MINERAL FUTURES DISCUSSION PAPER: SUSTAINABILITY ISSUES, CHALLENGES AND OPPORTUNITIES

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The Institute for Sustainable Futures (ISF) was established by the University of Technology, Sydney in 1996 to work with industry, government and the community to develop sustainable futures through research and consultancy. Our mission is to create change toward sustainable futures that protect and enhance the environment, human well-being and social equity. We seek to adopt an inter-disciplinary approach to our work and engage our partner organisations in a collaborative process that emphasises strategic decision-making.

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The Centre for Social Responsibility in Mining (CSRM) was established by the University of Queensland in 2001 in response to growing interest in and debate about the role of the mining and minerals industry in contemporary society. As a centre within the Sustainable Minerals Institute, CSRM has contributed to industry change processes through leading research, post-graduate teaching, professional education, research-orientated consulting and pro-bono work. CSRM has global reach, with particular experience in Australia and the Asia-Pacific region.

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Background and aim

Minerals and metals will continue to play an important role in underpinning the future prosperity of our society. However, to confront the challenge of sustainability, the way in which resources are currently used, and might usefully be used in future, merits serious and broad discussion. This paper explores the background issues relating to mineral futures as a first step in the three-year research program of the Mineral Futures Collaboration 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. Strategic questions, around which the paper is framed are:

- What global and local drivers are likely to influence the future use of minerals?
- How are commodity futures currently studied and understood?
- How adequate are attempts to close the loop[1] and other industry responses to sustainability drivers?
- How integrated is the minerals and metals product value chain when considering manufacture, use and disposal, or reuse and recycling of finished goods?
- What future role is seen for new technology in the minerals industry, and how are these technologies evaluated?
- How do communities plan for the future in resource-rich regions and how do they cope when the resources are depleted?
- What important cross-scale interactions between regions, technologies and commodity cycles need to be considered to address sustainability?

The ultimate aim of this discussion paper is to catalyse discussion – not just about how the minerals industry can be more sustainable, but rather, what an industry would look like which is an integral part of a sustainable society. How will the influences from globalisation and climate change affect the future of minerals? Should Australian industry structure its future business to focus primarily on resource extraction or include considerations of resource stewardship? Should technological innovation be paying more attention to recycling technologies in addition to minerals processing technologies? How can the communities of minerals-rich regions be made more resilient to future changes in the mineral industry?

These questions help frame the discussion on how to realise long term national benefit from Australia's mineral resources. Together with companion papers on foresight processes, this document will be used to inform the research pursued within the CSRIO Mineral Futures Initiative and Collaboration Cluster; in particular, the foresight processes used and how it links with the Cluster's projects on commodity futures, technology futures and regions in transition.

Reviewing drivers and futures research

Our paper begins with an overview of drivers that both affect the long-term structure of the industry and contribute to future uncertainty. These drivers include climate change (minimising impacts, adapting to constraints and realising opportunities); renewing social licence to operate with new practices, technologies and locations; responding proactively to the constraints and opportunities posed by Peak Oil and Peak Minerals (including increasing

[1] An economy in which any industrial outputs are recycled to create other products to conserve resources

costs and impacts as lower grade ores are processed); and issues of governance and social aspirations for strong sustainability.

Some of these drivers are industry specific and others affect the whole economy. A review of two prominent foresight projects: the *Limits to Growth* studies (Meadows *et al.*, 1972, 1974, 1992, 2004), and the Stockholm Environment Institute's *Great Transitions* (Raskin *et al.*, 2002), illustrate how uncertain drivers may be considered in long-term futures and also highlight the central focus that resources take when considering alternative futures. These broad conceptualisations of the future raise the issue of dematerialisation of the economy as a key issue for sustainable development.

A transition to a sustainable society is likely to highlight the role of new social values and more effective governance regimes to institutionalise sustainability principles. Issues such as reduced and more equitable global consumption, corporate social responsibility, the internalisation of the real social and environmental costs of goods and services are likely to be on-going, and increasingly urgent, topics of discussion. The prospect of a more dematerialised economy and closed-loop production/consumption cycles have consequences for commodity futures, technological innovation and the sustainability of mineral-rich regions.

How is future commodity use studied and understood?

This question was asked to assess how the long term thinking in respect to commodity extraction, processing and use is currently understood. What information and processes are used to inform future decisions? What deficiencies in current approaches could be addressed through the Cluster's research?

Production and demand forecasts dominate the futures thinking concerning minerals and metals – where increases in both are viewed as favourable. The future potential of reused and recycled metal in meeting demand receives relatively little attention, though some academic literature on Material Flows Analysis (showing stocks and flows of metals in ores, in use and in discarded scrap) gives some voice to this critical issue. Whilst such analysis is intended to guide policy, there are no examples of it doing so in Australia. In a world with growing resource, water, energy and carbon constraints it is prudent to consider how Australia might play a strategic role in minerals futures as a leading centre of minerals stewardship and recycling, not just as a major centre for minerals extraction. This may be a particularly critical issue for the strategic management of rare and high-value minerals that are essential for future technologies.

Many mid-term commodity forecasts (5–10 years) optimistically assume continuous growth in minerals demand, but the longer-term focus (50 years) taken in this work must necessarily consider other scenarios.

Remaining questions not adequately addressed in the literature include:

- How might changes in end-uses for minerals (for example, if world energy adopts large scale solar, hydrogen, nuclear or wind) cause changes in the demand for, and profitability of, particular minerals and attractiveness of different technologies?
- How might the shift towards greater recycling and reclamation technologies impact on the business model for minerals companies (might they become metal service providers who rent the metal)?
- How could carbon emission reductions and fuel costs affect mineral wealth by constraining extraction processes?
- What will the minerals industry look like if global mineral consumption declines or increases?

- What effect will Peak Oil have on mineral futures (including changed patterns of transport and international trade)?
- How can traditional mineral exporting countries, such as Australia, maintain a strategic influence as a minerals ‘superpower’ if there is a shift from ‘virgin ore’ to high levels of product stewardship creating an increasingly large pool of resources for use in new and existing product lines that are located outside of this country (*e.g.* Japan). In a recent speech in Western Australia, the former chief scientist of the Australian Federal Government, Dr Robin Batterham, sees this occurring within fifty years (Batterham, 2009).
- How will market liberalisation, a pattern that has been occurring in key world provinces over the past fifty years (including Indonesia, Philippines, Chile), affect industry access to resources?
- What future political constraints might influence access to the quality and quantity of resources? How might this access be affected by discussions concerning ‘free, prior, informed consent’, greater recognition of indigenous sovereignty, or by approaches to ‘conflict resources’?

Minerals and environmental sustainability

At present, activities towards addressing environmental sustainability with respect to minerals and metals are often limited to reducing energy and water inputs per tonne of product (rather than in absolute terms), and to ensuring mined land rehabilitation on-site. The need for a holistic and integrated approach to stewardship along the whole production and consumption cycle is recognised in industry visions, but remains limited in substantive implementation. This paper argues that the environmental dimensions of a sustainable minerals industry must be considered *throughout the metal extraction, processing, use and reuse stages* of the minerals system, in addition to the common focus on operational stages of mining and minerals processing. Importantly, these considerations should be made alongside considerations of the economic and social aspects of sustainability, which are discussed in detail by Schandl and Daras (2008).

Technology futures: innovation, assessment and policy

Technology futures are linked to societal and human-nature relationships and values. As the societal aspiration for sustainability progresses, principles promoting inter-generational and intra-generational equity ought to increasingly inform technology research and development choices and investments.

Technology roadmaps feature heavily as a foresight technique regarding minerals, with a focus on which technologies will open up previously inaccessible resources at reduced cost and impacts. There is little focus on the future of recycling or other technologies that could open up new profit points along the production consumption chain.

If companies are to profit from a dematerialised economy, technologies that incorporate design for environmental principles, which support closed-loop life cycles involving reuse and recycling, must be a focus of technological innovation.

Technologies that reduce landscape disturbance and pollution, and the energy, carbon and water-intensity of mining and minerals processing will become increasingly strategic for achieving sustainability in the minerals industry.

The acceptability of novel technologies (such as carbon capture and storage, submarine tailings disposal, *in-situ* leach and deep sea mining) will influence whether these, or alternative technologies, emerge as components required to realise a sustainable minerals future.

Technology Futures Assessment offers promise in shaping technology design to enhance environmental and community outcomes, but uptake to date has been slow in Australia. Public participation is critical to increasing the likelihood that the technologies under development will be acceptable to the community and be taken up by industry and governments.

Other issues yet to be addressed include the ability of the Australian minerals industry to remain influential and profitable in light of potential shifts in the commodity mix (for example, bulk commodities or higher value niche commodities), or in relation to the emergence of product stewardship drivers in the international economy.

Regions in transition

Regional futures were reviewed to explore current and emerging issues at the regional and community scales, and how planning for the future is undertaken at these scales. Cross-scale interactions from key global drivers (such as climate change, the global economy and Peak Oil) will extend their influence into mineral-rich regions and local communities will increasingly confront pressing social and environmental issues.

An integrated process of regional planning and governance are critical for the sustainability of resource-rich regions. Considerations include how to empower affected communities (Indigenous and non-indigenous) to ensure they are given avenues to gain meaningful involvement in determining their futures.

Currently, regional planning by governments focuses on issues of economics, housing, population and environment. Peak industry bodies have considered infrastructure requirements to realise increased commodity trade, but individual projects also require detailed environmental and social impact assessments. Integrated planning at the mine site has focussed on connections between catchment and social management planning with the corresponding regional plans (see for example in Queensland, Sustainable Resource Communities Policy). However, further work is required to integrate sustainability planning for regions, with a focus on ensuring long term prosperity linked to a detailed understanding of technology and commodity futures.

The geographic, temporal and spatial boundaries within which regional futures are assessed are global and long-term, and not restricted to the life of a mine, the mineral processing phase or waste disposal operations. Nor is it limited just to those stakeholders *in place*, but also extends to others with an *interest* (including future generations). Discussion must extend to planning for sustainable social and environmental benefits in mining regions *post-mining* – where minerals industry operations leave a positive legacy to the region or community. These considerations extend well beyond the lifespan of the mining or minerals processing operation.

Unanswered questions for resource-rich regions include: how to manage and govern mineral-rich regions to achieve sustainability through boom-bust cycles? How can affected communities enjoy long-term benefits from the wealth extracted while protecting local environments, and maintaining well-being and healthy community life (including traditional values and cultures) when confronted with mining development? How does the agency afforded by devolved or centralised decision-making affect outcomes for the region or community? What are the institutional arrangements associated with land use change at a regional scale and how can these be best integrated to achieve sustainable outcomes (particularly when considering the cumulative impacts of mining at the regional scale)?

Further discussion must also consider how to plan for a 'just transition' to an alternative economy in post-mining situations in order to protect the wellbeing of displaced workers and affected communities.

Over-arching questions for discussion

The specific issues discussed in the paper, and which have been identified above, highlight that there are many complex issues that must be included in the discussion about minerals futures in Australia. These include:

- What characteristics of the minerals industry might direct the potential approach to futures research within the Mineral Futures Cluster?
- How can futures research within the Cluster recognise the dynamic and complex socio-ecological systems that the minerals industry is located in, particularly the inherent capacity for surprise, uncertainty and discontinuity in these systems?
- How adequately can 'futures thinking' consider the impacts of interactions across spatial and temporal scales, and across ecological, social, economic and political domains of complex systems like those concerning the minerals industry?
- On what points do different stakeholders and perspectives align and diverge with respect to sustainability? Where do we need consensus and how do we incorporate a diversity of views?
- What would enable current approaches used for long-term planning (*i.e.* forecasting) to more adequately acknowledge the main uncertainties described in this paper – ecosystem distress and collapse, climate change, post-oil society, more or less globalisation, dematerialisation, societal transformation to a steady-state economy?
- How could the minerals industry be profitable in a more dematerialised economy with a focus on using and reusing metals to provide services?
    - Which commodities and technologies are compatible with such societies?
    - Which technologies can realise new profit opportunities in a closed-loop economy?
    - At what scale should we seek to close the loop? For which commodities?
    - How would Australia develop a leadership role?
- What local, national and global governance mechanisms need to be in place to more effectively empower and protect the well-being and sustainability of communities in resource-rich regions?

1. INTRODUCTION AND OVERVIEW

To develop Australia's long-term prosperity, we need to better understand the roles that our minerals resources can usefully play in supporting economies of the future, including our own.

This paper reviews the futures-oriented research that has been undertaken regarding mineral resources: with respect to global drivers, commodity cycles and their impacts, with respect to the role of technological innovation, and with respect to regional futures in mineral-rich communities. We identify points of agreement and dissent, prevailing themes and unanswered questions as a basis for informing discussion and future research.

This work is funded by the CSIRO Mineral Futures initiative within the Minerals Down Under Flagship and will be used to inform the research of the Flagship Collaboration Cluster comprising the University of Queensland (Centre for Social Responsibility in Mining at the Sustainable Minerals Institute), University of Technology, Sydney (Institute for Sustainable Futures), Curtin University of Technology (Research Centre for Stronger Communities), Central Queensland University, Australian National University and CSIRO, as well as inform future engagement with stakeholders.

1.1. RELATIONSHIP TO OTHER PROJECTS

This discussion paper is being developed in parallel with six companion papers:

(1) Foresighting for mineral futures (Prof. Ron Johnston, University of Sydney);
(2) Overview of scenario process stages (Prof. Ron Johnston, University of Sydney);
(3) Applications foresight approaches outside minerals (Dr. Chris Riedy, ISF);
(4) Stakeholder discussion paper (Dr. Kieren Moffat, CSIRO)
(5) Australian minerals industry in a global context (Dr. Heinz Schandl, CSIRO)
(6) Neighbour of Choice Partnership Model (Dr. Amma Buckley, Curtin University)

These discussion papers will be used collectively, together with this paper describing the minerals context, to develop the approach to foresight work pursued in the Cluster.

The research conducted in the Mineral Futures Cluster has been grouped into three themes (which will be informed by the findings of this discussion paper):

- Project 1: Commodity Futures
- Project 2: Technology Futures
- Project 3 Regions in Transition

In addition to the cluster research, CSIRO researchers are conducting related work as part of the CSIRO Mineral Futures initiative within the Minerals Down Under Flagship.

1.2. OUTLINE OF DOCUMENT

This discussion paper is divided into six sections as shown in Figure 1, overleaf. Following this introductory section, Section 2 identifies the global ecological, social and economic **context** in which the Australian minerals industry is located and discusses some of the key global **drivers** that are likely to influence the trajectory of the socio-ecological system in which the industry operates. To assess the ways in which complexity and uncertainties can be incorporated into long-term futures, two significant studies with implications for minerals futures are discussed: the *Limits to Growth* reports and the *Great Transition*s scenarios. Industry responses to sustainability drivers are outlined and a **Mineral Resources Landscape** framework is proposed as an integrating framework for understanding current and future activities that will promote sustainable metal cycles.

Section 3 discusses how commodity futures are studied and understood. It examines production and demand trends and forecasts, Material Flow Analysis and the environmental impact of operational phases at a mine site, and material flows along the production-consumption life cycle. The information and approaches used to inform future decision-making is explored, together with the underlying values fundamental to these approaches. The section highlights the need for a more integrated approach to assessing the future role of the Australian minerals industry in a less materially-intense, more closed-loop and carbon-constrained society.

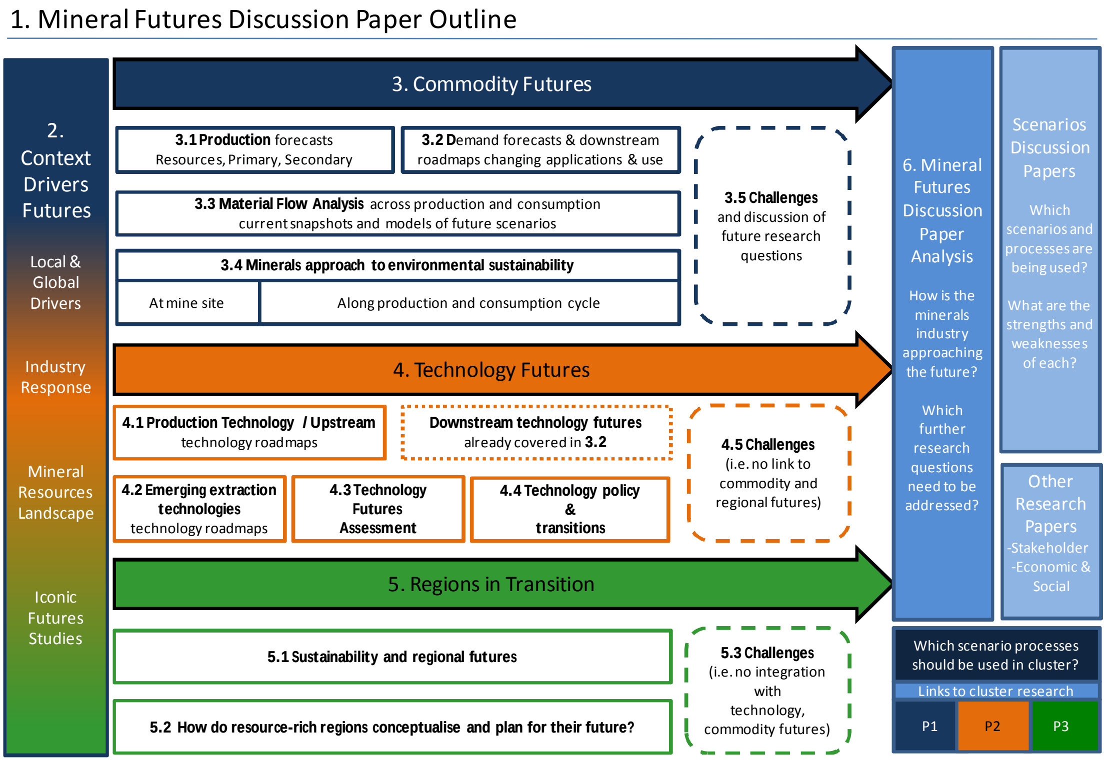


Figure 1: Outline of discussion paper

Technology futures are discussed in Section 4, which locates technology within the socio-ecological landscape. The section examines upstream technology roadmaps – where minerals come from, and the implications in developing emergent technologies for minerals extraction, processing and refining. It also looks at downstream technology roadmaps – where do minerals go? Downstream roadmaps take two distinctive forms: one identifies existing markets and products that utilise particular minerals; the second attempts to identify new products and use materials in new ways (*e.g.* lithium batteries in electric vehicles). Drivers for technologies for a less materials-intensive society are also examined, and the dearth of dematerialisation- and recycling-focussed roadmaps are noted. Key emergent minerals processing technologies are outlined and the process for their evaluation (technology futures assessment) is discussed and critiqued. The section concludes with a discussion of technology policy and its role in influencing minerals use and technology futures.

Section 5 discusses some of the key sustainability issues affecting the future of minerals-rich regions and how regions themselves plan for the future. This discussion extends to how regions will respond to global drivers such as climate change, the effect of new technologies on local minerals industry futures, how minerals-rich regions can capture more of the wealth generated from them and make transitions to sustainable futures in response to changing ecological, social and economic environments and pressures. The section concludes by identifying a range of issues that continue to be, or are emerging as, critical ecological and social sustainability issues that affect the mineral industry's social licence to operate, including the impacts of mining in Indigenous communities.

Section 6 draws together the points of agreement and tension across commodity, technology and regional futures. It then frames a series of questions, based on the remaining tensions and identified research gaps that can be used to prompt further discussion of where, and how in a changing world, Australian society will realise national benefit from its mineral endowment and its mining, minerals processing and recycling activities. Finally, some thoughts are put forward for discussion regarding how complexity, cross-scale interactions and uncertainty can be better understood and managed for in information systems and policy.

2. CONTEXT, DRIVERS AND FUTURES

DRIVERS AND FUTURES OUTLINE

This section explores the global context in which current discussions about the future of minerals is occurring (2.1) and identifies key system drivers that work at global, national and local scales (2.2). These drivers include the social movement towards sustainability and the integration of sustainability across ecological, social and economic domains, climate change, Peak Oil and peak minerals, industry consolidation, the pressures for corporate social responsibility, and for eco-efficiency and dematerialisation.

Industry responses to these drivers and issues are summarised (2.3) and the Mineral Resources Landscape is proposed as an integrating framework for considering drivers that affect the industry and identifying leverage points for responses (2.4). Having identified these drivers (and their associated uncertainty), future scenarios that anticipate change based on current or emergent properties of complex socio-ecological systems are reviewed (2.5); both to see how futures processes can be used to manage uncertainty and to show how mineral resources are perceived and located within comprehensive visions of the future.

2.1. CONTEXT

Global demand for minerals has grown rapidly over the last 20 years and the minerals industry has become a critical component of the modern economy. Over the last two decades the industry has changed with the emergence of new ecological and social stresses, new commodities, technologies and regional pressures.

With more of the world's population now living in cities than not, the material intensity of these livelihoods and the way that resources are managed and recycled in cities has become increasingly important. This century will witness the rise of the Global Mega-City Region (*e.g.* London and the adjoining region of South-east England) with trade between such regions now shaping patterns of global trade (Pain, 2008). Australia will play important roles in supplying material resources into east Asia and the Chinese economy, and in supplying the technological and knowledge services to these and surrounding economies. It should also be highlighted that rural and regional landscapes in Australia and elsewhere will provide most of the resources used in these global mega-city regions.

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 requires anticipating change, recognising the key drivers that currently, or will potentially, influence change within the system and acting in response to this insight (Folke *et al.*, 2002 p 40; Gunderson and Holling, 2002; Walker and Salt, 2006). The next section outlines the currently identified global and local drivers in the minerals context.

2.2. GLOBAL AND LOCAL DRIVERS

This section identifies key drivers that are likely to be powerful influences on the future of the minerals industry and are, therefore, critical issues for discussion and research in mineral future scenarios.

Global drivers in the minerals industry are those characterised by linked ecological, social, economic and political dimensions. Two key drivers include globalisation and sustainability, each of which has implications for the planet’s capacity to supply materials and absorb wastes, limits on human resource consumption patterns, and technology choices. Climate change (Intergovernmental Panel on Climate Change, 2007a; Intergovernmental Panel on Climate Change, 2007b), Peak Oil (Campbell and Laherrère, 1998) and a more comprehensive understanding of the health of the Earth’s ecosystems on which life depends (Millennium Ecosystem Assessment, 2005) are also becoming significant drivers for the minerals industry. Each of these drivers will affect different localities in different ways, particularly through their impact on water or energy use, or their effect on the location and scale of markets.

2.2.1 Sustainability – weak and strong

The Australian Government's National Strategy for Ecologically Sustainable Development (NSESD) process recognised ecologically sustainable development (ESD) as the foundation for sustainability and defined it as:

> *Using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased* (Ecologically Sustainable Development Steering Committee, 1992).

Sustainability, with its goal of intra- and inter-generational equity, is a powerful social driver influencing discussion and research on minerals futures. The debate about sustainability extends to a range of views about the extent to which natural capital can be transferred into financial and human capital. Sustainability can usefully be examined and discussed by distinguishing between ‘weak’ and ‘strong’ sustainability.

Weak sustainability suggests intergenerational equity is ensured by providing equal development opportunities for present and future generations. When measuring equity, the utility of manufactured capital is assumed to be perfectly substitutable with natural capital (provided, for example, by a healthy environment). Ayres and co-authors (1996) note that development consistent with weak sustainability can lead to environmental devastation. Phosphate mining on the Pacific island of Nauru provides a good example of weak sustainability. Profits from the country’s natural capital, in the form of phosphate, were used to establish a trust fund that could guarantee the economic sustainability of the country. However due to unforseen factors (primarily though poor investment choices) this fund was depleted, and the economic future of the country, once wealthy, is now limited (Gowdy and McDaniel, 1999).

Strong sustainability advocates assert that manufactured and natural capital are not interchangeable and that, in fact, human, environmental and economic capital must be independently sustained through generations (Costanza and Daly, 1992; Daly and Townsend, 1993; Wackernagel *et al.*, 1999). This is referred to as providing 'non-diminishing life opportunities' (Daly and Cobb, 1989)[2] and requires the maintenance (or improvement) of ecosystems that support life on Earth. This recognition underpins the need to assess the environmental impact of human activities, including those that supply metal to the economy. One point to note is that unlike timber or fisheries, terrestrial mineral resources are rarely a part of ecosystems, but their removal usually results in disturbance to the natural environment (Franks *et al.*, 2009).

Figure 2 shows that mineral extraction and processing and use activities, in various configurations, can be placed at different points on a spectrum of weak and strong sustainability. It is important to frame what we mean by the term 'sustainability' with respect to the minerals industry and to show that it is not possible to consider a sustainable industry within an unsustainable economy.

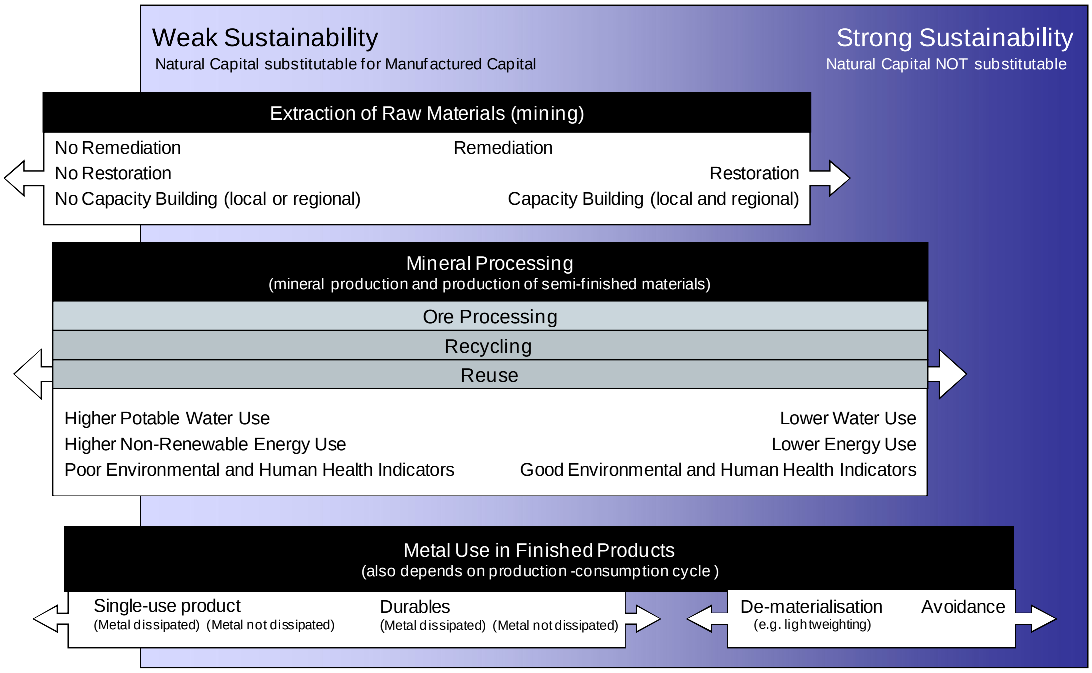


Figure 2: Minerals system on the weak-strong sustainability spectrum

Most raw material extraction and virgin material processing operations are located at the weak sustainability end of the continuum depicted above. They represent the stage where the minerals industry converts natural capital into commodities and financial capital (Ayres *et al.*, 1996). Based on this example, a minerals industry system embedded in a more sustainable economy must shift its activity to include active stewardship across closed-loop commodity cycles and metal reuse. It must increasingly seek opportunities to use less metal for service provision, and thus maximise ecological, social and economic value from mineral resources, while protecting landscapes, water, biodiversity and other aspects of ecosystems.

[2] There is an even stronger position of 'very strong sustainability' linked with the 'deep ecology' philosophy that all life forms have a right-to-life and should be maintained. This overlooks our current dependence on primary resources and that in the natural world species and ecosystems are in a constant flux and human activity is itself a part of nature (Ayers *et al.*, 1999).

2.2.2 Sustainability and ecosystem health

The ecosystem health perspective is another frame through which sustainability has been analysed. It focuses on maintaining or restoring the health of the Earth's ecosystems through achieving sustainable human livelihoods, human and animal health, and sustainable cultural traditions within a symbiotic relation of humans within nature (Rapport *et al.*, 1998; Rapport *et al.*, 2003). The emergence of widespread and growing ecosystem stress and linked human health distress attributable to non-sustainable human impacts on the ecosphere, including in mineral-rich regions (Connor *et al.*, 2004), may cause societies to move from general support for a relatively weak sustainability model to support for a stronger sustainability paradigm. Such a shift could potentially have a significant impact on the minerals industry, including the scale of production and consumption, and access to vital resources (including water) in critical and vulnerable ecosystems.

2.2.3 Risks associated with climate change

While climate change is a global phenomenon that will have major impacts on ecological, social and economic sustainability, it will also have highly localised impacts on Australia's minerals industry. In 1997, the IPCC noted that because of the size of the minerals industry in Australia, climate change impacts would have significant consequential effects on the Australian economy, and that the impacts on minerals industry operations would vary depending on the scale of change, the environmental conditions at different sites, and the nature of the operations (Intergovernmental Panel on Climate Change, 1997). A decade later, in its 2007 report on impacts adaptation and vulnerability, the IPCC noted a lack of research on the impacts of climate change on the Australian mining industry, despite its economic significance (Intergovernmental Panel on Climate Change, 2007b).

These impacts include rising average temperatures affecting the design and operation of minerals industry processes, and changes to rainfall and evaporation affecting materials handling. Impacts on the design and operation of infrastructure like mine pits, drainage systems, tailings and mineral waste disposal systems, roads and railways may also be impacted. It would also affect supplies of surface and groundwater, the quality and disposal of wastewater, management of dust and air quality, and site rehabilitation and re-vegetation. The IPCC reports also noted that storm events, particularly in Northern Australia, could have a significant impact on soil erosion, tailings stability and re-vegetation growth rates, while coastal storms and sea level change will have impacts on ports and other materials transport facilities. The reports also suggested increased insurance and investment risk with the likelihood of higher premiums would be likely (Intergovernmental Panel on Climate Change, 1997; Intergovernmental Panel on Climate Change, 2007b).

Mitigation measures to address climate change are likely to have their own impact. These could include a preference for low-carbon commodities and technologies, and a higher price on carbon dioxide emissions through carbon taxes and/or emissions cap and trading schemes. Furthermore, pressure for reducing carbon emissions, higher energy prices and water conservation in a climate change-affected world will be powerful drivers to encourage resource conservation, efficiency, recycling and reuse (Young and Sachs, 1994; von Hauff and Wilderer, 2008).

2.2.4 Environmental constraints, peak minerals and ore grade declines

As Australian ore grades continue to decline, the environmental impact of processing mineral resources continues to increase (Mudd, 2007). The range of impacts associated with declining ore grades and peak minerals[3] will also include those relating to costs, technologies and viability of primary extraction in relation to recycling. The lack of problem awareness and governance structures to manage peak minerals, like phosphorus for instance, has been highlighted by (Cordell *et al*., 2009)

Importantly, the ecological, social and economic health of many minerals industry-affected regional communities is diminished through loss of ecosystem services when landscapes are changed and biodiversity lost. Consideration of upstream and downstream sectoral links and dependencies provides opportunities to evaluate the potential for improving sustainability in minerals industry affected regions, due to increasing pressure for improved social and environmental outcomes in these areas. The issue of the legacy of mined land is also important and recent progress has been made in developing sustainability criteria and an indicators framework in this area (Worrall *et al.*, 2009).

For instance, the cross-sectoral, 'triple bottom line', analysis conducted by the CSIRO, entitled *Balancing Act*, provides a broad consideration of the ways in which economic, environmental and social concerns in one sector can have significant impacts or implications for a range of other sectors (CSIRO, 2004). The study identified factors that will become likely challenges to future extraction processes affecting iron ore, bauxite, gold, lead, and a range of other materials used in construction and agriculture, including:

- High water use;
- High energy use, and;
- Failing to deliver lasting benefits to regional communities in which mining activities have historically taken place.

The *Balancing Act* analysis also clearly indicates that the minerals industry presents challenges to developments in other industry sectors, such as agriculture, with which mining indirectly competes on the basis of land use and access to resources. Conflicts arising from competition for limited resources have been demonstrated by clashes between the minerals and agricultural industries. For example, conflicts in the Hunter and Liverpool Plains with respect to coal mining and are likely to become more intense as climate change impacts reduce the quantity and quality of water resources.

Further concern is raised as mining is considered in increasingly remote and vulnerable sites, such as in Antarctica and the deep seas (Halfar and Fujita, 2002; Littleboy and Boughen, 2007). Debate regarding these issues raises the possibility of 'No Go' mining areas, and the need to build the capacity of governments and governance regimes to effectively monitor impacts and limit harm. Such discussion also applies to socially or culturally vulnerable regions.

2.2.5 Resource depletion – contested views

There are contested views on whether we will run out of minerals. A recent debate on resource depletion has raised the question: what would be the impact of a global up-scaling in the use of minerals in developing countries to levels consistent with post-industrial nations (Gordon *et al.*, 2006; Gordon and Tilton, 2008)? Gordon and co-authors note that rates of

[3] Peak minerals refers to the point at which production from ore peaks for a particular commodity, particularly at a national scale. It is somewhat analogous to the concept of peak oil, where the finite resource is exhausted. Yet unlike oil, metals are unlikely to run out when we run out of ore. The main issues with peak minerals and metals are the environmental impacts of processing increasingly lower grade ores and the energy cost of recovering metals from secondary sources if dissipated in the economy.

consumption of some metals do not necessarily decline with GDP growth and that, on this basis, it is likely that stocks will become exhausted unless prices rise to reflect scarcity, or substitute minerals can be found. Tilton and Lagos (2007) suggest the fixed stock paradigm (that there is a given quantity of a resource available in the Earth) is a misleading indicator of resource availability, and that an opportunity cost paradigm (that suggests a useable resource quantity is better represented by price and the opportunity cost of using the resource) gives a better picture of resource depletion and availability. They argue that while minerals such as copper may become scarce and, thus more expensive, they may also become more available (because technology has the capacity to move a resource from its base, to a reserve and into the stock in use, consequently increasing the amount in use or as waste) with impetus for the development of new technologies provided by high returns on investment. They conclude that the resource base can be the only fixed stock, and there "…is no way to know the availability of copper decades in advance" (Tilton and Lagos, 2007, p 23).

Gordon and co-authors (2006) contend that the relative proportions of minerals in the lithosphere, in use, and in waste deposits, are a useful indicator of how scarce a particular resource will be under such circumstances, and that a steady flow of mineral resources from "virgin ores" to "waste" is difficult to justify in any case. The technology trend predicted by these authors is one that tends towards high levels of recycling and reuse, and substitution of appropriate alternatives where minerals are locked into use phases or whose useful qualities are "dissipated" by their use in particular applications (Gordon *et al.*, 2006).

An example of this trend in practice can be seen in Japan, where 'product stewardship' and 'extended producer responsibility' (EPR) initiatives are creating an increasingly large and progressively inexpensive pool of resources 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).

The position taken in this paper is that metals will not run out (unlike oil). Metals are inherently recyclable and also accessible at a range of grades, however the energy, environmental and social cost of doing so could constrain future usage. Metals are more readily recoverable from end uses where the metal is used in a pure form and not dissipated.

2.2.6 Peak Oil and energy intensity of minerals production and transport

Continued oil depletion is likely to have a significant impact on mineral futures, where high volumes of high-grade oil are a key foundation on which existing operations in the minerals industry have been established. As with climate change, Peak Oil will have local as well as global effects, with increased costs for equipment maintenance and fuelling, as well as increased costs for the transportation of ores and metals to national and international markets.

Less optimistic views of a post-Peak Oil society suggest a shift away from global trade in commodities such as minerals to local markets as a response to reductions in transportability (Heinberg, 2004; Heinberg, 2007; Moriarty and Honner, 2008; Nel and Cooper, 2009). Decreases in both the quality and quantity of oil that is available for use in the minerals sector have been identified by the CSIRO as a matter for concern (CSIRO, 2004). This concern is easily understood when Australia's comparatively small capacity for refining and storing oil-based fuels is taken into account. It is also worth noting that Australian fuel imports have already exceeded the monetary value of its coal exports.

2.2.7 Social licence to operate and project financing

A social license refers to the ongoing tacit support received by a mining operation from the local community and other stakeholders. Recent experiences have highlighted the critical importance of transparency and mutual reciprocity in establishing the trust essential for a social license to continue to operate (see for example Stehlik, 2005; Browne *et al.*, 2009).

Obtaining a "social licence" to undertake particular mineral production processes, or extract particular mineral commodities, has become more difficult as public attitudes to environmental, health, social and economic aspects of mining, minerals, and sustainability have changed over time.

The nature of mining operations and particular issues have been identified as having the potential to significantly reduce the mineral industry's social licence to operate include:

- extraction and use of fossil fuels, extraction and processing of uranium and other carbon-intensive minerals such as aluminium
- use of water in mining and minerals processing
- use of oil for mining, minerals processing and transport
- scale and location of mining, and minerals use, and the impact on bio-capacity for human consumption and waste
- community economic development and wealth capture in regional mining communities, including local training and employment, post-mining legacies and infrastructure (CSIRO, 2004)
- health issues with leaching, dust, air quality
- access and transportation
- consent from local communities (Indigenous and non-indigenous)
- competition over landscapes, the utilisation of landscape resources and how these are defined (Franks, 2007).

Obtaining a social licence to operate can influence project financing, particularly where financial industry benchmarks have been established for determining, assessing and managing social and environmental risk in large development projects, including in the mining and minerals sector. Mine project financing is an arena in which civil society organisations have played significant roles in policy and decision-making contexts. For example, the *Equator Principles* emerged from negotiations between NGOs (such as Friends of the Earth and the Rainforest Action Center in the US) and financial institutions in response to social and environmental concerns raised by communities affected by major development projects. Signatories are committed to refusing loans to projects where the borrower is unable to comply with social and environmental policies and procedures consistent with the Principles (Equator Principles, 2009). Additionally, environmental campaigns, NGO research (*e.g.*, the *No Dirty Gold* campaign *and* the *Dirty Metals*: *Mining, Communities and the Environment* report(Earthworks and Oxfam America, 2004)), and local communities in the vicinity of operations are maintaining the pressure on industry to respond appropriately to social and environmental issues.

Through constructive dialogue and advocacy the minerals industry has made many commitments and concessions. Pressure is currently being places on the industry to accept UN human rights and indigenous rights conventions; ILO labour law conventions; the right to free, prior, informed consent; full disclosure and accessible reporting systems of environmental and social effects of all phases of the mining process. As a result of such pressure, industry has responded with the development of internal competencies (for example, regarding community relations) and the appointment of management personnel responsible for social and environmental issues.

Of further critical importance is the relationship between the company and its local community. In particular, community expectations must now be addressed and incorporated in the decision-making processes throughout the project's life. The expectation, especially in Australia, is that major development and resource extraction projects involve community decision-making and information sharing from the very beginning of the project, including details of what arrangements have been put in place when the resources are depleted and the mine is being closed down.

2.2.8. Corporate sustainability reporting and corporate social responsibility

The development of corporate social responsibility (CSR) over the last twenty years has encouraged increasingly comprehensive disclosure of the integrated environmental, social and health impacts of mining, with growing standardisation of reporting guidelines. There has been a growing demand for mandatory rather than voluntary reporting at both corporate level, and site levels, and using sustainability indicators that can be verified by third parties (Jenkins and Yakovlova, 2006; Sampat and Cardiff, 2009). Sustainability reports are tending to cover an expanding range of issues within an integrated language of sustainable development, including increased reporting of the economic impact and benefits of operations to local communities.

Minerals industry sustainability principles and reporting initiatives that are used to demonstrate CSR include the Global Mining, Minerals and Sustainable development process (MMSD, 2002). This document informed the 10 Sustainable Development Framework principles adopted by the International Council on Metals and Mining (International Council on Mining and Metals (ICMM), 2009). Concern about sustainability has also informed the Minerals Council of Australia's *Enduring Value* principles (Minerals Council of Australia, 2005), corporate Sustainability Reports, as well as civil society policies such as the US-based Center for Science in Public Participation's Framework for Responsible Mining project (Miranda *et al*., 2005) and the WWF-led Mine Certification project (Solomon *et al*., 2008).

The Global Reporting Initiative (GRI) is another sustainability reporting framework that has been adopted by many mining operations that requires reporting on the impacts of operations on project stakeholders and systems, environmental inputs, outputs and expenditure, labour practices, human rights, and social risks to communities (GRI, 2006). The GRI has developed, in collaboration with the ICMM, a mining and metals sector supplement that details specific disclosures and indicators for the industry (GRI, 2009). The Extractives Industry Transparency Initiative (EITI) is another such approach, which provides a standard for transparency in oil, gas and mining that is implemented by both businesses and governments. EITI requires industry to publish what they pay, and for governments to disclose the revenues they receive from resource developments. Reporting may also be a requirement of certification schemes, such as the Kimberly Process, an initiative designed to restrict the trade of conflict diamonds, or participation in management systems, such the various standards of the ISO. A prominent example of corporate social responsibility along the supply chain, driven by several large companies, is the Green Lead™ initiative (http://greenlead.com/English_Index.html) for cycling lead. Yet even with this initiative in place, significant issues for regional lead mining and processing areas remain.

2.2.9 Eco-efficiency and dematerialisation

Eco-efficiency in the production processes seeks to minimise environmental impacts at the operational level (*e.g.* through energy efficiency, pollution prevention, minimising ecological disturbance).

Eco-efficiency along the production cycle maximizes potential for recycling and reuse through efficient material recovery and minimises contamination and dispersal of the material stock. Critical questions for material eco-efficiency in metals are outlined in The Five Winds (2001) study of the International Council of Metals and the Environment (ICME), and focus upon the need to maximise the utility and value of the metal elements through multiple product life cycles. This view notes the importance of considering the benefits and costs of particular uses of materials to both the environment and to the economy (Five Winds International, 2001). However, a sole focus on eco-efficiency may result in decreased resilience (Korhonen and Seager, 2008).

Dematerialisation seeks opportunities to reduce inputs and impacts associated with providing services in the economy. The concept of 'servicing the supply chain', which seeks to decouple economic activity from material throughput (*i.e.* to make money from selling services rather than products), has been demonstrated in other industries (Reiskin *et al.*, 2000), but has only seen limited examples of application with respect to minerals. A notable exception is the leasing of copper (rather than selling) by Codelco in Chile. Such a strategy is a way for the producing country to maintain control of the resource, rather than it going via discarded products to countries with well developed extended producer responsibility and resource recovery systems (*e.g.* Japan).[4]

2.2.10 Industry structure: consolidation and emerging players

The major consolidation of the minerals industry over the last decade has become a powerful driver affecting the relative power of fewer but larger major mining and minerals processing corporations relative to other stakeholders.

Furthermore, companies from the 'emerging economies' such as China, Russia, Brazil, Chile, South Africa and India, are an important feature of the global mining industry. Humphreys (2009) identifies five key factors that have combined to boost the role of emerging economy companies in mining over recent years: (i) market liberalisation and privatisation of state-owned companies; (ii) privileged access of local companies to significant and underdeveloped local resources; (iii) strong financial positions due to the mining boom of 2003-2008; (iv) drive for geographic and commodity diversification often with support of respective home governments; and (v) strategic expansion to ensure raw material supplies for their metallurgical operations.

Debates over the costs and benefits of consolidation focus on how increased consolidation improves technology development and capital raising through economies of scale. These discussions also raise questions that consider how spreading monopolies could weaken the influence of smaller industry players, buyers, labour unions, host governments and regulators, and communities. These trends have also been accompanied by a decline in the involvement of state-owned resource companies in the resources sectors (notwithstanding the resilience of state ownership in the oil industry, and the persistence of major state owned minerals companies such as Codelco, Chinalco and Chalco).

[4] This issue has specific characteristics in relation to uranium. On one hand some international stewardship is already in place tracking its use for civilian or military purposes, however reprocessed uranium does not return the metal to its original function (due to time-dependent radioactive decay IAEA, 2007)) in the same way that that copper wire could be recycled to high purity copper.

Most of the largest minerals corporations hold interests in a diversity of mineral commodities in different countries and continents. This increases their resilience to boom and bust in commodity prices and to political changes. It also allows corporations to influence global policy changes and shift norms in competitor countries by playing one country off against another[5], creating a 'race to the bottom' around issues such as market liberalisation, or the imposition of a carbon pricing system. Alternatively, global standards applied across the dominant global corporations in the industry can have the effect of raising industry-wide best practice and exposing bad actors.

2.2.11 Law and governance

Increasing concern for environmental and social sustainability has led to the formation of global, national and regional networks of communities and Non-Government Organisations focussed on mining and mineral issues. Concern has primarily been raised with respect to rigorous governance of the industry and the ecosystems and communities in which it operates. For example, the global civil society network, Mines and Communities, has affiliates from all continents and maintains as strong critique of industry claims to corporate social responsibility and sustainability and the potential of the minerals industry to contribute to social and economic development in host communities, particularly in emerging economies (Horowitz, 2006; Whitmore, 2006; Hilson, 2006).

These issues were examined during the World Bank's Extractive Industries Review. It has since influenced industry practices and operating environments, as have global environmental and development governance regimes, such as the Rio Declaration, the Global Reporting Initiative, the Global Compact, OECD Guidelines on Multinational Enterprises, World Bank Operational Guidelines, OECD Convention on Combating Bribery, ILO Conventions 98, 169, 176, and the Voluntary Principles on Security and Human Rights (International Council on Mining and Metals (ICMM), 2009).

The legal, policy and environmental management regulatory and governance environment in which the mining and minerals sector operates has been, and is likely to continue to be, subject to intense contestation and negotiation in the future. Financial and fiscal issues, public participation, polluter pays, extended producer responsibility, and higher standards of environmental and social impact management and reporting will all influence future trajectories for the sector (Bastida *et al.*, 2005; MacDonald, 2006).

2.3. INDUSTRY RESPONSE TO DRIVERS

The document thus far has outlined a broad, but not exhaustive list, of drivers that may affect the long-term future of the Australian minerals industry. The response to these drivers is now discussed from several perspectives. This section draws on work by the International Council of Minerals and Metals (International industry body); Australasian Institute of Mining and Metallurgy (Professional body); Minerals Council of Australia (Peak Industry body); Australian Government (initiatives to support industry) and the Centre for Sustainable Resource Processing (Technical research perspective).

The International Council on Mining and Metals is coordinating the follow up implementation of the Mining, Minerals and Sustainable Development project. A report on product stewardship (ICMM, 2006) renews the call for a systems approach to materials stewardship

[5] Although this is limited to some extent by the mineral industry's sunken capital and the geographic anchoring of resource processing to particular localities, which reduces mobility compared to manufacturers.

across the life cycle, and links its pursuit with a need for ensuring the social licence to operate is maintained, market access and development, regulation and cost savings.

At the national level, the Minerals Council of Australia (MCA) has primarily focussed on issues of future health, safety and environmental issues at the mine site in its *Enduring Value* initiative. Fostering stewardship along the production chain is more difficult given the number of actors involved. A recent response by the MCA to the proposed Australian Government's Carbon Pollution Reduction Scheme is critical of the proposal to auction permits (before the rest of the world adopts this practice), because of job losses which are likely to eventuate.

The Australian Government Department of Resources, Energy and Tourism coordinates the *Leading Practice Sustainable Development Program for the Mining Industry* which offers handbooks on a range of topics including water and tailings management, mine closure and rehabilitation. These volumes have been well utilised by industry, and a handbook on stewardship has been added to the series.

A large survey of over 9000 members was conducted by the AusIMM and CSIRO to determine how members prioritised issues and drivers (Moffat *et al*., 2009). Responses were obtained from 957 members and drivers were ranked from not at all important (1) to very important (7). The results for the drivers thought to be most important over the next 20-30 years are shown in Table 1. Notably, environment was rated the least important issue or driver.

Table 1: Future industry drivers ranked by AusIMM members (Moffat *et al*., 2009)

Drivers	Mean	Std Dev
Economics of mining: cost and return on investment for Australian operations compared to elsewhere (*e.g.*., declining ore grades, availability and accessibility of new ore bodies)	6.17	0.94
Global context: economic stability, rates of growth, and consumption patterns in consumer economies (*e.g.*, USA, China)	6.08	1.02
Australian society: expectations around how the industry operates (e.g., rehabilitation of mining operations) and treats its employees (*e.g.*, safety standards)	5.47	1.25
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)	5.21	1.39
Emissions trading: national and international frameworks that have the effect of imposing a price on carbon and/or greenhouse gasses	4.98	1.62
Environment: effects of increased climate variability and unforseen extreme weather events (*e.g.*, drought, cyclones)	4.73	1.66

The Centre for Sustainable Resource Processing has identified challenges facing the minerals industry as a result of climate change, greenhouse gas emissions and areas for technical innovation to respond to these challenges (Lund *et al*., 2008). It identified iron/steel and aluminium as the sectors with the greatest potential for emission reduction. This research highlights the part decreasied ore grades will play in increasing the CO_2 emissions of associated with the Australian minerals industry.

Given the complex nature of the drivers and industry response, the next section proposes a framework around which to structure an integrated conceptualisation of the minerals industry within the economy.

2.4. THE MINERAL RESOURCES LANDSCAPE: AN INTEGRATING FRAMEWORK

Research on minerals sustainability has generally focused on concepts of pollution prevention, cleaner production and eco-efficiency (Hilson, 2000b; Hilson, 2003; van Berkel, 2007a) (discussed further in Section 3.4). The need to extend such sustainability research to also understand a broad range of connected issues (including sustainable consumption, recycling, end of life management, society *etc*) is well established (Ehrenfeld, 2008; Jackson, 2005; Ryan, 2005; Tukker *et al.*, 2006). For example, the Minerals Mining and Sustainable Development Project (MMSD, 2002) clearly identifies the need to link minerals production and consumption in an integrated and trans-disciplinary framework as a key challenge facing the global minerals sector.

Cooper and Giurco (2009) propose the Mineral Resources Landscape, illustrated in Figure 3, as a framework for guiding integrated approaches to the contested and complex questions concerning mineral futures and sustainability. The Mineral Resources Landscape offers an expanded conceptualisation of minerals sustainability to link minerals production and consumption in an integrated assessment across the entire minerals supply chain. This framework guides an integrated approach to mineral futures by explicating the underlying and often unarticulated assumptions that affect the application of different conceptual, geographical, organisational, temporal; and life cycle scales by which mineral sustainability is defined (Cooper and Giurco, 2009).

The key leverage points identified in Figure 3 represent the flow of minerals through the supply chain, from a primary or secondary source, through to processing and production, to offering a 'service' or 'value' to society, with the rate of use being driven by consumption trends. As indicated in Figure 3, society, technology, the economy, ecology, and governance structures interact to shape the dynamics of the Mineral Resources Landscape, across local, national and global scales. When considered for a single commodity, the implications for connected commodity cycles should also be considered.

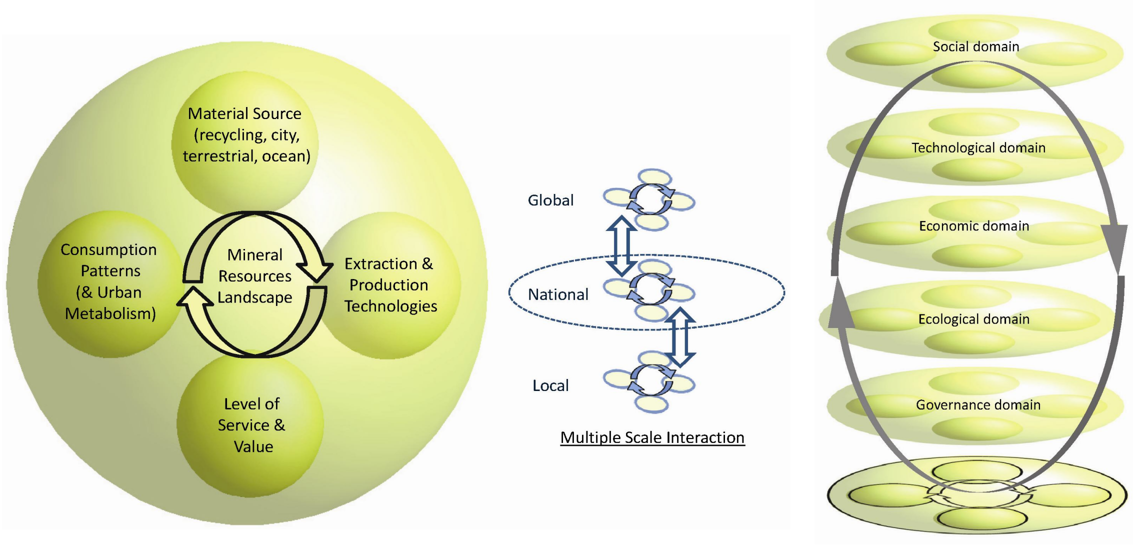


Figure 3: The Mineral Resources Landscape (Cooper and Giurco, 2009)

The mineral resources landscape is structured around the following nodes (explained with examples for copper).

- what's our starting material (and with what other metal cycles is it linked)?
  - land based copper ores may be connected with the production of lead, zinc, gold and other metals
  - secondary copper being recovered from printed circuit boards
  - copper from deep sea nodules
- how do we process it to metal (extraction and production technologies)?
  - over 15,000,000 t/a of copper is mined globally (USGS, 2008)
  - via hydrometallurgical and pyrometallurgical processes
  - almost 2,000,000 t/a is from secondary sources globally
- how do we use and value the metal to provide services in the economy (level of service and value)?
  - used to convey hot water in copper pipes
  - used to conduct electricity in copper wires *etc*.
- at what rate does the system cycle and what is driving this (consumption patterns)?
  - demand is increasing driven by growth from China

The key leverage points governing the Mineral Resources Landscape are further described in Table 2.

Table 2: Description of key variables governing the Mineral Resources Landscape (Cooper and Giurco, 2009)

Key Variable	Description
• Material source (raw material)	The primary or secondary material source, including terrestrial ore bodies, tailings that could be reprocessed, deep sea ore bodies, scrap for recycling, and re-use, including issues relating to the tolerability of trade-offs between natural and social capital, as well as the complexity and implications associated with linked metal cycles at the elemental level (Verhoef *et al.*, 2004)
• Extraction and production technologies (transformation technologies)	Considerations influencing current and new technologies, including issues relating to the eco-efficiency of minerals production.
• Level of service and value (ultimate use and potential for reuse)	The 'services' and 'value' that minerals products offer to society are related to their end use, for example gold may be used to make jewellery, nano-scale electronics or be stored in bank vaults. Such aspects are highly subjective, depending on individual and societal interests, wants and needs.
• Consumption patterns (rate of use)	Issues relating to the growing 'urban metabolism', demand, human aspects of behaviour, use, culture, needs, wants, wellbeing, as well as the distribution of resources between industrial and developing countries. Following use, the waste products have significant potential for reuse.

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. The foresight process to which this framework may be attached is yet to be defined and will constitute an initial activity of the Cluster to which this discussion paper is an important foundation.

Examples of some prominent approaches to reconciling uncertain drivers and using foresighting processes are explored in Section 2.5 (and also in the companion papers of Johnston (2009b; 2009a) and Riedy and Daly (2009)).

2.5. FUTURES STUDIES: WHAT ROLE FOR RESOURCES?

Given the diversity of drivers affecting both the industry and wider economy, this section explores prominent projects which have adopted a broad or long-view of human society and economy, namely:

- Limits to Growth
- The Great Transitions.

In considering these projects, we are seeking insight into two areas. Firstly, what approaches are possible to consider long-term futures whilst reconciling inherent uncertainty, and what are their merits and limitations? These insights, together with information in the scenarios discussion papers reviewing generalised foresight approaches and specific examples about potential foresight methods, will be applied in the cluster research. Secondly, this review illustrates the role of resources in future economies as seen from a whole-of-society perspective. In other words: how does research considering the future of society view mineral resources? rather than how does the minerals industry see itself positioned in a future society?. The second point is explored in Section 3.4

2.5.1. Limits to Growth

The first edition of the revolutionary, and highly controversial, *Limits to Growth* report (LTG1) was published in 1972 (Meadows *et al*., 1972). LTG1 and captured the results of a two year project commissioned by the Club of Rome. The work applied system dynamics theory and computer modelling to analyse the long-term consequences of growth in the global population and material economy. LTG1 presents 12 scenarios from the World3 computer model, demonstrating different possible trajectories of development from 1900 to 2100, with emphasis on the interactions between population growth, resource use and planetary limits to growth.

The second edition of *Limits to Growth* (LTG2) (Meadows *et al*., 1974) presented slightly updated versions of the scenarios presented in LTG1, following the alteration of a few numerical parameters in the World3 model. Even so, the general conclusions remain the same, contending there is an imperative to globally incite “profound, proactive, societal innovation through technological, cultural and institutional change in order to avoid an increase in the ecological footprint of humanity beyond the carrying capacity of planet earth” (Meadows *et al*., 2004, p X).

Upon revision of the global developments that transpired between 1970 and 1990, Meadows *et al.* (1992) published *Beyond the Limits* (BTL), 20 years after publication of LTG1 (Meadows *et al*., 1972). BTL presented 14 scenarios and demonstrated consistencies between the possible futures drawn from the scenarios of LTG1 and LTG2 (Meadows *et al.*, 1972; Meadows *et al.*, 1974) and the 2 decades of global development between 1970 and 1990. Most notably, BTL showed the population and economy to have grown beyond the support capacities of the Earth and define this observation as ‘overshoot’. In the scenarios presented in BTL, Meadows and colleagues (1992) demonstrated how the implementation of wise global policy, changes in technology and institutions, political goals and personal aspirations could shift the trajectory of global development back into sustainable territory.

In the decade of global development following publication of BTL, much data and evidence has arisen in support of the authors' contention that the world has overshot its human carrying capacity (Figure 4).

In order to capture the global developments from 1992 to 2004, and to better articulate the findings and intentions of LTG (Meadows *et al.*, 1972; Meadows *et al.*, 1974) and BTL (Meadows *et al.*, 1992) for a modern audience, Meadows, Randers and Meadows published *Limits to Growth: the 30 year update* (LTG30, Meadows *et al.*, 2004). LTG30 presents 10 alternative scenarios offering alternative visions of how population growth, resource consumption and global physical limits may interact over the coming century.

In accordance with the scenario trends presented in LTG1 (Meadows *et al.*, 1972) thirty years prior, the scenarios presented in LTG30 (Meadows *et al.*, 2004) indicate the first decade of the 21st century to be a period of growth, and thus don't conflict with the predictions of critics to the LTG theory. Meadows *et al.* (2004, p XXI) assert that "we must all wait another decade for conclusive evidence about who has the better understanding". Meadows *et al.* plan to update the LTG30 report in 2012 and expect that by then "there will be abundant data to test the reality of overshoot" (Meadows *et al.*, 2004, p XXII).

In the interim, through comparison of global historical data covering 1970-2000 with three World3 scenarios ('standard run', 'comprehensive technology' and 'stabilised world') from LTG1 (Meadows *et al.*, 1972), Turner (2008, p 410) "lends support to the conclusion from the LTG that the global system is on an unsustainable trajectory unless there is substantial and rapid reduction in consumptive behaviour, in combination with technological progress". Turner (2008) shows that the 'standard run' scenario aligns with the 'conventional worlds' scenarios of the *Great Transition* essay (Raskin *et al.*, 2002), in which the future is shaped by the physical, economic and social relationships currently governing global development. This scenario demonstrates exponential growth in food, industrial output, and population growth until resource limitations force a slowdown in industrial growth, after which collapse is shown to ensue in the middle of this century (Meadows *et al.*, 1974).

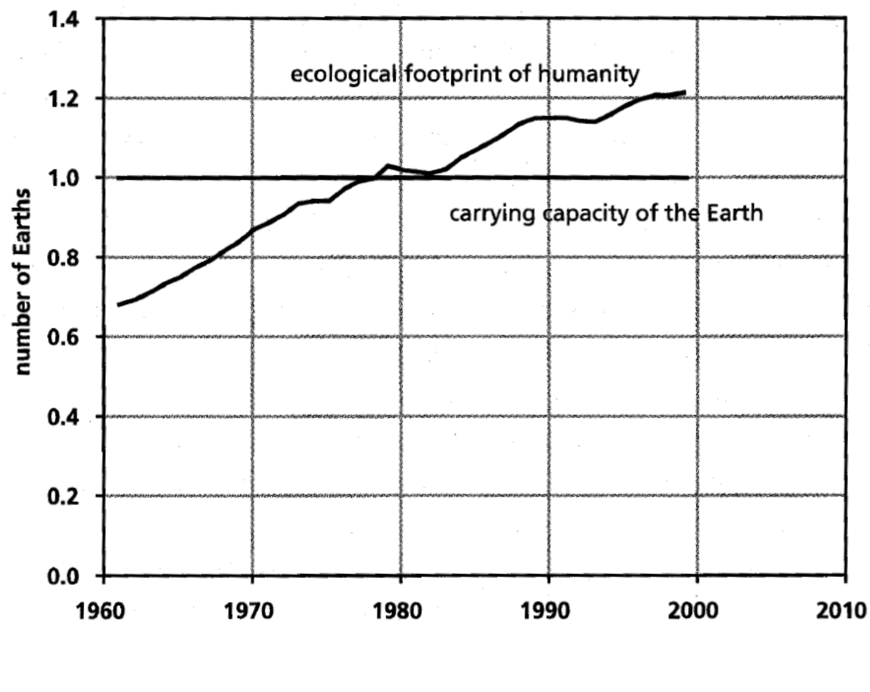


Figure 4: Ecological Footprint versus Earth's carrying capacity, from (Meadows *et al.*, 2004), illustrating 'overshoot' from the late 1970's.

A number of key insights presented in LTG30 (Meadows *et al*., 2004), offer highly relevant contributions to the discussion on mineral futures. These are summarised in the following points:

- Limits to growth do not represent direct limits to the number of people, cars, houses or factories, but rather limits to the rate at which humanity can extract resources and emit wastes without exceeding the productive or adsorptive capacities of the world, specifically that:

  "growth in the harvest of renewable resources, depletion of non-renewable materials, and filling of the sinks are combining slowly and inexorably to raise the amount of energy and capital required to sustain the quantity and quality of material flows required by the economy" (Meadows et al., 2004, p 51).

- The concept of 'physical limits to growth' is key in the discussion on minerals futures, defined as "limits to the ability of planetary sources to provide materials and energy and to the ability of planetary sinks to absorb the pollutions and waste" (Meadows *et al.*, 2004, p 9).

- Some sources and sinks are exhausted to the extent that they are limiting growth by increasing costs or environmental degradation. "The throughput flows presently generated by the human economy cannot be maintained at their current rates for very much longer" (Meadows *et al.*, 2004, p 9). This trend is clearly evidenced by minerals resources, whose extraction results in increased tailings volumes, greenhouse gas emissions, water consumption, energy consumption and waste rock as ore grades decline (Meadows *et al.*, 2004; Mudd, 2007). "Metal ore depletion hastens the rate of fossil fuel depletion and places greater burdens on the planet's sinks" (Meadows *et al.*, 2004, p 106).
- Possible avenues for reducing the global ecological footprint include lowering the population, altering consumption norms and implementing more resource efficient technologies.

  "current high rates of throughput are not necessary to support a decent standard of living for all the world's people" (Meadows *et al*., 2004, p 9).
- The scenarios show that technological progress and market transformation need to be supplemented with wisdom in order for a sustainable human society to be realised. Wisdom can be applied through changes in material consumption and family size, and:

  "it could focus on mindfully increasing the quality of life rather than on mindlessly expanding material consumption and the physical capital stack." (Meadows *et al*., 2004, p 12)

  "the only real choices are to bring the throughputs that support human activities down to sustainable levels through human choice, human technology, and human organisation, or to let nature force the decision through lack of food, energy or materials, or through an increasingly unhealthy environment." (Meadows *et al*., 2004, p 13)

  The urgency for action is stressed because the consequences of 'overshoot' are predicted to emerge in the next two decades.

- Recycling, greater efficiency, increased product lifetime, and source reduction have not yet reduced the vast materials flows through the economy. Surprisingly, they have at best slowed its rate of growth.

Meadows, Randers & Meadows (2004, p 106) also point to the work of the MMSD (2002) to indicate the potential limits that environmental and social factors may place on mineral extraction, as outlined below:

- availability of energy, impacts associated with energy inputs, increasing energy intensity with declining ore grades;
- availability of water, environmental impacts associated with water use, increasing water intensity with declining ore grades;
- land use conflicts surrounding issues of biodiversity, conservation, cultural significance, agriculture, food security;
- social licence to operate;
- changing patterns of use;
- ecosystem limits on the build up of mineral products or by-products (especially metals) in the air, water, topsoil or vegetation.

2.5.2. Great Transition

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.

Analysis of past and current transitions

The *Great Transition* essay (Raskin *et al*., 2002) presents an analysis of historical transitions, with a focus on three key periods of fundamental transformation: from Stone Age culture to Early Civilisation, approximately 10000 years ago; from early civilisation to the modern era over the last 1000 years; and what is proposed to be the third major historical transition in progress, referred to as the ‘planetary phase’. Raskin *et al*. (2002) show the global system to be in the early phase of the ‘planetary transition’.

Raskin *et al*. (2002) show these transitions demonstrate a pattern of development through sequences of quasi-stability, rapid chaotic change, and re-stabilisation. The analysis goes further to describe how various aspects of past socio-economic transitions have evolved through history. These trends are extended to describe the emerging properties of the prevailing ‘planetary phase’. Trends of increasing social complexity, technological complexity, spatial connectedness and paces of change, from one epoch to the next, are said to be affecting the emergence of global governance, globalisation of the world economy, and an information and communication revolution.

According to Raskin *et al.* (2002), “The ultimate shape of things to come depends to a great extent on human choices yet to be made and actions yet to be taken… A transition toward a planetary phase of civilisation has been launched, but not yet completed”. This sets the imperative for vision and action through the development of, and engagement with, a diverse array of possible paths of future global development.

> *“The rapidity of the planetary transition increases the urgency for vision and action lest we cross thresholds that irreversibly reduce options – a climate discontinuity, locking-in to unsustainable technological choices, and the loss of cultural and biological diversity”* (Raskin *et al*., 2002, p 11).

Imagination – the scenarios

Imagination is offered through narrative accounts of six alternative long-ranging global future scenarios, with consideration of their implications. Three classes of scenario are considered, referred to as 'conventional worlds', 'barbarization' and '*Great Transition*s'. Each scenario class represents a fundamentally different long-term outlook on the prospects for global development.

'Conventional worlds' assumes that the future is shaped by the dominant forces and values currently driving globalisation, and is founded on the premise of essential continuity. The 'Barbarization' futures are marked by fundamental but undesirable social change, while the '*Great Transition*' futures envision 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). For each of these three scenario classes, two scenarios are presented, making a total of six scenarios. Table 3 summarises the worldviews and philosophies underpinning the six scenarios, as well as an interpretation of the implications of what the development trends within each scenario might mean for commodity markets and subsequently for the future production and consumption of mineral resources.

Engagement with the Great Transition

Raskin *et al.* (2002) contend that a transition from current globalising trends to patterns of bio-regionalism and localism conveyed in 'eco-communalism' is an unlikely vision and therefore identify the 'new sustainability paradigm' as the *Great Transition*. The *Great Transition* is promoted as the preferred path and is further advanced by identifying the key values, strategies and agents for progressing the 'new global agenda'. Additionally, the *Great Transition* Initiative has further developed the *Great Transition* vision in a paper series addressing critical issues.

In comparing the key agents for change driving the 'conventional worlds' and *Great Transition* scenarios, Raskin and colleagues (2002) make a crucial contribution to the discussion surrounding questions of agency and the demarcation of key drivers that need to be addressed to ensure future sustainable systems of mineral production and consumption. The *Great Transition* scenario decouples the conventional link between wellbeing and consumption in a values led transformation of popular lifestyle and political priorities.

Table 3:Contrasting agents for change set forth in the Great Transition essay (Raskin *et al.*, 2002), with implications for mineral futures

Table 4:Contrasting agents for change set forth in the Great Transition essay (Raskin et al., 2002), with implications for mineral futures

	Scenario	Philosophy and values	Indicators of Change	Drivers of Change	Implications for minerals resources
Conventional Worlds	*Market Forces*	Market optimism, hidden & enlightened hand	Conventional link between consumption and wellbeing maintained	Proximate drivers – population, economy, technology, governance	• Commodity markets grow according to business-as-usual predictions, with market forces determining supply and demand. • Increasing consumption generates further throughput of natural resources and associated environmental impacts. • Environmental scarcity would increase prices and market demand for businesses supporting technological innovation, resource efficiency and resource substitution.
	Policy Reform	Policy stewardship	Conventional link between consumption and wellbeing maintained, Increased resource efficiency decouples consumption from throughput.	Proximate drivers – population, economy, technology, governance	• Commodity markets may grow or shrink (at least for some commodities such as fossil fuels), as regulation and 'environmental market' creation imposes full cost accounting and internalisation of environmental and social costs. • Wise policy on resource efficiency, renewable resources and environmental protection mitigate social and environmental impact. • Interventionist public policies (such as industry development, protectionism) may drive a shift towards dematerialisation, preferred technologies, and strengthened local and regional markets over global markets
Barbarisation	*Breakdown*	Existential gloom, population/ resource catastrophe	Conventional link between consumption and wellbeing collapses for all people. Survivalist regime for all people.	Proximate drivers – insecurity, survivalist values to meet basic needs.	• Trade in commodities breaks down and local and global markets collapse

	Scenario	Philosophy and values	Indicators of Change	Drivers of Change	Implications for minerals resources
Barbarisation	*Fortress World*	Social chaos, nasty nature of man	Conventional link between consumption and wellbeing maintained for some people. Survivalist regime for others.	Proximate drivers – insecurity, conflict, survivalist values. Maintaining power and contesting power structures,	• Commodity production and exchange systems break down as capacity to produce and trade declines in a permanent siege and conflict environment reduces reliable access to resources
Great Transitions	*Eco-communalism*	Pastoral romance, human goodness, evil of industrialism	Conventional link between consumption and wellbeing decoupled. Consumption decoupled from throughput through dematerialisation.	Ultimate drivers – values, needs, knowledge, understanding, power structures, culture	• Commodity production reduces as scale of production is geared to local rather than global demand, • Global markets give way to multiple local markets. • Shift towards low-tech/ 'appropriate' technology reduces demand for minerals, especially high tech minerals (*e.g.* aluminium)
Great Transitions	*New Sustainability Paradigm*	Sustainability as a progressive global social evolution	Conventional link between consumption and wellbeing decoupled. Consumption decoupled from throughput through dematerialisation.	Ultimate drivers – values, needs, knowledge, understanding, power structures, culture	• Commodity production and resource consumption reduces to fit local and global bio-capacity (guided by adoption of sustainability principles and shift to an industrial ecology): *'Resource requirements decrease as consumerism abates, populations stabilise, growth slows in affluent areas, and settlement patterns become more integrated and compact'* (Raskin *et al.*, 2002, p 92) • Includes rapid diffusion of environmentally benign technology along with a shift to less materially-intensive lifestyles. • A transition shaped by new values • Energy transition prompts an age of renewable technology • Materials transition instigates a reduction in resource throughput and phasing out of toxic materials • Agricultural transition instigates increased reliance on ecological farming

2.6. SUMMARY: GLOBAL DRIVERS AND FUTURES

This section outlined a range of **drivers** affecting the future of minerals and metals including:

- the degree to which societal aspirations and sustainability values change production and consumption practices
- dematerialisation and decoupling of well-being from material consumption
- climate change: both as a driver of a carbon constrained economy and with implications for minerals processing operations from extreme weather and changes to water availability
- ore availability, peak minerals and increasing environmental impacts from processing lower grade ores and potential of increased deep sea mining
- complexity of metals recycling
- peak oil and transport and energy availability and cost
- social licence to operate, corporate social responsibility and link to availability of project financing
- consolidating industry structure
- governance models; including degree of community participation.

Response to drivers (in particular sustainability) was reviewed from several perspectives:

- Global: International Council of Minerals and Metals
    - follows on from MMSD project; calls for systems approach to materials stewardship and links its pursuit with maintaining social licence to operate
- Industry: Minerals Council of Australia
    - *Enduring value* focuses on health, safety and environmental issues primarily at the mine site. Recent reports also foreshadow job losses resulting from CPRS.
- Government: Department of Resources, Energy and Tourism
    - *Leading Practice Sustainable Development Handbooks* have been recently updated and now include a focus on stewardship
- Professionals: Australasian Institute of Mining and Metallurgy
    - recent survey of 9000 members by CSIRO (Moffat *et al*, 2009) shows economics a more prominent driver than environment amongst members
- Research and Technology: Centre for Sustainable Resource Processing
    - identifies new technology in iron/steel and also aluminium as sectors for greatest emission reduction potential.

There is a need to better understand the linkages between drivers and actors when considering future scenarios and the **Mineral Resources Landscape** is proposed as an integrating framework. This approach:

- considers production consumption cycle and considers the service and value which metal provides in the economy
- articulates social, technological, economic, ecological, governance domains
- prompts consideration of multiple scale interactions (local, national, global).

The potential **foresight approaches** that could be used in the Cluster research are explored in companion documents. The two prominent future projects reviewed here (*Limits to Growth*; *The Great Transitions*) show the central role of considering resource requirement of futures and that we have already overshot Earth's carrying capacity (***Limits to Growth***). Exploring the six future scenarios outlined in **The Great Transitions**, their underlying values and implications for mineral resources will be useful for imagining radical change.

In the following sections, this background is linked to what is currently understand about commodity futures, technology futures and regions in transition to identify gaps and challenges.

3. COMMODITY FUTURES

COMMODITY FUTURES OUTLINE

This section explores the way future commodity use is studied and understood. It will:

- explore the commodity cycle from the perspective of anticipated futures for primary and secondary production and consumption based on current trends (3.1);
- discuss downstream demand forecasts that might reflect changes in end uses and the implications of closed-loop minerals cycles (3.2);
- consider production and demand through a Material Flow Analysis and explores models used for understanding commodity flows along the combined production and consumption cycle (3.3);
- identify systemic environmental sustainability issues of production and consumption through all phases of the minerals system (3.4);
- concludes by identifying some challenging issues regarding minerals in a sustainable future Australian economy and other commodity future issues that require further discussion and investigation (3.5).

3.1. PRODUCTION TRENDS & FORECASTS

This section gives an overview of the information available in production forecasts, their source and approach, intended use, implied assumptions and the time horizon considered. The focus in not on particular commodities, but rather, on the role that information on production forecasts fills in understanding mineral futures. Production forecasts are split into primary resources and production (*i.e.* production from primary resources being land based ores, re-mined tailings dumps and ocean resources) and secondary resources and production (*i.e.* production from recycled scrap).

3.1.1. Primary resources and production

Forecasts relating to primary resources are split into forecasts of resource reserves and forecasts of production and prices.

Resources

Estimates of future reserves available are periodically updated, rather than forecast. These are available from the Australian Bureau of Agricultural and Resource Economics (ABARE, 2008), and the US Geological Survey (www.usgs.gov). Geoscience Australia (2008; 2009a) also publishes important information concerning Australia's future capacity to produce mineral resources, including reference to the prospects of Australia's newest minerals frontier – offshore mineral resources. The Australian Offshore Minerals Locations Map (CSIRO and Geoscience Australia, 2006), recently developed and published through a collaborative project between Geoscience Australia, CSIRO's Wealth from Oceans Flagship and Division of Exploration and Mining and each of the state and Northern Territory Geological Surveys, identifies mineral deposits and occurrences within Australia's exclusive economic zone. This is an area significantly larger than Australia's land area and was recently expanded by the UN commission (Geoscience Australia, 2009b). As at April 2008, two mineral exploration licences (MELs) were active and 78 MEL applications had been submitted for exploration in offshore areas (Geoscience Australia, 2008).

Production

Historical production information for all Australia's main commodities is collated on a quarterly basis in the *Australian Mineral Statistics* (ABARE) reports. Medium term future forecasts by volume and value are given in *Australian Commodities* as shown in Table 5, together with growth projections.

Table 5: Australian energy and mineral exports (ABARE, 2009)

		volume				value		
		2007-08	2013-14	average annual growth		2007-08	2013-14	average annual growth
Oil	ml	15 975.05	17 156.28	1.4	$m	10 484	11 633	2.1
LNG	mt	14.80	26.72	12.5	$m	5 854	12 146	15.7
Thermal coal	mt	115.07	163.50	7.3	$m	8 365	17 947	16.5
Uranium	kt	10 139.00	14 250.00	7.0	$m	887	1 880	16.2
Iron ore	mt	294.29	473.54	10.0	$m	20 511	29 676	7.7
Metallurgical coal	mt	136.92	158.88	3.0	$m	16 038	25 282	9.5
Gold	t	381.58	424.37	2.1	$m	10 903	14 272	5.5
Alumina	kt	15 739.21	22 961.35	7.8	$m	5 809	7 222	4.4
Aluminium	kt	1 649.88	1 664.54	0.2	$m	4 967	4 352	2.6
Nickel	kt	165.54	212.85	5.2	$m	4 054	4 352	1.4
Copper	kt	803.85	1 114.31	6.7	$m	6 730	6 684	–0.1
Zinc	kt	1 572.03	1 424.50	–2.0	$m	3 350	2 794	–3.6

Additional detail for each commodity including primary and scrap resources is available. Table 6 provides and outlook for gold. Qualitative developments affecting technologies and markets are also provided.

Table 6: Gold outlook (ABARE, 2009)

	unit	2007	2008	2009 f	2010 z	2011 z	2012 z	2013 z	2014 z
World									
Fabrication consumption	t	3072	2 824	2683	2 691	2 872	2933	3012	3095
Mine production	t	2475	2 392	2464	2 485	2530	2503	2518	2491
Scrap sales	t	977	1 108	1050	950	800	800	800	800
Residual net stock	t	–380	–676	–831	–744	–458	–370	–306	–196
official sector a	t	485	280	220	320	320	320	320	320
private sector a	t	(418)	(610)	(921)	(1024)	(768)	(690)	(626)	(516)
producer hedging b	t	(447)	(346)	(130)	(40)	(10)	0	0	0
Price c									
– nominal	US$/oz	697	873	910	940	840	775	775	808
– real d	US$/oz	727	875	910	924	809	731	715	729
		2006 07	2007 08	2008 09 f	2009 10 z	2010 11 z	2011 12 z	2012 13 z	2013 14 z
Australia									
Mine production	t	251	228	225	246	260	264	252	248
Export volume	t	400	382	434	422	436	440	428	424
Export value									
– nominal	A$m	10320	10 903	17337	18 593	17197	15136	14023	14272
– real e	A$m	10885	11 122	17337	18 240	16460	14133	12775	12684
Price									
nominal	A$/oz	814	917	1284	1 371	1 226	1070	1020	1046
– real e	A$/oz	858	935	1284	1 345	1 173	999	929	930

a Sales (purchases). b Net additions (net reductions). c London Bullion Market Association AM price. d In 2009 US dollars. e In 2008-09 Australian dollars. f ABARE forecast. z ABARE projection.

Sources: Gold Fields Mineral Services; Australian Bureau of Statistics; London Bullion Market Association (LBMA); ABARE.

Similar information is available from the United States Geological Survey *Minerals Yearbook* and *Mineral Commodity Summaries* (http://minerals.usgs.gov/minerals/), which details information for the US by commodity, and world-wide by country.

Global Commodity Demand Scenarios, a report prepared for the Minerals Council of Australia by Access Economics (2008a), presents potential global mineral commodity demand scenarios between now and 2020. These forecasts are established upon 'business-as-usual' economic growth, which in turn is used to estimate global mineral demand, based upon historical commodity demand at various levels of income in 2006 (Access Economics, 2008a). The link between global economic growth and commodity demand is enriched by assumed "trend improvements in minerals intensity per unit of gross domestic product over time" and the potential economic impacts of carbon taxes (Access Economics, 2008a, p 12). Assumptions of 'trend improvements' stipulate that for most minerals, increasing demand will be met by growth in supply, with any supply constraints being resolved through hastened substitution. In addition to baseline 'business-as-usual' projections of global commodity demand, possible 'upside' and 'downside' demand scenarios are presented to estimate commodity demand in alternative futures operating on elevated and limited growth rates in productivity, modelled by one half a standard deviation above and below the baseline case respectively.

The projections, presented in *Global Commodity Demand Scenarios* (Access Economics, 2008a), point to the significant scale at which the minerals sector must increase production in order to meet projected commodity demand in 2020 (Figure 5). This potential 'global commodity boom' is driven primarily by strong industrial production growth in China and India, which is speculated to increase demands for base metals including aluminium, copper, nickel, zinc, lead and steel (Figure 5). By 2020, global coal, iron ore, and aluminium production needs to increase by 45%, 54% and 58% above its 2006 scale respectively. Access Economics (2008a, p 10) poses the question: "will the supply expansion now underway in Australia and around the world be rapid enough and large enough to meet the projected growth in world demand for commodities in the next few decades?".

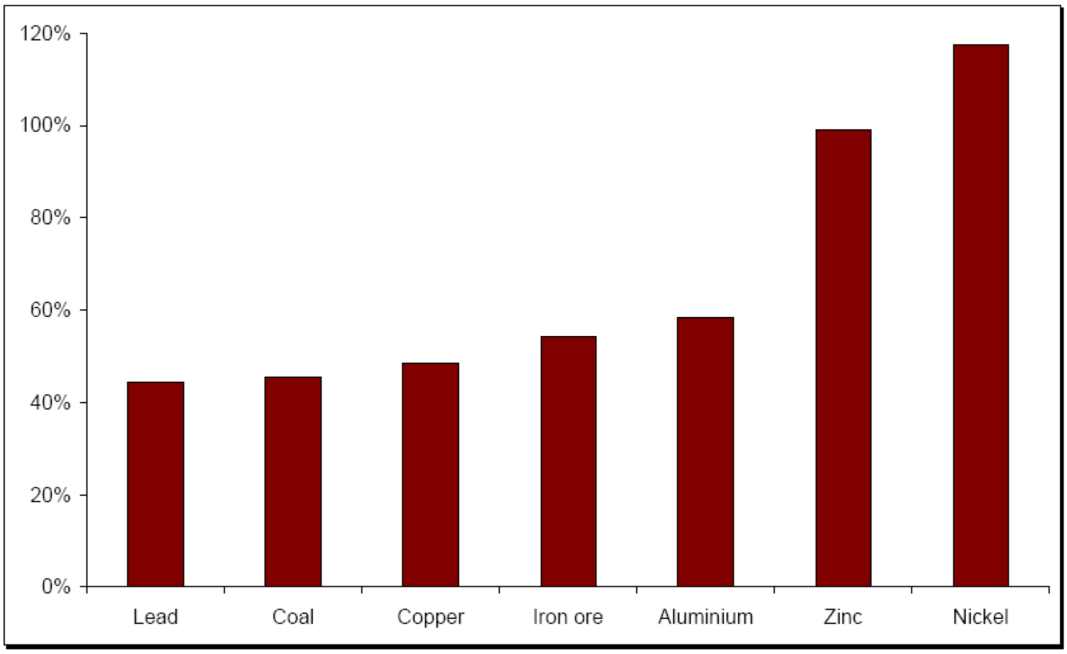
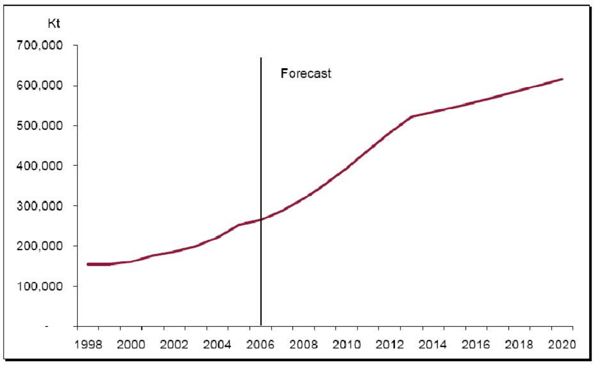


Figure 5: Production increase required by 2020 to meet demand (Access Economics, 2008a)

Infrastructure 2020 – Can the domestic supply chain match global demand? – a report for the Mineral Council of Australia prepared by Access Economics (2008c), examines the supply side implications for Australia's mineral industry following the commodity demand projections presented in *Global Commodity Demand Scenarios* (Access Economics, 2008a). Three scenarios of Australian mineral supply, termed 'decline', 'holding the line' and 'advance' are projected based on assumptions for market share of the global demand for minerals between now and 2020. These scenarios build upon the ABARE production forecasts for Australian mineral production through to 2013. For coal, iron ore, aluminium, copper, gold, nickel, lead and zinc, Access Economics (2008c) presents supply projections under the 'holding the line' scenario in the form of one chart showing the level of Australian output and another showing Australia's share of the global market, as shown in Figure 3(a) and (b) for iron ore.



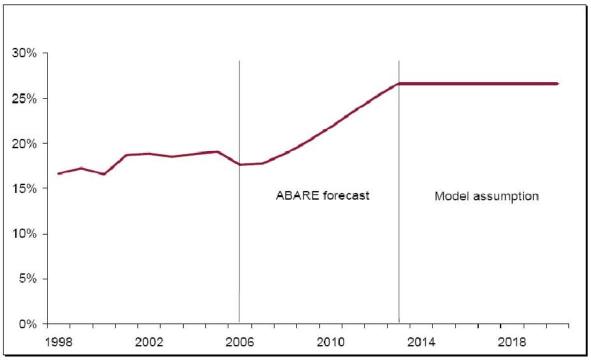


Figure 6: Australian iron ore production (a) and global market share (b) forecast under 'holding the line' scenario (Access Economics, 2008c, p 17)

The 'decline' scenario sees Australia relinquishing market share, by reverting back to the market share trend experienced in 2002, in the period from 2014 to 2020. Access Economics (2008b) comments on the undesirability of this scenario in terms of sustainable throughput and Australia's prosperity. Access Economics (2008c) refers to current mineral throughputs as being sustainable – a clear contradiction to Meadows and colleagues' (2004) interpretation of sustainable throughputs:

> *Such a scenario would be one of a failure to capitalise on Australia's strong comparative advantage in resources, held back by one or more of the many minefields that stand between the most prosperous possible position in 2020 and today's sustainable throughput of industrial commodities through Australian supply chains. After all, it only takes breaks in the chain – in the availability of skilled workers, or the adequacy of the State and Federal regulatory framework (such as for approvals), or the speed of native title negotiations, or the fumbling caused by the splintering of ownership along supply chains – to result in a lack of rail or mine or road capacity which then makes the difference between better and worse outcomes for Australia and the incomes of Australians* (Access Economics, 2008b, p 26)

The 'advance' scenario operates on the assumption that the mineral production forecast by ABARE between 2007 and 2013 is maintained between 2014 and 2020. For coal, iron ore, aluminium, copper, gold, nickel, lead and zinc, Access Economics (2008c) presents charts showing projections of production under the three different scenarios, as illustrated in Figure 7 for iron ore. The model assumes global production to equal global consumption and for the change in market share to be the same across all minerals.

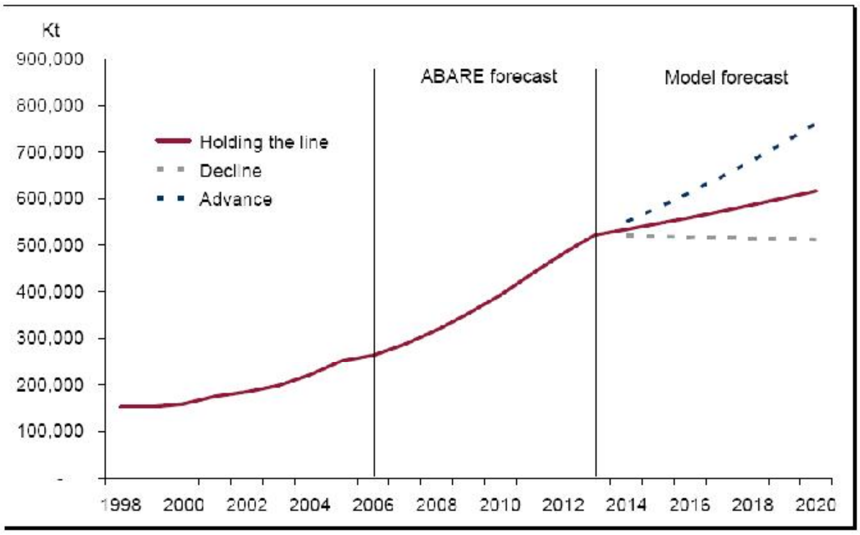


Figure 7: Australian <u>iron ore</u> production under 3 scenarios (Access Economics, 2008c, p 27)

Access Economics (2008c) estimates that Australia would be down $91 billion in national income in 2020 under the 'decline' scenario, compared to 'holding the line scenario'. In contrast, Australia is estimated to have almost $120 billion more in national income in 2020 under the 'advance' scenario, when compared to the 'hold the line scenario'. Access Economics asserts that:

> *Future prosperity requires policies to start adjusting now to help ensure that the supply chains and regulatory frameworks will be in place for Australia to pursue its comparative advantage in minerals production…Australia's comparative advantage on resources suggests that this is a once in a lifetime opportunity to surf an incredible wave of global development* Access Economics, (2008c, pp V-VII).

These forecasts assume that it is inherently preferable (notwithstanding sustainability considerations) for Australia to maintain or advance its market share. Due consideration is not given to how minerals production investment could match with to a holistic assessment of longer-term national benefit related to infrastructure investment and development goals, resource conservation, societal priorities, and biological capacity.

A paper by Mudd and Ward (2008) *Will Sustainability Constraints Cause 'Peak Minerals'?* tests the use of the Hubbert curve 'peak' modelling to project mineral production in Australia, USA and Canada to 2100 and beyond. Mudd and Ward show that if the trends such as ore grade decline continue, then:

> *Ultimately, the world may not physically 'run out' of copper, coal, gold or other minerals, but aggregate production must peak and decline as new mining operations become increasingly constrained by lower mineral deposits, greenhouse emissions, energy costs and water* (2008, p 9).

This has negative implications for the environmental impacts of continued mining discussed further in Section 3.4.

A comprehensive paper by Sohn (2005) entitled *Long-term projections of non-fuel minerals: We were wrong, but why?* examines production forecasts. Sohn uses economic forecasts, including an analysis of long term factors influencing demand, to examine the differences between forecasts and observed values. The role of economic factors in demand and as drivers of the Australian mineral industry will be addressed in greater detail by Schandl *et al*. (forthcoming).

3.1.2. Secondary resources and production

Publicly available forecasts for secondary metal production are more difficult to identify than for primary production. The US Geological Survey provides current and historical data, but no quantitative forecasts. Some predictions are given as part of dynamic material flow analyses described further in 3.2.

Information is available regarding secondary markets through private research firms (*e.g. The Global Market for Metals*, *Precious Metals*, *and Recycled Metals*, by BCC Research (BCC Research, 2009)[6]) offering "detailed analysis of the current and forecasted global market through 2013 for mined and secondary metals and their application markets".

The comprehensive Stocks and Flows (STAF) project based at Yale University (http://research.yale.edu/stafproject/) also considers the global stocks (including Australia) contained in secondary repositories (*e.g.* cities, landfills) for copper, zinc and steel. However these figures are a snapshot for a specific year only and do not consider production forecasts *per se*.

Econometric modelling of secondary markets is less common than for primary production, however a recent article considers an econometric model for secondary aluminium (Blomberg and Söderholm, 2009).

Having considered in this section the various strategies used to explore how the future of commodity production is forecast and studied, section 3.2 explores how future demands (including changes to end uses) are currently assessed.

KEY POINTS: PRODUCTION TRENDS & FORECASTS

- Resource/reserve estimates are updated periodically but not forecast into the future
- Production forecasts (volumes and prices) are available for primary production in the medium term (5-10 years)
  - sensitivities explored for primary production forecasts are not radically different scenarios, but rather high/low bounds around a mid-range forecast
- Forecasts for secondary (recycled) production are less common
- Production forecasts by industry and government agencies generally assume that more production delivers more economic wealth to Australia and is consequently preferable, capacity constraints are considered but not environmental constraints.
  - however, in the academic literature the implications of peak minerals for both production and environmental impacts are now being raised

[6] At a cost of US$5000

3.2. CONSUMPTION TRENDS & DOWNSTREAM ROADMAPS

Demand for commodities differs from production. Demand (consumption) is met by the combination of primary and secondary production plus any draw down of stocks that may have accumulated in a previous year. In addition to forecasting demand trends based on contemporary factors (*e.g*. increasing GDP/person in China), roadmaps also explore the future of demand from the perspective of new technologies, how metals may be used in future and what services metals could provide into the future.

3.2.1. Demand trends

Demand trends take a broad view of the value and use of particular materials, and where these materials are being drawn from at present, in order to provide some indications of where they are likely to be drawn from in the future.

The *Development of the Minerals Cycle and the Need for Minerals* report (CRU International, 2001) provides an overview of international production, recycling (secondary mineral production) and the state of markets more generally. It identifies a range of issues that are ignored by forecasting that is embedded in a national context. These include the growth of secondary sources of minerals, particularly metals such as aluminium and copper, changes in demand from established industries, and shifts in demand from developing regions.

The report also provides a very useful perspective on the complexity involved in determining the social value of minerals/metals in its consideration of employment in the minerals sectors:

> *The number of persons directly employed in metals and mining, whatever it is, is far smaller than the number of persons whose livelihoods depend on it.* (CRU International 2001, p. 40).

Other publications that forecast production (discussed in Section 3.1), such as the *Minerals Yearbook* series, also discuss consumption/demand trends resulting from the rise of China and India, as do private information providers such as CRU.

3.2.2. Demand (Downstream) Roadmaps

Industry 'roadmaps' have been one way in which the future of mining has been considered by the mining industries of various countries. Generally, these have been focussed on production requirements, and assess the actions thought necessary to achieve particular goals, through technological advances in existing processes. Production-oriented roadmaps are referred to as 'upstream' roadmaps and these are examined in more detail in section 4.1.

'Downstream' roadmaps direct attention towards trends for end-use applications of particular metals/minerals. By exploring how demand might change in future, downstream roadmaps have tried to facilitate technological advances that will increase the industry's share of these markets.

Some sectors use roadmaps to assess the possibilities of reasserting historical dominance in particular industrial applications or products. Examples can be seen in the approach taken by the *Automotive Steel Roadmap* (American Iron and Steel Institute, 2006) and its targeting of vehicle components that may be best suited to new lighter weight, high-strength steels. A more general approach can be characterised as identifying technological changes that will reduce costs and/or address environmental and social impacts that are likely to affect the price of the commodity for end-uses, and thereby, the profitability of existing and future operations.

Both the *Copper Applications Roadmap* (The International Copper Association, 2007), and the *Building Construction Technology Roadmap* (Copper Development Centre Australia Limited, 2004) view significant changes to existing end-uses of copper as an 'opportunity'. Unlike other roadmaps, this sectoral application of the roadmap paradigm looks at changes to downstream applications in a very positive light: as opportunities create new markets rather than trying to recapture previously held territory. It also assesses the likely market opportunities and 'enabling' factors that may be prerequisites for taking advantage of these opportunities (Copper Development Centre Australia Limited, 2004, p 3-4).

The *Building Construction Technology Roadmap* considers the "demographic, environmental and technological factors" that set the parameters for "where and how" people will live in the future, and outlines the likely implications for copper arising from changes in the construction and use in homes. This roadmap also provides an example of how the technologies of the future can serve as a useful reference point for strategic investments of time and research efforts, as the nature of applications and technologies change significantly over the long term.

3.2.3. Recycling as competition for primary production

The trend towards reducing the impact of waste from consumer goods (including end-of-life-vehicles, televisions, refrigerators, washing machines and air conditioners) is creating new dynamics for recycling versus primary production. Japan provides a very instructive example of how major producers of consumer goods are benefiting from the push to 'close the loop' to avoid environmental problems associated with these goods (Department of Trade and Industry (UK), 2005), by recycling and reusing these materials in new products. These producers are effectively stockpiling a range of mineral inputs to supplement their future production cycles.

Such activities are currently focussed on aluminium, steel, iron and copper. The use of precious metals in printed circuit boards and in LCD television screens is also creating opportunities for producers of consumer goods to 'capture' these resources by recycling. Some of these minerals include platinum, palladium, tantalum and indium from car electronics from end-of-life-vehicles (ELV) (Togawa, 2008).

KEY POINTS: DEMAND AND DOWNSTREAM ROADMAPS

- Demand (as for production) is commonly forecast over the medium term.
- Road-mapping exercises bring stakeholders together to agree upon shared goals and a path to achieving them.
- Downstream roadmaps:
    - attempt to forecast demand and anticipate or facilitate developments in end-uses for minerals.
    - take in a comparatively wide range of stakeholders for consultation (i.e. extraction, processing, primary and secondary transformation, producers of finished goods)
    - can raise questions about industry structure features (*e.g*. vertical integration)
- Fewer studies consider the material (metals or otherwise) required to provide services in future
- Few studies give serious consideration to secondary sources as competition to primary resources in an increasingly energy and water constrained operating environment

3.3. MATERIAL FLOW ANALYSIS

This section discusses literature that tracks the flows of metal quantities from reserves, through production to consumption and reuse. The aim of Material Flow Analysis (MFA) is the management of materials (including metals) towards improving resource efficiency (Wrisberg *et al*., 2002). MFA tracks only the stocks and flows of one or more materials, but not the social, economic or environmental impacts of the flows. Literature combining MFA and environmental impact assessment (*e.g*. through the use of Life Cycle Assessment) is discussed in Section 3.4.

Two types of approaches to MFA are described by Wrisberg *et al.* (2002) as:

- Accounting: often a snapshot of historical flows in a certain year.
- Modelling: either static or dynamic models used for prediction or exploration of future states.

3.3.1. Snapshot Accounting MFA studies

A series of snapshot accounting studies for copper (Lifset *et al*., 2002), zinc and steel have been undertaken by the *Stocks and Flows* project (http://research.yale.edu/stafproject/). The research questions posed by this literature are:

- (When) will we run out of metals (in ores)?
- Where are the current stocks of metals (yet to be mined, in use, discarded scrap that is potentially recoverable, dissipated uses from which recover is not practical)
- What stocks are available for cities to be mines of the future?

The strength and weakness of snapshot accounting is its simplicity. In the same way that a balance sheet gives a succinct snapshot of a company's finances, MFA does the same for a nation or region's material flows, but without any insight into underlying dynamics and drivers. The work of the *Stocks and Flows* project has less of a focus on the economic impacts of metal cycles, but emphasises geopolitical resource security (Where are the resources we use coming from? When might we run out?) and distribution (such as inequity between resource production and consumption between the South and North). In addition to academic research, industry associations also produce production figures that can constitute a partial MFA study (often with more of a focus on supply than demand, *e.g*. www.worldsteel.org, www.aluminum.org, www.eaa.net).

By way of example, an MFA study from the European Aluminium Association (EAA, 2006) is shown in Figure 8. The diagram shows the aluminium flows at each stage along the production and consumption cycle – such representations are especially useful for highlighting efficiencies at each production stage (i.e. how much aluminium proceeds toward finished product and how much is a waste process flow).

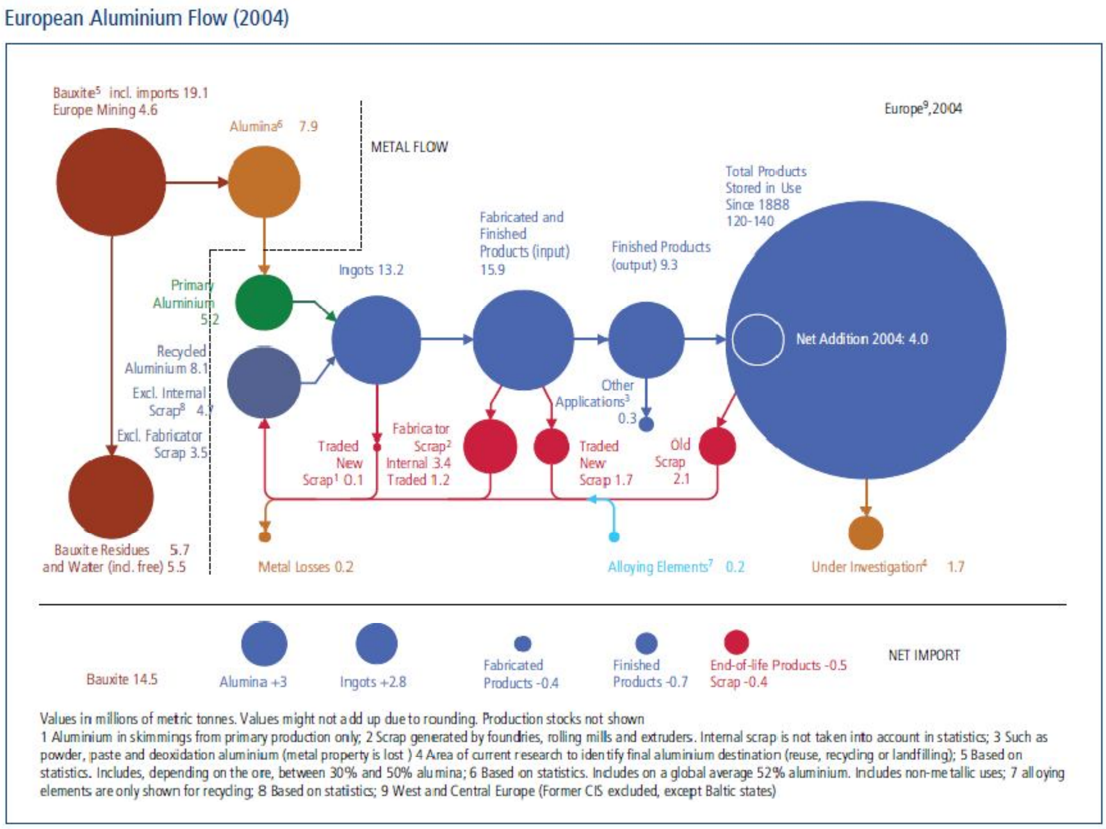


Figure 8: European aluminium flow 2004 (EAA, 2006)

3.3.2. Modelling MFA studies

Modelling Material Flow Analysis studies have been undertaken relating to both historical and projected future demand. Generally these have been performed for single commodities such as copper (Zeltner *et al.*, 1999; Spatari *et al.*, 2005; Ayres *et al.*, 2003) or a collection of commodities. For example van Vuuren *et al.* (1999) model iron/steel, and then also a composite MedAlloy consisting of nickel, tin, lead, silver and copper. McLaren and colleagues (2000b) use dynamic models for modelling steel recycling cascades. These models assess future states (in some cases to 2050) based on varying parameters such as future demand, recycling rate or production efficiency. Their aim is to show how the distribution of material in the stocks and flows, such as the example in Figure 8, changes over time, and identify the relationship between controlling variables and the observed changes. There is a divide between researchers adopting a 'fixed stock' paradigm asking, as MFA practitioners do, how can we manage the stock best, versus the 'opportunity cost' (economic) paradigm in which prices will go up as scarcity increases, and technology develops to access lower grade ores or as we will explore for new resources.

Whilst many studies are based on single commodities, Reuter (1998) highlights the importance of studying connected metal cycles, highlighting that for example, the banning of lead has consequences for copper production, where lead is often a co-product or by-product. The implication is that where a single commodity is studied, linkages to related sectors and associated effects should be acknowledged. Where possible, modelling connected cycles is preferred, however this significantly increases the complexity of the model.

Some MFA studies have been undertaken at the economy scale (i.e. not only for metals, but for all materials). A materially based model of the future flows in the Australian economy under different scenarios was developed by Foran and Poldy (2002). Entitled *Future Dilemmas*, it developed an economy-wide approach to future stocks and flows, emphasising connections between sectors. Whilst its strength was its long time horizon, it received criticism from economists for not including prices in future scenarios. However the authors pointed out that prices were linked to shorter time frames and that the main value of their work was that it was based on tangible, physical exchanges of goods.

MFA models can give an insight into the material intensity of alternate future scenarios. At the global level, the United Nations Environment Program has authored its fourth *Global Environmental Outlooks* (GEO-4) (UNEP, 2007), which contain forecasts of material flows under policy choices of 'markets first', 'security first', 'policy first' and 'sustainability first'.

Klee and Graedel (2004) note that human action dominates the cycles of the elements whose usual forms are highly insoluble, while nature dominates the cycles of those that are highly soluble. As consumption increases so too does human domination, or disturbances, to natural systems increase. Disturbance to the natural cycles of minerals includes dispersal into the environment, and so it is necessary to monitor the cycles of minerals for resource supply analyses, environmental impact assessment, and public policy.

The material flow models are helpful because they provide a picture of the available resources and how they move through the economy. However one must also consider the social, economic and environmental consequences of these flows. The environmental impacts of such flows are discussed in the next section. Social considerations are discussed in Section 5 and the economic consequences are the topic of a companion paper (Schandl, forthcoming).

KEY POINTS: MATERIAL FLOW ANALYSIS

- Material Flow Analysis (MFA) considers production and consumption, but only with respect to material flows, not impacts.
- MFA can either be a snapshot for a specific year or underpinned by dynamic models capable of future forecasts and sensitivity studies to changes in parameters.
- MFA is largely undertaken in the academic research community and the policy questions it is used to inform include.
    - (when) will we run out of metals (in ores)?
    - where are the current stocks of metals (yet to be mined, in use, discarded scrap that are potentially recoverable, dissipated uses from which recover is not practical)?
    - what stocks are available (to consumers) as the mines of the future?

3.4. ENVIRONMENTAL SUSTAINABILITY: MINERALS & METALS

This discussion of the environmental impacts associated with mining, processing and cycling metal through the economy is divided into two sections: Firstly, impacts over operational phases in the life of a mine or minerals processing plant; and secondly, a discussion of impacts along stages of the production and consumption cycle. There are sustainability issues and linkages between all operational phases and production/consumption stages shown in Figure 9. It helps to highlight that sustainability thinking must extend beyond the mine site to the total system. A holistic approach opens up scope for industry actors to engage with issues such as Extended Producer Responsibility and minerals custodianship as integral elements of sustainability practice.

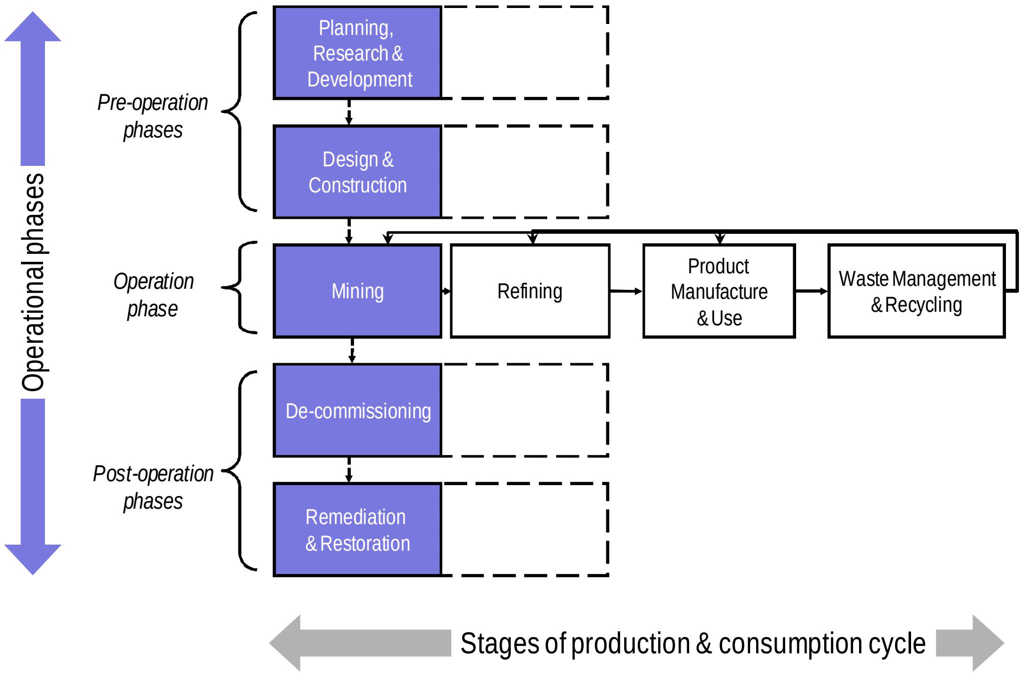


Figure 9: Operational *Phases* and *Stages* of production & consumption cycle (after Allen *et al.*, 1997)

3.4.1. Assessing operational impacts: Operational phases

Future sustainability in the minerals industry has been assessed prominently at the mine site, across operational phases and in many cases has been accepted as a definition of minerals sustainability. However a total systems approach would focus more attention on due consideration of stewardship across all stages of the production-consumption cycle (Giurco, 2009; McClellan *et al.*, 2009). Bridge (2004) proposes that 'metal use' must be decoupled from 'mineral extraction' to overcome the common policy of countries which promote using virgin materials to meet demand, instead of utilising mineral stocks which are already circulating in the economy. The literature pertaining to sustainability topics related to the operational phases of a mine and minerals processing site is broad. Authors discuss issues ranging from rehabilitation of mined land (Bell, 2001) and remediation of acid mine drainage (Evangelou and Zhang, 1995), to cleaner production (Hilson and Murck, 2000; Hilson, 2000a), sustainable design of mineral processing operations (McClellan *et al.*, 2009), decision support for sustainability (Petrie *et al.*, 2007) and indicators of minerals sustainability (Azapagic, 2004).

The long-term future of mining practices (with respect to labour, technology and public policy) affecting resource allocation and rights has been well characterised by Bridge (2004). Efforts to reduce impacts associated with mineral processing activities have been driven by the Global

Reporting Initiative, regional constraints (*e.g.* water scarcity in Australia), and to a limited extent, emissions trading systems (accounting for carbon intensity) – but these efforts have generally focussed at the plant scale. Most major mining companies conduct sustainability reporting (*e.g.* BHP Billiton, 2008). Often the emphasis is on reducing the environmental impact per tonne of product (van Berkel, 2007b), with less consideration of the total quantum of emissions or the services for which the metal product is used (Cooper and Giurco, 2009). An operation may reduce its greenhouse emissions per tonne of product, but if the tonnage of product sold increases the total emissions will increase overall. A total systems thinking approach would pursue policies aimed at reducing absolute demand by opening up new profit centres along the production-consumption chain. This would provide options for decreasing the material intensity of services in the economy for which metals are needed, but also accommodate recycled metal products.

3.4.2. Assessing production consumption impacts: Life cycle stages

Figure 10 highlights the stages of the production-consumption cycle. The topic of sustainable production and consumption is a significant area of research in its own right, relating to material inputs, consumption behaviours and the role of policy (see for example, the activities of the *Marrakech Process* and the United Nations Environment Programme). This section provides an overview of the literature that considers the impacts along the production and consumption chain from a minerals perspective, and which links to a longer-term focus. Much of the research seeks to explore possibilities for reducing environmental impact along the production consumption chain.

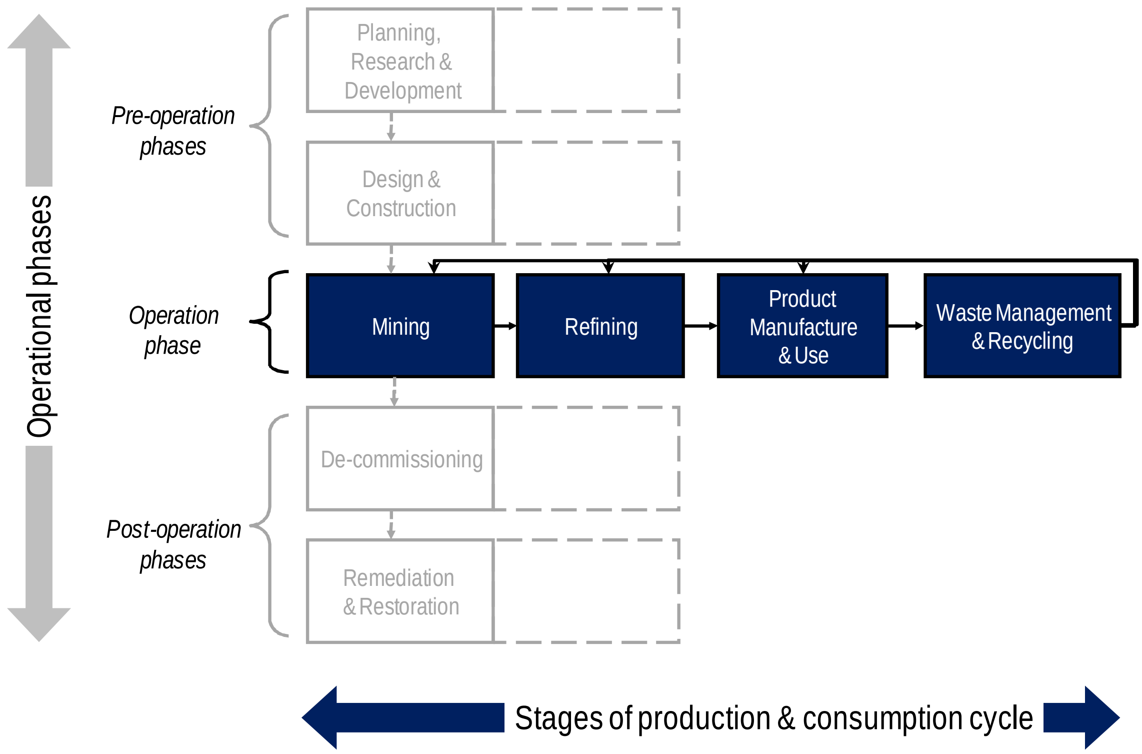


Figure 10: Stages of the production-consumption cycle

The *Mineral Mining and Sustainable Development* (MMSD) project (2002) identified the need for an integrated approach to using minerals as one of nine key challenges facing the minerals sector. As a guide to implementing such an approach, the MMSD advocates due consideration of the "use and downstream supply of mineral products" along with the mining and processing of minerals (MMSD, 2002, p XXI). This expands the assessment of mineral futures to also consider patterns of consumption behaviour, culture and the services minerals offer and contribute to these human characteristics.

> *Connecting the production and use of mineral-related materials is critical to ensuring that the minerals sector contributes optimally to sustainable development* (MMSD, 2002, p 286).

Additionally, the MMSD (2002) promotes the responsible stewardship of minerals throughout the entire supply chain, as well as the full internalisation of costs associated with metals and minerals production.

Decision-making concerning environmental impact issues cannot be delinked from social, economic, political and other issues, and are reflected, for example, by conflict over land use (MMSD, 2002, p xvii). The Hunter region provides a current case in point, where conflict is growing over the issue of whether land is used to grow food or mine coal implications for regional futures as.

Studies examining improvement along copper life cycle stages have been undertaken with respect to environmental impacts to 2050 (Giurco and Petrie, 2007; Giurco, 2009), for phosphorous with respect to efficiency, recycling and institutional arrangements (Cordell *et al*., 2009) and for steel (McLaren *et al.*, 2000a) where material, energy and exergy were modelled to 2019.

Whilst acknowledging the production-consumption cycle has a focus on impacts of mining and mineral processing, Mudd (2007) has mapped historical mining trends for main commodities. Future extrapolations of use question the increased environmental impacts associated with exploiting available resources in Australia (particularly associated with declining ore grades), and therefore incite a policy attention shift towards total system life cycle assessments if impacts are to be reduced over the longer-term.

Consideration of stages along the production-consumption cycle is inherent within life cycle assessment. The literature intersects with life cycle assessment of metals, and several production processes for metals are contrasted in Norgate *et al.* (2007) and Mudd (2007). The difficulty in undertaking a complete life cycle assessment of a metal along the production-consumption chain is the multiplicity of uses for metals, which in their end use are themselves combined with numerous other materials. A recent report also focuses on energy use in production processes but not consumption stages (Lund *et al*., 2008).

Economic and social considerations along the production-consumption cycle are discussed further in Schandl (forthcoming), while social issues at the local level are considered further in Section 5 of this document: Regions in Transition.

KEY POINTS: MINERALS AND ENVIRONMENTAL SUSTAINABILITY

- The existing focus of environmental sustainability has been at the mine or minerals processing site (*e.g*. cleaner production, rehabilitating mined land, reducing water and energy usage per tonne of product)
- The need to focus on impacts along the production and consumption cycle is acknowledged in MMSD and other high level strategy documents
    - some work has been undertaken including Life Cycle Assessment however, much research remains to be done
    - further work is needed to make an environmental sustainability focus the norm for industry decisions
- The impacts of recycling (which has its own energy requirements, emissions and technological requirements) have not been the focus of significant current research.

3.5. SUMMARY: CHALLENGES FOR COMMODITY FUTURES

Commodity production and demand estimates are established upon economic theories of growth and demand, without any consideration of qualitative aspects of growth and human choice, which are likely to become increasingly powerful influences in global transitions to possible futures.

Global commodity demand scenarios (Access Economics, 2008a) present business-as-usual trajectories of mineral commodity demand, established upon estimates of industrial production growth in the world's emerging economies and two key drivers of economic growth – population and US$GDP per head.

Demand estimates expect that both China and India "are carving out growth paths long since travelled by today's rich nations" (Access Economics, 2008a, p III), but there are many global drivers (such as ecosystem collapse, climate change, Peak Oil, increased local ecological and human health distresses, and global economic crises) that may make these predictions unreliable and therefore mineral commodity demand may, in fact, fall rather than grow.

Although it is acknowledged that "the future of development in industrialising economies may not mirror past paths of development due to global warming" (Access Economics, 2008a, p 17), no consideration is given to planetary limits or possible changes in societal values and cultural norms – considerations deemed necessary to achieve sustainable futures in the *Great Transition* essay (Raskin *et al.*, 2002) and the *Limits to Growth* reports (Meadows *et al.*, 1992; Meadows *et al.*, 2004; Meadows *et al.*, 1972; Meadows *et al.*, 1974). A precautionary approach suggests that it is prudent for forecasters to examine current circumstances for signals of breakdown and to assess the value of policy relevance and projections within alternative scenarios.

As such, questions requiring further discussion include:

- How will the minerals industry change if global mineral consumption declines?
- How might changes in end uses for minerals (for example, if the world shifts to solar, hydrogen, nuclear or wind energy) cause changes in the demand for, and profitability of, particular minerals?
- What are the likely impacts of changes to end uses and/or a narrower band of specific products on the economic parameters for different extractive techniques?
- How might the shift towards greater recycling and reclamation technologies impact on the viability of mining?
- What is mineral wealth if extraction processes are constrained by carbon emission reduction and fuel costs?
- What effect will carbon constraint on burning fossil fuels or Peak Oil have on mineral futures?
- What impact will carbon emissions and fuel constraints have on the transport of commodities, and to international markets and trade in minerals?
- How can traditional mineral exporting countries, such as Australia, maintain a strategic influence as a minerals 'superpower' if a shift from 'virgin ore' to high levels of 'product stewardship' and 'extended producer responsibility'(EPR) create an increasingly large and progressively inexpensive pool of resources for use in new product lines, which might be located outside of this country?

Having explored the way in which commodity futures and impacts of commodity cycles are currently studied and understood, the next section discusses the future role of technology and how it is evaluated.

4. TECHNOLOGY FUTURES

TECHNOLOGY FUTURES OUTLINE

This section explores the way future technology use is studied and understood. It:

- Locates technology within the dynamic human socio-ecological relationships, (4.1);
- Discusses emerging extraction technologies that might reduce environmental and social impacts, boost productivity and enable access to otherwise 'stranded' resources (4.2);
- Considers how technology is assessed and the range of tools that are used to systematically shape technology design to enhance environmental and community outcomes. This increases the likelihood that the technologies under development will be acceptable to the community and be taken up by industry and governments (4.3);
- Concludes by highlighting some challenging issues regarding the placement of minerals technology futures in a sustainable society that require further discussion and investigation (4.4).

4.1. TECHNOLOGY REFLECTS SOCIO-ECOLOGICAL RELATIONSHIPS

The word 'technology' is often interpreted to mean machines or artefacts. More broadly, technology can also include the social processes, including human relationships with their environments, through which artefacts are created and maintained. A holistic analysis of the influence of technology on the future of minerals therefore needs to consider the social, political, economic and ecological contexts in which technologies develop. This is discussed in the context of a socio-technical landscape.

The adoption of new technologies responds to the emergence of new disturbances, attractors, interactions and feedback involving many ecological and social actors across space and time (Allenby, 2009; Rotmans and Loorbach, 2009; Geels and Schot, 2007). Public participation in the trajectory of technology development can give greater prominence to the ecological and social impacts, and social acceptability, of new technology.

Successful adaptation in new situations has often been led by 'niche occupiers' or 'early adopters' of technological solutions because they form a different conception of an existing problem. Consequently, asking different questions and engaging with different stakeholders can be extremely valuable. Diffusion of innovation is a well-studied aspect of technological innovation (Rogers, 1962). The concept has more recently been applied in the context of attitudes and practices, for example in the diffusion of sustainable building practices in industry (Reardon, 2009).

Research in the Mineral Futures cluster will seek ways that technology can help us answer the following questions: 'how can we use this mineral in a way that recognises its inherent properties? How can its uses it in society maximise value and allow potential for future reuse? How can we recognise the social and environmental impacts of its utilisation?'

4.2. UPSTREAM INDUSTRY ROAD MAPS

Like demand-oriented 'downstream' roadmaps (discussed in section 3.2.2), production-oriented 'upstream' roadmaps focus on a particular material and those technological developments that address existing conditions within the industries involved.

How a rod map exercise is conducted depends heavily on the industry undertaking the exercise. Where one roadmap may relate only to the extraction and refining of ores, others may examine the full range of the production cycle from finished goods to end-of-life recycling of post-consumer goods. Differences in the scope of roadmaps reflect the characteristics and investments of the industry involved. If undertaken as a national industry roadmap, it is also likely to reflect the nation's investment in the industry as a manifestation of national wealth.

A comparison of two nationally based aluminium roadmaps demonstrates the potential differences. The first, *Aluminium Technology Roadmap* (2000) produced in a Canadian industry-government partnership, focussed on technology related to extraction and primary production to reflect the heavy investment of Canadian industry in these areas. The second roadmap, *Aluminum Technology Roadmap* (The Aluminum Association Inc., 2001) undertaken as a partnership between US industry and government, provides a much broader strategy for technological development. It addresses the US industry's engagement in refining, primary material production from ores, finished products *and* recycling from scrap. This diversity was captured because of the industry's broader engagement in these activities.

Both of the aforementioned roadmaps evaluate the prospects for technologies that reduce costs of production. Technology is expected to assist in reducing the cost of labour (through greater automation), and in reducing the current costs of identifying, extracting and processing materials. Although environmental and social effects of production are more of a focus for discussion in upstream roadmaps, than is the case with downstream roadmaps.

The largest driver for the considerations discussed here appears to be the need to reduce costs. *The copper technology roadmap* (AMIRA, 2004) is an upstream roadmap linked to the downstream copper applications roadmap discussed earlier in section 3.2. It seeks to lower the production costs and energy use with a balance of triple bottom line impacts, whilst managing technological risk and improving health and safety in the industry.

Challenges less extensively considered in roadmaps include those that are less susceptible to resolution through technological development. Although it may seem reasonable to focus only on the benefits of technological development, it is worth noting that both copper and aluminium roadmaps indicate that the market is oversupplied despite increasing consumption, and that there appears to be no consideration of how this should be understood and addressed by stakeholders. The basic assumption of both upstream and downstream roadmaps is that reducing costs will improve the industry's capacity to market what is produced.

Connections to Downstream Applications

As discussed earlier, upstream roadmaps, which consider the impact of changes and developments in downstream applications, appear to be a characteristic of an industry that is highly integrated. This approach can be seen in the roadmaps of the copper industry discussed earlier.

KEY POINTS: UPSTREAM ROADMAPS

- The balance of national (*e.g.* aluminium) *vs* international (e.g. copper) focus depends on material
  - Industry structure features – concern is for the costs of developing technology that addresses problems that are experienced by all (*e.g.* pre-competitive R&D collaboration)
  - Stakeholder consultation varies in breadth – also workshop based.
- Upstream roadmaps are less outward looking, in a market sense, than downstream roadmaps, but they appear to assume that the goal of greater production volume is worthwhile despite their identification of over-supply and lower returns.
- Some pay more attention than others to the inputs to their activities (i.e. energy and water).

4.3. EMERGING EXTRACTION TECHNOLOGIES

There are a range of technologies that are emerging that seek to access 'stranded' (previously inaccessible) resources. These technologies, many of which are undergoing current research and development or in the early stages of uptake, are expanding the mineral resources landscape in the following ways:

New extraction methods: Unconventional technologies to access conventional resources (*e.g.* coal seam gas, oil sands, oil shale, coal to liquids), which include techniques like phyto-mining (using plants to extract metals and minerals), and hydrometallurgy (including vat leaching, heap leaching of sulphide and oxide mineralogy and *in-situ* leaching).

Access to remote and difficult ores: technologies that improve the accessibility of ores in deep land-based locations (*e.g.* key-hole mining and underground mechanical processing) or at/under the deep oceans.

Processing of complex ores: technologies to extract resources from ores with impurities or in complex mineralogy.

Improved extraction effectiveness: technologies to maximise the extraction of ore at increasingly lower grades.

Improved extraction efficiency: technologies that improve the economics of resource extraction such as remote tele-operations and mine automation.

New and expanded markets: Innovations and technologies that create new markets for conventional resources (*e.g.* electric drive vehicles have the potential to expand the market for fixed energy production and battery components, and advances in mobile telecommunication have increased demand for tantalum and niobium) and demand for new resources.

Expansion of service infrastructure: New infrastructure that makes resources more economic to develop. The proximity of a resource to rail, ports, electricity, natural gas *etc*, is a major factor in the economics of extraction and processing.

Expansion of resource base: exploration technologies to locate resources (*e.g.* innovations in 'induced polarisation geophysics' to see beneath regolith cover, regolith bio-geochemistry, three dimensional mapping and improved processing of data).

Reduction of side-effects: technologies that reduce unwanted environmental or social impacts can improve the acceptability of a technology and thus the technology's uptake.

For example, thorium reactors may produce energy with decreased security risks; carbon capture and storage/sequestration may capture greenhouse gas emissions from fossil fuels; mine methane drainage may reduce fugitive emissions from coal mining; biomass blast furnace reductants may replace coal in the coking of iron-ore; improved amenity from noise reduced mine trucks; and, end of pipe technology such as scrubbers to reduce waste emissions.

New waste management and rehabilitation methods: innovations in waste management and rehabilitation may improve the feasibility and acceptability of resource extraction at some locations (*e.g*., deep sea tailings placement, where tailings are disposed below the ocean thermocline, is argued by advocates to improve the feasibility of operations in steep or limited terrain unsuitable for conventional tailings; paste and thickened tailings methods can drastically reduce water loss to tailings and improve tailings stability; desalination and reverse osmosis can increase water management options; and phyto-remediation, the use of plants to treat environmental problems, can improve rehabilitation outcomes).

Recovery of resources from wastes*:* improved processing efficiency can provide the means by which ore can be recovered from the reprocessing of mine waste, providing an economic opportunity to rehabilitate historical sites to stable landforms. Recycling, mineral stewardship and product stewardship can recover resources after use (*e.g*. tantalum from mobile phones; aluminium from beverage containers).

Utilisation of wastes as resources: extraction and processing waste streams may be an alternate source of resources (*e.g*. fly ash for use in cement; and red mud, a by-product of aluminium production, for use as a soil conditioner).

Each of these developments may have profound implications on mineral futures. Automation, and specifically remote tele-operation, has the potential to lead to cost savings and production efficiencies, and deliver better health and safety outcomes. However a likely collateral impact will be a reduction in direct employment opportunities at the local and regional level, particularly in operator roles such as truck and train driving. Indigenous people in mining regions, in particular, may be adversely impacted by large-scale automation, given that their main point of entry into mining and the wider workforce is typically through jobs such as truck driving, which are likely to be amongst the first to be automated. This, in turn, presents challenges for resource developers as a growing number of land use agreements contain commitments by mining companies to provide employment and training opportunities for Indigenous people and large-scale automation may make it difficult to honour these commitments.

4.4. TECHNOLOGY FUTURES ASSESSMENT

With the development of new technology, there is a need to assess the social impact, risks and opportunities that the technology presents to community and industry, and to consider these insights in the design process. The aim of such an assessment is to shape technology design to enhance environmental and community outcomes and thus increase the likelihood that the technologies under development will be acceptable to the community. Technology futures analysis “represents any systematic process to produce judgements about emerging technology characteristics, development pathways, and potential impacts of a technology into the future” (Porter *et al.* 2004, p 288). Analysis may include foresight to identify future technology developments and implications, forecasting to describe impacts at a point in the future and assessment to scope, analyse and respond to impacts.

Community perceptions can have significant implications for the uptake of technical processes in the minerals industry, including where investment should be directed. For example, public concern about the water and energy demands and the climate change impacts of minerals production may be a powerful driver of investment into technologies to support EPR and recycling, as well as renewable energy technologies such as solar thermal, wind and geothermal.

If public concern about a technology and/or a proposed new use of by-products is aroused, this can result in negative publicity, delays in obtaining regulatory approval, increased litigation, substantial reputational damage, and in extreme cases, loss of the 'social license to operate'. If technologists can understand and anticipate these factors, they will be better placed to develop technologies that meet public acceptance in a future where sustainability will be highly valued.

Assessments may utilise multiple methods, both qualitative and quantitative, including stakeholder analysis, risk assessments and scenario analysis, and may examine the social, economic, political and environmental domains. Technology assessments employ both technical and participatory approaches. They differ to project level impact assessments, which are undertaken with established and well-defined technology, a specific local and regional context and a tangible group of stakeholders. Technology assessments overcome the challenges of variable and changing technologies, unknown local and future contexts, and an unspecified community, by employing deliberative methodologies to facilitate community participation in locations where similar technology has been situated or in hypothetical situations; compare the technology under analysis to alternatives and future scenarios; and facilitate a process for incorporating these insights into the development, design and communication of the technology under development.

Technology assessment has a long history as a method to inform research, development and decision-making. Since the 1970s the United States Office of Technology Assessment provided technology analysis for the US congress to guide policy. The Office was disbanded in 1995, but the Federation of American Scientists hosts an archive of published material (http://fas.org/ota/). The European Union continues to undertake such analyses through the European Parliamentary Technology Assessment Network and the Science and Technology Options Assessment. In 2007 the European Union introduced regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) that requires industry to assess and manage the risks of chemicals.

Technological uptake by industry and government has been slow in Australia, despite a number of very prominent examples where technologies have addressed controversy when implemented. In the Australian minerals industry *in situ* leaching of uranium, the development of oil shale, and by products such as alkaloam are examples of technological controversies facing public opposition. In at least one case, opposition resulted in the abandonment of the development (Barclay *et al.*, 2009). A current Australian Research Council-funded project, *Technology Assessment in Social Context*, is seeking to advance technology assessment in Australia, particularly in the area of nano and food technologies. There is a need to extend such approaches to the development of technology in the Australian minerals industry, and this need will be addressed in the Mineral Futures Collaboration Cluster.

4.5. CHALLENGES: TECHNOLOGY FUTURES

Key points and remaining challenges for technology futures include:

- The challenge of ensuring stakeholders and policy makers consider technologies and technological transitions within the broader socio-technical system;
- Upstream technology roadmaps largely focus on technological solutions that can increase primary production, rather than the future potential of new technologies to increase production of recycled metals:
    - if society is to move to lower consumption in a more dematerialised economy, technologies that incorporate design for environmental principles and support closed-loop life cycles involving reuse and recycling should be an increasing focus of technological innovation;
- Emerging technologies are expanding the mineral resources landscape in these ways:
    - new extraction methods;
    - processing complex ores;
    - improving extraction efficiency;
    - expanding markets;
    - expanding service infrastructure (roads, rail, ports, energy, water);
    - expanding the resource base through better exploration technologies;
    - reducing environmental and social impacts;
    - new waste management methods;
    - recovering resources from waste and using wastes as resources
    - increased mine-site automation
- To assess the potential for these technologies, the approach of technology futures assessment must be strengthened and further utilised (application to date in Australia has been limited) with a broadened focus on including community and stakeholder perceptions into the process.
    - societal aspirations for maximising public participation in technology choices, and for expanding the spatial and temporal boundaries within which technology futures are assessed, will influence thinking about technology futures.

Technologies that reduce landscape disturbance, pollution, and the energy, carbon and water-intensity of mining and minerals processing will become increasingly strategic for achieving sustainability.

The approach taken in Australia, and overseas, to the acceptability of particular technologies (such as carbon capture and storage, submarine tailings disposal, *in-situ* leach and deep sea mining) will influence whether these, or alternative technologies, emerge as part of Australia's minerals future.

It will be important to continue to discuss and investigate the technologies that support the Australian minerals industry to identify those that will influence a potential shift to minerals stewardship and closed-loop minerals cycles in the future.

5. REGIONS IN TRANSITION

REGIONS IN TRANSITION OUTLINE

This section explores background research to regions in transition. It:

- Considers how regional futures are studied and understood (5.1);
- Reviews how resource-rich regions conceptualise and plan for the future (5.2);
- Identifies the remaining challenges in ensuring successful transitions (5.3).

5.1. SUSTAINABILITY AND REGIONAL FUTURES

The potential futures for mining and/or minerals processing regions need to be examined in the context of the global drivers influencing societal futures discussed earlier, namely climate change, the global economy and the scale of markets and globalisation, Peak Oil, resource depletion, corporate social responsibility, and social equity within and between countries. The rise or decline in demand in particular commodities and the emergence of technologies in response to these (and other) drivers influence the development of regions as mineral provinces.

A recent report to CSIRO (Solomon *et al.*, 2007) highlighted the gaps associated with research and practice in the following critical areas:

- Social performance;
- Mine site functional roles;
- Industry work and working conditions;
- Women and the mining industry;
- Indigenous employment and agreement-making;
- Public participatory processes;
- Community and regional development.

Importantly, the report also argued that regional, interdisciplinary and integration themes appear to “point towards a lack of studies or approaches that take account of a range of perspectives and issues” (Solomon *et al.*, 2007, p 2). Future research investment therefore would benefit from approaches that are: cross-regional; multi-disciplinary; place-based and incorporate the diversity and variety within and between communities.

Furthermore, research is also required on issues such as the cumulative impacts of minerals industry development on local ecological services (for example, the availability of water, biodiversity), on health (for example through pollution, dust and stress), and economic returns to affected communities (for example, capturing wealth and employment locally) that influence regional futures. If not addressed, these issues can lead to land-use conflicts and determine whether a social license to operate is established, maintained or lost (Brereton *et al.*, 2008; Franks *et al.*, 2009).

Mining and minerals processing are long-term and capital-intensive industry development initiatives. Major investments in energy, transport, housing, labour skills and research for minerals project development requires policy coherence, social and political stability, public safety, and investor confidence. Importantly, it also requires consultation with a diverse public, from *place* and *interest*-based communities, across the whole Minerals Landscape.

Infrastructure planning and investment for mineral-rich regional futures also extends into social investment, including schools, health services, recreation facilities, retail centres, and other goods and services needed for well-being. Social inclusion and equity, within mineral-rich communities, are essential elements for regional sustainability and for securing the industry's social license to operate (Chamber of Minerals and Energy of WA, 2009, Queensland Government, 2007b, Queensland Government, 2007a, ACIL Tasman, 2009). Equally important is the local community's capacity to successfully deal with large corporations, and possessing an understanding of the local governance arrangements essential to ensuring that communities at the boundaries of mining operations are actively involved in decision-making (Stehlik, 2005; Buckley 2009).

5.1.1. Managing the scale of impacts

Mining is increasingly occurring in environments that are geographically remote from major population centres, and that are socially and ecologically vulnerable. Furthermore, the scale of the impact of mining projects on local ecosystems and communities is increasing in response to greater global market demand. The impact of increased scale is compounded by declining ore grades, meaning more materials are being excavated to extract resources, with consequent greater amounts of waste, as well as greater demand for water, energy and other local resources required in processing lower grade ores.

Discussion must also extend to the capacity of local and regional communities to influence outcomes. A major discrepancy exists in the power of local communities to influence regional futures planning and decision-making relative to global corporations and governments. In some mineral-rich regions, citizens and non-government organisations have sought to expand their power and influence over decisions affecting them by building global advocacy networks (such as the *Global Mining* campaign and the *Mines and Communities* network), and by globalising local and regional concerns into a wider narrative of sustainable development and human rights. Other communities and organisations have participated in regional and local governance initiatives, and engaged directly with mining organisations to shape operations. Still others have mobilised in direct action and campaigns. The efficacy of each of these approaches is highly contextual. Consequences of these activities have recently materialised in a number of locations (*e.g*. the Hunter Valley and the Bowen Basin), and usually in areas where multiple mining operations are active (Brereton, 2008; Franks *et al*. 2009). There are also cases where regional ecological and social impacts have crossed scales to become issues of international concern. In such cases the *community of interest* can extend globally, well beyond the *community in place*, and dialogue between the regional and global 'communities' has a significant potential to influence regional futures.

5.1.2. Meaningful and empowering negotiation and consultation

Stehlik (2008) notes that developing a contemporary focus for research in engaging and empowering communities requires an exploration of several questions:

- What are the specific regional sensitivities associated with the exploration and development of future mining and mineral operations?
- How can partnerships for mining operations be developed that enable meaningful and empowered negotiation and consultation with affected communities – of *interest* and of *place*?
- How do such partnerships and understanding of regional sensitivities enable the delivery of a positive legacy from future minerals industry operations?
- What are the institutional arrangements associated with land use change at a regional scale and how can these be best integrated to achieve sustainable outcomes?

These issues are also pertinent in exploring relationships between Indigenous communities and the minerals industry regarding regional futures. Considerable attention is being paid to developing 'best practice principles'. The ANU's Centre for Aboriginal Economic Policy, for example, is engaged in a collaborative partnership with a number of Indigenous representatives and community organisations, Rio Tinto and the Committee for the Economic Development of Australia (CEDA). This partnership focusses on 'best practice' strategies to build community capacity to deal with the impacts of mining, including how local communities or their organisations involve themselves in partnerships with mining companies, and how economic flows, environmental agreements, and sacred site protection should be monitored. The project examines the role of national or state governments and indigenous regional representative organisations, like land councils or native title representative bodies, in decision-making and ensuring enhanced sustainable regional development.

Local issues that may affect the social sustainability of mineral-rich communities include pressure on social infrastructure, such as housing and community services, by industry expansion. The influx of new residents and industry into mineral-rich regions (such as North Queensland and the Pilbara, Western Australia) affect general quality of life issues, such as environmental health, access to housing, education and health services, and can disproportionately impact those not working for the mining sector. Rapid expansion of Queensland mining communities has led to escalated housing prices due to shortage of supply and the influx of high income workers, pressure on community support services such as domestic violence support services, significant increases in heavy vehicle traffic affecting road safety, and changes to the community dynamic resulting from predominantly single men moving to the community for work reasons (Queensland Government, 2008, p 1). The impact of fly-in-fly-out, and drive-in-drive-out workforces and the presence of single persons quarters, can also present unique challenges for regional communities.

The pressures from communities on governments and industry to minimise environmental and social impacts of the minerals industry, and to maximise local economic benefits, is a major driver influencing the social license of the industry at regional scales. Critically important is the capacity of the region to plan for the change brought about by mining, which generally falls to local government structures. Regional councils often have few resources and limited staff who are expected to represent the community in negotiations with the mining industry. Recent experiences in Western Australia have highlighted just how crucial such local governance arrangements are in the establishment of the 'social license', but have demonstrated the difficulty of managing expectations with limited resources from the community's perspective, and from the perspective of industry (Browne *et al.*, 2009).

Schandl & Darbas (2008) consider the recent community engagement process in the Surat Basin in Queensland. They note a key issue is the impact of expanding mining operations for the community's inadequate soft and hard infrastructure, which is 'already at capacity' and unable to absorb the increased mining pressures. Fragmented governance was cited as a frustration for community members, as was the tension caused by the awarding of mining contracts to local and national providers.

Conflict over mining and other land uses, particularly between mining and agriculture, reflects tension that is likely to increase as water and food security emerge as social concerns. For example, growing conflict between farming and coal mining interests in the Hunter and Liverpool Plains region of New South Wales demonstrate these new tensions. Another dimension of this issue is the relative proportion of public resources devoted to infrastructure to service the mining, agriculture, tourism and other industries, and the tradeoffs implicit in investment decisions. These and other issues challenge the efficacy of governance approaches orientated to the operational scale, and highlight the need to move toward regional initiatives in some regions.

5.2. HOW DO RESOURCE-RICH REGIONS THINK ABOUT AND PLAN FOR THEIR FUTURES?

There are multiple perspectives through which regional assessments can be undertaken. These depend on the assessor and the purpose of the assessment. Assessments conducted by industry, industry associations or governments are often focused on industry expansion, while assessments from a community perspective might be focused more on issues of health, environmental protection and post-mining sustainability.

Scenarios and forecasting are useful tools for envisioning alternative futures for mineral-rich regions. In 2001, the North American Mining Minerals and Sustainable Development (MMSD) process developed four scenarios covering a range of likely futures for the mining sector in North America over a period of 15 years. The scenarios were framed by different societal values: trust, openness, conflict and economic performance with respect to growth, productivity and prices. They provided a means to identify and discuss risks and opportunities, issues and challenges, and thereby inform potential strategies in a move to sustainable development (International Institute for Sustainable Development, 2002). In Australia, broader drivers have also been studied at the state level, for example *Drivers and Shapers of the WA Economy in the 21st century* (Western Australian Technology & Industry Advisory Council, 2000)

In 2009,as part of the Minerals Council of Australia’s 2020 project, ACIL Tasman produced an assessment of industrial and community infrastructure needs in Australia’s major resource regions which identified capacity constraints to projected growth (ACIL Tasman, 2009).

5.2.1. Identity

Assessments of mineral-rich regions also extend to questions of identity: the identity of regions for the people living in them, but also the identity of regions from the perspective of people observing them and making assumptions about them.

Local and regional identities reflect the particular ecological and social, cultural, economic and political features of a place or region. How a place is seen by both people living in it, and people observing it from outside, is a key element influencing how various social actors attempt to exert influence to make regions particular sorts of social, economic and political spaces. Differences in time, place and context mean that labels such as ‘community’ or ‘industry’ tend to gloss over the diversity, conflict and division that exist. This social variety presents a challenge to understanding, and at its essence, cannot be managed (Solomon *et al.*, 2007). Adding to the complexity, not everyone ‘thinks regional’. It is a useful concept for governance structures and analysis, but people are much more likely to think about their own community first, before considering a ‘whole of region’ approach.

Regions defined by a strong mineral identity, such as the North West Queensland Minerals Province and Western Australia’s Pilbara region, project an identity that may have both positive and negative impacts. Such a designation may have positive impacts for attracting particular types of investment, but ‘place branding’ with negative connotations can have negative impacts for regions attempting to attract quality services or skilled workers in a competitive market, as Singleton and McKenzie (2008) discuss with respect to the Pilbara. Watkins *et al*. (2006) noted the challenges that former coal-mining regions in the UK have faced in promoting alternative post-mining industries, such as tourism, because of their perceived identity.

Questions relevant to discussing the future of minerals-rich regions from the perspective of identity include:

- How do people inside and outside particular regions view the region, its identity and its potential future?
- Who or what is driving the identity and place branding process?
- What is the role of government, industry or community, or a combination of different sectors of society, in forging identities and desired futures?
- Are all affected and interested communities involved? How much weight is given to the views of different stakeholders?
- Is the regional identity making and future planning process driven by short-term economic growth and a resource extraction maximising agenda, and how might this fit with a longer-term sustainability agenda?
- What is the capacity of different stakeholders to have meaningful and empowering input into these processes? Do participants have the institutional capacity and information to meaningfully participate?

5.2.2. Local benefits and regional planning

International initiatives

The Mining Minerals and Sustainable Development (MMSD, 2002) project was just one of many research and policy development processes that investigated how the wealth gained in mineral-rich regions can be used to maximise local sustainability, by protecting environments and ensuring the benefits of development flow to local communities. The World Bank's Extractive Industry Review (World Bank, 2003) also investigated these issues.

The *Sustainable Development Framework* of the International Council on Metals and Mining (ICMM, 2009), the Mineral Council of Australia's *Enduring Value* principles (Minerals Council of Australia, 2005) on as well as policies of NGOs such as the *Principles for Responsible Mining* (Miranda *et al*., 2005) (which have all been referred to earlier in this paper) articulate a range of policy, regulatory and corporate social responsibility measures deemed necessary to ensure that mineral-rich communities benefit from their wealth.

Local benefits cover a wide range of issues, not just economic. The ten ICMM principles, for example, cover ethical business practices, integrating sustainable development considerations within the corporate decision-making process. It upholds fundamental human rights and respect for cultures, customs and values in dealings with employees (and others affected by mineral industry activities), health and safety performance, environmental performance, conservation of biodiversity. It also contributes to the social, economic and institutional development of the communities in which the industry operates, and implements effective and transparent engagement and communication through independently verified reporting arrangements (International Council on Mining and Metals (ICMM), 2009).

Australian examples of regional planning

Regional economic development strategies are undertaken for government (for example in the Surat Basin, AECgroup, 2007) to focus on the link between resource production, economic activity, employment, community infrastructure and population[7]. Whilst future oriented, and

[7] Population is a focus of planning in its own right, see for example Planning Information Forecasting Unit (2007) Household projections: Queensland Local Government Areas 2007. Department of Local Government, Planning, Sport and Recreation. Brisbane. Queensland Government..

linked to the broader planning context and parallel government initiatives, how the activities being undertaken in the region are positioned with respect to a sustainable national or global economy are not considered at length.

Such state government regional planning (again with a focus on housing, population, environment and economic activity) has also been undertaken with a view to coordination between council areas (Government of New South Wales, 2006). In Western Australia the regional planning focus was on labour, demand, water and energy implications under various scenarios in the medium term (The Chamber of Minerals and Energy of Western Australia, 2009).

A subset of such planning is infrastructure planning, namely what infrastructure requirements will be needed to capitalise on the resource base in the region (see for example Strategic Infrastructure Planning for Coal Industry Growth, Connell Wagner, 2007).

Another adjunct to regional planning is bioregional planning (Government of Western Australia, 2008) and regional environmental management strategies (Upper and Northern Hunter Regional Environmental Management Strategy Committee, 2002) (Western Australian Technology & Industry Advisory Council, 2000).

As an example of a collaborative model, the Surat Basin Regional Development Corporation was formed as a partnership between government, business and the community to promote sustainable development in the region (Hoffman and West, 2009). At a more targeted scale, there are also reports focusing specifically on mining potential considering associated water, heritage and agricultural issues (Government of New South Wales, 2005).

5.2.3. Regions in transition

Mining being an extractive industry, is sooner or later challenged by the issue of resource exhaustion determined by the acceptable economic, social and environmental costs, or in some cases, changes in the market for commodities. Therefore planning for diversification, or transition, post-mining, is essential for the future of mineral-rich regions.

There is potential for mining and mineral processing regions to diversify economically and maintain a minerals economy post-mining through promotion of business clusters. Western Australia's Kwinana Industrial Area is an example of building a diversified economy through a successful integration between mineral processing and related chemical and manufacturing industries in response to emerging opportunities.

Giurco *et al*. (2007) identified the potential for business clusters to diversify the development of minerals-rich regions (the Latrobe Valley, Vic), and how future visions can build on the region's minerals assets, using synergies between mineral resources, regional skills and co-located businesses to forge a pathway to prosperity in scenarios where mining is no longer the dominant activity. They identified three potential scenarios for alternative futures for the Latrobe Valley ranging from continued use of coal for electricity using carbon capture and storage technologies, use of coal for non-electricity generations purposes such as chemicals, and the development of an alternative economy based around renewable energy and bio-industry.

With a focus on the well-being of workers and communities during economic restructuring, Evans (2007) discusses the transition to a post-mining economy or where industry has shut down (examining the Hunter Valley coal industry and the closure of the BHP steelworks). He examines the role of government in protecting incomes during transition, fostering new industries and jobs, and how to provide training and education in new skills and restore environments.

5.3. CHALLENGES: REGIONS IN TRANSITION

Developing sustainable communities in mineral-rich regions remains a contentious issue with respect to how affected place-based communities can enjoy long-term benefits from the wealth extracted, be empowered to protect their local environments, and maintain well-being and healthy community life (including traditional values and cultures) when confronted with development. Several issues are particularly important:

- The key global drivers (climate change, the global economy, Peak Oil and the scale of markets and globalisation, *etc*) extend their influence into mineral rich regions.
    - changes in commodity production and consumption cycles and technological change also impact on regional futures.
    - the establishment of frameworks for sustainable development in the minerals industry is an on-going process that needs to engage all stakeholders.
- Regional-scale factors influencing potential resource-rich regional futures include those relating to ecological impact, water availability, land use conflicts, labour skills and availability, energy supply, social equity, human health and returns to host communities.
- Planning for sustainable social and environmental benefits to mining regions needs to extend well beyond the site and the lifespan of the mining operation, and beyond economic issues. Defining communities of interest requires recognition that the geographical, temporal and spatial boundaries within which regional futures are assessed includes not just those stakeholders *in place*, but others with an *interest.*
    - alleviating tensions between the minerals industry and Indigenous communities is a critical area of research.
- Implementing transparent and accountable governance regimes that ensure affected communities can shape development at a regional scale is a key area for future research. In some regions minerals development may not be appropriate, or even possible.
- Policy must consider how to manage and govern mineral-rich regions to smooth out the impacts of boom and bust cycles, the resource curse and to manage cumulative impacts of minerals development.
    - infrastructure planning for mineral-rich regions requires long-term investment to maximise efficiency and overcome capacity constraints in mining and metal processing, but also in social infrastructure such as schools, health services and community facilities
- Planning must incorporate a 'just transition' to sustainability after mining and/or minerals processing has ended - a pathway that protects the wellbeing of displaced workers and affected communities, and which ensures environmental rehabilitation so that ecosystem health is retained and future land-use options are maximised.

6. DISCUSSION QUESTIONS

This discussion paper has explored the drivers affecting the future of the Australian minerals industry and the way in which long-term futures are currently studied; for commodities, technologies and regions. This section of the paper aims to draw out common themes, tensions and future questions for discussion.

Minerals context essentials

What is it about the minerals industry that might define the potential approach to futures research within the Cluster?

- Long term futures will be linked to the complexity of ecological, social, economic and political drivers that create potential for uncertainty, identified in Section 2. These drivers are likely to play out within a changing ecosphere, growing societal aspiration for sustainability, and continuing cycles of boom and bust;
- As part of a global industry, Australia must understand global trends and possibilities, and our current and potential future position and capacity for influence;
- The future of minerals will be, in part, framed by its history and past. Unlike nanotechnology, the minerals industry is an established industry with technological and institutional inertia and trajectory. Hence a futures approach should recognise a mix of old and new technologies, patterns of resource ownership, governance, production and consumption;
- Sustainability requires that humanity reduces its ecological footprint to within the bio-capacity of the planet. This implies reduced consumption, as well as more equitable consumption among the world's people. Australia has relied on growing demand for its minerals as a important element of its economic growth, yet in a sustainable economy there may not be growth in minerals demand, dominant commodities flows may shift rapidly from mining to stewardship and closed-loop systems. In this situation, what would Australian industry stakeholders need to do to maintain an influential role in mineral futures, and ensure access to strategic minerals resources?

Contrasting perspectives on the benefits of minerals, their utilisation and sustainability

On what points do different stakeholders and perspectives align and diverge?

- Sustainability means different things to different stakeholders:
  - miners and mineral processing (less water and energy per tonne, whilst increasing tonnes sold; environmental and occupational health and safety; land rehabilitation on site),
  - regional communities (a sustainable community, ensuring healthy ecosystems and economic and social benefits during and after operations),
  - ecological sustainability (living within ecosystem limits locally and globally – where decreasing material intensity of the economy would assist),
- The path to avoiding the issues associated with the 'resource curse' and the development of a sustainable economy
- Ensuring the 'sustainability' of one community does not come at the expense of another – global standards and governance, extended producer responsibility, corporate social responsibility and accountability.

For a discussion on the long-term benefit of Australia's mineral endowment, the above tensions must be unpacked further.

Approaching future (uncertainties)

How adequate are the approaches used for long term planning (*i.e.* forecasting) to acknowledge the different perspectives described above?

- Forecasting dominates commodity futures yet has severe limitations for capturing circumstances different from business-as-usual:
    - what are the main uncertainties acknowledged and unacknowledged, *e.g*. low carbon, post-oil society, more or less globalisation, dematerialisation?;
- We need further discussion on how the minerals industry would be a positive contributor to preferred futures (*e.g*. The *Great Transition* Scenario)
- How will we use a deliberative scenarios approach or other foresight method to address the current shortcomings of long term thinking in the resources sector?

Cross scale and cross-domain interactions

How adequately does futures thinking consider the impacts of interactions across spatial scales and across ecological, social, economic and political domains of complex systems?

- Lack of integration along production and consumption chain leads to perverse outcomes (*e.g*. growing ecological footprint while smaller per tonne intensity)
- Strengthening integration of ecological, social, economic and political dimensions in futures thinking
- How are the important cross-scale interactions influencing futures thinking and adaptive management?
    - global-nation
    - national-region
    - global-region
    - region-nation

Further questions for discussion

- How could the minerals industry be profitable in a dematerialised, more closed-loop or less globalised economy?
    - what would be Australia's role?
    - which commodities and technologies are compatible with such societies?
- Which technologies are favoured in a more closed-loop economy?
    - at what scale should this occur?
    - for which commodities?
- What local, national and global governance mechanisms need to be in place to more effectively empower and protect communities in resource-rich regions?

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