Performance is accurately assessed and reported.

Source: Centennial Coal, *Environment and Community Policy,* http://www.centennialcoal.com.au/Environment/-/media/Files/Environment/Centennial%20Coal%20Environment%20and%20Community%20Policy%202011.ashx (accessed April 2016).

Energy management plan

An energy management plan outlines a framework and structured set of activities to be undertaken over a given period to deliver improved energy performance. Typically, such plans are developed to align with annual budgeting and reporting periods. While the structure of the plan varies from one organisation to another, the central elements outlined below are commonly incorporated into an energy management plan.

Introduction and rationale

The plan should outline the rationale for energy management and the scope of the operations that it is covering. For example, a plan developed for an individual mine site should describe:

- the main business drivers and the expected benefits from energy management
- any regulatory requirements that the plan will address
- the relevant corporate and/or site energy policies
- who has authorised the development of the plan
- how frequently the plan will be reviewed.

Describe the main operations that are covered by the plan. For example, does the plan focus only on operational energy use or are other activities, such as transportation from mine to port, included?

Performance, goals and targets

Outline performance goals or targets, which should be updated annually. As plans are reviewed, there should be an explanation of the reasons why targets were or were not met, including factors that may have been outside the control of the operation such as severe weather and unplanned shutdowns. It may also be appropriate to develop more complex energy performance indicators, such as regression models, that indicate changes in performance based on prevailing conditions. ISO 50006 provides guidance on appropriate performance indicators for different circumstances.[4]

Also ensure that any energy-efficiency measures that have been implemented are clearly described and explain the extent to which they have contributed to goals and targets.

Accountability, roles and responsibilities

Key accountabilities for energy management should be included in the plan. They might include the role of the site manager, production personnel and support staff, such as an energy, environment and sustainability champion. It is also important to include a description of the key reporting lines between a site and corporate management. Outline the make-up of an energy management team if one has been established.

Planned energy-efficiency measures and funding for the subsequent period

At the heart of an annual energy management plan is an outline of the actions that will be taken in the subsequent year, how they will be resourced and the energy savings and other benefits that they are expected to deliver.

4 ISO 50006:2014, *Energy management systems—Measuring energy performance using energy baselines and energy performance indicators—General principles and guidance.*

Actions can be categorised as:

- actions that are fully funded and scheduled for implementation
- actions that will be taken to further investigate and refine the business case for particular projects
- actions that will support ongoing identification, monitoring and verification of energy performance.

Also include information on any communication and training initiatives that are intended to improve understanding and awareness of the importance of energy management, together with improvements that will be made to energy measurement and reporting systems.

Budget and resources

Provide an overview of the resources allocated to energy management at the site. This may include overall spending on the energy-efficiency initiatives outlined in the previous section, as well as the time allocated to site stakeholders to drive energy management.

2.2 Monitor and track energy performance

The diverse range of equipment and operating processes on a mine site can make it difficult to understand where and how efficiently energy is being consumed. Many dynamic factors also influence energy consumption, such as mine design and layout, the age and efficiency of equipment and the motivation and skills of personnel. One important reason that energy management has received limited attention in the past is that accessible and reliable data has simply not been available. This reflects the relatively low cost of energy and the limited focus on greenhouse gas reduction when many mines were first established.

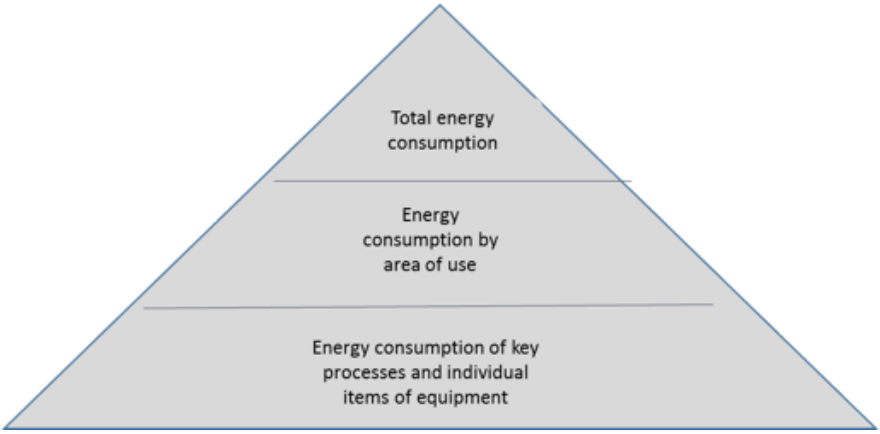
The term 'energy information system' is used here to describe the development of a system that supports the collection, interpretation and reporting of energy data in order to measure and verify energy performance and to locate opportunities for reducing energy consumption and cost. Since leading practice energy management is built on *evidence* rather than *assumptions*, addressing data limitations is essential.

However, improving energy data is not straightforward and typically requires investments of financial and human resources over a number of years to progressively improve the mining operation's energy information system. Therefore, it is important to establish the current state of any existing energy information system and then to develop an informed plan for improvement. Strategies for improvement may include enhancing data capture as well as improved modelling and analysis.

Taking stock of your energy information system

To determine the current state of the energy information for your site start by mapping out the energy data that is currently available. Energy data can be categorised in a hierarchy (Figure 5). At the coarsest level, it is appropriate to establish total energy use at the site and then identify what energy data is available by area of use and at the level of key processes and significant individual items of equipment. For each of those levels, document the frequency at which the energy data is available. This may vary from annual or quarterly down to frequent intervals for data captured by software every few minutes. The following section considers the types of questions that can be used to prompt an understanding of energy consumption and potential opportunities for improvement.

Figure 5: Energy use data hierarchy



Total energy use

Identify how much energy is consumed at the site by reviewing invoice data from your energy suppliers. Answer the following questions:

- What is the proportion of energy costs relative to the overall cost of operating the mine?
- How has that proportion changed over the past few years?
- What is the energy productivity of the mine (for example, energy per tonne of product)?
- Is energy productivity increasing or decreasing? Why?
- What are the overall trends in energy use?
- What are future trends likely to be?

It is also important to understand the quality of the data. Consider:

- Who is responsible for reviewing billing data?
- How is billing data checked?
- What meters are used and how accurate are they?
- How frequently are meters checked and calibrated?

Energy consumption by area of use

Identify the proportion of energy used in each part of the operation. At this point, it may become more difficult to obtain the necessary data. To determine what additional information is needed, explore the following questions:

- Where is energy being used—which areas, processes, vehicles, plant?
- When is it being used?
- Does energy use in any area appear excessive or high compared with the area's function?
- Are some areas suited to specific key performance indicators (such as GJ/tonne of ore quarried or processed)?
- Is there a clear area or grouping of equipment in one of the areas that should also be metered?

- How has the consumption of each energy source changed from last year, and what are the causes (such as increased because of mine depth, less rain so less dewatering, varying quality of ore, change in excavators or trucks or change in procedures or operator training)?

Working through these questions can help to identify opportunities for improvement. It can also help to highlight the areas in which additional energy data is likely to be valuable. This can inform the priorities for improvements to the energy information system.

Energy consumption by time of use

Consider what information you have that allows for the examination of energy consumption by time of use. Once again, this is a top-down process. Start with annual or monthly data. Examine trends in energy use over those periods.

If it is available, daily or hourly consumption data can provide more fine-grained insights. For example, if the operating process is considered to be continuous and relatively unchanging, major spikes and other anomalies in energy use might be identified and provide important insights into areas of the process that should be investigated in more detail. The data may also highlight the proportion of 'baseload' energy consumption. By examining energy consumption during production downtimes, unnecessary energy loads can be identified.

In comparing energy consumption against production over time, consider the following questions:

- What are the components of the baseload?
- How does the baseload compare with that of other similar operations?
- How does the baseload compare with the theoretical limits of the process?
- Can these loads be better controlled so that they only operate when they are contributing to production?

Options to improve energy information systems

While it might seem ideal to invest in a large number of energy meters in order to better understand energy consumption on a site, that might not always be the most appropriate course of action. Other options include:

- using manual records or electronic records from fuel dispensing systems
- using temporary data loggers to monitor pulses from existing billing or private meters
- using temporary metering or transducers on existing meters
- arranging the installation of a time-interval meter with the energy retailer
- reading an existing meter (for example, a billing meter) at the same time each day for a month.

The software systems that are used to collect and analyse the data are also critical. There is no point in obtaining additional data if it cannot be effectively accessed and utilised. Also consider other costs (for example, meters require ongoing calibration to ensure that the data being monitored is accurate).

Software systems are typically used to convert raw data into meaningful information. The sophistication of the software used can vary from a simple spreadsheet to customised energy management software linked to financial and operational data. The level of detail within the software system is likely to vary.

Balanced against the need for additional data is the difficulty of justifying investment in improved energy monitoring systems. Successful strategies might leverage other business drivers:

- There is a legislative requirement.
- Improved metering is a means of addressing production issues.
- There is enough information to show that there is a significant opportunity to save energy and contribute to production, but additional monitoring will improve the outcome.
- Specifications for the procurement of plant and equipment can include components of metering and feedback systems.

Where data is not available, it may still be possible to adequately quantify and evaluate opportunities by undertaking more detailed energy analysis, using temporary or spot measurements to test the accuracy of the analysis under different conditions. Manufacturers or suppliers may also have data or simulation models that can be used to examine specific opportunities. Sensitivity analysis can be used to determine whether a project is justifiable, especially when the project may be relevant to other parts of the business.

Box 3 provides an example in which the energy-efficiency benefits were just one part of the overall case for improved energy metering at the Yandicoogina Mine. The case study highlights the importance of:

- linking energy projects to current business priorities, such as improving power quality, reducing plant downtime and meeting compliance obligations
- involving the right technical expertise as the business case proposal is being developed to ensure that all costs, benefits and risks are considered and accounted for.

Box 3: Upgrading energy metering at Yandicoogina Mine

Yandicoogina is an open-cut mine in the Pilbara region of Western Australia. Iron ore is processed onsite and then transported 450 km by train to the port of Dampier for export. As part of the site energy management team's preparation for an energy efficiency assessment under the former Energy Efficiency Opportunities (EEO) Program, gaps in electrical energy data across the site were identified.

The investment required for electrical metering can be difficult to justify because the benefits are hard to quantify. At Yandicoogina the business case for metering was developed over a six-month period. An experienced electrical engineer, who was also the site energy champion, played a key role in developing the business case. His knowledge of power quality issues meant that he was able to demonstrate in the proposal the production benefits that the metering could help deliver through reduced plant downtime. The cost to install the meters was approximately $600,000.

The benefits presented in the business case included:

- improved power quality and less unplanned plant downtime
- compliance with EEO requirements
- identification and evaluation of energy efficiency projects that were likely to have been rejected due to a lack of energy data
- development of key performance indicators at the process level, which allows ongoing area-specific plant inefficiencies to be highlighted and investigated

- increased awareness of energy consumption in the workplace by communicating energy-related performance data more frequently
- streamlined review and analysis of energy data by linking the meters to the site's SCADA system.

Rio Tinto's corporate commitment to energy efficiency and regular briefings on energy efficiency risks and opportunities to the site management team were factors that also contributed to the final approval of the business case proposal for energy meters.

Fifty-six Schneider ION meters have been installed. The model of the ION meter varied depending on the engineering requirements: major substations had a higher end model installed so that power quality analysis could be done. The ION meters were specifically selected due to the ease with which they integrate into the site SCADA system and the consequent ease with which data can be interrogated.

A number of opportunities identified through the assessment that may have been rejected due to a lack of energy data have been evaluated more closely. For example, electricity consumption data from the meters was used to estimate the potential savings from modifying conveyor belt realignment and the idler replacement program.

Source: Department of Industry, *Building the Business Case Project,* Canberra, 2011, http://eex.gov.au/case-study/rio-tinto-iron-ore-investing-in-energy-metering-at-yandicoogina-mine/.

In summary, there are four important considerations in improving energy information systems:

- Understand what data is available.
- Use that data as well as you can to understand and improve energy use.
- Develop a plan for improvement based on your understanding of specific needs.
- Piggyback on other drivers to justify improvements to systems.

Establishing key performance indicators and targets

The use of key performance indicators (KPIs) is essential to evaluate the energy performance of a business, site or process and communicating when potential problems need to be addressed. The development of effective KPIs also yields insight into the key variables affecting energy efficiency, and they are essential for setting energy performance improvement targets.

It can be challenging to establish appropriate energy KPIs due to the many variables that affect energy use on mining operations. An example of how this has been addressed at Downer EDI Mining is presented in Box 4.

Box 4: The Downer EDI Mining Energy and Emissions Measure

To capture the effects of several variables in a single analysis, the Technical Services Department of Downer EDI Mining developed, trialled and implemented its own energy and greenhouse gas performance measure—the Downer Energy and Emissions Measure (DEEM). Given their leading role in mine planning, design and operations, the project engineers' involvement ensured that the DEEM is credible, accurate and transparent. This enables the company to measure and improve its fuel and energy efficiency with confidence—using the data to track performance and identify opportunities for improvement.

The DEEM considers the sources and destinations of material mined, together with the mass and volume of material moved and the fuel used to move the material. Two separate indicators are used. The indicator for haulage (GJ/tonne-km) applies to haul trucks, road trains, water trucks, scrapers and graders. The indicator for excavation-related equipment, such as excavators, dozers, loaders and surface miners is GJ/tonne material moved. Ancillary equipment, such as lighting plants, generators and pumps, is also considered in the non-haul indicator, as it is considered to be essential equipment for the operation.

The base data that is used to calculate the DEEM is the total fuel consumed and the bulk cubic metres (BCM) moved. This is converted to the common measure of litres of diesel per tonne moved (L/tonne). The L/tonne measure is then adjusted for equipment fuel use, distance travelled and change in elevation to normalise the effect of changes in the material movement task, resulting in a fuel efficiency factor measured in L/tonne-kilometre. As a final step, the fuel efficiency factor is converted to units of energy (GJ) and greenhouse gas emissions (tonnes CO_2-e).

The 'equivalent flat haul' (EFH) parameter was defined to describe the characteristics of the haul route travelled. The EFH is a calculated parameter that accounts for both the distance from the source to the destination and the elevation change from the source to the destination. The EFH normalises the elevation change and distance travelled, which enables a comparison of the energy consumed and tonnage moved for a mining activity.

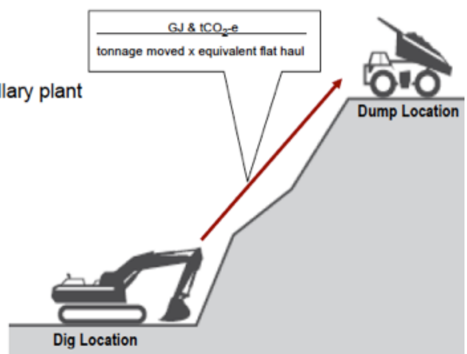
For a given material movement task, illustrated in the figure below, the DEEM accounts for the energy required to move the material, the tonnage moved, and the EFH.

Indicators:

1. GJ/tonne-km for haul trucks, water trucks & graders
2. GJ/tonne material moved for excavators, dozers & ancillary plant

Considers:

- Fuel types
- Plant types, models & fuel burn
- Material type, volume & mass
- Source & destination locations
- Distance moved & elevation change



The DEEM compares and links the weekly to monthly haul and non-haul energy performance to onsite operational activities, decisions and conditions. Performance data can be analysed and compared for a mine site to identify trends and factors that have either positively or negatively influenced energy efficiency. The DEEM can reveal many factors that have a direct or indirect influence on energy efficiency, such as changes in equipment size, the performance of different operators, the influence of production schedules or volumes on fleet efficiency, the effect of rainfall on road conditions, and many other factors. The DEEM's variation can be accurately correlated with and explained in terms of these and other quantifiable factors. These factors and their influences are then taken into consideration in future planning and operational decision-making.

While the DEEM is a useful energy tool for performance tracking and reporting, it is also more useful for informing business improvement decisions than a simple indicator such as litres/BCM. Downer EDI Mining applies this approach to identify where factors contributing to efficiency improvements at one mine and/or mine type may be measured and implemented at another.

Typical solutions include applying different mining methods, mine planning and design changes, haul road changes (length, gradients, design and materials), changing equipment operator behaviour, mining plant selection, and fuel types.

Source: Department of Industry, *Analyses of diesel use for mine haul and transport operations,* Canberra, 2013, http://eex.gov.au/files/2014/06/Analyses-of-Diesel-Use-for-Mine-Haul-and-Transport-Operations.pdf.

2.3 Establish accountability and teams

The first part of this handbook focuses on communicating the business case for energy management in compelling ways that are most appealing to management and other staff. It highlights that an argument is most compelling when managers can easily identify ways in which energy management activities is going to support their own goals. An energy management system presents an opportunity to formally integrate particular responsibilities into the job description and day-to-day activities of particular site stakeholders. A responsibility assignment matrix, such as the RACI model (Table 2), can be a useful way of formalising the roles of managers and personnel in relation to energy management.

Table 2: The RACI model for identifying roles and responsibilities

RESPONSIBLE	Required to actively work on energy management according to defined tasks ('the doers')
ACCOUNTABLE	Ultimately answerable for energy performance ('the buck stops here')
CONSULTED	Have important opinions and insights that should be drawn upon through two-way communication ('provide valuable input')
INFORMED	Kept up to date on progress through one-way communication ('keep in the picture')

Accountability for energy performance at the site level should be held with the site manager, since they can have a significant influence on the resources provided for energy management and the degree to which it is a priority on site.

An energy champion (who is also referred to as 'energy manager' and may have another title, such as 'sustainability manager') should be allocated and provided with the resources to enable them to be 'responsible' for overall energy management at the site. The responsibilities of the site-based energy manager may include:

- providing a central point of contact for energy management
- facilitating the identification and implementation of energy management initiatives
- monitoring and reporting onsite energy performance metrics and progress towards energy-efficiency targets
- coordinating site energy audits under the AS/NZS 3598:2014 series
- briefing management on and monitoring site energy-related compliance obligations
- ensuring that the site meets its energy-efficiency related legislative responsibilities
- maintaining documentation associated with site energy management
- ensuring that lessons learned about energy management are shared with corporate and other sites.

Other personnel may have specific accountability or responsibilities. For example, truck drivers may be both responsible and accountable for energy efficiency through KPIs such as those developed by Downer EDI Mining (Box 4).

Another important way to ensure that responsibility does not lie solely with the site energy champion is to establish an energy management team.

Energy management team members could include:

- **site and other managers**, who have the capacity to approve implementation, a good understanding of the business, often extensive experience in the industry and a whole-of-business perspective, and who can encourage cooperation from staff
- **operators,** who are familiar with the day-to-day issues involved in the current operation, so that they can help to identify problems and opportunities
- **subcontractors and service providers,** who are likely to be familiar with the detail of onsite issues and who, from their use or knowledge of equipment, may have ideas about how practices can save energy and bring other benefits
- **finance staff,** who can assist in developing proposals so that they are suitable for consideration by management, may identify mechanisms (such as tax arrangements and financing options) that facilitate implementation, and may also help to clarify and overcome internal and external financial barriers to action, such as the separation of capital and operating budgets, tax and contractual issues
- **marketing and public relations staff,** who can provide input on the importance of various product attributes, assist with the presentation of proposals to management and other staff, and provide advice on building relationships, organisational and behavioural change, effective communication, and raising the profile of energy efficiency
- **business improvement staff or external consultants,** who have analytical and facilitation skills and a broad perspective on strategies for identifying opportunities and creatively capturing them across the site, and who can also promote learning across the site and the organisation

- **technical staff,** who have detailed experience and knowledge of plant, equipment and operational issues, as well as insights into why certain priorities or procedures have evolved
- **energy procurement staff,** who can advise on the financial and supply risks and opportunities associated with energy supply contracts.

Whatever role individuals play in the energy management team, it is important that they are appropriately resourced. This includes ensuring that training is provided to allow them to achieve the goals that they are responsible for.

2.4 Secure funding and resources

Funding and resources are needed to manage and implement an energy management program successfully. For example, time needs to be allocated to personnel who will be responsible for implementing the program, and funds are required for external consultants. Requirements such as these are typically allocated through the business's normal budget processes.

Because energy-efficiency projects are often cross-cutting, funding may come from a variety of sources. It is important to be fully informed of funding options and the timing associated with them, because those factors can make the difference between a project being implemented or just sitting on the shelf. Potential funding sources are summarised in Table 3.

Table 3: Potential funding sources for energy-efficiency projects

FUNDING SOURCE	DESCRIPTION
Operational expenditure (Opex)	Funding to maintain business operations. Opex funds have a short-term focus and so are more suited to lower cost / shorter payback projects.
Capital expenditure (Capex)	One-off expenditure on items required to generate income in the future. Capex funds often have a mid- to long-term focus and may require a more competitive business case to secure funds.
Business improvement funds	Some organisations have business improvement programs. Energy-efficiency projects may be eligible for funding through those programs where there is a significant productivity benefit.
Corporate funding	Funding may be available from corporate head office to support trials and other initiatives where there are significant company-wide benefits but funds are not available at the site or divisional level, or where a project has application across a number of sites and buildings or across a fleet of vehicles. In some cases, corporate funding may be available through a dedicated energy-efficiency fund.
Government funds	The federal and state governments provide funds, tax rebates and a range of other initiatives. A list of current government initiatives is available on the programs section of the Energy Efficiency Exchange website (http://eex.gov.au/business-support/programs/).

Where possible, align your efforts with the budget cycle to ensure that momentum is not lost. Where that cannot be done (as described in Box 5), it may be appropriate to make other funds available.

Box 5: Dedicated Energy Efficiency Fund at Centennial Coal

Centennial Coal began energy-efficiency assessments in response to state and federal government legislation. The management team wanted to ensure that their commitment to energy efficiency went beyond identifying projects to practically implementing them on the ground. However, the completion of the assessments did not align with standard budget processes, and this would have delayed the availability of funds to implement projects.

A dedicated energy-efficiency fund was established to overcome this problem. The fund allows energy-efficiency projects to be assessed against other energy-efficiency projects rather than other capital expenditure. The aim is to ensure that these important projects get maximum consideration in the distribution of corporate funds. To date, over $630,000 of funding has been allocated for projects, including waste heat utilisation in bathhouses and power factor correction.

Source: Department of Industry, *Business Case and Beyond Project,* Canberra, 2011, http://eex.gov.au/case-study/centennial-coal-supporting-project-implementation-through-an-energy-efficiency-fund/.

2.5 Conduct an energy-efficiency assessment for existing operations

When a business and its operations are reviewed through the lens of energy efficiency, a wide range of opportunities is typically identified. Even companies that have worked on energy efficiency for a number of years can use the focused attention of an energy-efficiency assessment to drive their energy performance further.

A rigorous and comprehensive assessment can be achieved through the interaction of:

- demonstrated leadership and support
- good data and effective analysis
- involving the right people
- having a process in place that brings the right people and effective analysis together to identify opportunities.

No single person has all the answers. In the past, there was typically an emphasis on an external energy expert reviewing an operation and providing a list of recommendations. External experts can provide extremely useful input, but their effectiveness is limited if they operate without the active involvement of site stakeholders and other key people. This is why the AS/NZS 3598:2014 series has been designed to be performed by external auditors, internal auditors, or both. The standards also explicitly consider the needs of a business and include the evaluation of various aspects of energy management at a site, including the availability of data.

Companies may use other approaches, but it is important to have a process that provides an opportunity to step back from day-to-day work and to encourage a broader perspective on how energy is used and where new opportunities might be found.

The goal of your assessment should be to identify a broad range of opportunities that have both short-term and longer term potential. In the short term, you might focus on more straightforward projects that can be implemented immediately to demonstrate the practical focus and benefits of the assessment. This can help build management support at your site and within the organisation more generally. For more complex opportunities that require significant capital for implementation or further investigation, it is important that you plan for the level of investigation required and consider the best timing for implementation in relation to budget cycles, shutdowns and other factors that could influence the implementation of a project.

Planning and resources

An energy-efficiency assessment requires proper planning and resourcing, coupled with a communication strategy that engages with all relevant stakeholders. Planners may consider a progressive approach to conducting the assessments in particular areas of the business, with a plan to complete assessments of the whole business process over a period.

The project plan for the assessment should detail the assessment's objectives, scope, planned activities, timing, resource requirements (personnel, financial and technical), expected deliverables, and potential risks and strategies to manage them. The plan should also outline actions to be taken after the assessment, including reporting on outcomes and timelines for tracking and reviewing and potentially undertaking future assessments. The assessment project plan often evolves as the project team is established.

The amount and cost of energy use for the organisation can be a guide to the level of resources dedicated to the assessment.

People and skills

The value of an energy-efficiency assessment can be dramatically increased by seeking the input of stakeholders within the organisation. The necessary skill sets may exist within disparate parts of the business, which reinforces the need to use a team-based and company-wide approach.

Ideas for energy-efficiency improvements can be found at all levels of the organisation, from shop floor through to head office. Relevant stakeholders also include the people who have influence over capital and operating budgets, people with the authority to make changes to processes and procedures, and people who have a role in implementing energy-efficiency improvements.

Energy-efficiency assessors should include not only those with energy and process expertise, but also people external to the process who can provide alternative perspectives and encourage different ideas. A cross-silo approach to the assessment often results in more innovative solutions. Typically, the identification stage needs broad input but the data analysis and evaluation require specific technical understanding.

Using external resources

The capacity of organisations to perform energy-efficiency assessments varies, depending on the available resources and skills. Depending on factors such as the organisation's energy expenditure, size and resource availability, it may be reasonable to create full-time positions that are dedicated to improving energy efficiency or deploying existing internal resources to particular assessment tasks.

For other organisations, it may make more sense to source external technical expertise. External experts can also offer specialist advice to fill skills or knowledge gaps. A wide range of energy services companies support specific aspects of an assessment, including data collection, opportunity identification and analysis, facilitation, and reporting.

Preparing a focused scope of works helps to clarify the job, the expectations and the input required to facilitate the work of external consultants. The scope of works should contain the principles discussed in these pages to ensure that the consultants perform thorough assessments. This also ensures that accurate cost estimates can be obtained from different firms. The scope should also clearly outline how analysis and recommendations will be presented for findings to be incorporated into business cases. This includes any assumptions made in the estimation of project costs and energy savings. The three types of audits specified in the AS/NZS 3598:2014 series—basic site audits, detailed site audits and precision subsystem audits—provide a sound basis for a comprehensive scope of work.

Understanding energy use

Developing an understanding of energy use and relating energy to core business activities can bring many insights into the relationship between energy and productivity. Data analysis techniques that may be applied are as follows:

- **Graphs of energy use over time (seasonal, monthly, weekly, daily, hourly)**—Understanding the reasons behind energy use patterns and changes in energy use in relation to business activities can often yield new insights.
- **X-Y plots of energy use versus production or other parameters**—This technique can reveal whether or not there are relationships between energy use and production. It can also highlight whether there are production thresholds at which a dramatic change in energy use occurs.
- **Benchmarking**—Using energy performance indicators reveals whether a process, facility or business unit is operating at its optimal performance level. Benchmarking can be used to compare actual energy use with theoretical (calculated or simulated) energy use. Comparisons with other plants, sites, processes, shifts, operators or other factors can be made.
- **Pinch analysis**—Pinch analysis is a design method based on graphical analysis that can be used to optimise the design of complex thermal systems so as to maximise heat recovery. For processes or plants with complex flows of hot and cold streams, it can be used to evaluate whether there are further opportunities for better heating and cooling through the placement of heat exchangers at optimal locations within the process. This method requires engineering expertise.
- **First principles (theoretical calculations)**—A theoretical calculation of estimated energy use can be used to assess systems that cannot easily be measured. Theoretical models are less costly to interrogate than changes to the production system, allowing different scenarios to be explored through the manipulation of operating modes, variables and parameters.
- **Energy–mass balance**—Modelling the energy and material flows within a site, facility or piece of equipment or machinery can provide a deep understanding of those flows and indicate where energy is exiting the process through heat or steam losses, and where opportunities to improve efficiency may exist.[5]

Identifying opportunities

Use the data that has been analysed to identify areas where energy-saving opportunities may exist. Providing the results of the energy analysis to a broad range of people throughout the organisation can often result in further ideas and insights.

5 For further detail, see Australian Government, *Energy savings measurement guide, version 2.0,* 2014, http://eex.gov.au/files/2014/06/ESMG.pdf.

The importance of involving a cross-section of personnel to identify opportunities cannot be overstated. Workshops are a common means of gathering the relevant experts to discuss the data and other information gathered during the energy-efficiency assessment and brainstorm potential ideas and opportunities. Further collaboration can be achieved through focus groups, site visits, staff suggestions, and consultation with suppliers or external experts.

All identified opportunities should be documented in a ‘register of opportunities’ or similar document. This often becomes an enduring record used to track ideas and outcomes and to revisit potential opportunities if operating conditions or energy prices change.

Detailed analysis of selected opportunities

The detailed investigation phase determines the feasibility of each opportunity and gives decision-makers the information they need to make a final investment decision. Further analysis is often needed before a decision is made on which opportunities to pursue. This may require time to collect more data or investment in equipment to improve measurement accuracy.

Businesses often have established practices for evaluating and seeking funds for new projects, such as project charters or templates. Energy-efficiency opportunities that merit a more detailed analysis should use those processes.

A whole-of-business approach improves the understanding of the overall costs and benefits of energy efficiency opportunities. Project risks also need to be understood and addressed.

Other factors that may be considered in this analysis are:

- shutdowns or downtime needed to implement the change
- changes in production output
- changes in other process inputs, such as water or raw materials
- changes in maintenance costs
- hardware changes that make spare parts inventories obsolete
- business plans or forecasts that affect the lifetime or throughput of the process that is being changed
- costs of training or new skills that might be required.

Comprehensive and detailed analysis builds confidence in the findings among the project team and senior management.

Business decisions and implementation

Existing business processes should be used to arrive at decisions on energy-efficiency opportunities. This helps to integrate energy efficiency into the organisation as a regular business activity. If external experts are used to help conduct the energy-efficiency assessment, their findings should be documented in a way that facilitates the integration of the findings with internal business case or project planning processes.

In some cases, one manager may be able to review and approve requests based on information gathered during a detailed analysis. Larger projects often need to go through more extensive approval processes.

Tracking and communication

Opportunities implemented as a result of the assessment must be monitored over time to determine their effectiveness. Measurement and verification can yield further insights into energy use, track any issues or unintended consequences that have resulted from a change, and build internal knowledge and expertise in energy management.

Communicating the status and outcomes of the energy-efficiency assessment to senior managers and the rest of an organisation establishes a shared understanding and basis for action. It also records valuable lessons and helps build senior management support for future energy management initiatives.

2.6 Conduct an energy review for new developments and expansion projects

Decisions that are made in the planning and design stage of new mine developments and mine expansion projects have significant implications for energy use across the life of a mine. For this reason, it is important to establish accountability for energy efficiency as early as possible during planning and design. There should also be a very clear plan for the milestones at which specific energy inputs will be considered.

For example, at the concept study and pre-feasibility stage, energy efficiency should be established as an important design consideration. Accountability for energy efficiency should be given to a senior member of the core multidisciplinary engineering team. During the development of feasibility studies and front-end engineering design, technical studies may be commissioned to ensure that optimal energy-efficiency outcomes are considered. For example in-pit crushing and conveying (IPCC) might be compared to a conventional haul-to-surface operation. Energy cost savings should be considered together with the benefits of an increase in the rate of production and the potential for fuel, tyre and labour costs to increase more than other operational costs.

Following construction, commissioning is an essential part of the process. Good commissioning is needed to ensure that design intentions are effectively met.

Box 6 describes the process and outcomes from an assessment of options in the design phase of the Olympic Dam Expansion project.

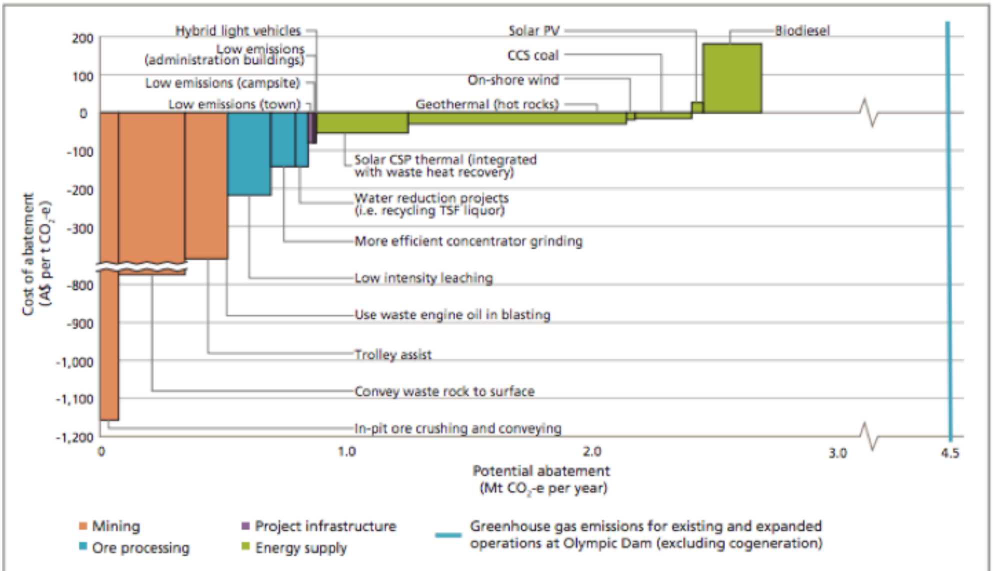
Box 6: Establishing energy efficiency and greenhouse gas improvement options in the design of the Olympic Dam Expansion

BHP Billiton developed a detailed greenhouse gas management plan for the expansion of South Australia's Olympic Dam mine, which is the fourth-largest copper deposit and the largest known single deposit of uranium. The plan identified initiatives to reduce emissions from all sources, including scope 1 and scope 2 energy-related emissions.

The company applied modelling using McKinsey & Company's Australian carbon reduction methodology. This involved a three-step process:

1. Establish a project baseline.
2. Identify emissions-reduction opportunities through project workshops and fact-based estimates of the costs and potential abatement volume presented by each opportunity. Make assumptions about factors such as power capacity forecasts, expected learning curves and initial generation costs.
3. Combine the costs and volumes to form carbon reduction cost curves for the project.

One of the cost curves is shown below. The project baseline (horizontal axis) represents the total carbon emissions if no effort were made to address climate change. The vertical axis represents the cost of carbon reduction. The measures that have a negative cost are the most cost-effective to implement.



Sources: A cost curve for carbon abatement, McKinsey & Company; BHP Billiton analysis

Figure L1.11 Carbon reduction cost curve for the proposed expansion (Year 2050 at 60 Mtpa of ore)

Source: BHP Billiton, *Olympic Dam expansion: draft environmental impact statement,* Appendix L: Greenhouse gas and air quality, BHP Billiton, 2009, http://www.bhpbilliton.com/home/society/regulatory/Documents/odxEisAppendixLGreenhouseGasAndAirQuality.pdf. project-implementation-through-an-energy-efficiency-fund/.

PART 3: TECHNOLOGY AND OPERATING PRACTICES—DELIVER RESULTS

Leading practice energy management ultimately requires that existing equipment, operating practices (or 'business as usual', in the case of mine design and procurement), or both be modified to use less energy to deliver product.

The first two parts of this leading practice guide emphasise that optimising energy use requires a clear understanding of the business case that supports energy management to motivate staff and management and that energy management needs to be integrated into management systems.

This chapter outlines the range of technical and operating practice changes that can deliver improvements in each major area of mining operations. It draws on information developed by the Department of Industry for the Energy Efficiency Exchange website and publicly available case studies. The case studies include some that have been publicly reported by mining businesses under the Energy Efficiency Opportunities Act between 2006 and 2014.[6]

Traditionally, energy management has focused on ancillary equipment such as pumps, motors and fans. The opportunities described in this section show that leading practice energy management requires a wider focus in order to identify and implement opportunities in core operational processes, including onsite materials movement and minerals processing. Those opportunities should be considered from a 'systems' perspective; that is, the interactions between equipment, processes and operating practices should be explored in order to deliver deeper shifts in the way energy is consumed.

For clarity, improvement options have been structured into seven categories:

- Energy supply and procurement
- Buildings
- Blasting
- Onsite materials movement
- Minerals processing
- Air, water and ancillary equipment
- Product transportation.

Within each category, opportunities should be considered not just in operational mode. New developments, mine planning and procurement all present significant opportunities to identify and implement improvements.

6 Energy Efficiency Exchange, http://eex.gov.au/technologies/opportunities-register/.

3.1 Energy supply and procurement

While the main focus of this handbook is on improving the efficiency with which energy is used, it is also important to consider the supply side of energy management. This includes examining the way energy is procured, as well as opportunities to develop and use cogeneration and renewable energy.

Energy supply options

Determining the most appropriate energy supply options is a critical aspect of mine planning. Considerations include:

- cost
- onsite generation versus options to import energy
- safety and security of supply (for example, transporting fuel long distances can be dangerous, and supply may be affected by severe weather and other disruptions)
- environmental impacts and benefits
- the availability of existing infrastructure, including gas pipelines and electricity grids
- the availability and cost of emerging technology options, such as solar photovoltaic (PV) cells and other renewable energy sources, and confidence in those sources.

Cogeneration

As fuel prices change over time and new technologies become available, it is important to periodically review the energy supply options that are available and cost-effective. While an examination of the full range of options is beyond the scope of this handbook, one important onsite option that can deliver cost savings, energy security and environmental benefits is cogeneration. Box 7 outlines the benefits that have been achieved at Alcoa's Pinjarra Alumina Refinery.

Box 7: Cogeneration at the Alcoa Pinjarra alumina refinery

The Alcoa Pinjarra alumina refinery is about an hour's drive south of Perth in Western Australia. In 2005, Alcoa partnered with Alinta to build cogeneration power plants at the refinery. Cogeneration is around 75% energy efficient, compared with 30–50% for other power plants operating in Western Australia.

These plants produce both electricity and heat from gas. The heat is used to generate steam, which Alcoa uses in the refining process. A year's electricity from each cogeneration unit saves around 450,000 tonnes of greenhouse gas emissions each year compared to a similar sized coal-fired plant. In addition, the cogeneration plants reduce Alcoa's refinery emissions by 270,000 tonnes per year through more efficient steam generation—equivalent to preventing the emissions from around 67,000 cars.

Source: Alcoa, *Energy use in Western Australia,* http://www.alcoa.com/australia/en/info_page/Energy_WA.asp.

Renewable energy

The mining industry has traditionally relied on fossil fuel based energy sources such as coal, oil and gas to meet energy demands. As renewable energy technologies improve and become more cost-effective, renewable energy can present a viable and cost-effective option to power a component of mining operations. Renewable energy plants can be developed in-house or developed, funded and built by third parties, as described in Box 8.

Box 8: Solar photovoltaic installation at Weipa

Developing renewable energy at remote sites is not easy, even where it is replacing expensive diesel generation. Until economic energy storage is available, renewable energy can replace the use of diesel but the diesel generation capacity has to be retained as back-up. And the cost of building and maintaining renewable generation in remote locations is much greater than in urban locations.

Rio Tinto Alcan faced these challenges in developing renewable generation at its Weipa bauxite mine in northern Australia. In 2014, Rio Tinto Alcan, First Solar and the Australian Government renewable energy agency, ARENA, reached a joint agreement to develop a 1.7 MW solar photovoltaic (PV) facility at Weipa.

The plan was for First Solar to construct and operate the facility, which uses 18,000 solar panels employing First Solar's thin-film technology. ARENA made an initial commitment of $3.5 million, and Rio Tinto Alcan is buying the electricity under a 15-year purchasing agreement.

The designed output of the system is an average of 2,620 MWh per year, saving up to 600,000 litres of diesel. In the middle of the day, electricity generated by the solar farm offsets up to 20% of existing diesel-generated electricity.

Source: Rio Tinto, *Remote mine using the power of the sun: solar power at Weipa saves up to 600,000 litres of diesel each year*, http://www.riotinto.com/sd2014/casestudies/remote-mine-using-the-power-of-the-sun.html.

Energy procurement

Energy procurement is a specialised area that requires a good understanding of energy markets, energy requirements and opportunities to reduce energy costs through demand management. While most mining businesses have specialised staff involved in energy procurement, it is useful to examine the procurement process during the energy-efficiency assessment to identify areas for improvement. Start by asking the following questions:

- What are the main energy sources?
- How frequently are invoices received?
- What is the tariff structure? For example:
  - is energy (electricity or gas) charged at different rates depending on when it is used?
  - is there a peak demand charge?
  - are there 'take-or-pay' clauses in the energy contract that mean your operation is obliged to purchase a certain minimum amount of energy?
  - what is the capacity or demand charge, and is it levied as a fixed charge on the energy bill?

Understanding the way energy is charged is essential when establishing the costs and benefits of a particular energy-efficiency improvement. When contracts are being negotiated, understanding current and projected energy consumption can lead to a more cost-effective energy supply arrangement.

It is also important to examine whether the bills are accurate and to ensure that the appropriate tariffs are being changed. For organisations that do not have strong review practices, identifying billing errors as part of an effort to improve energy management can provide an important 'early win' if it leads to a refund from the energy provider.

Electricity demand-side management

The price you pay for energy is influenced by when and how you access the network.

The energy that end users require from the system is called 'demand' or 'load'. Demand profiles are an important determinant of both short-term wholesale prices and longer term network prices. When overall demand is high or capacity is constrained, the underlying wholesale price of energy can be very high. 'Peaky' demand requires more responsive and expensive generation to be brought online. It also requires network service providers to construct more network capacity in parts of the network that are likely to become heavily loaded.

Retailers use the demand characteristics of end users to plan their purchases from wholesale markets. Typically, they charge end users more if the end user has a more volatile or less predictable demand profile. This compensates the retailer for risks, such as users requiring significant volumes of energy at peak times or requiring different levels of energy from those forecast. It is possible to reduce your costs through agreeing to a certain demand profile and then ensuring that your business complies with the profile.

Demand profiles are also used by network service providers to configure your connection to their network and determine which network tariff is most appropriate for each site. The maximum demand, or peak load, for end users drives the cost of supply incurred by your network service provider, particularly where the peak load occurs at the same time as for other users connected to the same part of the network. End users are typically charged at a rate that is directly related to their maximum demand, levied in $/kW or $/kVA1. They may also be charged a penalty if they exceed the maximum demand agreed to in their contract—their contract maximum demand.

Understanding your energy demand profile is essential to managing demand cost-effectively. This requires detailed data from your retailer and an analysis of how energy is used in your key processes and equipment. You need to be able to forecast, with reasonable accuracy, your maximum consumption in any single day (for gas) and in any single half-hour period (for electricity). Being armed with detailed usage data helps you to negotiate the best possible deal from energy retailers, energy management service providers or other intermediaries. Usage data will also help to identify what opportunities exist to gain benefits from demand-side responses. Retailers can provide you with your usage data or demand profile, but you need to ask for it. Ideally, the data should cover a minimum of a year, but may be confined to winter or summer periods, depending on the load profile. Alternatively, you can use the services of a registered meter service provider who is authorised to read your meter and provide the data to your retailer.

It is essential that you engage with representatives at the significant energy-using sites in your organisation to develop a better understanding of current and future requirements. Energy assessments can also give you a detailed understanding of how energy is used within your site, key energy-using processes and pieces of equipment. This knowledge is critical when making decisions on how to manage your demand profile and the effect it may have on production outputs or service quality.

In analysing this data, some companies look at optimising maximum demand settings. This involves modelling the previous year's load and looking for a demand setting for the following year that achieves the lowest cost. This means setting a maximum demand that may incur penalties on a number of occasions but ensures that the total cost is lower than setting a demand that meets the highest peak load.

Different options to lower costs include:

- **reducing demand charges** by changing the levels or mix of business activities to flatten your demand profile and reduce your peak demand
- **reducing the volatility in your load,** enabling you to negotiate a lower premium for managing wholesale price volatility
- **shifting energy consumption** so a greater percentage takes place during off-peak rather than peak periods, enabling you to negotiate a lower energy price
- **improving energy efficiency** through investment in new equipment, changing production processes or introducing more energy-efficient practices, which reduces your overall consumption.
- **understanding future needs** (such as plans for expansion) and considering whether it is better to enter a one-year energy contract and revisit negotiations when you have a clearer picture of future requirements.

3.2 Buildings

While the energy used in mining buildings is typically only a small proportion of overall energy consumption, energy-efficiency initiatives implemented for buildings can provide a tangible example of the organisation's commitment to reducing energy use and greenhouse gas emissions.

Improvement options are typically low cost and relatively straightforward. They include:

- installing timers on air conditioning units and lights
- using solar hot water systems
- replacing incandescent and mercury vapour lights with LED technology
- designing mining camp buildings to ensure good insulation and shading
- installing water-efficient showerheads and other fittings to reduce demand for hot water and to reduce the energy required to pump water around a site.

As with other initiatives, it is important to combine technology changes with information and behavioural change initiatives.

3.3 Blasting

Effective blasting has long been recognised as an opportunity to enhance efficiency and productivity on mine sites. Improvements in resource characterisation, combined with smart blasting, ore sorting and waste removal, can significantly reduce the energy required in the comminution process while at the same time increasing product throughput.

Improve resource characterisation

The level of ore concentration variability and other characteristics of rock types significantly influence 'mine to mill' design and operational efforts to minimise total energy usage. Typically, geologists' predictions about the ore body and mineral processing performance from observations at the core scale are different from the reality faced by engineers. Geometallurgy helps to address this difference by first performing many smaller volume (lower cost) tests and then using the data obtained to construct a three-dimensional (3D) geometallurgical model of the ore body.[7] The 3D geometallurgical model is used to inform a 'smart' blasting approach that targets the sections of the ore body with the highest ore grade concentration.[8] Leading companies, which have partnered with the CRC ORE, have shown that this process can reduce business-as-usual trends in energy use per tonne of metal by 10–50%.[9]

3D geometallurgical models of the ore body can also enable the optimal design of mine-to-mill circuits and the integration of energy efficiency into the measurement and accounting of energy use per unit of metal produced. For example, the Sustainable Minerals Institute at the University of Queensland, in partnership with Anglo Platinum, has developed the 'Geology–Mine–Plant Management Tool' to optimise energy use, water use and greenhouse gas emissions across the whole geology–mine–plant extraction process.

Selective smart blasting

Conventional blasting is focused on the entire region of a mine to achieve the top size that can be transported in haul trucks and processed through the primary crusher.[10] Selective or smart blast design technology uses geometallurgical data to target relatively high ore concentration sections of the ore body with greater blast energy. This significantly improves the grade of ore being fed to the crusher and grinding mill.[11] The net total energy consumed at the crushing and grinding stages is reduced because:

- a reduction in the feed size to the primary crusher requires less energy to crush the ore to the same product size
- additional macrofracturing and microfracturing within individual fragments from the blasting makes fragments easier to fracture further in the crushing and grinding phases[12]
- an increased percentage of relatively small mineral ore particles can bypass stages of crushing, decreasing the percentage of total tonnes crushed.

7 AR Bye, *The application of multi-parametric block models to the mining process,* South African Institute of Mining and Metallurgy International Conference: Platinum Surges Ahead, Sun City, South Africa, 2006.

8 A Bye, *Case studies demonstrating value from geometallurgy initiatives,* 1st International Geometallurgy Conference (GeoMet 2011), 2011.

9 CRC ORE, 2010–11 *annual report: transforming resource extraction,* CRC ORE, St Lucia, Queensland, Australia, 2011.

10 MS Powell, AR Bye, *Beyond mine-to-mill: circuit design for energy efficient resource utilisation,* Proceedings of 10th Mill Operators Conference, Australasian Institute of Mining and Metallurgy, Adelaide, Australia, 12–14 October 2009, pp. 357–364.

11 AR Bye, *Case studies demonstrating value from geometallurgy initiatives,* 1st International Geometallurgy Conference (GeoMet 2011), 2011.

12 K Nielsen, J Kristiansen, *Blasting–crushing–grinding: optimisation of an integrated comminution system,* Proceedings of FRAGBLAST 5: Fragmentation by Blasting, Montreal, Canada, 25–29 August 1996, pp. 269–277.

Research has been undertaken to consider blasting techniques that can achieve energy savings through the crushing and grinding process.[13] Savings of up to 30% have been reported.[14] Software packages are also available to assist in designing effective blasting techniques, including analysing and evaluating energy, scatter, vibration, damage and cost. Research by Aditya Birla Minerals Limited found that modifications to the blasting patterns at Aditya Birla mine would result in energy and cost savings (Box 9).

Box 9: Altering blast patterns at Aditya Birla mine

The Birla Nifty copper mine is in the Great Sandy Desert region of the East Pilbara in Western Australia, about 1,250 km north of Perth and 350 km east of Port Hedland. In conducting an energy-efficiency assessment at the Birla Nifty mine site, Aditya Birla Minerals Limited examined opportunities to modify the blasting pattern to produce a more optimally blasted rock size for crushing and grinding.

Studies estimate that altering the blast pattern would save around 25,000 GJ of energy for an estimated cost saving of $900,000/year. The investment return for the project was less than a two-year simple payback.

Source: Aditya Birla Minerals Ltd—Opportunity C, EEO Opportunities Register, 2011, http://eex.gov.au/opportunities-register/aditya-birla-minerals-ltd-opportunity-c/.

Ore sorting and waste removal

Gangue usually occurs in the ore body as large clumps that contain little or no valuable mineral. It is usually harder than the valuable minerals because it usually contains a high concentration of silicates.

Ore sorting and rejection of gangue can help the progressive upgrade of ore concentration in the ore body undergoing comminution. This enables the mill to process material at a very high concentration of ore grade, without low-grade material and gangue driving down the average. The sorting criteria should also be integrated with the mine plan and blast design (selective blasting and screening) to ensure that only the right parts of the ore body are sent to the sorting section, and that they are blasted into a size distribution suited to sorting.[15]

Once mined, gangue can be rejected by progressively processing the ore using a series of separation devices. Such devices include ore-sorting devices, screens, density separators (such as heavy media circuits or drum separators) and magnetic separators. Optical, radiometric, X-ray and laser ore-sorting devices can also be used for gangue rejection. The effectiveness of each device depends on the ore's texture, which is defined by properties including mineralogy, mineral grain size, mineral shape and the association between minerals.[16] A better understanding of ore texture is critical in the selection of a separation device.[17]

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13 J Eloranta, L Workman, 'Saving money from the start: a look at the effects of blasting on crushing and grinding efficiency and energy consumption', *Pit & Quarry,* 2004, 96(8):30.

14 Ibid.

15 MS Powell, AR Bye, *Beyond mine-to-mill;* see footnote 10 for details.

16 L Vink, 'Textures of the Hilton North deposit, Queensland, Australia and their relationships to liberation', PhD thesis, University of Queensland, Brisbane, 1997.

17 MS Powell, AR Bye, *Beyond mine-to-mill;* see footnote 10 for details.

3.4 Onsite materials movement

The movement of overburden, ore and waste accounts for a significant proportion of energy use and operating costs on mine sites. Energy consumption is influenced by decisions that are made in mine design and asset selection and procurement and through day-to-day operating practices.

Many energy-efficiency strategies can improve the fuel efficiency of haul trucks through fleet optimisation and upgrades. There are also alternative material movement strategies to complement haul trucks, including in-pit mobile crushers, conveyor systems, overburden slushers, electric draglines, lighter haul trucks and diesel–electric trolley haul trucks. These opportunities are explored in this section.

Haul trucks

Trucks are used to haul overburden and ore from the pit to a dump site or stockpile or to the next stage of a mining process. Their use is scheduled in conjunction with other machinery, such as excavators, loaders and diggers, according to the site layout and production capacity.

Trucks use a significant amount of diesel and are expensive to purchase and maintain. Operating procedures influence energy use and maintenance costs. Truck velocity, especially cornering speeds and braking patterns, and road surface characteristics can affect tyre wear and replacement costs.

Many parameters can affect the efficiency of the fleet, such as:

- mine plan and mine layout
- speed, payload and cycle time
- tyre wear and rolling resistance
- age and maintenance of the vehicles
- dump site design
- idle time
- engine operating parameters and transmission
- shift patterns.[18]

The main opportunities for improved energy performance in haul trucks include optimising payload management, implementing improved driver practices, benchmarking performance across the haul truck fleet, improving mine design, purchasing larger haul trucks and lightweighting tray liners, and considering technology options in asset selection and procurement.

18 Department of Industry, *Analyses of diesel use for mine haul and transport operations,* Canberra, 2013, http://eex.gov.au/files/2014/06/Analyses-of-Diesel-Use-for-Mine-Haul-and-Transport-Operations.pdf.

Optimising payload management

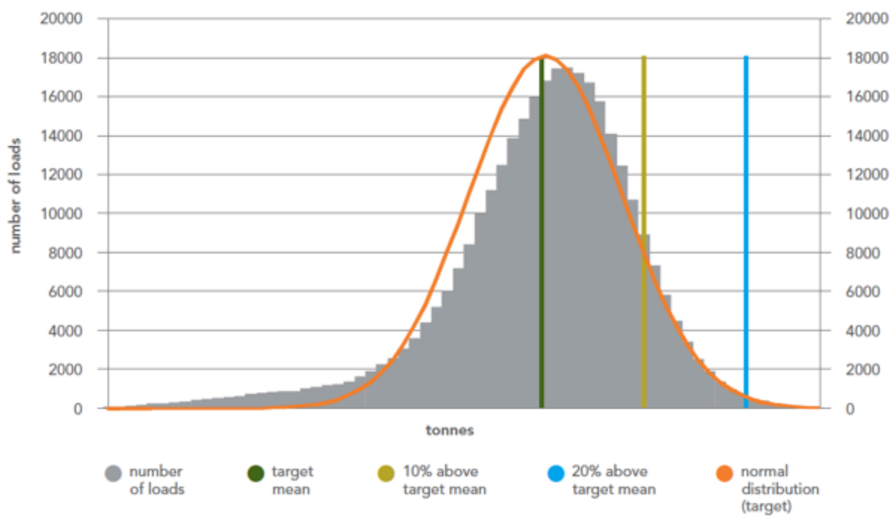
Payload management ensures that each haul truck carries the optimal tonnage of material to increase fuel efficiency. In some cases, this approach can also reduce the number of trucks needed to complete tasks. The approach that has been taken at the Thiess Australian Mining Business Unit is outlined in Box 10.

Box 10: Optimising payload management at the Thiess Australian Mining Business Unit

Thiess has implemented payload management system improvements that have been estimated to save up to 117,300 GJ and 8,200 tonnes CO_2-e of emissions per year across 12 Australian mine sites.

The opportunity to improve fuel efficiency and productivity through payload management was examined and progressed as part of an energy-efficiency assessment. An important part of the assessment was a review of data on payload performance.

The graph below shows the payload distribution for a particular class of dump truck. The payload is measured as the weight of material carried by the truck. If the truck is underloaded, more diesel is needed to transport the total payload. If the truck is overloaded, truck warranties may become void and maintenance costs increase due to additional wear and tear on the vehicle. The graph demonstrates the potential to reduce diesel use by having trucks more frequently loaded to the set target level. This type of analysis was used in the assessment to compare performance across sites and to identify specific actions to be taken on each site to improve energy efficiency.



The following key initiatives were identified and implemented across all Thiess' mining operations:

- Daily payload data was downloaded and reviewed more frequently.
- The actual versus targeted payload was communicated to operators more frequently.
- Supervisors asked truck operators for payload data more frequently.
- Senior management regularly reviewed payload performance.

The availability of timely and accurate data, clearly articulated targets and ongoing feedback have been central to achieving energy-efficiency and productivity improvements through changes to payload management.

Source: Department of Industry, *Thiess' Australian Mining Business Unit,* Canberra, 2009, http://eex.gov.au/files/2014/06/Thiess-Australian-Mining-Business-Unit.pdf.

Implementing improved driver practices

Improved driver practices, or eco-driving, refers to a system of driving in which the driver achieves optimal fuel economy. The system incorporates a range of driving behaviours, such as smoother driving (gentle acceleration and braking) and driving more slowly with less idling. The approach to operator training that has been adopted by Downer EDI Mining is outlined in Box 11.

Box 11: Downer EDI Mining: Operator training program

Operator training was identified as a potential energy-efficiency project during site-based workshops conducted as part of Downer EDI Mining's assessments for the Energy Efficiency Opportunity program. The team reviewed proposals from a number of companies offering driver training services. Considerations that were taken into account included each company's training approach, delivery mechanism, cost and alignment with the Downer EDI Mining company culture.

Individual meetings were held with personnel at the site level to obtain their support and to understand any concerns they may have had about the project. The benefits that the project could deliver were clearly communicated and linked to the priorities of each individual. They included:

- reducing fuel and maintenance costs—of primary interest to senior site managers
- prolonging engine and tyre life—which appealed to the workshop and maintenance staff
- greenhouse gas reductions and safety benefits—a priority for health, safety and environment representatives
- the opportunity to promote the benefits of training—relevant to learning and development staff.

For the drivers, a key message was that 'being hard on trucks is being hard on yourselves'.

Care was taken in setting up a trial and evaluating the outcomes to ensure that the findings were reliable, credible and consistent. Site management identified a number of concerns early in the trial. One was that reducing the speed at which trucks were driven would have an impact on productivity. No impact on productivity was found, but concerns such as these highlighted the importance of conducting the trial rigorously.

The project has been integrated into Downer EDI Mining's equipment simulator training program and is delivering a fuel saving of approximately 2%. Many of the other benefits, including for maintenance and servicing, are still being evaluated. The training is being progressively rolled out to other mine operations through the learning and development department.

Source: Department of Industry, *Business Case and Beyond case studies,* http://eex.gov.au/case-study/downer-edi-mining-approach-to-energy-efficiency/.

Benchmarking performance across the haul truck fleet

Benchmarking provides a means to measure and identify best practices within a single organisation or across multiple organisations. Many variables can affect haul trucks' energy efficiency, so simplistic performance indicators, such as litres of diesel per tonne moved, are often too blunt to provide useful insights into the factors that drive efficiency because they do not account for factors such as the distance travelled, the payload per cycle or other characteristics of an individual hauling task.

Calculations of theoretical energy efficiency might not reflect the level of performance that can realistically be achieved but can be a useful tool to track improvements in energy efficiency. The development of relevant theoretical benchmarks provides organisations with a practical energy-efficiency measurement tool that quantifies best practice and highlights areas where improvements can be made. The approach that Leighton Contractors adopted to address these challenges is described in Box 12.

Box 12: Application of the best truck ratio model at Leighton Contractors

Leighton Contractors developed a 'best truck ratio' (BTR) model to evaluate and benchmark the efficiency of fleet operations across a single site and multiple operations where the nature of the work varied greatly. The model provides an indication of how efficient Leighton's fleet is in comparison with what is practically and realistically possible. It is providing a rigorous analytical tool that Leighton is using to support decision-making.

One of the factors that can affect the fuel consumption of haul trucks is the type and condition of the haul road. The figure below illustrates the use of the BTR model to analyse how road condition can change the rolling resistance of the haul trucks. A dry and hard-packed haul road keeps fuel costs and tyre wear to a minimum. Wet conditions can increase the rolling resistance experienced by the vehicle. In moving 20 million tonnes over a specific path, the BTR indicates that a wet haul road will result in the consumption of an additional 820,000 litres of diesel. This analysis can help fleet managers to determine the optimal use of haul trucks in wet conditions and can inform decisions on road design and maintenance.

Source: Department of Industry, *Analyses of diesel use for mine haul and transport operations,* http://eex.gov.au/files/2014/06/Analyses-of-Diesel-Use-for-Mine-Haul-and-Transport-Operations.pdf.

Mine design

Many different factors influence mine design, and considerable effort is made to ensure that a site layout maximises productivity. Design decisions influence the initial location of haul roads, processing plant, dumps and transportation assets such as conveyors. Mine design is dynamic, and decisions are made throughout the life of the mine. An example that demonstrates the influence of the location of haul roads is outlined in Box 13.

Box 13: Minimising energy costs by reducing haul truck stops at the Fortescue Metals Group

As part of an energy-efficiency assessment at its Cloudbreak and Christmas Creek sites in the Western Australian Pilbara region, Fortescue Metals Group identified an opportunity to review the haul road design to enable trucks to achieve and maintain an optimal trip speed. A considerable fuel saving would result if the road design could allow the removal of stop signs, where that did not compromise safety.

The truck manufacturers were asked to do modelling for a fully loaded truck to accelerate from stationary for 100 metres and to advise the final speed at that distance. They were also asked to model the same truck operating at this same final speed, but using that speed for a distance of 1,000 metres, so that the steady-state fuel consumption could be calculated. In this way, the fuel saving as a result of the truck not having to stop was the difference between the two scenarios.

Evaluation of this opportunity revealed that Caterpillar 777 haul trucks could save an estimated 361 kL/year and Terex 3700 AC haul trucks could save 407 kL/year for each stop-sign intersection removed.

Source: Fortescue Metals Group—Opportunity F, *EEO Opportunities Register,* 2011, http://eex.gov.au/opportunities-register/fortescue-metals-group-ltd-opportunity-f/.

Purchasing larger haul trucks and lightweighting tray liners

Using larger haul trucks will typically reduce the number of trucks in a circuit and the amount of fuel needed to move equivalent tonnages. Similar outcomes can be achieved by lightweighting tray liners. These improvement options are illustrated in Box 14 and Box 15.

Box 14: Increasing the size of haul trucks at Homestead mine

The Homestead mine is owned by Norton Gold Fields Limited and is 35 km north-east of Kalgoorlie in Western Australia. Underground mining at Homestead was undertaken with underground trucks whose capacity was limited to 40 tonnes per load.

During the contract, the opportunity to increase to trucks capable of carrying 50 tonnes per load with similar burn rates was investigated and ultimately implemented for an estimated energy cost saving of $25,000/year.

Source: Norton Gold Fields Ltd—Opportunity B, *EEO Opportunities Register,* http://eex.gov.au/opportunities-register/norton-gold-fields-ltd-opportunity-b/.

Box 15: Reducing the weight of dump truck trays at Rio Tinto

Dump truck trays that are used across Rio Tinto mine sites are fitted with heavy-duty wear plates to make them last longer. Mine maintenance staff involved in an energy-efficiency assessment observed uneven wear in the tray liners. The trays have now been redesigned using thinner plate in low-wear sections. This has resulted in a weight reduction of approximately 10 tonnes/tray without affecting the trays' longevity.

The benefits of this project are reduced diesel usage, reduced maintenance costs and increased payload capacity. The new tray liners will be progressively installed as new liners are needed. It is expected that an average 3.4% reduction in overall tray weight will be achieved.

Source: Rio Tinto Ltd—Opportunity K, *EEO Opportunities Register,* http://eex.gov.au/opportunities-register/rio-tinto-ltd-opportunity-k/.

Asset selection and procurement

Decisions on the selection and procurement of mine transportation options can significantly influence the energy intensity of mine operations. Some of the key improvement opportunities are as follows:

- Use trolley trucks that use tram power lines to access or feed in electricity to enable energy to be recovered as the trolley trucks descend back into the mine.
- In-pit crushing conveyor (IPCC) systems are the most energy-efficient systems for hauling ore, overburden and waste from open-cut mines.[19] Innovations in IPCC system technologies in the past decade have resulted in IPCC systems being used at most types of open-cut mines. However, IPCC systems have significantly larger up-front costs compared to haul trucks.
- Overburden slushers can be used instead of electric draglines. Slushers use two winches, one on each side of the open cut, to drag a large bucket across the overburden, then to the top of the mine. Existing draglines can be converted.
- Use lightweight hybrid diesel–electric trucks, which are more fuel efficient and can recover energy through regenerative braking on descent into a mine.
- Conveyor belt systems have been shown to be significantly more energy efficient in transporting materials than haul trucks, using about 20% of the energy required by heavy-duty trucks.[20] There is also scope to improve their performance through optimisation using simulation models and improved monitoring and management, as outlined in Box 16.

19 D Tutton, W Streck, The application of in-pit crushing and conveying in large hard rock open pit mines, Independent Consultant Mining Engineers, Germany, 2009.

20 '340 million tons of good reasons for climate protection', ContiTech News, 2012.

Box 16: Reducing conveyors' run time at Port Hedland—Fortescue Metals Group Ltd
Conveyors at Port Hedland carry ore from train unloaders to stockpile stackers and then from stockpile recovery equipment out to ship loaders. During the port operations, conveyors would be left running with no load for long periods for a number of reasons, some necessary and some not.

It was suggested that conveyors should be limited to a period of 30 minutes running unloaded before being automatically shut down. Maintenance requirements can override this programming rule if necessary.

The port operations team agreed and implemented program changes that limit the unmanaged 'no-load' running periods. The port has several train unloader – conveyor circuits and several ship loading conveyor circuits, so the conveying system is designed into a set of 'routes' through the multitude of conveyor paths in the port. Any conveyor running unloaded that is not part of a scheduled route shut down after a very short controlled time. Conveyor segments within a scheduled route are allowed to run a little longer unloaded before they, too, are shut down by the program.

It is estimated that this project will deliver annual energy savings of $126,864/year at an investment return of less than two years.

Source: Fortescue Metals Group—Opportunity I, *EEO Opportunities Register,* http://eex.gov.au/opportunities-register/fortescue-metals-group-ltd-opportunity-i/.

3.5 Minerals processing

Comminution (crushing and grinding) is responsible for at least 40% of total energy usage in mining and mineral processing.[21] Improved flow sheet design strategies reduce the direct and indirect energy usage for comminution by:

- maximising gangue rejection ahead of the next downstream step to reduce the amount of material that requires treatment by comminution
- ensuring the use of the most energy-efficient crushing technologies ahead of the energy-intensive grinding step
- ensuring the use of the most energy-efficient grinding technologies.

There are many specific energy-efficiency strategies for comminution, which are outlined below. Note that these strategies are best applied to the design of greenfield comminution circuits, when an increase in capacity is required, or when a change in ore hardness is expected for an existing operating circuit.

Use new and more energy-efficient grinding technologies

Studies show that in some mines the amount of input energy going into the grinding process can be reduced by as much as 40% using the latest efficient equipment.[22] Computer simulations using the discrete element method show that most rocks larger than the discharge grate size do not break in the first

21 See, for example, Z Pokrajcic, R Morrison, 'A simulation methodology for the design of eco-efficient comminution circuits', in DZ Wang, CY Sun, FL Wang, LC Zhang, L Han (eds), *Proceedings XXIV IMPC,* volume 1, 2008.

22 For example: Z Pokrajcic, RD Morrison, NW Johnson, 'Designing for a reduced carbon footprint at greenfield and operating comminution plants', in D Malhotra, PR Taylor, E Spiller, M LeVier (eds), *Proceedings of Mineral Processing Plant Design 2009—An update conference,* Society for Mining, Metallurgy and Exploration, Tucson, Arizona, 30 September – 3 October 2009, pp. 560–570.

collision. Instead, they accumulate damage in multiple collisions before breaking, which is an inefficient use of energy.

A wide range of comminution equipment is available for many materials and for many different conditions. The choice of equipment and design of circuits has a significant influence on energy use.

In addition, the combination of the use of energy-efficient crushing and fine grinding equipment helps to reduce energy use by:

- reducing the primary and secondary recirculating loads, leading to lower power requirements, a smaller volume of ore to handle, and potentially a switch to a smaller mill
- creating a steeper distribution of particle sizes, leading to easier mineral liberation and more efficient downstream processing
- reducing the need to use grinding media that have high embodied energy (for example, as HPGR circuits do).

Select the coarsest possible grind size

The target product size, or grind size, has a large influence on the size and energy use of a comminution circuit. As the product becomes finer, the internal flaws in each particle become fewer, the particles become more difficult to fracture, and the grinding energy increases.

An alternative approach for the selection of a target product size for multi-mineral ores is the progressive liberation strategy. This involves liberating one mineral or one group of minerals at a time by applying the following concepts:

- Multiple valuable minerals are grouped, increasing their effective concentration, and enabling the desired level of liberation to be achieved at coarser target product sizes.
- Fully liberated particles (100% valuable mineral) are recoverable in a flotation process.
- Particles containing at least 15% valuable mineral by sectional area are recoverable in a flotation process using the appropriate flotation conditions and flotation reagents.[23]

If minerals are sufficiently liberated or recoverable (in composite particles), they can be separated from the ore before further comminution. This strategy can also be used to remove gangue from the ore, leading to less grinding energy and more efficient separation in downstream processes. However, this strategy requires a good understanding of the particle composition at different product sizes.

Optimise particle size

The reduction ratios for each successive crushing and grinding process influence the distribution of particle sizes and the energy use of the process. Energy use is relatively low when particle sizes are consistent. Finer particles, having less microcracks and being more difficult to fracture, resist breaking and are instead displaced, causing energy to dissipate; they also lead to the generation of slimes.

Screens and filtering devices help to achieve a more consistent particle size. A consistent distribution of particle sizes is expected to produce superior flotation performance.

Use more advanced and flexible comminution circuits

Using a single comminution circuit with very large semi-autogenous grinding mills has enabled companies to expand economically into large, low-grade ore bodies and treat large volumes of ore. A disadvantage of this approach is that comminution becomes less efficient as ore body concentrations decline but there is only one circuit operating. Therefore, many companies have moved to using comminution circuits with at

23 Pokrajcic et al., 'Designing for a reduced carbon footprint at greenfield and operating comminution plants': see footnote 22 for details.

least two (in some cases, more than four) parallel milling circuits. This allows high- and low-grade ores to be processed simultaneously, but on separate circuits, enabling each grade to be ground closer to its optimal recovery size, increasing grinding efficiency and reducing energy use (Box 17).[24]

It is possible to optimise, design and build comminution equipment perfectly fitted for each ore body. Advances in modelling by CSIRO and the University of Queensland can now assist in determining and optimising the design of the most energy-efficient comminution equipment. Research teams have developed theoretical approaches and software packages for modelling different combinations of comminution circuits to minimise overall energy use across the circuit.

The discrete element method (DEM) is increasingly useful as a tool that can help provide fundamental insights into comminution processes and into the behaviour of specific comminution machines.[25] It can contribute to the design and rapid manufacture of new comminution equipment, the improvement of existing equipment, and increases in the operational efficiency of all comminution unit processes. For example, DEM modelling can now allow detailed exploration of the particle flow and breakage processes within comminution equipment, allowing a clearer and more comprehensive understanding of those processes.

Box 17: Modifying the secondary dry circuit for Wonnerup mine

The North Shore mineral separation plant receives mineral-rich ores, known as heavy mineral concentrate, from the Cristal Australia mining site at Wonnerup, which is near Busselton in Western Australia, and the Broken Hill mineral separation plant. Changes to the physical characteristics of the concentrate occur, which generally relate to the location of an ore body or other factors. The new ore body at Wonnerup contains increased amounts of leucoxene and finer grain secondary minerals. The existing equipment at the North Shore secondary dry circuit will only be able to process the non-magnetic portions of this heavy mineral concentrate at a feed rate of 7.2 tonnes/hour without significant loss of product recovery. Additionally, the existing technology will not capture all of the fine grain materials. This results in:

- higher energy consumed per unit of product available for sale
- a higher proportion of material returned to site, increasing freight costs and diesel consumed and CO_2-e produced.

An opportunity was identified to implement process changes that increase product recovery and the processing rate, reducing energy per tonne produced.

The existing process relies on the magnetic and conductive properties of the leucoxene and uses induced roll magnetic and electrostatic separators to separate the target mineral. However, an induced roll magnetic separator machine uses electricity to maintain the magnetic field. New rare earth roll magnetic separator machines use permanent magnets, without electricity.

24 MS Powell, AR Bye, *Beyond mine-to-mill.*

25 GW Delaney, PW Cleary, MD Sinnott, RD Morrison, Novel application of 'DEM to modelling comminution processes', IOP conference series, *Materials Science and Engineering,* 2010, 10(1), CSRP Project 2B1 Extension.

The process change includes the introduction of a new 300 mm rare earth roll magnetic separator machine, reducing the energy in the early stage of the process. For the Wonnerup mineral, this change will allow an increase in production of 39% to 10 tonnes/hour. However, for the Wonnerup ore body, the old induced roll magnetic equipment will be introduced to the back end of the circuit to increase the recovery of Wonnerup's finer grain secondary minerals. This will:

- reduce total electrical energy consumed
- reduce the energy per unit of production
- reduce greenhouse gas emissions
- increase production throughput by 39%.

It is estimated that this project will reduce energy consumed by around 808 GJ, resulting in a net reduction of greenhouse gas emissions of 200 tonnes CO_2-e/year. The change has a capital cost of $560,000. The value of the increase in production, plus energy and maintenance savings, is $770,000, giving the project a payback of less than 9 months.

Source: Cristal Australia Pty Ltd, *EEO Opportunities Register,* http://eex.gov.au/opportunities-register/cristal-australia-pty-ltd-opportunity-o/.

Improve the efficiency of separation processes

Froth flotation is a method of mineral separation that relies on the different chemical properties of minerals compared to gangue. Optimising the chemistry in the flotation cells reduces energy intensity. Energy savings are possible through using more advanced froth flotation technologies and control engineering.

For example, technologies such as the Jameson cell produce smaller bubbles more consistently than previous flotation cells, enabling the process to be more energy efficient. Mixing and adhesion occur more quickly and in a smaller space compared to traditional froth flotation cells. A higher percentage of mineral is recovered, improving the economics of a mine. The Jameson cell also has no need for a motor, air compressor or moving parts.

Improvements are also being made in control engineering of flotation systems to achieve further energy-efficiency improvements.

Optimise existing systems

Systems optimisation is an ongoing process involving the use of frequently measured and calculated system inputs in order to manage and optimise productivity and quality. It sits above existing process control systems, which are widely used to monitor and control particular processes within a mining, manufacturing or infrastructure plant. Based on information received from remote stations (sensors), automated or operator-driven commands are sent to remote station control devices (actuators). These systems control factors such as raw material feed rates or boiler temperatures in a manufacturing process.

Systems optimisation is more dynamic than traditional approaches to analysing energy performance. It can support effective energy management by helping to identify areas of wastage, helping to understand the energy consumption of the process, highlighting changes to energy consumption patterns and reaching an optimal condition for the supply of power. In most cases, energy-efficiency benefits are achieved by improving productivity.

While the benefits are dependent on the primary objectives of the project, the following outcomes are those that are generally achieved through effective implementation of systems optimisation:

- increased output
- increased energy efficiency
- reduced energy cost
- increased product quality
- reduced emissions
- reduced downtime
- reduced environmental impact
- reduced human input
- improved work health and safety.

An example of the application of systems optimisation to the processing plant at Anglo Gold's Sunrise Mine is outlined in Box 18.

Box 18: Process optimisation at Anglo Gold's Sunrise Mine

AngloGold owns and operates the Sunrise Dam goldmine near Laverton, Western Australia. The mine, which has been in operation since 1995, began with open-pit operations and in 2003 began underground mining. The processing plant at Sunrise Dam is typical of many goldmining operations, consisting of crushing and grinding processes, and carbon-in-leach technology to recover gold.

The company initially considered systems optimisation as a means to improve productivity by reducing downtime in the milling and crushing plant. The objective was to improve throughput by maximising the productivity of the plant. The project team sought to increase production by finding the optimal processing rate and sustaining that rate as much as possible by eliminating causes of downtime or process bottlenecks.

Before looking at any equipment upgrades, the engineers first investigated how they could unlock the potential of the operating equipment that was already installed. The existing control systems and operating methodologies were designed to avoid out-of-control events or unstable events, and were working reasonably well in this regard. However, the plant was avoiding unstable events by running well below the capability of the equipment.

Many of the operating costs of the processing plants are fixed regardless of throughput, while other parts of the process become more efficient at higher levels of utilisation. Maximising the throughput of the plant lowers the energy consumption cost per tonne. Increasing the throughput results in an increase in power demand, but the overall energy intensity improves, resulting in an improvement in profitability.

The project team investigated options to minimise idling time in crushing and milling equipment, and the time that equipment spent operating outside its ideal speed or throughput range. They also investigated instances when the circuit became unstable, to gain a better understanding of the constraints and limitations of the plant.

For example, if the feed supplying ore into the mill stopped but the mill continued to operate, the mill would still draw a substantial amount of power while adding to wear and tear on the milling balls. One area of optimisation was to ensure that the mill ran only when sufficient feed was supplied. Other problems can occur if the mill is optimised to run at a certain throughput and the throughput is increased, resulting in an overload. This may require the circuit to be stopped while the overload is rectified, resulting in a net loss of productivity.

Before making any changes to the control system, the project team developed a full understanding of the ideal operating range for each part of the circuit. They looked for other events that caused faults and downtime, and those were fixed first.

Implementing systems optimisation

All systems optimisation upgrades were implemented through changes to the logic and control algorithms of the programmable logic controllers. Before implementation, the initiative was given a high profile and promoted by the processing manager at Sunrise Dam. It was regularly discussed in production meetings and became a part of the performance evaluation process. The process manager for each area of the plant was responsible for identifying opportunities, developing the business case, implementing opportunities and measuring the results with SCADA. Optimisation projects were scoped and budgeted and then ranked based on payback period and production improvement. Once changes were approved, external contractors were engaged to implement the programming changes.

Training operators

As new control system upgrades were implemented, it was important to minimise manual intervention by the plant operators. Systems were put in place to monitor how often control loops were in automatic mode and to log times when the plant was switched to manual control.

A training program for plant operators was introduced to support the changes. Under the old system, operators had to intervene regularly in the process to make changes, often prompted by warnings or alarms from the SCADA system. The training focused on how to use the data in the control system to be proactive rather than reactive.

Operators were still able to take manual control of the system at any time, and were instructed to do so if they felt the need to switch off the automatic control system. They were also asked to make a note of the reason they had to switch out of automatic mode, so that the process engineers could understand what the limitations of the automatic control system were, and which issues to address next.

Benefits achieved

The operators now proactively use the control system to keep the plant working within defined operational parameters. The benefits achieved to date include:

- fewer maintenance events (less downtime)
- increased throughput
- improved energy efficiency
- reduced unit costs.

Source: Department of Industry, *Case studies in systems optimisation to improve energy productivity,* Canberra, 2013, http://eex.gov.au/files/2014/08/Systems-Optimisation-Case-Study-2013.pdf.

3.6 Air, water and ancillary equipment

Air ventilation

Relatively low-cost energy savings can be achieved through maintenance improvements in ventilation systems. For example, fan impellers or blades should be cleaned regularly to avoid fouling in dusty environments, which causes static pressure losses.

Energy-efficiency savings can also be achieved by ensuring that air ventilation supply matches demand. Since ventilation is a major health and safety issue, most mines run air ventilation systems harder than necessary. Mine ventilation systems are also subject to changing system characteristic curves as the workings move. This means that a system that is initially optimised will deviate from the optimum over time.

For underground mines, air ventilation is a significant area of energy usage. Energy savings can be achieved by ensuring that air ventilation supply matches demand (Box 19 and Box 20), minimising energy use in air and water flows and reducing the area required to be cooled. Often fan and pumping energy losses are high due to the long distances air and chilled water must be moved. Localised systems using the latest high-efficiency air conditioners, fans and pumps can be more efficient.

Box 19: Minimising ventilation fan operation to reduce energy use and defer major capital expenditure at Newmont's Jundee mine

At Newmont's Jundee underground operations, which are 520 km north of Kalgoorlie in Western Australia, detailed investigation and energy analysis have highlighted opportunities to turn off ventilation in non-operational parts of the mine.

The project is projected to reduce load requirements by 1,400 MWh/year. Beyond the energy saving, however, the project has meant that a capital upgrade to the ventilation system can be deferred by around two years. This is a major benefit, particularly at a time of significant capital constraints.

Source: Department of Industry, *Business Case and Beyond case studies,* 2011, http://eex.gov.au/case-study/newmont-asia-pacific-business-case-and-beyond/.

Box 20: Reducing ventilation restrictions at Northgate Australian Ventures Corporation Pty Ltd

Unnecessary restrictions to ventilation airflow in underground mines waste the power required to deliver that flow. Reducing those restrictions not only increases ventilation airflow rate but also improves the air quality in the mines.

Depending on the fan curve, this will also generally reduce power somewhat. Slowing rotational speed of the prime mover (the fan or pump) to return airflow rate to the original level decreases energy consumption further.

Northgate Australian Ventures Corporation Pty Ltd found that an estimated 1,470 GJ in potential savings from the implementation of this opportunity was possible at its Stawell, Victoria, goldmine.

Source: Northgate Australian Ventures Corporation Pty Ltd—Opportunity G, *EEO Opportunities Register,* 2012–13, http://eex.gov.au/opportunities-register/northgate-australian-ventures-corporation-pty-ltd-opportunity-g/.

The energy–water nexus

On a mine site, water is involved in many different activities, including extracting and processing ore, suppressing dust, cooling, washing, and transporting waste as tailings.

Therefore, ensuring that there is a consistent supply of water, in terms of both quantity and quality, is critical. This can be particularly challenging on mine sites where there is water scarcity, high climate variability or competing users, where production is set to increase, or where any combination of those factors applies.

The University of Queensland examined the trade-off between water and energy savings as part of the Australian Coal Association Research Program (ACARP).[26] ACARP developed a model that allowed the nexus between energy and water use to be examined.

Sometimes sites can make water and energy savings simultaneously. For example, the use of additives in dust suppression requires road water trucks to be used less frequently. However, at other times reducing water and energy use are competing objectives and so trade-offs between the two must be made. For example, treating water can reduce the volume of high-quality water withdrawn or purchased by a site, but also increases energy used on site. Therefore, any attempt to solve a water problem without considering the associated energy impacts will simply be shifting problems, rather than providing a genuine solution.

While every site is different, the ACARP report highlights just how important it is that decisions about energy and water use be made on a site-by-site basis. This should be kept in mind when considering the energy-efficiency opportunities discussed in Box 21.

Where dewatering is required, the energy efficiency of pumping systems can be optimised by using efficient motors and pumps, using smooth pipes with a large diameter, and running the pumps continuously at low speed instead of for short periods at high flow. In open-cut mines, rather than pumping water from the bottom of the mine up to the top, the water can be put into dust-suppression water tankers at the bottom to be used as spray water while the trucks are driven uphill (tankers usually spray while being driven downhill).

26 A Woodley, G Keir, E Roux, D Barrett, J White, S Vink, *Modelling the water, energy and economic nexus,* ACARP research report C21033, Australian Coal Research Limited, February 2014.

Box 21: Reducing friction head losses to process water line at the Wonnerup mine

The Cristal Mining Wonnerup mine, which is near Busselton in Western Australia, excavates mineral-rich sand and processes it to separate the target minerals such as titanium, monazite and zircon as a heavy mineral concentrate. The sand is above the watertable, so dry mining techniques are used to excavate it, after which it is transported into the primary screening plant and then the secondary screening plant, which is regularly moved to always be adjacent to the excavation area. The primary screening plant uses a large volume of water to separate and remove large rocks and debris. The target materials are then pumped as slurry to the concentrator plant, which can be 400–1,500 metres away. The water used in the pumped slurry is recycled, being pumped from the concentrator back via the water cleaning circuit and production water storage facility to the primary and secondary screening plant.

An opportunity was identified at the mine to:

- increase the diameter of the high-density polyethylene pipeline from 280 mm to 315 mm to reduce friction head losses, which allows the installation of a smaller motor, thereby reducing the energy required
- change the 110 kW motor to an available spare 90 kW motor (possible because of the reduction in friction losses).

This opportunity was initially identified during energy-efficiency opportunity identification workshops for a mine at Gwindinup, which has now ceased mining. At Gwindinup, the project was not financially attractive due to implementation costs and the relatively short remaining life of the mine.

Cristal's mine planning is designed around the relocation and reuse of mine infrastructure, which in this case was to be moved to its new Wonnerup mine. This energy-efficiency opportunity was re-evaluated and the pipe change was implemented during the initial development at Wonnerup.

When fully implemented, this innovation will reduce the risk of line failure, which reduces the risk of environmental incidents and increases reliability and production run times. It will also reduce annual maintenance costs for the pump and allow for a reduction in the energy load due to a reduction in the pump head of about 18 metres.

The project will reduce energy consumption by 600 GJ, resulting in a net reduction of greenhouse gas emissions of 150 tonnes CO_2-e per year. It has a capital cost of $30,000, producing annual energy and maintenance savings of $26,000 and a payback period of 1.2 years.

Opportunities in ancillary equipment

Further energy-efficiency opportunities can be achieved by implementing improvements in specific technologies, such as motors, pumps (Box 22), fans (Box 23), lighting (Box 24) and air compressor systems. These systems consume a significant amount of energy in mining and mineral processing.

Box 22: Modifications to pump controls at Mount Isa Mines

A pump is required for water delivery to head tanks, which are filling stations for the water trucks used for dust suppression at Mount Isa Mines' Black Star open-cut copper mine. The existing pump control is an externally mounted box in an area subject to a high number of lightning strikes.

This project will disconnect the pump and remove a hired diesel generator, attach mains power, provide lightning protection for the motor control centre with a full earthing system, and provide dual redundancy in the soft-start unit and the ability to power washing at targeted times. This project is expected to deliver annual energy savings of $270,300 for a simple payback of less than two years.

Source: Glencore Investment Pty Ltd—Opportunity G, EEO *Opportunities Register,* 2012–13, http://eex.gov.au/opportunities-register/glencore-investment-pty-ltd-opportunity-g/.

Box 23: Fan replacements at Barrick's Kalgoorlie mine

A project was implemented to replace the single primary vent fan at Barrick Pty Ltd's Kalgoorlie goldmine with multiple lower rated fans. This resulted in one 530-kW fan being replaced with three 37-kW fans

Post-implementation measurements showed energy savings of 15,000 GJ with a better than two-year payback.

Source: Barrick (Australia Pacific Holdings) Pty Ltd, *EEO Opportunities Register,* 2011–12, http://eex.gov.au/opportunities-register/barrick-australia-pacific-holdings-pty-ltd-opportunity-e/.

Box 24: Automating mobile lighting equipment at Thiess

Thiess runs 24-hour mining operations, so good lighting is essential to support safe and efficient work practices. Due to the geographical spread and changing location of operations, diesel-powered mobile lighting units are used.

Workshop personnel identified an energy-efficiency opportunity that involved fitting automated systems to the lighting plants to ensure that they operated only in low-light conditions.

The estimated diesel saving is 165,000 litres/year (6,400 GJ/year), with an investment return of less than two years. Other benefits from the project include a reduction in operator labour time and light vehicle diesel use (as people no longer need to travel on the site to turn the lighting units on and off), improved safety, and reduced maintenance and longer operational life of the lighting units.

Source: Department of Industry, *Thiess Australian Mining Business Unit case study,* http://eex.gov.au/files/2014/06/Thiess-Australian-Mining-Business-Unit.pdf.

3.7 Product transportation

Mineral ores are often transported long distances to mineral processing plants or to port for export. There is potential to save energy by using the most energy-efficient mode of transport and by improving the efficiency of the chosen mode.

Opportunities in rail include driver-assistance IT systems, such as portable loggers and GPS receivers, which enable freight trains to optimise their fuel efficiency. The onboard computer calculates fuel efficiency, based on the type of train, weight, speed, fuel consumption, gradient and curvature of the track, GPS location and driving techniques. The software provides instructions to optimise power, such as slower acceleration to maximum permitted speeds, coasting and running at lower speeds to allow more gradual deceleration before braking.

Other energy-efficiency opportunities and a more detailed examination of rail freight are available at the Energy Efficiency Opportunities website.[27]

Similarly, there are many opportunities to improve energy efficiency in the road transport sector. This includes initiatives that improve aerodynamics and tyre performance, lightweighting, investment in efficiency engines and driver training. More information and examples are on the Energy Efficiency Opportunities website.[28]

27 Rail freight transport, *Energy Efficiency Opportunities,* http://eex.gov.au/industry-sectors/transport/rail-freight-transport/.

28 Road transport, *Energy Efficiency Opportunities,* http://eex.gov.au/industry-sectors/transport/road-transport/.

GLOSSARY

Energy efficiency	Using less energy to achieve the same or a greater level of production output.
Energy information system	A system that supports the collection, interpretation and reporting of energy data in order to measure and verify performance and to locate opportunities for reducing energy consumption and cost.
Energy performance	Using the minimum amount of energy necessary to meet business objectives.
Energy productivity	The ratio of energy input to product output.
ISO 50001	The international standard for energy management systems published by the International Organisation for Standardization (ISO). The full title is ISO 50001:2011 *Energy management systems—requirements and guidance for use.*
Leading practice energy management	The best way to improve the energy performance of a given site in a way that best contributes to its business objectives.
M&V	Measurement and verification.
Programmable logic controller	A digital computer used for the automation of industrial processes.
SCADA	Supervisory control and data acquisition. A system operating with coded signals over communication channels so as to provide control of remote equipment.

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