



*A roadmap to double ENERGY PRODUCTIVITY
in Mining
by 2030*

AUTHORSHIP OF THIS ROADMAP

This roadmap is published by the Australian Alliance for Energy Productivity (A2EP). A2EP is an independent, not-for profit coalition of business, government and environmental leaders promoting energy efficiency and decentralised energy. A2EP aims to inform, influence and advance the efficient use of energy in Australia.

The 2xEP program is a project of A2EP to double energy productivity in Australia by 2030. The 2xEP program is led by a Steering Committee of business leaders. A mining working group, reporting to the Steering Committee and comprising representatives of major industry associations, researchers, companies and representatives of the Commonwealth Department of Industry, Innovation and Science, provided significant input in the preparation of this roadmap. A2EP would like to thank the members of the 2xEP mining working group for volunteering their time. The views expressed and the recommendations offered in this draft roadmap are those of A2EP and not necessarily of individual working group members.

This roadmap sets out a range of recommendations to improve energy productivity in the mining sector. A2EP will promote the mining sector roadmap to government; support the implementation of energy productivity recommendations; and monitor and report on progress. A2EP's aim is to develop the roadmap into a continuously evolving platform that a wide range of industry organisations and businesses will be invited to join.

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The views expressed in this text are those of A2EP and not necessarily those of our collaborators, supporters and partners. All responsibility for the text rests with us.

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Executive summary

Economic productivity is a key driver of international competitiveness and economic growth. However, many sectors of the Australian economy, including mining, are characterised by flat or declining economic productivity. Until 2011, the deterioration in national economic productivity was masked to a great extent by high commodity prices.

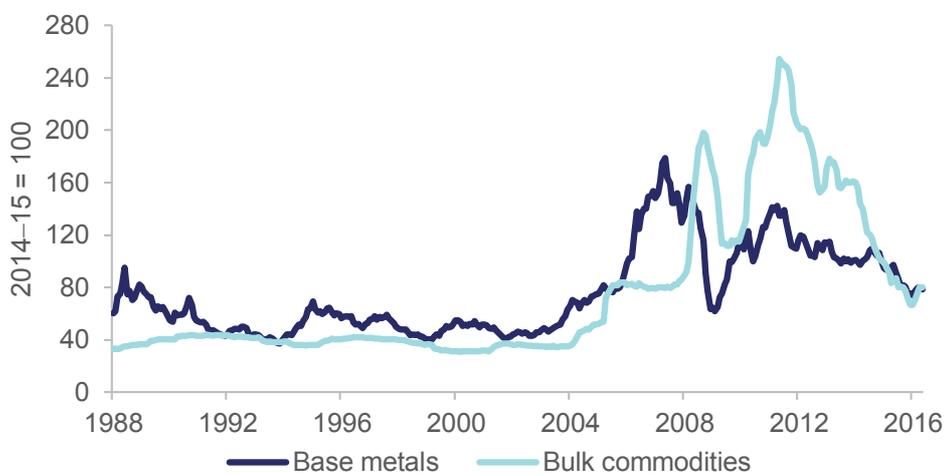
Initiatives to enhance energy productivity can cost-effectively contribute to improving Australia's economic productivity and competitiveness; this is a primary reason for energy productivity being declared a policy priority by federal and state governments. Initiatives to improve energy productivity will also be central to meeting Australia's international commitments to reduce carbon emissions; commitments that are expected to become more ambitious over time.

Energy productivity is a measure of the total economic value delivered from each unit of energy utilised, expressed at the national level as dollars of gross domestic product per unit of primary energy usage. Energy productivity aims to capture the co-benefits that accrue from investment in more efficient plant and equipment such as reduced operating and maintenance costs, and reduced downtime. In some cases this also includes increased output or improved quality of output.

The Australian Alliance for Energy Productivity, A2EP (formerly the Australian Alliance to Save Energy, A2SE) commenced the 2xEP Roadmap initiative in February 2014 to set out a path to double energy productivity in Australia by 2030. Roadmaps outlining how individual sectors of the economy can contribute to the national 2xEP goal are being prepared. Roadmaps will be published for the following sectors: mining; agriculture; built environment; manufacturing; freight transport; and passenger transport. In addition, an innovation roadmap will cover increasing energy productivity across all sectors of the economy through innovation. This roadmap proposes a range of initiatives to improve energy productivity in the mining sector. Please note this roadmap does not include the oil and gas extraction industry in its consideration of the mining sector.

Energy productivity in the Australian mining sector has been adversely impacted in recent years by factors such as depressed prices, particularly for bulk commodities; increased energy cost per unit of production; and increased energy intensity of production for base and precious metals. Declining ore grades have been a major contributor to the increase in the energy intensity of the production of base and precious metals. Initiatives to improve energy productivity in the Australian mining sector present an opportunity to enhance economic productivity and lock in long-term competitive advantage.

Initiatives to improve energy productivity can embed permanent reductions in mine operating costs and increase operating profit margins, building the resilience of the sector to withstand price volatility and periods of cyclical downturn. The graph below, reproduced from *Resources and Energy Quarterly June 2016* (Department of Industry, Innovation and Science, 2016c), illustrates the historical volatility of commodity prices, particularly over the last decade. Minimising operating costs is particularly crucial in the latter years of mining operations in order to maximise the economically viable life of a mine. As noted above, initiatives to improve energy productivity also often result in co-benefits, such as more productive deployment of labour and materials, lower materials costs and reduced carbon emissions.



Many opportunities to improve the energy productivity of mining operations exist. These opportunities can be divided into four strategy areas: traditional energy management; systems optimisation; business model transformation; and preservation/increase in product output and quality. Examples of aspects of mining operations that provide significant opportunities to improve energy productivity include: intelligent blasting; comminution processes; haulage; and optimised ventilation in underground mines. An integrated approach to energy productivity is necessary to optimise the energy productivity of a mine operation as a whole.

Where the high capital costs can be justified, deployment of on site renewable energy generation or forms of co-generation may enhance energy productivity initiatives by reducing exposure to future energy price increases and embedding permanent reductions in operating costs. In addition, renewable energy provides other benefits such as reduced exposure to the risk of interruptions to energy supplies, for example, diesel used for onsite generation, and a reduced carbon footprint of mine operations. A2EP supports the deployment of renewable energy as being in alignment with the goals of 2xEP where decisions to deploy renewables are made on the basis of a thorough assessment of the relative risks and rewards associated with energy source options.

This roadmap is structured to provide the contextual setting for the recommended initiatives in this document. The roadmap outlines competitiveness challenges facing the Australian mining industry and describes how improving energy productivity can make a contribution towards addressing these challenges. A summary of opportunities to improve energy

productivity in mining is presented, followed by discussions regarding the energy productivity metrics appropriate for mining and the barriers to improving energy productivity in the sector.

This contextual information is followed by policy and program recommendations for the mining sector to improve energy productivity. These recommendations include industry initiatives, joint government/industry initiatives and government initiatives and policy changes to facilitate 2xEP.

The objective of the roadmap recommendations is to support and facilitate exploitation of cost-effective energy productivity opportunities that will boost the economic productivity and competitiveness of Australian mining sector into the future. A2EP strongly encourages organisations operating in the mining sector to review the mining roadmap; assess the relative benefits and costs of the recommended initiatives to their business; and implement all cost-effective initiatives.

2xEP target

Australia has fallen behind many nations in terms of our relative rate of improvement in energy productivity. This problem has been compounded by sharp increases in energy prices, resulting in declining energy competitiveness. Accelerating the rate of improvement in energy productivity would have a beneficial impact on Australia's economic growth, prosperity and global competitiveness.

The 2xEP initiative proposes doubling energy productivity across the Australian economy by 2030 from \$222 real GDP (2010\$) per unit of energy input (primary energy measured in GJ) in 2010 to \$444 in 2030. This target is in line with maintaining competitiveness with comparable economies. 2xEP is a voluntary business stretch target that will require changes in business models and products, attitudes and practices, as well as significant technological innovation. The following points justify the national 2xEP target:

- 2xEP is the minimum level of energy productivity improvement that will at least maintain our energy productivity relative to OECD economies in the future. Doubling the target ensures focus on the significant step changes, including major infrastructure investments, required to restore Australia's competitiveness. 2xEP provides a common goal, guiding the alignment of policies, strategies and, ultimately, resources to execute plans.
- Improved energy productivity can generate broader positive flow-on effects such as more productive deployment of labour and materials and reduce maintenance costs.
- Energy productivity improvements will be a significant contributor to meeting Australia's international carbon emissions reduction commitments, with the National Energy Productivity Plan playing a key role in delivering these emissions reductions (Energetics, 2016).
- Innovation and technology improvements will make a significant contribution to energy productivity. There will be a separate 2xEP innovation roadmap published later in the year on this topic. Our strategy needs to facilitate development and transfer of

innovative technologies in the Australian market. Development of export markets for innovations originating in Australia will also be sought. Export of innovation is particularly relevant to the mining sector. Innovation in the mining sector is supported by, for example, METS Ignited, an industry-led, government funded Growth Centre focused on strengthening Australia's position as a globally competitive hub for innovation in the mining equipment, technology and services (METS) sector. METS Ignited is currently developing a Sector Competitiveness Plan to enhance the competitive advantage of the Australian METS sector (METS Ignited, 2016).

- 2xEP aligns with the voluntary target that has been accepted in the USA. In June 2015 the 'Global Alliance for Energy Productivity' (GAEP) was established to extend 2xEP aspirations to India, China and Europe.

Each sector will set its own energy productivity goal that contributes to the overall national target to double energy productivity by 2030. Some sectors may be able to more than double energy productivity, while other sectors may need to increase efforts simply to maintain current levels of energy productivity.

An appropriate 2030 energy productivity target for the mining sector needs to be set in close consultation with the mining industry as part of the roadmap process and will need to reflect the rapidly changing realities of the industry. As discussed in Section 4 of this roadmap, careful consideration of appropriate metrics is required when setting a target for the mining sector. In particular, it should be noted the volatility of commodity prices will result in misleading trend data if only dollar sales value per unit of energy metrics are used to track target outcomes. Further, differentiation between targets for existing and greenfield mining operations, with higher targets for new operations, may be an option.

The mining sector has a particular set of operational challenges that will impact the setting of its energy productivity target. These challenges include: the significant variability in energy usage over the life of mining operations as, for example, ore grades decline; the difficulty in comparing the energy intensity of extracting and processing different commodities; and the difficulty in comparing different modes of mining operations represented by open-cut and underground mines. In addition, current low commodity prices are placing pressure on margins, resulting in capital and human resource constraints and reducing the ability of mining companies to investigate, evaluate and implement energy productivity initiatives.

Summary of initiatives for the mining sector

In December 2015, the COAG Energy Council (including Commonwealth, state and territory energy ministers) approved a framework for energy productivity, the National Energy Productivity Plan (NEPP), with a 40 percent energy productivity improvement target over the period 2015 – 2030. The 2xEP steering committee and mining working group congratulate COAG on this program, and see the NEPP as a valuable framework for change. We are pleased there is support from all major parties for such energy productivity initiatives, and we seek to gain long-term budget commitments from governments to ensure the rapid implementation and long-term continuity of NEPP measures.

The mining sector strives to achieve productivity improvements and energy productivity improvements are likely to be by-products of existing industry frameworks and programs. This roadmap will enhance focus on better defining, measuring and managing energy with the objective of improving energy productivity in the mining sector and promote business leadership in this area. The recommended government initiatives should be considered for incorporation in the NEPP (and by states in their policies where initiatives fall under state jurisdiction).

Listed below are the initiatives recommended by 2xEP to improve energy productivity in the mining sector. Section 7 of this document provides details of each initiative. These initiatives are not ranked in priority order.

Proposed government initiatives and policy changes to facilitate 2xEP

1. Ensure energy price structures do not impede the implementation of energy productivity initiatives.
2. Maintain the R&D tax incentive system to encourage the development and commercial application of new, more efficient mining technologies.

Joint industry/government initiatives

3. Promote awareness within mining companies of the practical benefits of participation in the 2xEP Challenge program.
4. Build business capability to scope, identify and deliver energy productivity improvements, including through collaborative innovation.
5. Develop energy productivity metrics for the mining sector – these include metrics appropriate for measurement of energy productivity at site and commodity levels.
6. Develop a data mapping pilot program to identify areas of focus for energy productivity.

Industry initiatives

7. Examine the role of industry associations in providing energy productivity-related information to businesses in the mining sector.

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1. The purpose and limitations of this roadmap

This roadmap includes industry initiatives, joint industry/government initiatives and recommended policy initiatives for government to overcome market barriers to improvements in energy productivity.

A2EP aims to ensure this roadmap integrates with broader national and state productivity, innovation, and carbon mitigation agendas. Later versions of this roadmap will more explicitly identify the points of integration with these other initiatives.

The roadmap is intended to be a living document that will evolve with developments in the market and in technology, and will take into account the level of success of initiatives implemented. Some initiatives recommended in this report can be implemented in the short term, whereas others require further investigation. Some of the initiatives are interconnected, so progress in one area will smooth the path for subsequent initiatives.

In considering this roadmap, please note the 2xEP Innovation Working Group is planning to release an innovation roadmap by September 2016 that will examine the likely impact of new and evolving technologies and new business/societal models over the next 15 years. This innovation roadmap will provide additional recommendations for initiatives to accelerate the development and transfer of technologies.

Fostering bi-partisan support for 2xEP to enable the delivery of a long term, stable policy framework for change is a key feature of the roadmap development process. Policy stability is required to encourage business investment in energy productivity, and this is particularly the case for the mining sector where much capital investment is in long-lived assets. Having a 15-year target and trajectory for change is crucial to build business confidence and drive continuous improvement.

An indicative assessment of the initiatives recommended in this roadmap indicates these initiatives are likely to be cost-benefit positive if introduced. Further work will be needed to develop a full cost-benefit analysis to support the introduction of the initiatives to both forecast their contribution towards the 2xEP 2030 targets and define the remaining gap to be addressed with supplementary initiatives. We are seeking input from industry and governments to refine this roadmap proposal and further funding to complete the analytical work.

2. Competitiveness challenges and the case for improved energy productivity in mining

Productivity improvement is a key determinant of Australia's economic growth. For nearly two decades economic productivity in many sectors of the Australian economy, including mining, has been flat or declining. Until 2011, the deterioration in Australia's economic productivity had been masked to a great extent by high commodity prices.

Australia now needs to rapidly and substantially lift its performance on key productivity metrics across all economic sectors to maintain global competitiveness and national income growth. The mining sector, including the mining equipment, technology and services (METS) industry, can play a key role as discussed below.

Focusing only on labour and capital productivity improvements however is no longer sufficient. For example, in order to counter the effects of an ageing population and falling terms of trade, growth in labour productivity would need to increase to 2.7 percent per annum – almost double the rate of the past decade – just to *maintain* historical levels of growth in per capita income (Fraser, 2015).

The productivity focus needs to be broadened to deliberately target the optimisation of other production inputs, such as energy, where potential productivity gains are not fully exploited at present. Australia's national energy productivity, as measured by the ratio of real GDP to primary energy consumption, has improved at an average rate of 1.6 percent per year from 2000-01 to 2012-13 (Department of Industry and Science, 2015). Australian gains in energy productivity have been smaller than the increases in energy productivity made in many other developed economies (Department of Industry, Innovation and Science, 2016a). If economic and energy productivity issues are not addressed, Australia's long-term competitiveness is at risk.

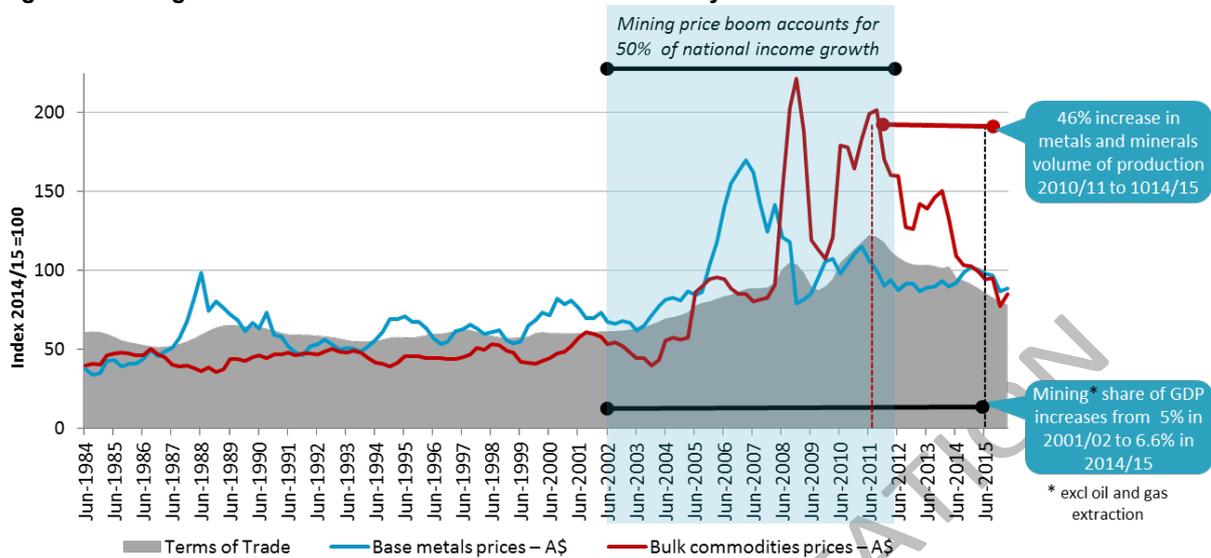
2.1. The mining sector's role in Australia's productivity challenge

The fortunes of the mining sector have a significant impact on the Australian economy – household incomes, business profits and government revenue. In fact, 50 percent of national income growth over the period 2002 to 2012 is attributable to factors associated with the commodity price boom (Gruen, 2012).

However, since 2011 Australia's terms of trade have been deteriorating, in a large part due to the decline in bulk commodity prices, to the lowest level in nearly a decade as illustrated Figure 1 (ABS 2016a,d; RBA 2016a). During the prior period of high commodity prices producers, particularly of bulk commodities, commissioned new infrastructure capacity. However due to lead times, much of this new capacity came online as prices fell, with production increasing by 46 percent in the period 2010/11 to 2014/15. Consequently, the mining sector's¹ share of Gross Domestic Product (GDP) has continued to increase to 6.6 percent in 2014/15 in spite of the prices of iron ore and coal remaining very low (ABS 2004 and 2016c; Department of Industry Science and Innovation, 2016b).

¹ excluding the oil and gas extraction industry

Figure 1: Mining sector contribution to the Australian economy²



The outlook for the Australian mining industry remains challenging, characterised by price volatility and increased uncertainty as the Chinese economy, a key driver of the commodity price boom, transitions from infrastructure investment and manufacturing to less resource intensive domestic consumption (Department of Industry, Innovation and Science, 2016b). Projections suggest prices of bulk commodities and gold will remain subdued for some time as illustrated in Table 1 (Department of Industry, Innovation and Science, 2016b; PwC, 2016).

Table 1: Medium term price projections

Spot prices (US\$/t, except Gold)	2015 Price ³	High in period to 2021	Low in period to 2021	Profit margin of Australian Mines (2014/15 or latest available)
Iron ore	49.1	64.7	45.0	27.60%
Metallurgical coal	102.1	89.5	79.8	-8.50%
Contract thermal coal	68.0	62.0	56.0	
Gold (US\$/oz)	1,160	1,185	1,003	10.50%
Copper	5,678	7,100	4,786	-9.4% ⁴
Zinc	1,933	2,398	1,705	2.3% ⁵

Mining companies have aimed to deliver value to shareholders through the current cyclical downturn by increasing production, reducing capital expenditure and containing operating costs. On aggregate across the mining sector, excluding oil and gas extraction, over the period 2011/12 to 2014/15:

- The Capex:Opex ratio has declined from 35.5 to 19 percent (ABS 2016d). Capital expenditure is projected to reduce further to nearly half the 2014/15 levels by 2016/17 (RBA 2016b).

² Base metals - aluminium, lead, copper, zinc and nickel; bulk commodities - iron ore, metallurgical and thermal coal

³ Average spot price with the exception of thermal coal which is based on Australia-Japan average contract price assessment for steaming coal with a calorific value of 6700 kcal/kg gross air dried

⁴ Profit margin applies to copper ore mining for 2013/14

⁵ Profit margin applies to silver-lead-zinc ore mining for 2013/14

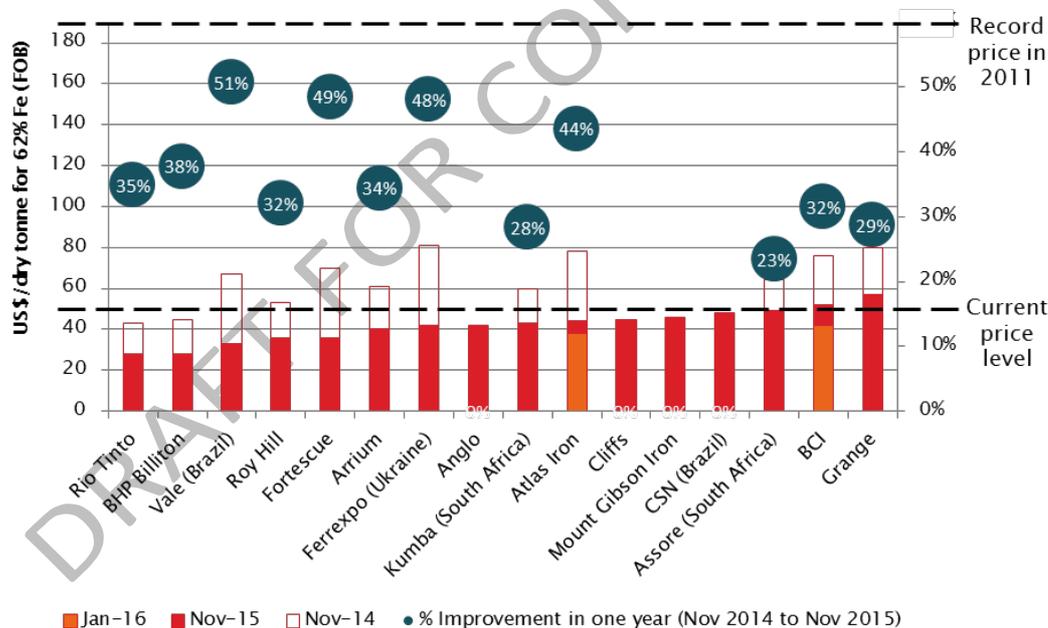
- Operating costs increased by only 0.8 percent per annum in spite of the increased production. A key factor in containing cost has been a reduction in employees of 18 percent between 2012/13 and 2014/15, as well as freight and maintenance cost. Over this time contract mining expenses grew broadly in line with production (ABS, 2016b; Department of Industry Science and Innovation, 2016b; Ingram, 2016).

However, profit margins across the sector are under pressure as indicated in Table 1. For the mining sector, excluding oil and gas extraction, operating profits have deteriorated from 34.6 percent in 2011/12 to 8 percent in 2014/15 (ABS, 2016d). Despite challenging market conditions and China’s structural transition to slower growth, the medium to long term outlook for the mining sector is positive, backed by projected increases in demand from emerging markets, especially in Asia (Department of Industry Science and Innovation, 2016b; Rio Tinto, 2015b).

2.2. Mining sector competitiveness

Many Australian mining companies have been able to adapt rapidly to the bulk commodity trading conditions, with most producers reporting a decline in the ‘break-even’ point per tonne of dry ore produced of more than 30 percent in a year (see in Figure 2). Australian majors, Rio Tinto and BHP Billiton are still the lowest cost producers, but key competitors have been able to reduce cost at a faster pace (Ferrier Hodgson, 2016; Ingram, 2016; UBS Securities, 2015).

Figure 2: Break-even point for major iron ore producers globally⁶

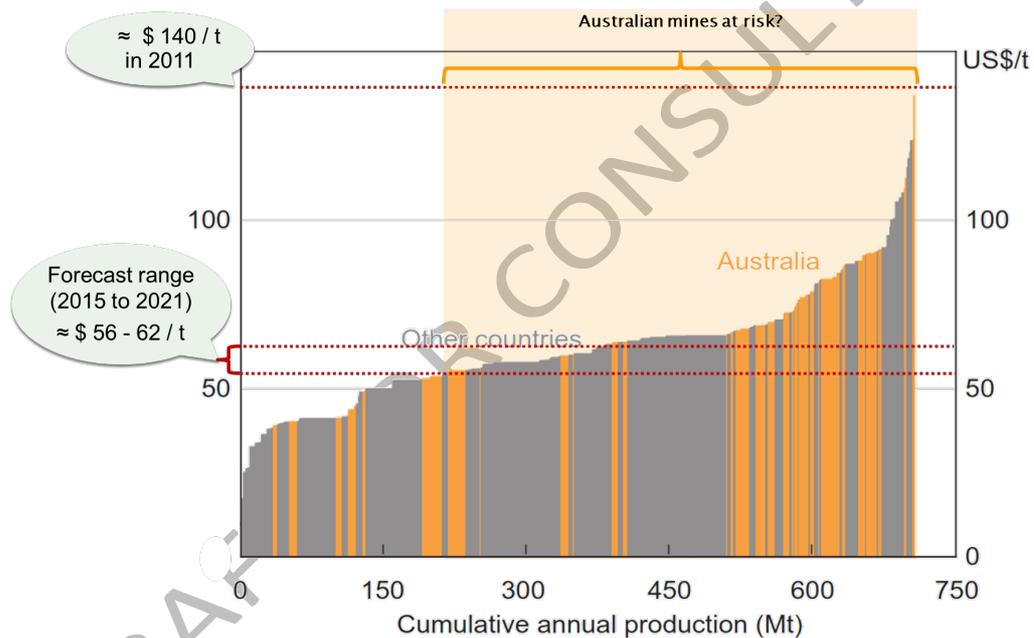


⁶ Australian diesel prices decreased by 14 percent over the period November 2014 to November 2015 (Australian Institute of Petroleum, 2016). However, due to the differences in operations, oil price movements do not impact producers to the same extent. For example, Wood Mackenzie estimated that in the 12 months to March 2015 when diesel prices dropped by 17 percent, the impact on Australian coal production cost would have been \$1.80 per tonne, compared to \$3 for Indonesian coal miners (Macdonald-Smith, 2015). Low oil prices also impact shipping costs, which could increase the competitiveness of Australia’s competitors on a CFR-basis (i.e. cost inclusive of freight), pushing them down the cost curve. As highlighted in a 2015 Bloomberg report, the drop in bunker fuel prices wiped out the price advantage of leading Australian iron ore producers over Brazil’s Vale, which could land a tonne of iron ore in China more cheaply than its Australian rivals (Riseborough & Spinetto, 2015) even though Australia is physically closer to the Asian markets and requires shorter shipping distances.

This rapid decline in iron ore producer ‘break-even’ point per tonne of dry ore has been supported by a weaker dollar and falling freight cost linked to lower oil prices. Management has limited control over these two factors, which accounted for 51 percent of the reduction in cost according to CitiBank research (Ingram, 2016). Upward pressure is therefore expected to return as analysts suggest that maintenance costs may have been cut too low to be sustainable, whilst freight cost will increase when oil prices recover from the extremely low levels. Furthermore, the continued strong supply outlook for bulk commodities, coupled with weaker short and medium term demand, is flattening the production cost curve further (Ng, 2016; PwC, 2016; UBS Securities, 2015). Consequently, the economic viability of miners on the right of Figure 2 remains under threat.

The coal industry faces a similar challenge as illustrated with reference to thermal coal in Figure 3. Unless Australian sites outside the first quartile move down the production cost curve, the negative impact on the Australian economy, rural communities and investors, could be significant (Department of Industry, Innovation and Science, 2016b; Kannan, 2015; RBA, 2014).

Figure 3: Thermal coal production cost curve and pricing (free on board basis)⁷



From mid-2011 to the end of May 2016, Australian miners also benefited from a 34 percent drop in the exchange rate relative to the US dollar. Further weakening of the Australian dollar could provide some support to marginal Australian mines. However, weakening of the Australian dollar due to an increase in the US Federal Reserve Bank rate (i.e. likely strengthening of the US dollar) will also benefit key competitor nations to varying degrees (e.g. Brazil, Ukraine, Russia and South Africa).

In addition to the economic head-winds facing the bulk commodities industry in particular, the base and precious metal industry are facing a long-term decline in ore grade. This has been

⁷ Cost curves, reproduced from the RBA, August 2014 Statement on Monetary Policy (RBA, 2014) and forecast data from Department of Industry, Innovation and Science, 2016b

one of the key drivers of the observed downward trend in Australia's mining productivity (Fisher & Schnittger, 2012). The decline in ore grade has had a direct impact on the energy intensity of production and therefore the energy productivity of the mining sector (Ballantyne & Powell, 2014). This is discussed in section 2.3.

The mining sector's response to the economic and energy productivity challenges will shape its future competitiveness and, to a large extent, that of Australia.

2.3. Mining sector energy productivity

Energy consumption at the mine site is broadly split 50-50 between mining (i.e. excavation and materials handling) and processing (i.e. ore concentration at the mine). However, the end use of energy varies between sites, depending on the commodity mined, as well as whether it is an open-cut or underground mine, on-grid or off-grid.

Typically open-cut mines use mainly diesel for materials transport, while mills are powered by diesel for off grid sites, and electricity for on grid sites. Underground mines can use limited diesel for moving people with energy use being dominated by electricity for ventilation, moving rock and processing. This electricity can be sourced from on site generation or the grid depending on the location of the site. Waste rock removal and ore excavation are the most significant energy consumers in open-cut iron ore mining, whilst comminution (blasting, crushing and grinding) is typically the largest energy user on gold and copper mines (Ballantyne, Powell & Tiang, 2012).

Energy cost in the mining sector⁸ typically represents between 10–20 percent of total operating cost (Energetics, 2014). The most recent estimate of energy spend by the mining sector⁹ (2012/13) is \$9.1 billion (ABS, 2016d).

From 2010/11 to 2012/13, the most recent period for which both energy spend and production data are available for the Australian mining sector, production output increased by 15 percent, whilst energy use increased by 13 percent. This is an improvement in the aggregate energy intensity of production. However, energy cost increased by 33 percent over the same period (ABS, 2016d). This is a near doubling of energy cost per unit of production. The unit cost of diesel to miners increased by 10 percent over this period and electricity by 36 percent (ABS, 2016). This increased unit cost of electricity may in part be attributable to lack of focus on the management of energy contracts which could result in significant peak demand charges and higher "peak" time of use rates, but also coincides with a time when many states experienced significant increases in electricity prices. Since 2012/13 many jurisdictions have experienced sharp increases in electricity costs and some, particularly Tasmania and South Australia, have experienced extensive load shedding. It should be noted that the handling and storage cost associated with diesel on remote mine sites is not reflected in these numbers.

The increase in energy consumption by bulk commodity producers would have increased further since 2012/13 in line with increased production. However, a number of other long-term trends could make it increasingly difficult to maintain current levels of energy intensity:

⁸ excluding the oil and gas extraction industry

⁹ *ibid*

- Mine sites are increasingly remote with more complex operating environments and mine geology, which drive up development and operating costs. The energy associated with the movement of people and production inputs to the sites and output to markets also drives up the cost of remote sites.
- The deterioration in base and precious metal ore grade means it is necessary to break, sort, process and move more rock before saleable concentrate leaves the mine gate. This influences key production metrics such as tonnes of material moved (TMM) as a ratio of saleable tonnes (TMM/t). As a result, ore grade has a direct impact on the energy intensity of production (Ballantyne & Powell, 2014). For mine sites experiencing a decline in ore grade, an increase in energy consumption will be necessary to just maintain output levels unless processing strategies are adapted significantly.
- Increased mine depth and overburden ratio (waste material to ore or coal production) as sites mature.
- Best resources are typically exploited first. Consequently, the quality of ore at future sites may be lower (impurities, milling characteristics), which will require finer grinding (using more energy) and/or require more complex extraction methods.

Whilst these trends could have a negative impact on the competitiveness of the Australian mining sector, most competitor nations face similar challenges. Actively driving energy productivity is an opportunity to lock in a source of long term competitive advantage.

2.4. The business case for change

Energy is a manageable cost, with demonstrable cost effective savings achievable. For example, savings in the range of 5 - 30 per cent of comminution energy use are attainable by adopting best practice (Napier-Munn, 2014). Where this best practice focus on energy management and innovation is economic, it can improve the net productivity of mines, and the profitability of marginal mines in particular. With industry profit margins, on aggregate, 8 percent in 2014/15, a net 30 percent improvement in a line item accounting for approximately 10 percent of operating cost would be equal to a 3 percent increase in profit margin (or a near 40 percent improvement in profit). Given the inherent volatility of commodity prices and the increasing trend of energy costs, a focus on energy productivity can drive sustainable cost reduction to improve the commercial viability of a mine's ore reserves and extend the economic life of the mine.

However, the rationale for investing in energy productivity goes beyond reduction in energy consumption and cost. Applying an energy productivity paradigm which takes account of the future value at risk beyond the typical three year payback horizon (Lane & Rosewall, 2015) will also influence investment decisions that positively impact capital and labour productivity – which flows through to shareholder return. This is already recognised by industry leaders who are investing in energy using infrastructure and processes with the aim to:

- Create a hedge against future price rises and mitigation of fuel supply risk. Noting that 100 percent of diesel, the main on site transport energy source and fuel source

for power generation on many remote mines, will most likely be imported in the near future (Blackburn, 2014).

- Improve the output-per-unit of labour (e.g. automation of mines and intelligent blasting have the potential to improve the energy productivity of mines if designers are 'energy smart'.)
- Manage investor expectations of management adopting rigorous cost control measures, including energy cost, especially in the prevailing commodity price market conditions. Furthermore, investors are increasingly concerned about the risk of stranded assets. In fact, climate change and the risk of stranded assets have been named as two major areas of increasing investor focus and concern in the latest global survey of institutional investors by Ernst & Young (E&Y, 2015). The Ernst & Young survey found that 63.6 percent of respondents believe companies do not adequately disclose the environmental, social and governance (ESG) risks that could affect their current business models (E&Y, 2015; Smith, 2013).
- Enhance the reliability of energy supply – particularly for diesel powered off-grid sites or electric powered fringe-of-grid-sites. The value proposition of renewable energy supply, as an alternative or complimentary source of energy is improving in line with the falling cost of renewable energy. As recently as 2013, AECOM estimated that using diesel for electricity generation cost between \$240-\$300/MWh (for diesel costs only) for larger mines and that the levelised cost of electricity (LCOE) of a medium size solar PV plant in a remote location such as the Pilbara was around \$226/MWh without grants or subsidies (AECOM, 2013). Today, the LCOE of renewables is falling below \$100/MWh (CEFC, 2016).
- Furthermore, the addition of battery storage to solar-diesel hybrid systems is making increasingly good economic sense as the price of storage is forecast to continue falling. The largest integrated off-grid solar and battery storage project in Australia was recently installed at the Sandfire Resources' DeGrussa Copper-Gold Mine in Western Australia, with the assistance of recoupable grant funding from the Australian Renewable Energy Agency and debt finance from the Clean Energy Finance Corporation (CEFC, 2016). In another case study, while upfront capital cost currently remains high, Rio Tinto is demonstrating at its Weipa bauxite mine, processing facilities and township in Queensland that this transition can be achieved without diverting capital away from critical mine operations by entering into long term power purchase agreements (Rio Tinto, 2016a).

3. Improving energy productivity in mining

Energy 'efficiency' and energy 'productivity' are frequently, but erroneously, used interchangeably. It is therefore useful to start by defining energy efficiency. Energy efficiency is the ability to deliver the same level of service or output using less energy. Energy efficiency is generally measured as end use energy consumed (typically in GJ) per unit of output (typically tonnes).

Energy productivity is a measure of the total economic value delivered from each unit of energy utilised, expressed at the national level as dollars of gross domestic product per unit of primary energy usage. Energy productivity aims to capture 'multiple dividends' that accrue from investment in more efficient plant and equipment such as reduced operating and maintenance costs, and reduced downtime. In some cases this also includes increased output or improved quality of output, but in all cases it considers the qualitative dimensions of the societal impacts of production, including the management of water, chemicals and waste.

In the 2xEP program energy productivity opportunities are divided into four strategy areas:

- Traditional energy management;
- Systems optimisation;
- Business model transformation; and
- Value creation/preservation.

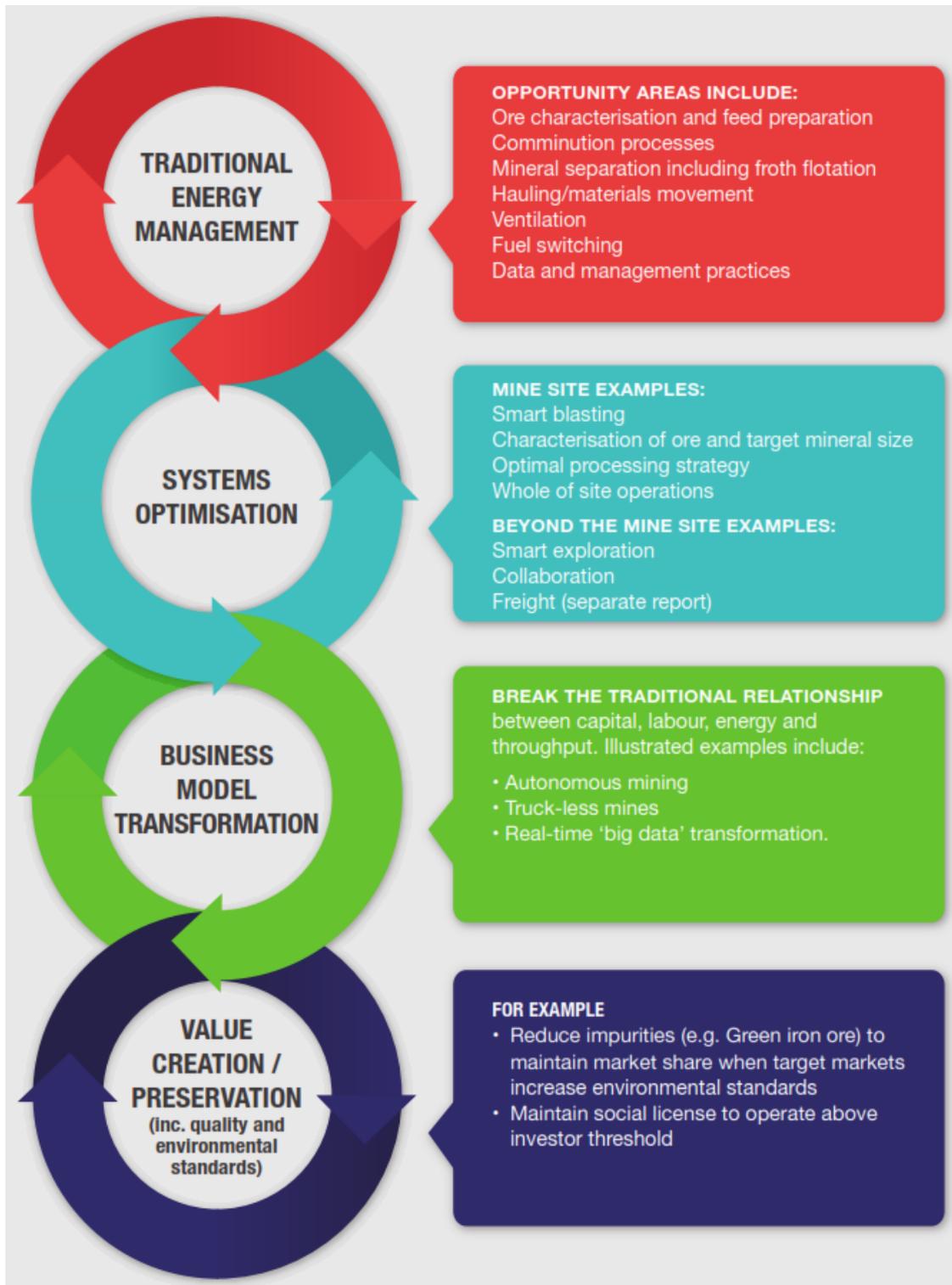
These strategy areas are represented diagrammatically in Figure 3, with examples of opportunities to improve energy productivity in the mining sector listed in the boxes to the right of each strategy area.

It should be noted that two themes run across all four strategy areas, namely *innovation*, be it technology, process or whole of business model; and *data management*, which is an increasingly central part of mining operations.

Energy productivity is not just about reducing inputs: it is also about increasing the value and quality of outputs. In some instances, this may lead to increased energy consumption, but improved energy productivity.

Increased energy productivity, and the associated improvements in other drivers of mine productivity, enhances the competitiveness of mining operations. Therefore implementing initiatives to improve mine energy productivity builds in long-term benefits such as permanent energy cost savings, boosting the economic resilience of mining operations throughout the inherently volatile commodity price cycle. An enduring benefit of energy productivity improvement may be the extension of the commercial viability of a mine's ore reserves and thus the economic life of the mine.

Figure 3: High level mining sector opportunity framework



Please refer to Section 4 of the 2xEP Mining Sector Overview, found at www.2xep.org.au/sectors/mining.html, for a detailed discussion of opportunities, including examples, to improve energy productivity in mining.

4. Energy productivity metrics for the mining sector

Energy productivity is a measure of the total economic value delivered from each unit of energy utilised. For the purpose of tracking energy productivity over time, it is necessary to develop a framework that is flexible enough to accommodate the diverse issues impacting this sector, as well as to counterbalance what is, in the short term, a volatile metric (e.g. by adopting a five-year moving average)¹⁰. It is envisaged that an integrated framework will ultimately guide the cascading of metrics from the consolidated (i.e. total sector) level down to the level of the individual mine site.

To ensure the relevance of measures at the sector, commodity and individual mine levels, this flexibility could be attained through the development of a ‘dashboard of metrics’ with three levels:

- **Primary** (sector and commodity measure as per Equation 1): This metric is intended to most closely align with a national measure of energy productivity, such as dollars of gross domestic product per unit of primary energy usage, used to set targets and compare relative energy productivity at an international level.

Equation 1: Proposed primary sector and commodity level energy productivity measure

$$\text{Primary Energy Productivity metric (mining)} = \frac{\$ \text{ Sales (Real \$)}}{\text{Units of primary energy (GJ)}}$$

- **Secondary** (sector and commodity measure as per Equation 2): This is an indicator of energy price competitiveness – i.e. the value created for each dollar spent on energy – and could assist in reflecting the relative importance of energy as the operating margin of miners fluctuates with the rise and fall of commodity prices. Also note that a further key difference between Equations 1 and 2 is that the denominator used in Equation 2 refers to delivered or final energy, whilst Equation 1 uses primary energy. Equation 2 also uses nominal, rather than real dollars.

Equation 2: Proposed secondary sector and commodity level energy productivity measure

$$\text{Secondary Energy Productivity metric (mining)} = \frac{\$ \text{ Sales}}{\$ \text{ energy cost}}$$

A2EP note there are many initiatives sites can introduce to reduce the total cost of energy without reducing the total quantity of energy consumed on site. For example, negotiating an electricity contract that suits the time based operations of a site, and ensuring equipment is operated at times when electricity is cheapest, such as only pumping water at off-peak times. Where economic, the deployment of on-site renewable energy could also play a role in driving down cost in the medium term.

¹⁰ The 2xEP Foundations Paper (Stadler et al, 2014) canvasses these issues more extensively. <http://www.2xep.org.au/2xep-foundations-the-opportunity.html>

- Tertiary** (flexible suite of measures applicable at commodity and mine-site level): A set of tertiary level index-based indicators can be developed. Index-based measures are unit insensitive and can be particularly useful at mine site level (i.e. tonnes, dollars or any other output unit that is an appropriate measure of economic value added for a commodity). Nonetheless, in some cases, simpler energy efficiency metrics may suffice. For example, a composite yield and energy use (GJ) index may be a practical and sufficient operational indicator of energy productivity at some sites. Benchmarking tools such as the CEEC Energy Curve Program and Energetics' Coal Benchmarking tool may be used to compare the performance of a mine site relative to best practice amongst an appropriate peer group and provide an early indicator of the potential for energy productivity improvements (Stadler & Boucaut, 2015).

The indices could be rolled up into a higher-level composite energy-productivity index for mining, which, in turn, could be incorporated in a national index. Appropriate methodologies will be developed as part of the 2xEP roadmap process. It is recommended a decomposition analysis of the energy productivity metrics selected be carried out in order to understand the relative strength of the drivers underlying each metric.

The proposed measurement framework for the mining sector is illustrated in Figure 4.

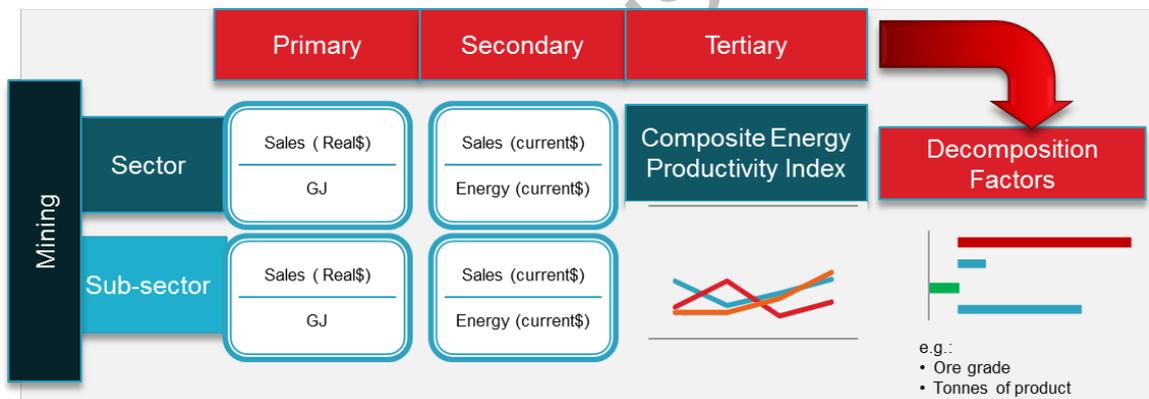


Figure 4: Conceptual overview of an integrated measurement framework for mining

For a detailed examination of energy productivity metrics applicable to the mining sector, please refer to Section 3 of the 2xEP Mining Sector Overview found on the 2xEP website:

www.2xep.org.au/sectors/mining.html.

5. Barriers to improving energy productivity

The Australian mining sector has advanced capabilities in mining technology innovation with the National Energy Resources Australia (NERA) established to deliver the activities of the Oil, Gas and Energy Resources Growth Centre. In addition, the mining equipment, technology and services (METS) subsector has been identified as one of the five Australian Industry Growth Centres. However, there are significant indications that the widespread adoption of proven technologies has not occurred and unexploited opportunities to improve energy productivity exist in the Australian mining sector. As an example, more extensive implementation of energy management best practice and increased accountability for energy management could result in significant improvements in energy productivity in the sector.

As a consequence of the current soft commodity prices, many mining companies are resource constrained as they seek to minimise costs and adapt to a lower profitability environment. Given pressures on profitability, it is imperative that barriers to the adoption of new technologies and implementation of energy management best practice are identified and overcome. Initiatives to improve energy productivity should aim to maintain and improve the competitiveness of the Australian mining sector.

Major barriers to improving energy productivity in the mining sector are briefly outlined below. A more detailed discussion of barriers to energy productivity in the mining sector is contained in Section 5 of the 2xEP Mining Sector Overview, found at www.2xep.org.au/sectors/mining.html.

5.1. Benefits of energy projects pursued in isolation are perceived as lacking materiality

Mining companies have significantly reduced capital spend in the wake of the mining downturn (PwC, 2016). This has resulted in intense competition for internal capital, with core operational projects being prioritised over other projects, such as energy productivity initiatives.

Falling commodity prices and declining margins highlight the importance of managing energy costs, particularly for marginal mines. However, potential investments in energy projects are often considered in isolation, ignoring the flow on benefits for the site as a whole. Consequently the benefits that accrue from an individual energy project may not be considered material enough to warrant management attention.

This incremental approach to assessing potential investments in energy projects is in contrast to a strategic systems approach, which takes into account the flow through benefits of energy projects across an entire mine site. Ideally each project should constitute an element of a systematically implemented energy master plan involving a number of integrated energy projects across a site.

5.2. Short payback threshold for investments

In response to the current low commodity price environment many mining companies have ramped up production, reduced capital spend and minimised operating costs where possible in order to maintain a level of profitability. This short-term orientation places pressure on return on investment (ROI) cycles. Consequently energy productivity strategies that require longer ROI periods may not meet investment thresholds.

The Net Present Value (NPV) method is commonly used to assess potential energy projects. NPV analyses discount the future energy cost savings that result from up-front energy productivity investments. It may be helpful to include alternative methods, such as real options analysis, in energy project evaluation processes, or reduce the extent to which future savings are discounted in the NPV calculation. Taking a longer-term 'value at risk' perspective of energy costs would also be useful.

5.3. Management practices and internal barriers

Innovation will become increasingly important to the mining industry's efforts to improve productivity, including energy productivity, and adapt to changing market conditions. However, the industry tends to display a cautious approach to investment in innovation, as revealed in the *2014 Mining Innovation State of Play Survey* (VCI, 2014). Of the large mining company survey participants, 75 percent described themselves as conservative or fast followers in their approach to technology-based innovation. The corresponding figure for small mining companies was even higher, at 81 percent. Only 25 and 19 percent of large and small mining companies respectively described themselves as having a leading approach to adopting technology-based innovation.

Capital investment in the mining industry is often in long lived assets, possibly explaining the risk averse approach to innovation investment common in the industry. In addition, a lack of systems knowledge in the face of increasing systems complexity provides little incentive to be an early adopter, with the gap between project owners and engineers on one side and technology developers on the other hindering innovative technology transfer (Napier-Munn, 2014).

The prolonged investment phase may have impacted the way mining businesses operate, creating a focus on maximising throughput. Consequently, practices in some organisations may not be focused on maximising efficiency. It should be noted that significant improvements in energy productivity may be made by implementing energy management best practice.

Energy is a system that is pervasive across all functions of an organisation. Some mining companies have 'silo structures', with weak accountability for energy efficiency across functions, leading to sub-optimisation of energy productivity opportunities. Those responsible for making decisions about energy productivity at a corporate level may be unaware that a few simple changes to existing processes can have a significant impact on energy productivity, and those at the operations level capable of implementing these changes may be unaware of the impact on the overall value chain.

5.4. Split incentives for energy efficient site development and operations

Unless energy is a key consideration in contracts with mine designers, developers and operators, the long-term energy profile of mines can be adversely impacted and energy cost become a driver of operating expense. A guide produced by the Department of Industry, Innovation and Science (Smith & Stasinopoulos, 2014) illustrates this point by means of an example in which a mine owns and operates the mills, but contracts out the extraction and transport of ore bodies from mine-to-mill on a \$/tonne basis. This KPI in itself does not consider the energy cost associated with crushing and grinding rocks into smaller particle sizes. Spending more on smart blasting to break up ore bodies into smaller particle sizes could save much more energy (and cost) in the crushing and grinding phase of mineral processing.

5.5. Availability of relevant information

'Silo' structures, as discussed above, limit the cross-pollination of ideas, shared insights and understanding of 'the whole picture'. Silos may result from different reporting structures and processes evolving for different business units within a single organisation. Implementation of integrated, site-wide systems can provide opportunities for cross-disciplinary reporting and therefore collaboration which can assist in removing silos.

At an energy-specific level, tracking of energy consumption using metering and sub-metering equipment is required to understand and improve energy productivity performance. Unless companies use more detailed energy tracking systems on an enterprise-wide basis, the true energy cost of different aspects of operations will be difficult to determine. Sub-metering of energy consumption on site is not a common practice and the lack of detailed energy consumption data is an impediment to building robust business cases to justify investment in energy productivity projects.

As noted throughout this document, the market downturn and consequent cuts in staffing levels have created human resource shortages and a narrow focus on core operational issues in many mining companies. This situation limits the ability of mining companies to investigate, evaluate, implement and monitor energy productivity initiatives. However, on the other side of the coin, implementation of energy productivity initiatives can reduce operating costs, increase operating margins and increase the resilience of companies during periods of market downturn.

6. Initiatives proposed to improve energy productivity in the mining sector

The National Energy Productivity Plan (NEPP) was launched in December 2015. The NEPP has a modest target for energy productivity improvement of 40 per cent improvement by 2030 from the 2015 base and included reference to several recommendations put forward by 2xEP in November 2015 (see www.2xep.org.au – 2xEP and the National Energy Productivity Plan). However, we believe that further support and guidance is required to enable the mining sector to optimise energy productivity.

The following section sets out a range of program and policy recommendations developed with the objective of driving increased energy productivity in the mining sector. The recommendations require business leadership in this area supported by consistent long term bi-partisan government policy support. Policy stability is required to encourage business investment in energy productivity initiatives; this is particularly the case for the mining sector where a high proportion of capital investment is in long lived assets.

The principles below were used to guide the formulation of the proposed recommendations:

- Action is targeted where there are market failures and/or a demonstrated need to accelerate energy productivity improvement to improve our competitive position; a pragmatic approach should be taken to select the best initiative to address the specific market barrier, with no type of initiative excluded in principle.
- An integrated package of initiatives is required to deliver sustainable change, with the imperative that all elements of the integrated package be put in place.
- National harmonisation of government policies and programs to the greatest extent possible.
- Regulation is proposed where it is demonstrably cost effective and supported by business.
- Initiatives have a strong linkage to the National Innovation and Science Agenda.
- A solid fact base is used to support a cost-benefit analysis.
- Detailed stakeholder consultation occurs before implementation.
- Business and government work towards achieving Australia's commitments under the Paris Climate Agreement while maintaining and increasing Australia's prosperity. Doubling energy productivity across the economy as a whole would deliver over 60 percent of the reduction required to meet Australia's current 2030 target.

7. Policy and program recommendations

Listed below are the initiatives recommended by 2xEP to improve energy productivity in the mining sector. Details of each initiative are tabulated in subsequent pages of this section. These initiatives are not ranked in priority order.

Summary of recommendations

Proposed government initiatives and policy changes to facilitate 2xEP	
1.	Ensure energy price structures do not impede the implementation of energy productivity initiatives
2.	Maintain the R&D tax incentive system to encourage the development and commercial application of new, more efficient mining technologies
Joint industry/government initiatives	
3.	Promote awareness within mining companies of the practical benefits of participation in the 2xEP Challenge program
4.	Build business capability to scope, identify and deliver energy productivity improvements, including through collaborative innovation
5.	Develop energy productivity metrics for the mining sector
6.	Develop a data mapping pilot program to identify areas of focus for energy productivity
Industry initiatives	
7.	Examine the role of industry associations in providing energy productivity-related information to businesses in the mining sector

Key to recommendations

	Ready to go
	To be trialled now
	Needs further investigation

High-level benefits/costs analysis – Energy productivity improvement

A2EP has conducted a high level qualitative assessment of costs and benefits for each of the proposed initiatives. The analysis also includes reference to other assessments previously conducted where relevant and applicable. A more robust approach is required for assessing the initiatives prior to implementation. An overview of the potential costs and benefits of improving energy productivity in all sectors of the economy is set out below.

Summary of potential benefits

Boosting productivity and competitiveness	Likely to result in improved output and a reduction in energy intensity as well as reduced costs and improved competitiveness
Improving company value and brand	High performance companies are more profitable, attract investment and customers, attract and retain staff
Reduced government outlays	Once implemented a reduced number of government staff required to administer the initiative. Additional savings are also achieved through a reduction in infrastructure and on-costs.
Reduced company resources	Reduced company resources required to access support and assistance as a result of streamlined and consistent processes
Red tape reduction (by industry)	Consistent and streamlined processes resulting in reduced regulatory burden
Improved investment certainty	Potential for increased investment as a result of increased certainty about the policy and regulatory environment and in the performance of plant and equipment
Contributing towards Australia's emissions reduction	Assisting Australia meet its emissions reduction goals through improved energy productivity
Reducing the cost of energy	Potential to reduce the amount of company expenditure on energy
Protecting energy security	Potential to reduce reliance on imported liquid fuels, particularly diesel

Summary of potential costs

Additional government outlays	Additional staff may be required to develop, administer or deliver the initiative taking into account additional salaries, infrastructure (i.e. office space and equipment) and on-costs.
Increased company resources	Increased company resources required to access support and assistance
Increased energy prices	Potential to increase energy prices. For example a nationally consistent white certificate scheme might increase retail energy prices in jurisdictions that currently don't have schemes.
Increased red tape	The potential for increased government involvement leading to delays in development and implementation
Government funding/support	Financial costs associated with providing either direct or indirect funding, incentives and support

Benefits of improving energy productivity in mining

Each of the initiatives tabulated in the following pages of this section include a list of costs and benefits associated with that specific initiative. All initiatives aim to improve energy productivity in the Australian mining sector. The following is a list of overall benefits associated with improving energy productivity, and as such are applicable to all initiatives included in this document, in addition to the benefits specific to each initiative:

- Reduced cost of energy – energy productivity initiatives often result in reduced expenditure on energy per unit of production.
- Improved energy security – energy productivity initiatives may result in reduced reliance on imported liquid fuels, particularly diesel.
- Contribution towards Australia's emissions reduction – energy productivity initiatives often result in reduced emissions.
- Improved productivity and competitiveness – improved energy productivity will enhance the economic productivity of businesses that institute energy productivity initiatives and hence improve their competitiveness.
- Improved company value – improved energy productivity can reduce operating costs and increase operating profit. Improving energy productivity may be positively perceived as demonstrating a cost-conscious and efficient organisational culture. If carbon emissions are reduced as a result of energy productivity initiatives, the social licence to operate of the business may also be improved.

Industry examples of the benefits of improving energy productivity in mining

A2EP strongly encourages organisations operating in the mining sector to review the mining roadmap; assess the relative benefits and costs of the recommended initiatives to their business; and implement all cost-effective initiatives. These initiatives provide an impetus for organisations in the mining sector to view their operations through an energy lens. The following case studies illustrate the benefits of taking an energy-focused perspective in the mining sector:

- Rio Tinto iron ore – optimising the rail network yielded significant fuel savings for Pilbara iron ore operations. For example, an initiative involving turning off one of three loaded locomotives and using the locomotive auto engine stop start feature resulted in savings of three million litres of diesel and approximately eight thousand tonnes of carbon dioxide equivalent during 2014. (Rio Tinto, 2016)
- Barrick Gold Corporation – ore grinding accounts for a significant proportion of Barrick's total energy consumption and energy costs. Innovative methods of evaluating and improving the performance of grinding mills in several operations around the world has allowed Barrick to reduce energy consumption related to ore grinding. Net energy improvements of more than 20 percent have been achieved in some mines, and an annual reduction in emissions of more than 43 thousand tonnes

in carbon dioxide equivalent was achieved in three operations where initiatives were implemented. (Buckingham, Dupont, Stieger, Blain & Brits, 2011)

- Xstrata Mount Isa Mines copper – investing in waste heat recovery allowed the conversion of water heat into steam at a copper smelter, resulting in production of 77 thousand MWh of zero emissions electricity in 2009, thereby avoiding consumption of 1.15 petajoules of natural gas. (Queensland Resources Council, 2009)

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Category: Government initiative (Commonwealth and states)	
7.1. Ensure energy price structures do not impede the implementation of energy productivity initiatives	
Overview	<p>Elements of electricity network tariff restructuring by supply utilities and a growing tendency of suppliers to achieve income stability by increasing fixed charges have reduced customer incentives to improve energy productivity. Greater productivity in customer use of the network should also help defer expensive network investment.</p> <p>2xEP recommends the Commonwealth, in conjunction with the Australian Energy Regulator, does not allow network tariff structures that unnecessarily inhibit the ability of users to reduce their energy bills by improving their energy productivity (e.g. high fixed charges as a proportion of total costs).</p> <p>Governments and the Australian Energy Regulator should also ensure that appropriate information and advice are readily available ahead of significant tariff structure changes to encourage consumers to respond to cost reflective price signals.</p>
Current barriers to doubling energy productivity	<ul style="list-style-type: none"> • Availability of relevant information • Split incentives for energy efficiency/productivity
How the approach will address the current barriers	<ul style="list-style-type: none"> • Provide a market mechanism for companies to invest in energy efficiency/ energy productivity
Factors to consider	<ul style="list-style-type: none"> • Role of the Australian Energy Regulator and existing network rules • Ensure reasonable costs and timeframes are applicable to connecting renewable energy and storage systems to the network. • Network service providers should be obliged to invest in measures that reduce demand when it is cheaper than investing in supply side measures.
Cost/benefit	<p>Costs:</p> <ul style="list-style-type: none"> • Increased red tape – increase in regulation of energy suppliers. <p>Benefits:</p> <ul style="list-style-type: none"> • General benefits of improving energy productivity, as listed in the introduction to section 7. • Remove barriers related to energy pricing structures that impede uptake

	of energy productivity initiatives.
Relationship with NEPP (COAG 2015)	NEPP measure 1: Transition to cost-reflective pricing NEPP measure 26: New market mechanisms for demand response
Linkage to other relevant programs	

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Category: Government initiative (Commonwealth)	
7.2. Maintain the R&D tax incentive system to encourage the development and commercial application of new, more efficient mining technologies	
Overview	<p>The R&D tax incentive is an effective, economy-wide, market-driven measure that should be maintained in its current form. A stable policy framework will encourage future additional investment in R&D and innovation.</p> <ul style="list-style-type: none"> • The R&D tax incentive is an effective means of encouraging additional business R&D expenditure in Australia. As a market driven measure, the R&D tax incentive is efficient in that only innovating firms will seek to gain access to it. It does not involve governments ‘picking winners’. • The R&D tax incentive also encourages collaborations – both within industry and between industry and researchers. • There have been a large number of changes and mooted change to the incentive in recent years. It is important that Australian businesses now be afforded a stable policy framework in this area to encourage future additional investment in R&D and innovation. • Increasing the ability of the mining industry to access these rebates has the potential to enhance their innovation and address the “fast follower” approach.
Current barriers to doubling energy productivity	<ul style="list-style-type: none"> • Short payback thresholds for investments
How the approach will address the current barriers	<ul style="list-style-type: none"> • Reduce the risk of investing in new mining technologies which lead to improved energy productivity
Factors to consider	<ul style="list-style-type: none"> • Policy stability is essential to attract investment in mining R&D.
Cost/benefit	<p>Costs:</p> <ul style="list-style-type: none"> • Additional government outlays – time of government staff involved in reversing action to make changes to the R&D tax incentive system. <p>Benefits:</p> <ul style="list-style-type: none"> • General benefits of improving energy productivity, as listed in the introduction to section 7. • Improved investment certainty – policy uncertainty regarding the R&D tax incentive system may lead to companies becoming more risk averse

	<p>towards investment in R&D and innovation.</p> <ul style="list-style-type: none"> • Reduced company resources – maintaining the current R&D tax incentive system will avoid the need for mining company staff and service providers to learn changes in the rules of the R&D tax incentive system.
Relationship with NEPP (COAG 2015)	NEPP measure 13: Support innovation and commercialisation
Linkage to other relevant programs	<ul style="list-style-type: none"> • R & D Tax Incentives • Entrepreneurs' Program – Australian government support to business through three elements: <ol style="list-style-type: none"> 1. Accelerating Commercialisation – helps small and medium businesses, entrepreneurs and researchers to commercialise novel products, services and processes 2. Business Management – experienced Business Advisers and Facilitators review business operations, including business direction, strategy, growth opportunities and supply chain 3. Innovation Connections – experienced Innovation Facilitators work with businesses to identify knowledge gaps that are preventing business growth

Category: Joint industry and government initiative	
7.3. Promote awareness within mining companies of the practical benefits of participation in the 2xEP Challenge program	
Overview	<p>2xEP recommends:</p> <p>Establishing a voluntary business program that supports leadership and commitment to improving energy productivity in business and supply chains.</p> <p>The concept of the program:</p> <ul style="list-style-type: none"> • Leadership program to light the way for other companies • Memorandum of Understanding (MoU) between CEO/senior executive and Challenge administrators • Commitment to Challenge leads to recognition and support • Aligns with other voluntary programs including international programs e.g. Energy Productivity 100¹¹ and state and territory energy efficiency programs • Participating companies report annually against their milestones, commercially sensitive information will not be published • Entirely voluntary program • The proposed program will initially focus on larger companies
Current barriers to doubling energy productivity	<ul style="list-style-type: none"> • Availability of relevant information • Management practices and internal barriers • Benefits of energy projects pursued in isolation are perceived as lacking materiality
How the approach will address the current barriers	<ul style="list-style-type: none"> • By providing a leadership program to demonstrate and celebrate energy productivity gains by the pilot companies and encourage other companies to obtain senior management commitment to continuous improvement in energy productivity. The Challenge aims to increase awareness of best practice and a strategic systems approach to energy productivity (as opposed to implementation of isolated projects).
Factors to consider	<ul style="list-style-type: none"> • Investment largely from industry • Government funding commitment to develop and implement program elements particularly relating to recognition, capacity building, and case study development and promotion is also essential for success • Stakeholder support, particularly the potential to involve the investor community and align elements with their changing expectations in this space. This may raise the profile of the initiative and highlight the broader benefits of participation.

¹¹ <http://www.theclimategroup.org/what-we-do/programs/ep100/>

	<ul style="list-style-type: none"> • Company uptake and acceptance by senior management
Cost/benefit	<p>Costs:</p> <ul style="list-style-type: none"> • Additional government outlays i.e. government resources to administer the program should cost less than \$5,000/participant/year. • Government funding/support – budgeted at a cost per participant of \$14-17,000/year. • Increased company resources i.e. company resources required to access support and assistance. <p>Benefits:</p> <ul style="list-style-type: none"> • General benefits of improving energy productivity, as listed in the introduction to section 7. • Development of a formal, credible program with public recognition will provide a clear framework for senior management to measure branding and related benefits as well as the direct energy productivity improvement incentives. • Provide case studies to demonstrate of successful implementation of energy projects. • Raise awareness of best practice and a systems approach to energy productivity. • Potential for linkages to other international programs over time (e.g. Energy Productivity 100). <p>The following provides examples of past programs with parallels to the Challenge program as an indicator of likely costs and benefits of the Challenge program:</p> <ul style="list-style-type: none"> ▪ The results of the very similar SEDA program identified savings of 3.1 PJ (3.5 PJ program target from 25 PJ coverage) had resulted in 0.667 PJ of implementation. The cost of the program to the NSW government was about \$30 million over 10 years or about \$15,000/participant/year, and the benefit/cost ratio for the program would have been well over 5 based on participant savings/government investment. • While this program is voluntary and EEO reporting was mandated, the evaluation of the first full cycle EEO program conducted by consultants ACIL Tasman in 2013 found that the ‘additional’ improvement in energy efficiency attributable to the EEO program was approximately 40 percent of the energy efficiency improvements in the Australian industrial sector, with energy savings (88.8 PJ) and net financial benefits (\$808 million per year) reported from opportunities to be implemented. The cost to the government per customer was approximately \$15,000/customer.
Relationship with NEPP	NEPP measure 7: Recognise business leadership and support voluntary action in business

(COAG 2015)	NEPP measure 17: Promote leading practice
Linkage to other relevant programs	<ul style="list-style-type: none"> • State and territory energy efficiency programs • Energy Productivity 100 international energy productivity program

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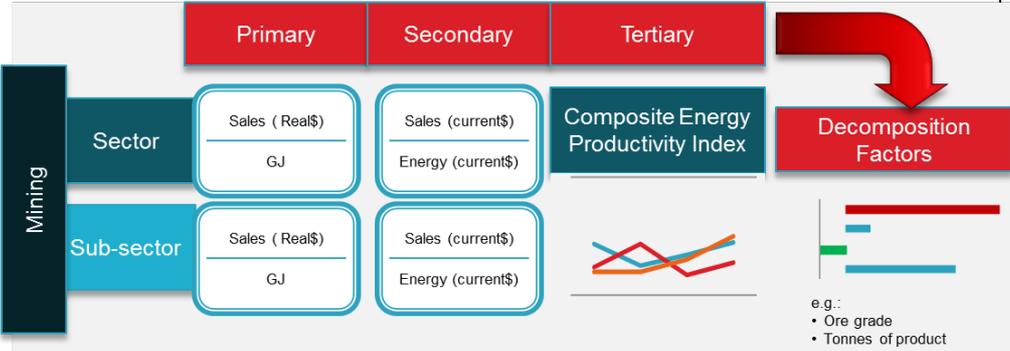
Category: Joint industry and government initiative	
7.4. Build business capability to scope, identify and deliver energy productivity improvements, including through collaborative innovation	
Overview	<p>Energy productivity first and foremost must come from corporate and mine-site leadership, reinforced by an organisational culture of continuous development of competence and excellence in execution. Energy productivity is a cross-functional metric and accountabilities must be assigned accordingly.</p> <p>This initiative supports building internal business capability to understand, develop, implement, measure and verify energy productivity opportunities.</p> <p>Many energy productivity-related training resources are currently available but are not fully utilised. Repackaging of existing resources or tailoring of general productivity training to emphasise energy productivity issues could improve energy productivity capability. For example, the LEAN Six Sigma program in place on many mine sites could be enhanced to emphasis energy productivity.</p> <p>Where appropriate, investment in research and development through collaborative innovation should be encouraged. Government funding, e.g. ARENA grant funding for demonstration of next generation mining technology, could be utilised to accelerate investment in R&D.</p> <p>2xEP recommends the Commonwealth fund the development where applicable (a good deal of this course material already exists), and to 50 per cent fund the cost to business of attending short course training that covers the different functions and steps within energy productivity including, but not limited to:</p> <ul style="list-style-type: none"> • Link between energy productivity, plant performance, reliability and mine life • Certified energy manager training (CEM) • Continuous improvement and productivity including ISO50001 • Building the business case – training for engineers and commercial managers including procurement managers on business benefits of energy productivity • Energy productivity scanning for managers – focus on how to improve overall mine productivity with an energy focus • Training of trades and engineering management on improving energy productivity through improved maintenance and understanding impact of plant specification. <p>Training aims to link into existing educational institutions including universities, TAFE institutes and other registered training organisations, as well as engaging relevant industry skills councils.</p>
Current	<ul style="list-style-type: none"> • Availability of relevant information

barriers to doubling energy productivity	<ul style="list-style-type: none"> • Management practices and internal barriers • Short payback thresholds for investments
How the approach will address the current barriers	<ul style="list-style-type: none"> • Provide the necessary skills to help companies identify and implement energy productivity initiatives and overcome skills and information barriers across all levels of the organisation. • Participating in collaborative innovation initiatives will assist businesses in the mining sector access information and expertise not otherwise available to them, and spread the risk of R&D expenditure.
Factors to consider	<ul style="list-style-type: none"> • Cost and time required to develop accredited training • Ensure training content provided is appropriate to an individual's role in the value chain e.g. operators who may be making changes; operations managers who need to support changes; business improvement managers who will be recommending changes; and C-suite executives and managers who will need to drive change. • Ensure knowledge is shared and linked, and funding does not duplicate existing programs. • Linkage with existing innovation and knowledge hubs around the country and the globe. • Mechanisms through which business, industry and research institutions can collaborate on innovative solutions can also provide a platform for information sharing and capacity building.
Cost/benefit	<p>Costs:</p> <ul style="list-style-type: none"> • Government funding/support – an estimate of the cost of preparing/updating short course materials would be less than \$200,000, as most of the materials already exist. The cost of attending a short course would be in the order of \$5,000 if delivered by a commercial organisation. Based on a 50 percent subsidy, the cost to the government for say 1,000 participants /year, would be \$2.5 million/year. • Increased company resources – companies would pay the unsubsidised 50 percent of short course fees. Participation in short courses will also result in staff unavailability for the duration of the course (say approximately 5-7 days). <p>Companies may also incur costs by participation in collaborative innovation ventures. This may be by way of financial and/or human resource contributions.</p> <p>Benefits:</p> <ul style="list-style-type: none"> • General benefits of improving energy productivity, as listed in the introduction to section 7. • Increase business capability to identify and implement energy

	<p>productivity initiatives.</p> <ul style="list-style-type: none"> • Improved investment certainty – by participating in collaborative innovation ventures, mining companies can reduce their exposure to the risk of investing in R&D. • Leverage existing domestic and international innovation and knowledge hubs. • Identification and highlighting of examples of good practice. Many examples of collaborative innovation already exist, however the information is not widely disseminated.
<p>Relationship with NEPP (COAG 2015)</p>	<p>NEPP measure 6: Help business self-manage energy costs NEPP measure 7: Recognise business leadership and support voluntary action in business NEPP measure 13: Support innovation and commercialisation NEPP measure 17: Promote leading practice NEPP measure 18: Collaborate internationally NEPP measure 25: Build service provider capacity</p>
<p>Linkage to other relevant programs</p>	<ul style="list-style-type: none"> • JKTech, the technology transfer company for the Sustainable Minerals Institute (SMI) at the University of Queensland, offers a range of courses and training on plant optimisation and sustainable productivity.¹² • Sustainable Minerals Institute – Centre for Social Responsibility in Mining (CSRMI) provides tailored training on social aspects and impacts of extractives and energy projects. The training is designed to suit a range of groups, from frontline community relations practitioners to community representatives, government officials and regulators, journalists as well as industry executives. Short courses and master classes are designed to build capacity across the industry and up-skill external stakeholders to engage with industry in a productive way. • Australian TAFE Certificate IV qualification Automation Technician, developed in response to the rapid adoption of automated mining practices. This course targets electrical workers wishing to up-skill in instrumentation, digital technology, process control, SCADA and human machine interface (HMI) in automated industrial applications (CRCMining, 2014) • METS Ignited is the not-for-profit company responsible for delivering the activities of the Mining Equipment, Technology and Services Growth Centre. It is working to improve collaboration between businesses in the sector with a view to strengthening the competitive advantage of the Australian METS sectors nationally and globally. • NSW Government supported industry-led Innovation Hubs such as the NSW Energy Innovation Knowledge Hub, based at Newcastle Institute

¹² http://www.minemanagers.com.au/sb_cache/associationnews/id/17/f/mirm

	<p>for Energy and Resources (NIER).</p> <ul style="list-style-type: none"> • CSIRO Mining strategic research into technologies that maximise the long term value of resources. • ARENA/Clean Energy Innovation Fund, • CEEC, the Coalition for Energy Efficient Comminution, was established and is supported by a broad range of mining sector companies keen to accelerate awareness, knowledge transfer, and improve energy and cost outcomes in comminution. CEEC offers workshops and can also provide recommendations on relevant training courses for industry practitioners. • Entrepreneurs' Program – Australian government support to business through three elements: <ul style="list-style-type: none"> ○ Accelerating Commercialisation – helps small and medium businesses, entrepreneurs and researchers to commercialise novel products, services and processes. ○ Business Management – experienced Business Advisers and Facilitators review business operations, including business direction, strategy, growth opportunities and supply chain. ○ Innovation Connections – experienced Innovation Facilitators work with businesses to identify knowledge gaps that are preventing business growth.
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Category: Joint industry and government initiative	
7.5. Develop energy productivity metrics for the mining sector	
Overview	<p>Develop appropriate metrics for site, commodity and sector levels utilising the conceptual integrated measurement framework (see figure below).</p> 
Current barriers to doubling energy productivity	<ul style="list-style-type: none"> • Availability of relevant information • Management practices and internal barriers
How the approach will address the current barriers	<ul style="list-style-type: none"> • Provide business management, the industry as a whole and government with information to measure trends in energy productivity and to drive improvements in energy productivity.
Factors to consider	<ul style="list-style-type: none"> • Sensitivity to commodity and energy price movements including consideration of the changing value of the Australian dollar. • Utilisation of moving average metrics over at least 5 years • Review metrics currently in use • Consult with industry regarding most appropriate metrics for different commodities, types of mining operations and life stages of mines. Consider ability to normalise metrics for factors impacting energy productivity such as grade, mine depth and complexity of ore body.
Cost/benefit	<p>Costs:</p> <ul style="list-style-type: none"> • Increased company resources – human resources involved in development of metrics. • Government outlays – time of Department of Industry, Science and Innovation staff involved in development of metrics. • Work conducted by commodities on emissions intensive and trade exposed activity under Clean Energy Regulations would suggest a cost of \$200,000 to \$500,000 per commodity; this excludes costs to industry of people taking part in workshops and cost of making information available for analysis. <p>Benefits:</p> <ul style="list-style-type: none"> • General benefits of improving energy productivity, as listed in the introduction

	<p>to section 7.</p> <ul style="list-style-type: none"> • Developing robust metrics will lay the critical groundwork for measurement and improvement of energy productivity across the sector. This is particularly important for the mining industry due to the range of factors that affect the energy profile of different mine types in different ways. • Collation and analysis of effective metrics will provide valuable information and overarching context to justify energy projects that contribute to facility-wide energy productivity programs.
Relationship with NEPP (COAG 2015)	NEPP measure 8: Research business benchmarks and success factors
Linkage to other relevant programs	<ul style="list-style-type: none"> • CEEC Energy Curve program • Energetics' Coal Benchmarking tool

Category: Joint industry and government initiative	
7.6. Develop a data mapping pilot program to identify areas of focus for energy productivity	
Overview	<p>More accurate tracking of data through improved metering of energy use is necessary to understand and improve energy productivity performance, and to justify investment in energy saving projects. For example, tracking of diesel consumption has great potential to provide companies with data that can be utilised to drive energy productivity improvements in diesel usage.</p> <p>Currently energy data collection processes are only scrutinised at the facility level (and in some cases down to broad end-use categories only) for National Greenhouse and Energy Reporting (NGER) compliance requirements, which can be met by reconciling overall purchased fuel records. Tracking fuel and energy consumption to individual sections of a mine site’s operations or to individual pieces of equipment is done in a variety of ways for a variety of purposes, without necessarily a strong focus on granularity or a high level of accuracy.</p> <p>Industry and government support for initiatives to drive common communications and data exchange protocols and standards will become increasingly important to ensure that the benefits of ‘big data’ are available to miners of all sizes in the years to come, e.g. use in autonomous trucks.</p> <p>2xEP recommends the development of a data mapping pilot program to identify areas of focus for energy productivity. The pilot program would comprise of a data ‘mapping’ exercise across several representative mine sites (or potentially sub-sections of mine sites) to identify where current energy data collection processes are most effective, and where they are least effective. The intent would be to identify high priority opportunities on a ‘typical’ mine site to invest in improved energy data collection. High priority opportunities would be those where improved data would directly result in improved decision-making capabilities for management to identify, assess and execute optimal energy productivity projects or operational activities for the site.</p> <p>These data mapping case studies would be documented and successful examples used to build the business case for investment. A guiding principal for the pilot program will be acquiring information to support decision making, as opposed to gathering information for the sake of gathering information.</p>
Current barriers to doubling energy productivity	<ul style="list-style-type: none"> • Availability of relevant information – lack of information is a key barrier to quantification of energy use and potential savings, which can be used to justify investment in energy productivity projects.
How the approach will address the	<ul style="list-style-type: none"> • Data is the foundation for automation and other initiatives with energy productivity benefits on mine sites. • Provide companies with information to assist them develop robust business

current barriers	cases and drive investment in energy productivity monitoring and reporting.
Factors to consider	<ul style="list-style-type: none"> • Budgetary requirements • Human resource availability • Safety as a constraint on some technologies, particularly underground installations • Confidentiality of company data. Pilot program would focus on flow of information, as opposed to collection of numerical data.
Cost/benefit	<p>Costs:</p> <ul style="list-style-type: none"> • Government outlays – development, implementation and assessment the pilot program. • Company resources related to participation in the pilot program. • Cost of the data mapping exercise may be between approximately \$1 million and \$2 million to start, noting cost would be a strong function of the project brief. • Typical project costs are in the region of \$1 million to \$5 million to install site-wide metering and monitoring; though can be as little as \$20,000 to install a single meter on one piece of kit. <p>Benefits:</p> <ul style="list-style-type: none"> • General benefits of improving energy productivity, as listed in the introduction to section 7. • Improved investment certainty – pilot program reduces risks to broader mining industry in adopting data management processes demonstrated to be of value through case studies. • The case study approach recognises the variability in data collection approaches and standards across the sector and for different fuel types and areas within a mine site (e.g. diesel fuel logs versus electricity smart meters). It takes a bottom up approach to assess where increased accuracy of information will demonstrably add value to the operation over time through testing the linkages to energy productivity-related decision making.
Relationship with NEPP (COAG 2015)	NEPP measure 6: Help business self-manage energy costs
Linkage to other relevant programs	<ul style="list-style-type: none"> • CSIRO Common Mine Model (http://www.austmine.com.au/Portals/25/Content/Documents/Stephen%20Fraser%20CSIRO.pdf) • Global Mining Standards Group - Onboard Technology and Connectivity Working Group (http://www.globalminingstandards.org/working_group_categories/onboard-technology-connectivity-t-c/)

Category: Industry initiative	
7.7. Examine the role of industry associations in providing energy productivity-related information to businesses in the mining sector	
Overview	<p>2xEP recommends industry investigates the role of industry associations in providing information to businesses working in and with the mining sector to improve energy productivity. For example:</p> <ul style="list-style-type: none"> • Raise decision-makers' awareness of the benefits of improved energy productivity and its co-benefits, such as more productive deployment of labour and materials and lower maintenance costs. These benefits can contribute to improving overall mine productivity, competitiveness and economic mine life. Where energy productivity initiatives are assessed to be cost-effective, decision makers are encouraged to sanction implementation of these initiatives. • Provide information regarding appropriate energy productivity-related KPIs for staff and mine contractors, cognisant of existing contractual obligations and agreements. Note, an integrated view of energy productivity is required to incentivise decision making in each part of the process that contributes to the enhancement of energy productivity of the operation as a whole.
Current barriers to doubling energy productivity	<ul style="list-style-type: none"> • Availability of relevant information • Benefits of energy projects pursued in isolation are perceived as lacking materiality • Management practices and internal barriers
How the approach will address the current barriers	<ul style="list-style-type: none"> • Increase collaboration and understanding within the mining industry of the direct and indirect benefits of improved energy productivity, and the associated positive impacts on competitiveness and economic mine life. • Provide practical assistance in implementing changes to bring about energy productivity improvements.
Factors to consider	<ul style="list-style-type: none"> • Risk of lower mine productivity compared to global competitors if energy productivity issues are not addressed: link energy productivity to overall mine productivity and competitiveness. • Success of international industry groups in bringing together members to better understand sector-wide performance and improve energy performance (e.g. World Steel Organisation, EU Copper Alliance). • Diversity of companies within mining industry groups and challenges in providing information relevant to all mine/product types. • Resourcing challenges within industry group staff given the range of responsibilities and initiatives coordinated across the mining sector. • The business case for energy productivity is not always clear using typical financial tools. For example, NPV analysis discounts future energy cost reductions relative to up front investment in energy productivity

	<p>projects. It may be helpful to include alternative methods of valuation when assessing energy projects e.g. real options analysis. Taking a long-term 'value at risk' perspective of energy cost may be useful.</p>
Cost/benefit	<p>Costs:</p> <ul style="list-style-type: none"> Increased industry association resources – staff in industry associations may require energy productivity training and additional human resources may be required to provide information to companies in the mining sector. The cost to industry associations of implementing this initiative may be significant. <p>Benefits:</p> <ul style="list-style-type: none"> General benefits of improving energy productivity, as listed in the introduction to section 7. Leveraging established networks to share knowledge will likely accelerate the development of a cohesive approach to energy productivity for the sector. The unique challenges in measuring and improving energy productivity in the mining sector will be well understood by industry groups. This strong subject matter knowledge will result in more relevant and effective content in the materials developed and communicated.
Relationship with NEPP (COAG 2015)	<p>NEPP measure 6: Help business self-manage energy costs</p> <p>NEPP measure 7: Recognise business leadership and support voluntary action in business</p>
Linkage to other relevant programs	

8. 2xEP Steering committee and working group members

2XEP Steering Committee

Kenneth Baldwin, Director, Energy Change Institute, Australian National University
Graham Bryant, Deputy Chair, Energy Users Association of Australia
Tony Cooper, Chief Executive Officer, Energetics
Bo Christensen, Manager Sustainability, Linfox
David Eyre, General Manager, Research & Development, NSW Farmers
Chris Greig, Fellow, Australian Academy of Technology, Sciences and Engineering
Travis Hughes, Head of Energy Services, AGL Energy
Jonathan Jutsen, Chairman, Australian Alliance for Energy Productivity
Andrew Lamble, Co-Founder and Chief Operating Officer, Envizi
Sid Marris, Director, Environment and Climate Change, Minerals Council of Australia
Luke Menzel, Chief Executive Officer, Energy Efficiency Council
Brian Morris, Vice President, Energy & Sustainability Services, Schneider Electric
Gordon Noble, Managing Director, Inflection Point Capital
John Osborn, Director of Economics & Industry Policy, Australian Chamber of Commerce & Industry
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