

# Resourcing the future: foresight to secure long-term national benefit from Australia's minerals. #

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## Abstract

Sustainable mineral production requires substantive changes to patterns of consumption in our global economy. As a global mineral supplier, Australia must play a significant role in reaching the sustainability goal. Yet our ability to do so is influenced by a range of associated challenges: declining ore grades and increasing environmental stewardship; "peak minerals" and the move toward product recycling and extended producer responsibility; changing societal expectations and aspirations, sustainability values and global consumption practices; and, climate change and energy uncertainty. Business as usual cannot deliver on the sustainability imperative.

Technological research has been an important focus in seeking to address many of these challenges, however, this alone is inadequate. Such research must be accompanied by foresight into the long-term strategic challenges, future scenarios, social, economic and regional contexts in which the technology will be situated for it to achieve transformative change toward a sustainable mineral industry. This paper reports results from a scenario foresighting project being conducted with Australian stakeholders, identifying future issues and challenges for the industry, and exploring their implications for a sustainable Australian economy.

Our research focuses on understanding how Australia can remain a competitive arena for minerals and metals processing while delivering long-term national benefit. Further, it seeks to examine what cross-scale value or benefit means for different stakeholders and how this affects the future of the minerals sector. This research explores how Australia's mineral endowment can deliver national benefit across a range of plausible future scenarios in the longer term (to 2050).

A multi-stakeholder deliberative process is underway that aims to establish and explore plausible future scenarios and strategies that could support an industry transition toward long-term national benefit. Three key interlinked procedural steps were identified and considered during the process design stage: the methodology to be used (foresight process), the audience to be engaged, and the objectives to be met. To support this work, significant stakeholder mapping was conducted in conjunction with desktop research examining the key issues, sustainability challenges and opportunities facing the Australian minerals industry.

We articulate what the implications of sustainability are for Australian resource processing with respect to global production and consumption cycles, the national economy, communities in mineral-rich regions and urban centres. By addressing cross-scale sustainability challenges we identify risks and opportunities within scenarios and develop strategies for improved resource governance that can maximise the national benefit of Australia's mineral endowment.

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# Presented at the International Society for Ecological Economics (ISEE) 11th Biennial Conference, Oldenburg/Bremen, Germany, August 22-25.

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## **Mining in Australia**

Australia is known globally as a significant mineral producing country, and the economic, political, social and cultural importance of the sector drives a close societal reliance on the revenues from the local minerals industry. This reliance may be a reflection of Australia's rich mineral resource base. Indeed, Australia's Economic Demonstrated Resources (EDR) – known resources that are economically retrievable – of nickel, silver, uranium, zinc and lead, rank as the world's largest, with EDRs of copper and gold the second largest globally (Geoscience Australia, 2009). Australia has fully embraced this vast mineral endowment. Mineral production contributed almost \$160 billion in export earnings to the Australian economy in 2009 (ABARE, 2009), or 7.7% of total GDP. These figures place Australia firmly within the United Nation's criteria for a mineral-dependent economy (Maxwell and Guj, 2006; Eggert, 2003). Mineral dependence translates to a reliance on the minerals industry and the employment and wealth it provides. So what does this mean for the future?

Natural materials and objects hold different meaning for different members of our society, and this influences how we attribute value. Whether economic, cultural or physical, the attribution of value designates what we consider to be resources (Blunden, 1985). Minerals and metals are among Australia's most valuable natural resources because of the diversity of their uses, for which demand on the world market is increasing (Access Economics, 2008).

The value we place on resources is determined by the function or functions those materials or objects perform in our society. In Australia, value from mining and mineral processing is derived in two ways: through the provision of metals, and from the money earned from their production. We value the properties and functionality of metal containing goods and the services they provide, and we value the ability to purchase goods and services with the revenue and royalties mining and metal processing provides.

The research reported here is framed around an understanding that the fundamental benefits and impacts of mineral resource extraction and processing in Australia are changing. This paper reports on preliminary outcomes from a deliberative multi-stakeholder scenario foresighting process that aims to establish and explore how the Australian minerals industry might need to change over the next 30-50 years in order to play a role in a more sustainable Australian economy. We begin with a brief description of the industry, and outline the challenges and opportunities that may be associated with establishing a sustainable minerals sector, and reflect on what these changes may mean in a global context. We provide a detailed methodology and preliminary results, and conclude by establishing this work as a first step in developing a preferred vision for the future of the mining sector in Australia. We relate the local, regional and global implications these changes might present for strategies that support a transition aimed at deriving long-term national benefit from Australia's mineral resource endowment.

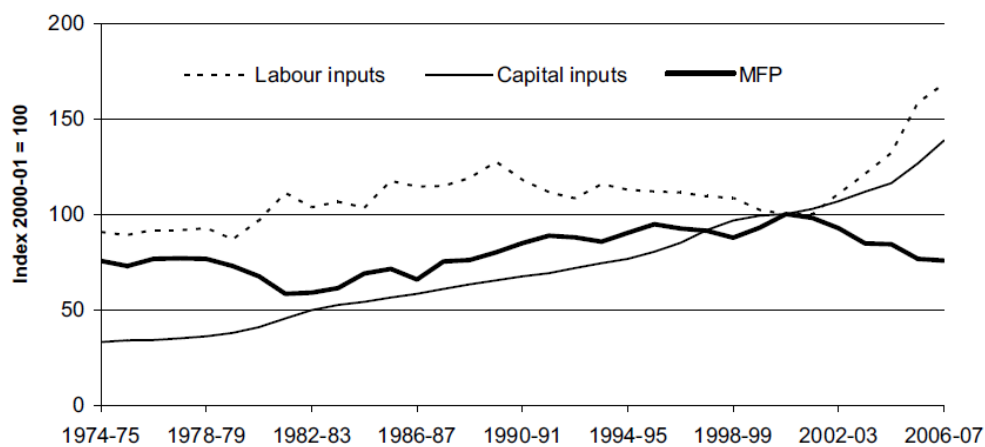
### **Local production, Global consumption**

As noted earlier, Australia has developed a strong economic dependence on mineral production and export – although production of key commodities like copper, iron ore, gold and nickel occur locally, these commodities provide an income for Australia on global markets. Minerals play a major role in Australia's capacity to participate in international trade and contribute to the international strength of its currency (Maxwell and Guj, 2006). A dependence on the mining industry for export earnings has shaped, and continues to shape the industry, and the relationships the industry has with all facets of Australian society. It is essential that Australia considers the global context in which sales occur when establishing mechanisms for sustainable management of its mineral resources.

Australia's vast mineral endowment and cheap transport have fostered a comparative advantage in primary production, and export of large quantities of processed ores. Because labour is expensive in Australia, little secondary processing, and still less manufacturing with those processed raw materials occur here (Maxwell and Guj, 2006). Rapidly industrialising countries with cheaper labour like India and China, are buying large quantities of Australia's minerals, and consequently the Australian economy has effectively been shielded from the impact of the recent global economic crisis, by what some call a "Chinese wall" (Mining Australia, 2009).

However, multi-factor productivity – the efficiency by which labour and capital inputs are converted to goods and services – in the Australian mining industry is declining (see Figure 1, Topp *et al.*, 2008) partly because of unrealised capital investment, but most importantly because of declining ore quality and quantity (Mudd, 2010; Mudd and Ward, 2008; Mudd, 2007c). Ultimately these changes will require steadily increasing investments of capital and labour to produce one unit of output. In addition to the economic consequences of declining ore grades and ore qualities, greater effort has resulted in growing social (*e.g.* land use competition, nearest neighbour impacts, post-closure social impacts) and environmental costs (*e.g.* water scarcity, carbon emissions, waste rock and tailings) (Giurco *et al.*, 2010).

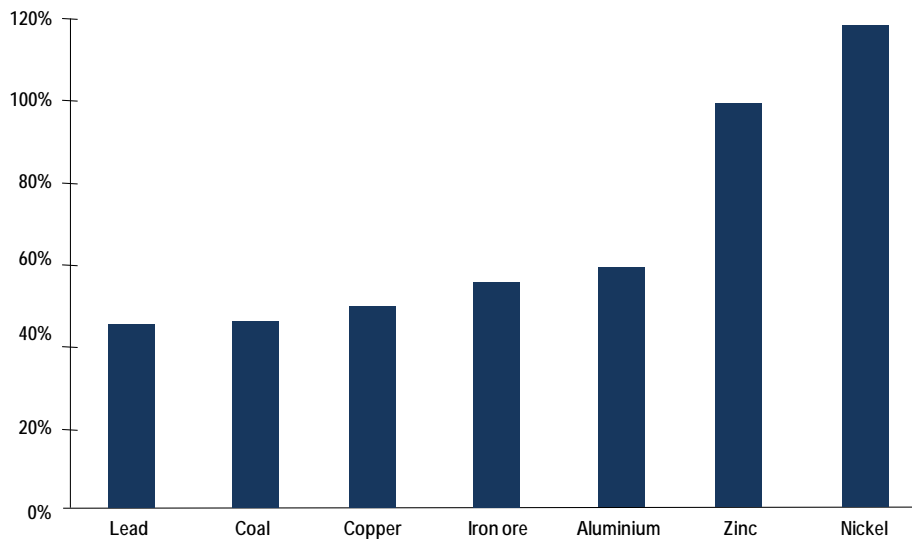
Analysis by the Australian Productivity Commission (Topp *et al.*, 2008) and by Giurco and colleagues (2010) emphasises the importance of developing a strategy to link the use of Australia's mineral resources to national long-term benefit, and to anticipate and develop a response to a future characterised by greater effort for the same output. Such a strategy must be informed by a deeper understanding of the implications of sustainability for Australian resource processing with respect to global production and consumption cycles, the national economy, and Australian communities in mineral-rich regions.



**Figure 1: Productivity in the Australian mining sector is steadily declining (from Topp *et al.*, 2008).**

While multi-factor productivity is declining, demand is increasing. Global consumption of Australia's minerals is forecast to increase dramatically in the next decade (Figure 2) (Access Economics, 2008). For example, demand from China for Australian iron ore drove a ~600% price increase over the last decade (World Bank, 2010). This demand increase is being matched by increases in the Economic Demonstrated Resources of a wide variety of Australian minerals (Geoscience Australia, 2009), but primarily through intensified exploration efforts, technology development and rising commodity prices rather than new discoveries (Geoscience Australia, 2009; ABARE, 2009; DFAT, 2009). Mineral production in Australia is matching these increases (Mudd, 2007a; Mudd, 2010). Mudd (2007a) points out that in order to meet this increase in demand, mines are becoming larger, and more reliant on larger ore bodies and higher-grade deposits, to reduce unit costs of production by

increasing the economies of scale. These characteristics of the minerals industry run contrary to the nature of mineral resources as finite, highlighting the need to more adequately consider how Australia’s resource endowment should be managed into the future.



**Figure 2: Forecast demand increase for Australian commodities to 2020 (Access Economics, 2008).**

Global markets, and demand for Australian minerals, will consequently play an even larger role in Australia’s ability to manage mineral resource production sustainably. Global consumption patterns, and Australia’s reliance on this consumption also strongly influences the way value is attributed to these resources. This poses a variety of potential challenges and opportunities to the development of a sustainable resources sector in Australia, and frames how we can realise long-term national benefit.

### **Challenges and opportunities for a sustainable Australian minerals sector**

Almost every aspect of our daily lives is affected by the availability of many mineral resources, and current mineral production and consumption patterns reflect the values we implicitly or explicitly attribute to these resources. The *value* Australia gains from its minerals and metals will continue to play an important role in underpinning the future prosperity of Australian society. However, to confront the challenge of sustainability, and realise the opportunities that lie therein, the way in which resources are currently used, and might usefully be used in future, requires deeper exploration (Giurco *et al.*, 2009).

Many factors influence the future of minerals within the complex socio-ecological systems that operate across linked local, national and global scales. Aiming for resilience and long-term national benefit from a sustainable minerals sector requires anticipating change. Recognising the key drivers that currently, or will potentially, influence change within the system, and acting in response to these insights (Folke *et al.*, 2002; Gunderson and Holling, 2002; Walker and Salt, 2006), is an important step in establishing a direction towards strong sustainability (Neumayer, 2003).

Giurco *et al.* (2009, p 14) point out that the key global drivers of the minerals industry are those “characterised by linked ecological, social, economic and political dimensions.” In an Australian context, these authors identify four broad drivers that will influence the long-term structure of the industry, and contribute to future uncertainty. These drivers include: climate change (the ability to minimise impacts while adapting to constraints and realising opportunities); renewing the ‘social license to operate’ (through new practices, technologies and locations of operation); responding proactively to the constraints and opportunities

posed by peak oil and peak minerals (particularly the increasing social, environmental and economic costs and impacts of mining ores of lower quality and quantity); and lastly, addressing issues of resource governance, stewardship and social aspirations for *strong* sustainability.

One of the key challenges that mineral resource dependence presents to the Australian economy is the 'resource curse'. The resource curse describes an apparent paradox where natural resource abundance and exploitation actually has a negative impact on the growth of the national economy. The negative impacts associated with the resource curse are of a political, social, environmental and economic nature (Goodman and Worth, 2008). While mineral dependence allows a nation to realise huge gains from exporting minerals, the strengthened local currency has other consequences – because other nations must buy its currency to obtain the commodity, forcing the price of the currency up. The resource curse leads to a contraction of manufacturing, and other tradeable-goods export sectors within the economy because exports become more expensive as the currency's value rises – this is termed the 'Dutch Disease'. Furthermore, the stronger currency makes importing foreign goods cheaper, increasing the competition for locally produced goods on the national market (Goodman and Worth, 2008; Palma, 2005). Ultimately, without sound macro-economic policy, the economic dependence on resources squeezes other sectors out of the economy, and because mineral resources are finite, the long-term viability of the mineral dependent economy is questionable.

Several key foreseeable opportunities that are becoming increasingly apparent are mineral resource stewardship, recycling and reuse. Presently, only a small number of countries are realising the potential of these activities (Chong *et al.*, 2009). Japan is implementing product stewardship processes and extended producer responsibility initiatives, to establish a pool of resources sourced from existing products for use in new product lines. Metals (including copper, steel and aluminium) that may have originally come from a range of other continents are effectively captured by Japan's vertically integrated production, disassembly, recycling and reuse system (Department of Trade and Industry (UK), 2005).

Additionally, a large number of mineral resource dependent countries (not Australia) have established macroeconomic mechanisms to deal with the inevitable exhaustion of the mineral resources that sustain their economies. For example, Norway (Larsen, 2006), Chile (Chile Finance Ministry, 2009), Oman, Kuwait, Venezuela and Papua New Guinea (Davis *et al.*, 2001) have all established successful sovereign wealth funds (among many others, see SWF Institute, 2010 for a complete list and ranking of sovereign wealth funds globally), primarily as mechanisms to smooth out the cyclical nature of wealth generated from resources.

As an important global minerals commodity supplier, Australia has the opportunity to place itself as a leader in the realm of minerals stewardship and intelligent mineral supply, thus ensuring minerals sustainability and avoiding some of the issues associated with an economic dependence on minerals (Eggert, 2003; Gowdy and McDaniel, 1999; Larsen, 2006; Goodman and Worth, 2008). Recent government policy directions are now leaning towards more equitable distribution of wealth from minerals, but the proposal for a resource rent tax on super profits from mining (see Australian Government, 2010b, and described briefly in the following section) has been met with vigorous industry opposition (Coorey, 2010; Hannan, 2010; Pannet, 2010). In contrast to most other resource-rich countries that have implemented resource rent taxes, Australian policy makers have not indicated that funds from the tax (estimated at AUD 12 billion annually) would be used to establish a sovereign wealth fund.

Addressing challenges and seeking opportunities requires an integrated approach to deal

with the contested and complex questions concerning mineral futures and sustainability (Giurco *et al.*, 2009). The Mineral Resources Landscape (Cooper and Giurco, 2009) offers an expanded conceptualisation of minerals sustainability to link minerals production and consumption in an integrated assessment across the entire minerals supply chain. In particular, it identifies key leverage points in the supply chain where opportunities can be found in production, processing and ultimately in the way a commodity can be used to offer a 'service' or different/new value to society. The landscape is intended to provide a framework to map drivers, stakeholders, current and missing domains of research activities, and the leverage points for change – with the objective of establishing a foresight methodology that can deliver a more sustainable minerals industry in Australia, and long-term national benefit.

### **Seeking long-term national benefit is confounded by production difficulties**

Identifying how to seek long-term national benefit from Australia's mineral endowment will present a significant challenge for Australian society, and for the minerals sector in Australia. Recognising that without better minerals stewardship, Australia's mineral endowment will eventually become depleted, it is imperative that the problems associated with depletion are identified and met with considered solutions – before the resources that might pay for these solutions are gone (Ehrenfeld, 2005). Unfortunately, it is inherently difficult to define 'long-term national benefit', simply because different sectors, and different elements in Australian society hold a completely different perception of 'benefit' and 'value' in the context of minerals. Such differences present problems in setting goals that might help us to reach long-term national benefit.

The deliberative scenario forecasting process reported on here will attempt to establish a shared vision for the future of the Australian minerals industry. An element of this process will explore and share perspectives on long-term benefit among an array of mining stakeholders from government, industry, community and research sectors. Here we initially explore a range of factors that may influence perspectives on, or impact on our ability to find or establish mechanisms for gaining long-term national benefit.

A key issue that must frame the discussion about long-term national benefit is the depletion of those mineral resources that are currently a mainstay in the Australian economy. Yet the science of mineral resources depletion is contested (Giurco *et al.*, 2010; Gordon *et al.*, 2006; Tilton and Lagos, 2007; Williams, 2008). Gordon and colleagues (2006) support the fixed-stock paradigm, which posits that because the Earth is finite, so too will be its stock of minerals. As a mineral is extracted and used, the stock in the lithosphere is transferred to stock in-use, until the quantity in the lithosphere is relatively smaller than the quantity in use, indicating resource depletion (and rising scarcity value).

Alternatively, Tilton and Lagos (2007) advocate an opportunity cost paradigm. They contend that this approach avoids inaccuracies in estimating *actual* stock sizes by acknowledging that *viable* stocks vary in response to technology and commodity price. As the real price of a commodity rises, scarcity increases because society must sacrifice other goods in order to obtain the same quantity of the commodity.

These paradigms differ largely on whether they consider depletion in a physical or economic sense, and with regard to the role technology might play in offsetting scarcity. As Gordon *et al.* (2007) point out in line with many other authors, mineral resources are finite, and their stock can be exhausted. However, as traded goods, the monetary value of minerals is dependent on supply, demand and scarcity (Maxwell and Guj, 2006), and unit costs of a resource will determine the economic viability of their extraction, providing an indication of

their availability to markets. As such, both fixed stock and opportunity cost paradigms for depletion are useful.

The peak minerals depletion paradigm proposed by Giurco *et al.* (2010) effectively mixes, and builds on, aspects of both the fixed stock and opportunity cost paradigms. The authors argue that changes in physical depletion factors, like falling ore quality and quantity (see Mudd, 2010; Mudd and Ward, 2008) as a result of continuing production, are matched by rising social and environmental costs and impacts of mining (Figure 3). These costs will increase the cost of production into the future, and decrease the viability of currently economic demonstrated resources (EDRs) in Australia (see also Lambert, 2010), leading to economic scarcity.

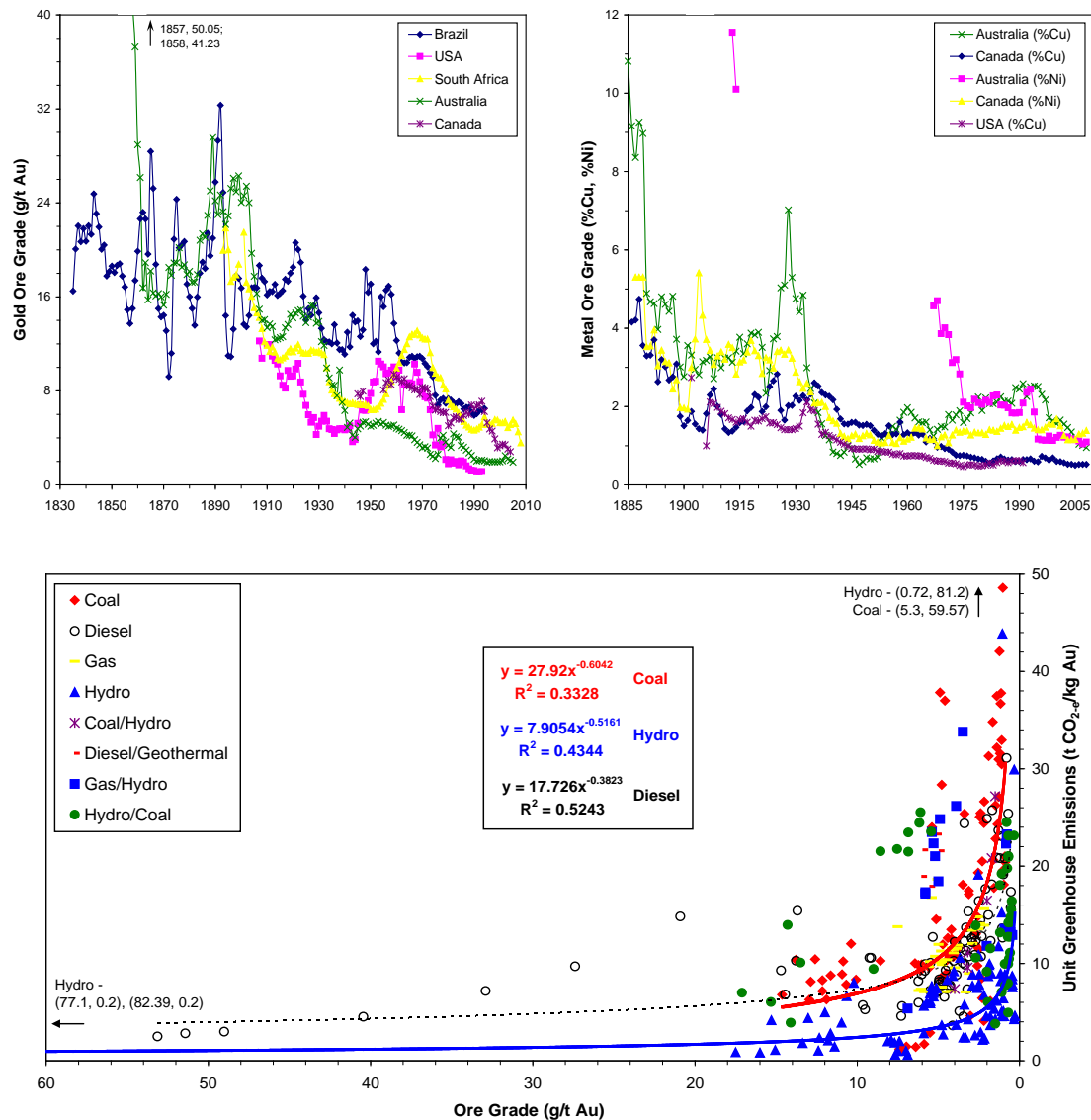


Figure 3: Declines in ore grades for gold (a: top left) and copper (b: top right), and (c: bottom) carbon intensity of Au production versus ore grade (Mudd, 2007b; Mudd, 2007c; Mudd, 2010 including unpublished data).

Current debate between the Australian government and the mining sector concerning the introduction of a resource rent tax has centred on whether the tax will stifle economic development. The industry's position supports continued primary production following the *status quo* in Australia (where we hold the comparative advantage), recognising that when demand falls, so too will commodity prices and the economic viability of Australian mines. They cite the need to maximise profit margins while demand from rapidly industrialising

nations is elevated (Access Economics, 2008). On the other hand, the government recognises the quality and quantity of Australia's resources are declining (Lambert, 2010; Australian Government, 2010a), and the need to ensure adequate returns from the nation's mineral endowment to society (Australian Government, 2010b) while these resources can support such returns.

The goal of the larger research project on Australian mineral futures, of which this paper reports the first stages, aims to identify what national benefit is, and how it can be reached. That the concepts of 'national benefit' and how we 'value' mineral resources certainly vary considerably between mineral industry stakeholders is clear, but this merely raises the necessity for discussion to be wide-ranging, deliberative and robust. To accommodate varying viewpoints, and examine how these may be important for the future of the Australian mineral industry, we will use scenario foresighting techniques, in which a consideration of national benefit can be made freely and exploratively. These scenarios will also help to develop and establish consistent indicators that allow the country to eventually reach the goal of long-term national benefit from the minerals industry.

The multi-stakeholder deliberative foresighting process used here will establish plausible future scenarios and explore the consequences of these scenarios for the Australian mining industry. This work will contribute to an industry transition toward long-term benefit from Australia's mineral resource endowment. Understanding the relative contributions of macroeconomic policy measures, new technologies and stewardship approaches to achieving sustainability goals is imperative. These issues must be examined in the context of growing social pressures and environmental consequences, and their economic repercussions. The goal will be the creation of processes for sustainable use and production that don't jeopardise the industry, but do yield greater benefits to Australia's wider society.

## **Foresighting methodology**

A multi-stakeholder deliberative process is underway that aims to establish and explore plausible future scenarios and strategies that could support an industry transition toward long-term national benefit. Three key interlinked procedural steps were identified and considered during the process design stage: the methodology to be used (foresight process), the audience to be engaged, and the objectives to be met. To support this work, significant stakeholder mapping was conducted in conjunction with desktop research examining the key issues, sustainability challenges and opportunities facing the Australian minerals industry.

As this project is ongoing at the time of writing, we report here on the work completed to date.

## **The pre-foresight scoping stage**

During the pre-foresight scoping stage a number of key strategic and process decisions were made by the project team. The project team considered the overall goals of the foresighting exercise and with these goals in mind, a number of objectives and expected outcomes were established. A preliminary work plan was developed and continuously refined. In addition, decisions were made regarding the process, including the coverage, scale and time horizon.

To inform the decisions made at this stage, some preliminary work was carried out. This preliminary work included: 1) a literature scan of foresight and futures methods; 2) a review of foresight processes covering different industries; and, 3) meetings with foresight experts and practitioners. This preliminary work revealed a diverse set of foresight methods, perspectives and experiences (Johnston, 2009b; Johnston, 2009a), which have been used to establish the methodology used here.

Importantly, the project continues to provide opportunities for stakeholders to deliberate on a vision for a preferred future, and subsequently, begin to consider the steps needed to reach that point. As such, the process has sought input from multiple stakeholders including from industry, community and government. The foresight process has benefited hugely from deliberative components that allow for the diverse views and values of the variety of stakeholders to be reflected and captured. Given the aim of developing a vision and strategies for the future of Australian minerals and mining, effective stakeholder participation has been critical to the development of ownership of the project and broad acceptance of the project outputs by participants.

In addition to considerations of objectives, process and audience, other aspects of the foresight exercise were explored – scale, time horizon and methodology. A regional/national scale was chosen for the foresighting process, but considered in the context of the Great Transition Scenario (Raskin *et al.*, 2002), and the recently-established World Economic Forum Metals and Mining scenarios (WEF, 2010). A longer time horizon, to 2050, was chosen to accommodate outcomes that may be irrelevant at shorter time frames. The chosen methodology included reviews of relevant literature (Giurco *et al.*, 2010), an analysis of Australian and global megatrends (Giurco *et al.*, 2009; Hajkowicz and Moody, 2010; Moffat *et al.*, 2009), interviews and surveys, scenario planning and (deliberative) futures workshops. This methodology permitted an interpretation of existing global scenarios in an Australia-specific context.

## **The scenario planning process**

With the foresight objectives and parameters established, the scenario planning process was initiated. The process followed during this work has been established by Johnston (2009a) and involves six distinct stages:

1. Identification of the focal issue
2. Identification and analysis of the drivers
3. Rank by importance and uncertainty
4. Select scenario parameters
5. Flesh out the scenarios (for plausibility, differentiation, consistency, decision making utility, challenge)
6. Consider implications of scenarios

As this project is ongoing and at the time of writing this paper, we report here on the work completed to date, which includes stages one through four.

### ***Stage 1: Identification of the focal issue***

As discussed earlier in this paper, the focal issue of the foresight exercise is to develop scenarios and consider strategies for improved resource governance that can maximise the national benefit of Australia's mineral endowment.

### ***Stage 2: Identification and analysis of drivers***

The second stage of the process identified the key drivers that related to social, technological, political, economic and environmental forces that might have an impact on the issues considered (Johnston, 2009a). The aim was to develop 'a conceptual model of the relevant environment that includes critical trends and forces and maps out the cause and effect relationship among the forces' (Johnston, 2009a, p 22)

The identification and analysis of drivers involved mainly desktop research, surveys and interviews. A range of existing and newly created input information was initially synthesised to establish the foundations for scenario exploration in an Australian context, as described

above. These inputs include: a) stakeholder-identified priority actions that may help to position the minerals industry within a more sustainable Australian economy (with input from Giurco *et al.*, 2009; Giurco *et al.*, 2010); b) key issues and drivers identified through a survey of 959 members of the Australasian Institute for Mining and Metallurgy concerning the development of the Australian minerals industry over the next 20-30 years (Moffat *et al.*, 2009); c) an analysis of key 'mega-trends' that describe the changes that may affect our future world in terms of how we live, what we demand, and the technology that can support these changes (Hajkowicz and Moody, 2010).

All of these inputs have identified trends and drivers for the Australian minerals industry. The inputs were analysed within the context of the WEF and Great Transitions scenarios as these provided a more global context. All of these pieces of work have been synthesised to form four draft scenarios for consideration by stakeholders during the upcoming stages of the project.

### ***Priority actions for a sustainable Australian economy***

The National Peak Minerals Forum, held in Sydney in April 2010, provided a forum where stakeholders of the Australian minerals industry could discuss the issue of peak minerals in Australia. Discussion focussed particularly on the underlying drivers, the current situation, dominant trends and impacts, and the future challenges and opportunities for research, technology and policy. There was general acknowledgement that 'peak minerals' in Australia will place increasing pressure on the competitiveness of Australian mining, though for most minerals a peak in production had not yet occurred. The macroeconomic impact of the minerals industry on Australia was also discussed, noting the challenges of increasing commodity prices, a stronger dollar and higher interest rates. A sovereign wealth fund was explored as a way to avoid currency appreciation and capture long-term national benefit from minerals processing. Participants from government, industry and the research community identified four overarching priority actions that were considered by participants to be the most pressing. These included:

1. Technological advances as key factors in the future sustainability of the mining industry.
2. Structures for long-term decision-making that can assist the development of effective minerals policy.
3. The establishment of Australia as a minerals services hub, not simply a quarry for global mineral needs.
4. Ensure impacts from mining are balanced by better and fairer distribution of wealth from minerals.

### ***Australian Institute of Mining and Metallurgy drivers (Moffat *et al.*, 2009)***

Moffat and co-authors conducted a survey of members of the Australian Institute of Mining and Metallurgy (AusIMM) to understand how the Australian minerals industry may be shaped in the future. The AusIMM represents the interests of professionals working in the global mining industry. The surveys identified a range of issues and drivers for the industry. Issues were characterised as intrinsic and controllable problems or opportunities for the industry, while drivers described extrinsic factors that could influence the industry, but were out of its control.

For the purposes of this paper, we focussed on using only the drivers that were identified during the study. These included in order of importance:

1. The economics of mining: cost and return on investment for Australian operations compared to elsewhere (*e.g.* declining ore grades, availability and accessibility of new orebodies).
2. Global context: economic stability, rates of growth and consumption patterns in consumer economies (*e.g.* USA, China).
3. Australian society: expectations around how the industry operates (*e.g.* rehabilitation of mining operations) and treats its employees (*e.g.* safety standards).
4. Substitution: availability of substitutes for mineral commodities in upstream production processes and end user preferences (*e.g.* alternatives to coal for electricity, alternatives to aluminium for packaging).
5. Emissions trading: national and international frameworks that have the effect of imposing a price on carbon and/or greenhouse gases.
6. Environment: effects of increased climate variability and unforeseen extreme weather events (*e.g.* drought, cyclones).

### ***CSIRO megatrends (Hajkowicz and Moody, 2010)***

The CSIRO megatrends are based on analysis of trends identified by scientists and business development staff across CSIRO (Hajkowicz and Moody, 2010), the Australian Government's flagship research organisation. The trends were reviewed and discussed by over 50 leading CSIRO scientists and business development staff. Of the identified trends, 19 key trends were grouped, synthesised and reviewed, leading to the development of five interlinked megatrends. These are described briefly below.

**More from less: a world of limited resources:** This relates to the world's depleting natural resources and increasing demand for those resources through economic and population growth. Coming decades will see a focus on resource use efficiency.

**A Personal Touch: Personalisation of services:** Growth of the services sector of western economies is being followed by a second wave of innovation aimed at tailoring and targeting services.

**On the Move: Urbanisation and increased mobility:** The populations of OECD countries are ageing and experiencing lifestyle and diet related health problems. At the same time there are high fertility rates and problems of not enough food for millions of poor countries.

**Divergent Demographics: Older, hungry and more demanding:** People are changing jobs and careers more often, moving house more often, commuting further to work and travelling around the world more often.

**World: Digital and natural convergence:** Everything in the natural world will have a digital counterpart. Computing power and memory storage are improving rapidly. Many more devices are getting connected to the internet.

### ***World Economic Forum Mining and Metals Scenarios (WEF, 2010)***

In collaboration with its Mining and Metals constituents, the WEF launched the Mining and Metals Scenarios to 2030 project in January, 2009 (WEF, 2010). The year-long project brought together representatives from the private sector, government, academia and international and non-governmental organisations in a strategic scenario planning process to question: "How will the environment for the global mining and metals sector look in 2030?" (WEF, 2010, p 2). The discussion aimed to:

- stimulate dialogue between the public and private sectors and civil society regarding the future of the mining and metals industry

- deepen insight into the complex contextual environment in which the industry operates by bringing together multidisciplinary and multi-stakeholder perspectives
- strengthen the Mining & Metals community by providing a non-threatening context in which diverse stakeholders with conflicting worldviews are encouraged to share their perspectives and develop mutual understanding
- provide useful tools to improve stakeholders' strategic decision-making, and identify strategies for collaborative action.

Three scenarios were established during this process: “Green Trade Alliance”, “Rebased Globalism”, and “Resource Security”. The scenario development process primarily explored how the geo-economic and geo-political landscapes might vary under different scenarios. In doing so, they predicted the economic and environmental outlooks resulting from the scenarios.

**Green Trade Alliance** (WEF Scenario 1): In 2030, the world is divided with countries defined economically by whether or not they belong to the Green Trade Alliance (GTA), formed in 2013 to promote “environmental sustainability without compromising competitiveness”. GTA states, which include industrialised, resource-rich and developing countries, have seen accelerating innovations and lifestyle change. Non-GTA states are fragmented and diverse.

**Rebased Globalism** (WEF Scenario 2): In 2030, the world is committed to realising the benefits of global interconnectedness but has become far more complex and multi-polar. Power comes from possession of resources as well as possession of capital, with resource-rich countries playing by their own rules. Societal power increases, resulting in various local laws that affect global corporations.

**Resource Security** (WEF Scenario 3): In 2030, the era of globalisation is a distant memory as nations prioritise narrow self-interest. They hoard their domestic resources, enter cartels based on regional and ideological alliances and resource blocs, and engage in neo-colonialism and import substitution strategies.

### ***The Great Transition scenario (Raskin et al., 2002)***

The *Great Transition* essay proceeds from the contention that “humanity has the power to foresee, to choose and to act”, to transition to “a future of enriched lives, human solidarity and a healthy planet”, (Raskin et al., 2002, p IX). The essay draws together the research efforts of the Global Scenario Group. The Group was developed through an initiative of the Stockholm Environment Institute and the Tellus Institute in 1995 as an international, independent body for engaging in the process of scenario development to decipher what is needed to transition towards sustainability. The *Great Transition* essay (Raskin et al., 2002) is described as a composition of analyses, imagination and engagement, in the following elements.

The ‘*Great Transition*’ future envisions fundamental and favourable social transformation, whereby “new values and development paradigms ascend that emphasise the quality of life and material sufficiency, human solidarity and global equity, and affinity with nature and environmental sustainability” (Raskin et al., 2002, p 15).

## **Results**

Future drivers of the Australian minerals industry derived from the National Peak Minerals Forum, a survey of members from the Australian Institute of Mining and Metallurgy (AusIMM), and from CSIRO’s *Our Future World* report were explored in the context of the World Economic Forum (WEF) Metals and Mining Scenarios and the Great Transition (GT) scenario. This exploration yielded four Australian draft scenarios, grounded in the global

context provided by the WEF Mining and Metals scenarios and Great Transition scenario.

Possible implications for each driver under each scenario were established in draft format among the research team members (see Appendices 1-4). Appendix 1 provides a matrix for the drivers under the “Green Trade Alliance” scenario of the WEF. Appendix 2 provides a matrix for the drivers under the WEF “Rebased Globalism” scenario, and Appendix 3 provides a matrix of driver implications under the WEF “Resource Security” scenario. Lastly, Appendix 4 provides a list of driver implications under the “Great Transitions” scenario (Raskin *et al.*, 2002).

Based on the exploration of the implications of these drivers, four draft scenarios were established. These scenarios have been developed by the research team to begin discussion within a select group of diverse and representative stakeholders as a means of validating the research team’s work. These scenarios will also be used to gain feedback that will streamline the deliberative scenario development workshops with a much broader stakeholder group, which will follow this validation. The development of these scenarios provides an important step in the foresighting process used in the large research project of which this forms a part.

### ***Australia joins the Green Trade Alliance? (Appendix 1)***

Australian decision makers teeter on the edge of a decision to become a part of the Green Trade Alliance. Multinational mining companies, loath to explore strong environmentally sustainable options because of concerns that the Australian industry’s competitiveness will be compromised by the changes real sustainability might bring, drive this indecision. The government recognises the strong societal expectations for sustainability in the sector, and government election cycles have been extended to seven years. This has fostered government policy that is noticeably more considerate of long-term environmental and social concerns over short-term financial interests (for example, by adopting a world-leading carbon emissions trading scheme and introducing a mineral resource rent tax to establish a sovereign wealth fund). The historical closeness of government and the mining industry in Australia, which has been eroded during consultations on the value of joining the GTA, presents another significant point of contention in these important decisions. Those multinationals operating in Australia are also keen to maintain exports to the growing middle classes of India and China, but these countries will not join the GTA, and if Australia does join, the agreement will prevent trade with non-GTA countries. In the melee caused by the GTA’s introduction globally, multinationals have started to cease Australian operations and move to non-GTA countries, and fear of the loss of income from these operators has driven considerable investment in smaller, more vertically integrated operators, whose operations are partly being supported by investment from Australia’s sovereign wealth fund as a means of stimulating sectoral diversity in Australia.

### ***Rebased Globalisation in Australia (Appendix 2)***

Australia plays an important part in a fully globalised world, with mining companies realising huge wealth and power from the country’s significant mineral endowment. Australia maintains a comparative advantage in the export of unprocessed ores, but realising ore grades and ore quantities are falling, has improved production efficiency and expanded downstream processing to prolong supplies, value add and maintain a hold on power. Yet, Australia’s increasing reliance on global markets sees the ‘tyranny of distance’ become an increasingly important factor influencing export competitiveness, and mineral rich regions in Central Asia are beginning to change the rules by their growing resource-defined power. These regions are also closer to, and begin to supply the growing middle class affluence of China and India. The power of globalisation has caused government in Australia to focus on economic, political and resource issues outside of Australia, and has overlooked detrimental

changes in the Australian society and sidelined environment protection legislation that might disrupt Australia's mineral export potential. Wealth from minerals is held by companies, and government policy is used to support the operations of the largest multinationals, without attempting to transfer part of that wealth for the national benefit.

### ***Australia seeks resource security (Appendix 3)***

Nations prioritise mineral self interests. Comparative advantage is no longer a driver of national economic specialisation. With the realisation that its minerals are running out (particularly the increasingly valuable rare earth elements that are imperative for the expansion of the electronic age), Australia hoards what remains – exporting primary ore minerals to strategic trading partners only. The situation is exacerbated by unprecedented low ore grades and reserves, and climate variability caused by worsening global warming, which has not been addressed through market mechanisms due to the decline in globalisation. However, declining global markets do foster greater vertical integration in the Australian mining sector (which promotes a diversification of the local manufacturing sector), production efficiency, materials stewardship and investment in recycling technology and mineral substitutes. Vertical integration helps to offset some of the growing issues associated with increased urbanisation in Australia, and policy development focuses on the establishment of a sovereign wealth fund to protect against inevitable mineral resource exhaustion and the anticipated detrimental demographic changes in the Australian population (higher average age and worsening human health).

### ***Australia's Great Transition (Appendix 4)***

Australia is a world-leader in sustainable resource processing, use and consumption. Knowledge of falling ore grades, declining mineral reserves and the growing environmental and social costs of mining was proactively addressed by the Australian government. The introduction of a resource rent tax to establish a sovereign wealth fund was a first step towards encouraging sustainable resource production and dematerialisation in Australia. Australia becomes a technology leader in the development of mineral substitutes, metals recycling and renewable energies, recognising many of its major trading partners are legislating against the import of goods whose production results in negative environmental and social consequences. This legislation has partly contributed to changes in global consumption patterns, which have moved towards the desire for truly sustainable goods. Changing consumption patterns result in significant changes in how Australian society values mineral resources – environmental quality, ecosystem services and social sustainability are valued considerably more, and this new attribution of value further erodes the economic viability of primary ore production. Sovereign wealth is used to address changing demographic and health issues, and moderate a transition to a sustainable Australian economy, supported by diverse and successful secondary and tertiary sectors. Once characterised by negative adjusted net savings (genuine savings), adjustments in macroeconomic policy coupled with the implementation of strong sustainability actions in the minerals sector, has increased the genuine savings rate dramatically, significantly increasing long-term national benefit in environmental, social and economic terms.

## **What are the sustainability implications of these scenarios?**

The scenarios outlined above provide a range of possible futures for the Australian minerals industry, and demonstrate the variability these future drivers may bring in the context of existing minerals and metals scenarios. The interpretations of those drivers within the context of existing scenarios yields a useful starting point for the development of plausible scenarios of the future of the Australian minerals industry through deliberation among industry stakeholders. However, an exploration of what might be possible or plausible will

not necessarily advance sustainable environmental, social or financial practices in an industry of central importance to Australia's future.

These scenarios are intended to provide a point of discussion in the development of a preferable future for the Australian minerals industry that incorporates mechanisms for realising long-term national benefit from minerals. In establishing matrices of how key drivers play out against important global scenarios, and condensing these matrix components into brief stories (draft scenarios) of the future, we have articulated some of the most important sustainability implications facing the Australian minerals industry. Australia's ability to realise long-term national benefit from minerals hinges on our capacity to recognise that the future drivers of the industry are changing, and will present new constraints and opportunities for those organisations that plan for the future of the minerals industry. The results presented in this paper highlight the importance of several cross-scale sustainability challenges that will influence strategies for improved resource governance that can maximise the national benefit of Australia's mineral endowment.

### ***The Australian minerals industry is facing resource depletion***

Although mineral production in Australia is increasing, it is becoming increasingly characterised by greater effort and higher costs. Giurco and colleagues (2010) refer to the concept of 'peak minerals' to describe a paradigm that parallels much of Australia's mineral production: from easy and cheap in the industry's infancy, to harder and more expensive now and into the future. Depletion of many Australian mineral resources has recently been masked by new technologies (Hackl, 2010) and increasing resource prices (Lambert, 2010), which act to increase Economic Demonstrated Resources. However, as miners exploit deeper, lower grade ores, in new, sensitive or remote areas, the social, environmental and economic costs of these activities rise, and these additional costs will have a dramatic impact on the economic viability of many mining operations even in the short-term (the production of nickel in Australia provides a case in point, see Mudd, 2009; Treadgold, 1999).

While patterns of depletion vary between commodities (Mudd, 2010), recognising the onset of peak minerals is imperative. The concept helps to frame a discussion concerning the management of Australia's mineral endowment, and the wealth it provides to our society. When considered in light of the concept of peak minerals, Australian mineral production is currently unsustainable – not because resources are finite, but because of the growing impacts associated with processing and use (Giurco *et al.*, 2010).

### ***Patterns of consumption and demand for Australian minerals are changing***

More expensive mining, and more intense environmental impacts result in significant social flow-on effects. The looming consequences of resource depletion are also likely to influence consumption and demand. Societies are already actively seeking products with low embedded social and environmental costs, and campaigns against "dirty" gold (Sarin, 2006; Earthworks and Oxfam America, 2004) and "blood" diamonds (Pearce, 2002; Fishman, 2004) have already influenced the consumer markets for these precious resources.

More importantly for Australia may be the need to meet future import restrictions aimed at regulating the importation of commodities whose production has negative social or environmental consequences. The European Union REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) legislation already places tight controls over the importation of minerals and metal products that may impact on human or environmental health during production and processing. While Europe is not a large importer of Australian minerals, the REACH legislation is likely to be a forerunner for other nations' legislative mechanisms that will influence demand for, and restrict production of minerals where such regulations are not met.

In contrast, Australia is currently increasing production of many minerals to meet soaring demand from the rapidly industrialising economies of India and China. Demand from these countries has been forecast to increase in the next ten years (Access Economics, 2008), but beyond this the forecast is uncertain, but likely to decline. The financial imperative of multinational mining companies will certainly drive a desire to exploit the profitability while it lasts. However, this market-focussed driver must be tempered by government policy that is cognisant of the finite nature of mineral resources, and the need for long-term sustainability in terms of the national economy and society.

### **Strong sustainability requires innovative policy to support alternative production, use and stewardship strategies**

As a resource-rich nation, Australia has historically derived a comparative advantage in the production and export of high quantities of low-value commodities. Along with other pressures this advantage has dissuaded innovative production that adds value to our export commodities. Yet, as the social and environmental impacts of primary production continue to force production costs up, our comparative advantage will ultimately be eroded. In order to establish a strongly sustainable minerals industry, while remaining competitive as a minerals exporter, Australia must make considerable investment in establishing minerals stewardship mechanisms.

The prospect of peak minerals highlights the necessity of planning a transition in the way we produce (*e.g.* through recycling), use and reuse (*e.g.* sustainable design and extended producer responsibility) minerals in our society. Supplementing traditional production with alternative mineral and metal sources will contribute to a more sustainable minerals sector that maximises long-term wealth from minerals. Anticipating the growing demand for secondary and tertiary minerals and metal production should help to place Australia at the forefront of a new and innovative global minerals industry.

Indeed, many countries have already realised the long-term precariousness of dependence on a supply of raw minerals (Chong *et al.*, 2009; DTI, 2005). Countries like Japan, South Korea and Taiwan have implemented metals recycling and extended producer responsibility programs that can ensure their significant manufacturing sectors will not be exposed to falling minerals and metals supply in the coming decades. Australia can maximise long-term national benefit by reducing dependence on in-ground mineral resources and boosting the activity and competitiveness of secondary (and tertiary) sectors that develop to realise value from in-use stocks and end-use mineral services. Such innovation will also minimise many of the environmental and social implications of traditional mining that are reducing the nation's genuine gains from the exploitation of our mineral endowment.

### **Resource dependence is financially beneficial, but unsustainable**

It is easy to become economically over-dependent on mineral resources when they are in abundance. In his seminal text on *The Principles of Political Economy and Taxation*, Ricardo (1911) points out that a nation should fully embrace its comparative advantage to develop maximum of wealth for society. He also suggests that after the national resource endowment has been depleted, the economy's focus will shift to other sectors where the comparative advantage can be secured. But this assumes alternative sectors remain strong contributors in a national economic sense while the resources sector dominates.

Australian policy has arguably followed Ricardo's advice by historically favouring and subsidising the development of the local minerals sector (Productivity Commission, 1991). A booming resource sector not only provides attractive government revenue but also offers employment (Goodman and Worth, 2008). However it is widely known that such favouritism

creates economic imbalance towards the resource sector at the expense of other sectors (Larsen, 2006; Ye, 2008; Goodman and Worth, 2008; Gordon and Tilton, 2008; Stevens and Dietsche, 2008). In competing with a strong minerals sector, the capacity of other sectors to competitively provide goods or services in an international context is reduced (for example, because export demand for minerals drives local currency up, and flourishing industry can pay higher wages and lure the workforce away from other sectors).

Another negative aspect of the focus on mineral extraction and the lack of downstream activities in the minerals sector is the strong dependency on the economic conditions of other countries. That these conditions cannot be regulated from an Australian context poses an uncontrollable risk in a national economic perspective. Two main issues can endanger the Australian economy: Australia's capacity to participate in international trade is of course highly vulnerable to fluctuations in the international demand for its minerals; and, due to its paucity of downstream activities, Australia imports many goods produced from its exported raw or partially processed minerals. This conundrum can be observed in the situation where Australia exports crude oil, but at the same time imports fuel and diesel – we tend to sell dirt to buy diamonds. Australia's ability to import depends hugely on our ability to export, creating a significant dependence not only on our resources, but also the economic conditions of the countries that buy the resources. If demand falls, commodity prices collapse, or production is inhibited, Australia may lose the capacity to satisfy import demand for mineral services and goods (Goodman and Worth, 2008).

## Readjusting notions of value for long-term national benefit

Realising monetary benefits from our mineral endowment into the future requires a re-appraisal of what resource value means, and how cost is characterised within this meaning. Re-valued resources must reflect the true costs of production. For example, early stages in the mineral production chain (extraction and processing) have significantly higher environmental and social costs than later stages. Addressing this disparity through technological, operational or managerial advancement to minimise these costs will yield both environmental and social benefits, but will also create economic value from these hitherto undervalued stages.

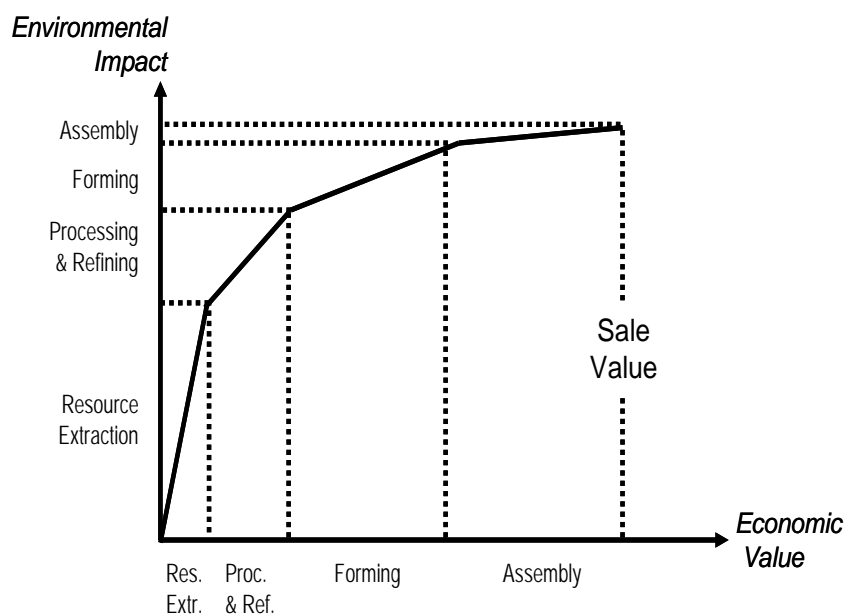


Figure 4: The relationship between added economic value and environmental impact at resource processing stages (after Clift and Wright, 2000).

Properly characterising the true costs of production will ensure an understanding of how these costs arise, and what impact they have on the economic viability of the minerals industry and the value it presents to society. Maximising genuine gains from minerals will become a key indicator of the industry's economic performance. Where profit-loss statements and healthy dividends have traditionally demonstrated wealth from minerals, future returns must also cover the expenses incurred while creating this form of wealth. Internalising the non-economic costs of mineral production attributes new value to these resources, and increases the likelihood that these resources are utilised for long-term national benefit.

Understanding the true costs of mineral production, and re-valuing our mineral wealth will ultimately influence our capacity to provide minerals and metals to market. As the economic, environmental and social costs of traditional minerals and metal production increase with peak minerals, in-use stocks will become more valuable. Our ability to realise this value through investment in recycling and re-processing technologies for existing products will yield significant national benefit: both in the contexts of ethical consumption and international competition from countries already acting to realise the value of in-use stocks. Development of reuse technologies that result in the economic viability of these activities will also substantially increase the resource base of commodities, which could supplement traditional production. Re-valuing these product-bound resources will also promote the necessity to realise end-use services for providing long-term access to minerals and national wealth without relying solely on traditional resource extraction.

## Acknowledgement

This research has been undertaken as part of the Minerals Futures Research Cluster, a collaborative program between the Australian CSIRO (Commonwealth Scientific Industrial Research Organisation); The University of Queensland; The University of Technology, Sydney; Curtin University of Technology; CQ University; and The Australian National University. The authors gratefully acknowledge the contribution of each partner and the CSIRO Flagship Collaboration Fund. The Minerals Futures Cluster is a part of the Minerals Down Under National Research Flagship.

## References

- ABARE (2009) Australian Commodity Statistics. Australian Bureau of Agricultural and Resource Economics, Canberra.
- Access Economics (2008) Global commodity demand scenarios, A report for the Minerals Council of Australia.
- Australian Government, (2010a). Budget Strategy and Outlook. Treasury Department & Department of Finance and Deregulation. Canberra. Australian Government.
- Australian Government, (2010b). The Resource Super Profits Tax: a fair return to the nation. Treasury. Canberra. Australian Government.
- Blunden, J. (1985) *Mineral Resources and their Management*, Essex, UK, Longman Group Limited.
- Chile Finance Ministry (2009) Annual Report: Sovereign Wealth Funds, 2008. Ministry of Finance, Santiago.
- Chong, J., Mason, L., Pillora, S. & Giurco, D. (2009) Briefing Paper – Product stewardship schemes in Asia: China, Taiwan, Japan and South Korea. Paper prepared for Department for the Environment, Water, Heritage and the Arts. Institute for Sustainable Futures, UTS, Sydney.
- Clift, R. & Wright, L. (2000) Relationships between environmental impacts and added value along the supply chain. *Technological Forecasting and Social Change*, 65, 281-295.

- Cooper, C. & Giurco, D. (2009) The Mineral Resources Landscape: an Expanded Conceptualisation of Minerals Sustainability. *Sustainable Development Indicators in the Minerals Industry (SDIMI)*. Gold Coast, QLD.
- Coorey, P. (2010) Sort out mining row, PM told. *The Sydney Morning Herald*. Sydney, Fairfax Publishing.
- Davis, J., Ossowski, R., Daniel, J. & Barnett, S. (2001) *Stabilization and savings funds for nonrenewable resources: Experience and fiscal policy implications.*, Washington D.C., International Monetary Fund.
- Department of Trade and Industry (UK) (2005) Waste electrical and electronic equipment (WEEE): innovating novel recovery and recycling technologies in Japan. Department of Trade and Industry (UK),,
- DFAT, (2009). Composition of Trade Australia 2008-09. Department of Foreign Affairs and Trade. Canberra, Australia. Australian Government.
- DTI (2005) Waste electrical and electronic equipment (WEEE): innovating novel recovery and recycling technologies in Japan. Global Watch Mission Report. Global Watch Mission on behalf of the Department of Trade and Industry, UK.
- Earthworks & Oxfam America (2004) Dirty Metals: Mining Communities and the Environment. [http://www.nodirtygold.org/pubs/DirtyMetals\\_HR.pdf](http://www.nodirtygold.org/pubs/DirtyMetals_HR.pdf).
- Eggert, R. (2003) The mineral economies: Performance, potential, problems and policy challenges. In United Nations Economic Commission for Africa (Ed.) *Managing Mineral Wealth*. Addis Ababa, Ethiopia, United Nations Economic Commission for Africa.
- Ehrenfeld, D. (2005) Recalculating Future Oil Reserves. *Science*, 309, 54.
- Fishman, J. (2004) Is Diamond Smuggling Forever-The Kimberley Process Certification Scheme: The First Step down the Long Road to Solving the Blood Diamond Trade Problem. *U. Miami Bus. L. Rev.*, 13, 217.
- Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S. & Walker, B., (2002). Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations. Council, E. A. Stockholm, Sweden. Swedish Government.
- Geoscience Australia (2009) Australia's identified mineral resources 2009. Geoscience Australia, Canberra.
- Giurco, D., Evans, G., Cooper, C., Mason, L. & Franks, D. (2009) Mineral Futures Discussion Paper: Sustainability Issues, Challenges and Opportunities. Institute for Sustainable Futures, UTS and Sustainable Minerals Institute, University of Queensland, Sydney.
- Giurco, D., Prior, T., Mudd, G. M., Mason, L. & Behrisch, J. (2010) Peak minerals in Australia: a review of changing impacts and benefits. Prepared for CSIRO Minerals Down Under Flagship. Institute for Sustainable Futures (University of Technology, Sydney) and Department of Civil Engineering (Monash University), Sydney.
- Goodman, J. & Worth, D. (2008) The minerals boom and Australia's resource curse. *Journal Of Australian Political Economy*, 61, 201-219.
- Gordon, R., Bertram, M. & Graedel, T. (2006) Metal stocks and sustainability. *Proceedings of the National Academy of Sciences of the United States of America*, 103, 1209-1214.
- Gordon, R., Bertram, M. & Graedel, T. (2007) On the sustainability of metal supplies: A response to Tilton and Lagos. *Resources Policy*, 32, 24-28.
- Gordon, R. L. & Tilton, J. E. (2008) Mineral economics: Overview of a discipline. *Resources Policy*, 33, 4-11.
- Gowdy, J. M. & McDaniel, C. (1999) The Physical Destruction of Nauru: An Example of Weak Sustainability. *Land Economics*, 75, 333-338.
- Gunderson, L. & Holling, C. (Eds.) (2002) *Panarchy: Understanding Transformations in Human and Natural Systems*, Washington DC, USA, Island Press.

- Hackl, R. (2010) Processing Technologies and Peak Minerals - What is CSIRO doing? National Peak Minerals Forum. Sydney, Australia.
- Hajkowicz, S. A. & Moody, J. (2010) Our Future World: An analysis of global trends, shocks and scenarios. CSIRO, Canberra, Australia.
- Hannan, E. (2010) Super-profits tax splits union movement *The Australian*. Sydney, News Corporation.
- Johnston, R. (2009a) Foresighting for Mineral Futures. Prepared for the Mineral Futures Collaboration Cluster. Australian Centre for Innovation, Faculty of Engineering, University of Sydney, Australia.
- Johnston, R. (2009b) Roadmap for the Mineral Futures Foresighting Project. Prepared for the CSIRO Mineral Futures Collaboration Cluster. Australian Centre for Innovation, Faculty of Engineering, University of Sydney., Australia.
- Lambert, I. (2010) Australia's national minerals inventory, discoveries and some strategic issues for sustaining a strong resources sector. National Peak Minerals Forum. Sydney, Australia.
- Larsen, E. R. (2006) Escaping the Resource Curse and the Dutch Disease? *American Journal of Economics & Sociology*, 65, 605-640.
- Maxwell, P. & Guj, P. (Eds.) (2006) *Australian Mineral Economics: a survey of important issues*, Monograph 24. Carlton, Victoria, The Australian Institute of Mining and Metallurgy.
- Mining Australia (2009) The high-stakes game of mining.  
<http://www.miningaustralia.com.au/news/the-high-stakes-game-of-mining>.  
01.06.09
- Moffat, K., Mason, C. & Littleboy, A. (2009) Preparing for uncertain mineral futures: A survey of AusIMM members on the future issues and drivers for the Australian minerals industry. Sustainable Development Indicators in the Minerals Industry (SDIMI) Conference, . Gold Coast, Queensland, Australia.
- Mudd, G. M. (2007a) An analysis of historic production trends in Australian base metal mining. *Ore Geology Reviews*, 32, 227-261.
- Mudd, G. M. (2007b) Global trends in gold mining: Towards quantifying environmental and resource sustainability. *Resources Policy*, 32, 42-56.
- Mudd, G. M. (2007c) Gold mining in Australia: linking historical trends and environmental and resources sustainability. *Environmental Science & Policy*, 10, 629-644.
- Mudd, G. M. (2009) The Sustainability of Mining in Australia: Key Production Trends and their Environmental Implications for the Future. Research Report No RR5.,
- Mudd, G. M. (2010) The Environmental Sustainability of Mining in Australia: Key Mega-Trends and Looming Constraints. *Resources Policy*, 35, 98-115.
- Mudd, G. M. & Ward, J. D. (2008) Will Sustainability Constraints Cause "Peak Minerals"? 3rd International Conference on Sustainability Engineering and Science: Blueprints for Sustainable Infrastructure. Auckland, New Zealand
- Neumayer, E. (2003) *Weak versus Strong Sustainability: Exploring the limits fo two opposing paradigms*, Cheltenham, UK, Edward Elgar.
- Pannet, R. (2010) Rudd acknowledges poll woes. *The Wall Street Journal*. New York, News Corporation.
- Pearce, F. (2002) Blood diamonds and oil. *New Scientist*, 174, 36.
- Raskin, P., Banuri, T., Gallopin, G., Gutman, P., Hammond, A., Kates, R. & Swart, R. (2002) Great Transition: the Promise and Lure of the Times Ahead. A Report of the Global Scenario Group. Stockholm Environment Institute, Boston.
- Ricardo, D. & Kolthammer, F. W. (1911) *The Principles of Political Economy and Taxation*, London, J.M. Dent & Sons, Ltd. London.

- Sarin, R. (2006) No dirty gold: consumer education and action for mining reform. *Journal of Cleaner Production*, 14, 305-306.
- Stevens, P. & Dietsche, E. (2008) Resource curse: An analysis of causes, experiences and possible ways forward. *Energy Policy*, 36, 56-65.
- SWF Institute (2010) Sovereign Wealth Fund Rankings. <http://www.swfinstitute.org/fund-rankings/>. June 9, 2010
- Tilton, J. E. & Lagos, G. (2007) Assessing the long-run availability of copper. *Resources Policy*, 32, 19-23.
- Topp, V., Soames, L., Parham, D. & Bloch, H. (2008) Productivity in the Mining Industry: Measurement and Interpretation. Productivity Commission Staff Working Paper, December,
- Treadgold, T. (1999) Resources: the nickel dream loses its shine. *Business Review Weekly (BRW)*. Australia.
- Walker, B. & Salt, D. (2006) *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*, Washington DC, USA, Island Press.
- WEF (2010) Mining and Metals Scenarios to 2030. World Scenario Series. World Economic Forum, Geneva, Switzerland.
- Williams, N. (2008) The exhaustion of mineral resources – a truism or a state of mind? International Geological Conference. Oslo, Norway.
- World Bank (2010) Commodity Price Data. <http://go.worldbank.org/5AT3JHWYU0>. June 9, 2010
- Ye, Q. (2008) Commodity booms and their impacts on the Western Australian economy: The iron ore case. *Resources Policy*, 33, 83-101.

**Appendix 1: An exploration of drivers of the Australian minerals industry under the World Economic Forum Green Trade Alliance Scenario.**

<b>Green Trade Alliance?</b> <i>Green Trade Alliance for environmental sustainability without</i>	More from Less		A Personal Touch	On the Move	Divergent Demographics	i World
	Trend closely mirrors this scenario. Australian miners increase production efficiency substantially in order to maintain competitive advantage. Technological advances have focussed on reducing energy and water use in mining to improve economic performance, and this has also improved the sustainability ratings of Australian resources.		Consumers seek products that are more consistent with their values. Focus on product design for more specific requirements than lowest cost will drive efficiency in production.	Mineral resources increasingly soaked up by global trend of urbanisation. However, the 'Tyranny of Distance', which was experienced acutely in Australia prior to the development of fossil fuelled vehicles, begins to challenge our ability to meet GTA trade guidelines and agreements.	Value of GTA agreements perceived differently throughout Australian society causing conflict. Growing global middle class places huge demand on Australian resources, and ability to operate sustainably.	Growing demand for electronic goods mirrors demand for rare earth minerals in particular. Australia's ability to sustainably produce rare earths compromises our competitiveness.
	Mining will be more expensive	Global context is important	Australian expectations change	Substitution is more important	Emissions trading	Environmental variability
	Growing cost of mining will place pressure on companies to remain competitive.	Complex relationships between GTA and non-GTA countries influence Australian potential for export earnings.	Societal desire for sustainable mining and environmental stewardship key drivers in operations.	Sustainability objectives reached through greater investment in finding possible mineral substitutes.	Australia adopts an emission trading mechanism, driving costs of production even higher, and increasing.	Environmental variability and extreme weather events interrupt production.
	Technological advances		Long-term decision-making	Australia as minerals services hub	More even distribution of wealth from minerals	
	Directed at improving resource competitiveness. Development of cradle to cradle stewardship		Long-term political cycles support environment policy-making	Australia focuses on stewardship and protectionism to foster strong mineral services	GTA and Sustainable trade organisation ensure Australia implements mechanisms for long-term national benefit	

**Appendix 2: An exploration of drivers of the Australian minerals industry under the World Economic Forum Rebased Globalisation Scenario.**

<b>Rebased Globalisation</b> <i>Power comes from possession of resources – resource-rich countries play by</i>	<b>More from Less</b>	<b>A Personal Touch</b>	<b>On the Move</b>	<b>Divergent Demographics</b>		<b>/ World</b>	
	Where cost remains the main concern for advantage in trade, countries that improve production cost efficiencies increasingly hold power under this scenario.	Consumers seek products that are more consistent with their values. Focus on product design for lowest cost will continue drive efficiency in production.	Increasing costs for transport tempers the nation’s ability to extract, process and bring its resources to more distant markets.	Changing global demographics drives demand for Australian minerals, challenging sustainability objectives, but contributing to the nation’s resource power. This power is unequally distributed between resource-rich states and those without significant resources. Gaps between rich and poor in Australia widen.		Increasing globalisation drives electronic dependence for connection. Rare earths and other electronic component metals in Australia depleted.	
	<b>Mining will be more expensive</b>	<b>Global context is important</b>	<b>Australian expectations change</b>	<b>Substitution is more important</b>	<b>Emissions trading</b>	<b>Environmental variability</b>	
	Increased costs of production in Australia reduce our power in relation to resources.  Scenario favours countries with low-cost resources.	Strategic importance of Australian minerals on export markets offsets some of the market share lost through higher production costs. However, transport costs become more difficult to offset.	With increasing costs, companies may not invest money in environmental remediation or mine safety – public expectations may not be met resulting in the potential for conflict.	The scenario is likely to divert attention away from substitution, as this would mean a loss of power.	Australia would not adopt an emission-trading scheme under this scenario.	Environmental variability might increase with little movement in CO <sub>2</sub> abatement.	
	<b>Technological advances</b>	<b>Long-term decision-making</b>		<b>Australia as minerals services hub</b>		<b>More even distribution of wealth from minerals</b>	
	Technology directed at capturing downstream value from processing to gain power	Increased globalisation influences decision making – proliferation of local regulations on resource use in Australia		Australia’s rich mineral endowment and ability to value-add to processes increases international influence		Stronger globalisation and power struggles make even distribution of wealth difficult in Australia	

**Appendix 3: An exploration of drivers of the Australian minerals industry under the World Economic Forum Resource Security Scenario.**

<b>Resource Security</b> <i>Globalisation is a distant memory as nations prioritise narrow</i>	<b>More from Less</b>	<b>A Personal Touch</b>	<b>On the Move</b>	<b>Divergent Demographics</b>	<b>i World</b>	
	Australia has increased production efficiency. Vertical integration of industry is key, and the local manufacturing sector is expanding.	Rather than exporting primary products, increased local processing and manufacturing allows Australia to supply more personalised products to the local market.	Vertical integration prevents some of the impacts of the Tyranny of Distance, but urbanisation in Australia is placing pressure on scarce resources.	Different sectors of Australian society seek different benefits from the mining industry, and conflicts over resource production, appropriation and use are widespread.	Australia hoards electronically important minerals. Contracting global markets cause decline in limitations caused by the comparative advantage, and local electronics industry flourishes.	
	<b>Mining will be more expensive</b>	<b>Global context is important</b>	<b>Australian expectations change</b>	<b>Substitution is more important</b>	<b>Emissions trading</b>	<b>Environmental variability</b>
	Changing mining conditions exaggerate hoarding of resources and restrictions on exports.	Australia develops tight, strategic minerals trading partnerships.	Changing nature of markets prevents many of Australia's social expectations from being met.	Countries without minerals rely on substitution. Australia relies on trade with partners for income and goods.	No emissions trading to price CO <sub>2</sub> .	Growing environmental variability places pressure on Australia's ability to produce the metals needed locally, and by close trading partners.
	<b>Technological advances</b>	<b>Long-term decision-making</b>	<b>Australia as minerals services hub</b>	<b>More even distribution of wealth from minerals</b>		
	Australia focuses technology on in-country recycling, manufacturing, materials stewardship	Policy development focuses on protectionism.	Decreased export of Australian minerals negates this priority action	Falling exports lead to lower demand for Australian minerals, less foreign income, less pressure on resources		

Appendix 4: An exploration of drivers of the Australian minerals industry under the Great Transition Scenario (Raskin *et al.*, 2002).

<b>Great Transition</b> <i>Futures envision fundamental and favourable social transformation.</i>	<b>More from Less</b>	<b>A Personal Touch</b>	<b>On the Move</b>	<b>Divergent Demographics</b>	<b>i World</b>	
	Dematerialisation and decoupling of consumption from wellbeing in Australia. These actions driven by resource use efficiency in Australia.	Consumers want less and primary resource demand falls. Consumers choose recycled and/or energy efficient goods resulting in lower global demand for Australian minerals	Australian population growth stops and 'bio-capacity' determines urbanisation. Infrastructure development prioritises transport efficiency. Settlements become integrated and compact.	Australia uses a sovereign wealth fund from minerals to support an aging population and limit health issues from lifestyle changes. Sustainable resource production is actively achieved through limited exports to the growing middle class countries.	Materials efficiency and substitution will result in falling demand from electronics producers for Australia's minerals, particularly rare earth elements.	
	<b>Mining will be more expensive</b>	<b>Global context is important</b>	<b>Australian expectations change</b>	<b>Substitution is more important</b>	<b>Emissions trading</b>	<b>Environmental variability</b>
	Growing environmental, social and financial costs of mining drive exploration of alternatives.	Global minerals consumption declines and Australia seeks to establish a position as a global mineral services provider.	Changing social expectations in Australia impact on metals consumption and resource values. Dematerialisation is called for.	Dematerialisation is a key, and seeking way to substitute current resources will compliment this process.	Technologies development for climate change mitigation occurs in conjunction with the introduction of a strict emission trading scheme with prices set through global agreement	Decreased variability through a proactive approach to reducing CO <sub>2</sub> emissions.
	<b>Technological advances</b>	<b>Long-term decision-making</b>		<b>Australia as minerals services hub</b>	<b>More even distribution of wealth from minerals</b>	
	Australian technologists focus on dematerialisation. Renewable energy technologies developed, and fit-for-use becomes very important.	Decision-making focuses on establishing long-term sustainability principals. Key policy areas ensure closed loop, low impact commodity cycles and lower environmental costs		Closed loop commodity cycles reduce Australia's need to be a service hub in the global minerals sector.	The nature of Wealth is reconceptualised. Mechanisms for benefit sharing are enhanced, particularly through regional development – development of sustainable communities	