THE ROLE OF THE MINING INDUSTRY IN SUSTAINABLE DEVELOPMENT

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ABSTRACT

Sustainable Development is associated with the idea of intergenerational equity: the principle that the present human population of the planet is responsible for leaving it in a fit state to be inhabited by our descendants. It is also generally recognised to have three essential dimensions: *techno-economic* development within the *environmental* capacity of the planet to meet the *social* needs of present and future generations. The implications of this vision for the mining industry represent a serious challenge. On the one hand, mining extracts non-renewable resources which are then unavailable for future generations. On the other hand, if primary materials are extracted efficiently and cheaply, then the incentive for materials to be recovered and re-used after use is reduced. Applying Life Cycle Assessment in a form appropriate to mining and minerals processing can help to address this challenge.

INTRODUCTION

Worldwide, the mining and minerals industry is coming under increasing public scrutiny and pressure to justify its existence by reducing its environmental impacts and demonstrating that its social and economic benefits justify its impacts on the environment and, in some areas, on indigenous people. The continuing debate over exploitation of uranium deposits on Aboriginal land in Northern Australia is just one example of how these pressures become manifest, albeit a particularly high profile example.

The primary resource industries find themselves in a position which is significantly different from that of industries located further along the value chain. The newer approaches to evaluating and improving environmental performance, such as Life Cycle Assessment (LCA), have to be reinterpreted for mining and mineral processing. More fundamentally, the concept of Sustainable Development must be explored to understand how the primary resource industries can justify their "social licence to operate".

Sustainable Development

The idea of Sustainable Development, which became central to international debate with the 1992 Rio Conference, was classically articulated in "The Brundtland Report" of the World Commission on Environment and Development (WCED, 1987):

> *Humanity has the ability to make development sustainable – to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.*

At first sight, this vision of Sustainable Development, with the embedded ethical principle of responsibility to future generations – intergenerational equity – represents a particular challenge for the mining industry: by exploiting non-renewable resources, mining is making them unavailable to future generations. It is therefore necessary to explore the principles behind Sustainable Development, by interpreting the general ethical principle quoted above to give practical guidelines for planning and operation.

It is now generally recognised that Sustainable Development has three essential dimensions: *techno-economic* development within the *environmental* capacity and resources of the planet, to meet the *social* needs of present and future generations (see e.g. Clift, 1998: Perdan et al., 2000). Conventional approaches to improving environmental performance combine the techno-economic and environmental dimensions: planning and operating mining and mineral processing operations to minimise their environmental impacts. Life Cycle Assessment can be a useful tool to aid in improving environmental performance; it underpins the approach known as Clean Technology (Clift and Longley, 1995), which seeks to obtain both economic and environmental improvements by approaches such as avoiding pollution at source and finding beneficial uses for wastes and by-products. However, inclusion of the social dimension takes us beyond the conventional application of LCA and raises difficult questions over the role of the primary resource industries (Cowell et al., 1999).

LIFE CYCLE ASSESSMENT

"Cradle-to-Grave" Analysis

Life Cycle Assessment has been developed as a systematic approach to identifying and quantifying total resource use and environmental impact associated with delivering a product or service (Consoli, 1993; Lindfors et al., 1995). LCA can be thought of as a form of environmental system analysis (Petrie and Clift, 1994). The conventional first phase of an LCA is definition of the *system* to be assessed, and of the *functional unit* which provides the basis for comparing alternative products or systems. For a product or service LCA, the complete supply chain must be included as shown schematically in Figure 1. The second phase, known as *Life Cycle Inventory Analysis*, consists, of "identifying and quantifying energy and materials used and wastes released to the environment" (Consoli, 1993) over the entire cradle-to-grave product system. The results of this mass and energy balance are expressed as the Inventory Table. In the next phase, *Life Cycle Impact Assessment*, the mass of detailed information in the Inventory Table is aggregated into its contribution to a set of recognised impact categories such as Global Warming and Abiotic Resource Depletion. *Improvement Assessment* then uses the results to identify ways to reduce environmental impact (and possibly also costs, taking the Clean Technology approach), for example by identifying parts of the life cycle which give rise to the main environmental impacts.

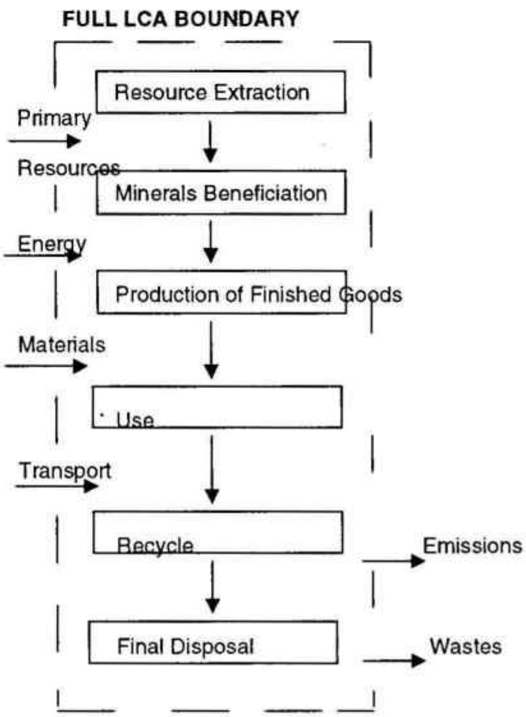

Figure 1 – "Cradle-to-Grave" Life Cycle, after. Clift and Longley (1995) and Stewart and Petrie (1996)

Application to Mining and Minerals Processing Operations

Obviously the primary resource industry represents only a part of the overall life cycle of a product or service. Even so, LCA is valuable in guiding process selection and operations, using a cradle-to-gate system analysis shown schematically in Figure 2. The feature which differs from more conventional approaches to environmental management is that off-site emissions and impacts are included. Thus Azapagic and Clift (1999, 2000) used Life Cycle Assessment to demonstrate the environmental benefits of on-site energy conversion and compare different mining approaches and processing operations to optimise environmental and economic performance, of a boron mining complex in their specific application.

It is important that wastes are considered to be part of the operating system until they are emitted or dispersed (see Figure 2). Stewart and Petrie (1996) showed how this approach can be applied to a complete industrial sector, as large as the entire South African Minerals Industry, divided into six sub-sections: gold, coal, base metals, platinum group metals, ferro-alloys and titanium-rich products from beach sands. Using the cradle-to-gate approach enabled generalised flow sheets to be derived for each of these sub-sectors. This in turn provided a basis for compiling reliable waste inventories, which lead on to identifying ways to use or reduce wastes.

Application over the Life of a Project

For a project like a mining development, exploiting a finite resource and therefore necessarily having a finite life, it is also important to consider the full Life Cycle in the temporal sense, from the "cradle" of starting activities to the "grave" of closing operations. As regards environmental impacts, this puts into the context of the overall life cycle approach the need to remediate the site, stabilise tailings deposits, etc. However, it also provides a way to approach the problem of interpreting Sustainable Development for mining (Cowell et al., 1999; Argust, 2000). The natural resource to be exploited can be regarded as "natural capital" which must not be expended without adequate return. If the returns benefit future generations, then the mining can be carried out to "meet the needs of the present without compromising the ability of future generations to meet their own needs". Thus, if the finite life of the mine can be used to build up local economic activities which can continue after cessation of mining, the industry has a basis for arguing that it does contribute to Sustainable Development by using an *environmental* resource - the resource to be mined - to provide for the *social* needs of future generations. This conceptual approach is relatively new to the primary extraction industries, but it is being developed by several major mining companies.

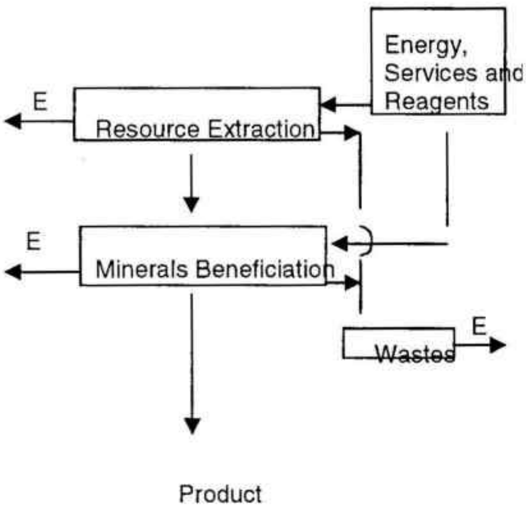

Figure 2 – "Cradle-to-Gate" System for application of LCA to mining and minerals processing, after Stewart and Petrie (1996). E - emissions

INDICATORS OF SUSTAINABLE DEVELOPMENT

Rio Tinto has decided to pursue the interpretation of Sustainable Development introduced above, making explicit links between the economic, environmental and social dimensions. To quote from a company Consultation Paper (Rio Tinto, 1999):

> *Rio Tinto believes that for the minerals industry, a contribution to sustainable development can be made through the development of mineral resources that are managed at a local level such that a lasting legacy of diversified economic activity, education, skills, public health and rehabilitated land remains once mining activity ceases. Mining converts the intrinsic value of a metal in the ground into the capital and capacity that allows a community to establish itself according to its wishes. It is Rio Tinto's belief that the potential for mining to generate significant economic revenue from a relatively small land area, most of which can be returned to an alternative, productive land use following mining is a special advantage that can provide unique opportunities for local communities.*

To aid implementation of this approach, Argust (2000) has proposed a set of Key Performance Indicators which are currently being tested and refined. The indicators draw on the work of various bodes such as the Organisation of Economic Cooperation and Development (OECD) and the World Business Council for Sustainable Development (WBCSD) and fall within a common general framework for indicators of Sustainable Development (Azapagic and Perdan, 1999).

The indicator framework is constructed to present results at several levels:

1. Indicators for Scientists and other Specialists. For environmental performance, for example, the indicators can correspond to contributions to a set of recognised environmental impact categories, as used in Life Cycle Impact Assessment (see above) and by some companies in other industrial sectors (see e.g. Wright et al., 1997); they result from simple manipulation of data collected from operating sites.

2. Indicators for use by Policy Makers. These inevitably involve some interpretation of the Level 1 indicators, for example using the Pressure-State-Response model to estimate the significance of environmental impacts.

3. Indicators for the General Public. Recognising that a non-specialist audience will respond to indicators which reflect matters of general concern, they may be aggregated further. An example is the

set of five so-called Safeguard Subjects used by some Scandinavian Countries: Human Health, Biodiversity, Resources, Productive Capacity and Aesthetic Values.

While it is relatively straightforward to develop a set of indicators for environmental performance of a techno-economic activity such as mining and mineral processing, treatment of social performance is much harder and more potentially contentious (Argust, 2000; Azapagic and Perdan, 2000). Social indicators might include number of jobs generated and quality of employment (indicated, for example, by skill level). The social indicators may also subsume established occupational factors such as work-place health and safety. But, to adequately represent contributions to Sustainable Development, the indicators must represent the development of "social capital", for example training local employees to higher skill levels for employment, not just in the mining and minerals operations but in other economic activities. This is the principal route by which the primary extraction industries can meet the Sustainable Development responsibility to future generations.

SUPPLY CHAIN ANALYSIS

The roles and responsibilities outlined in previous sections represent a new paradigm for mining and minerals processing - to provide social benefits as well as economic profits. However this new paradigm does not fit comfortably with the position of the primary extraction industries in the global economy

Returning to the complete life cycle shown in Figure 1, it is possible to examine how environmental impacts arise and how economic value builds up along the supply chain (Clift and Wright, 2000). Figure 3 shows schematically the results of this kind of analysis; Clift and Wright developed the analysis quantitatively for a specific product - mobile telephones - but concluded that the form of relationship shown in Figure 3 is more general. The ordinate represents the contribution to any of the broad impact categories used in Life Cycle Impact Assessment; Greenhouse Warming emissions and Solid Waste arisings for example.

As shown in Figure 3, the environmental impacts tend to be concentrated in the early stages of the supply chain, i.e. mining and minerals processing. The impact per unit of added economic value in these stages is much larger than the overall average for the life cycle, indicated by the broken line in Figure 3, and is typically orders of magnitude larger than in manufacturing and distribution (Clift and Wright, 2000).

This analysis shows starkly why the mining and minerals industry is under such pressure: it is associated with substantial environmental impacts yet receives disproportionately small economic returns compared with the other parts of the value chain. This distribution of added value along the life cycle has a further unfortunate effect : undervaluing primary commodities makes recycling of manufactured goods after use relatively uneconomic. To take the specific case of mobile telephones examined by Clift and Wright (2000), the costs of collection ("reverse logistics", as it is sometimes known) and segregation or dismantling can be so high that, in effect, the metals in a used mobile telephone are less usable than the same metals in a virgin ore.

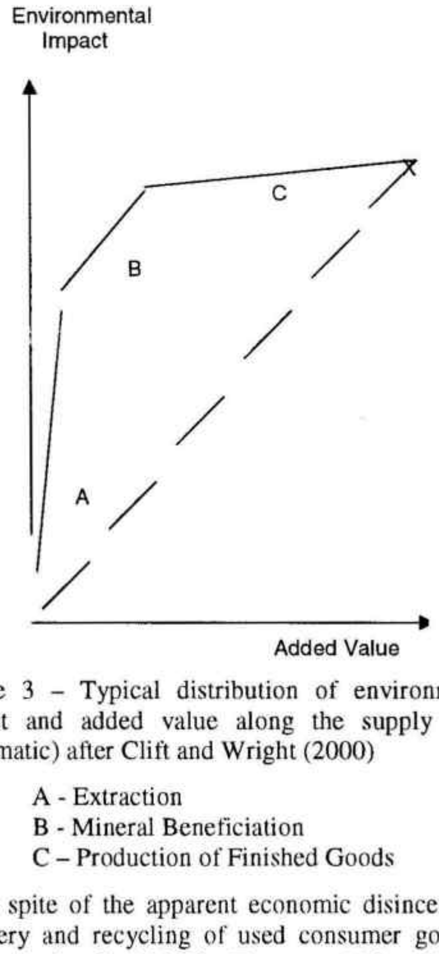

Figure 3 – Typical distribution of environmental impact and added value along the supply chain (schematic) after Clift and Wright (2000)

A - Extraction
B - Mineral Beneficiation
C – Production of Finished Goods

In spite of the apparent economic disincentives, recovery and recycling of used consumer goods is being mandated within the European Union, through Directives such as those covering Waste Electronic and Electrical Equipment (WEEE) and End-of-Life Vehicles (ELV) which require manufacturers to take back their products at the end of their service lives. The Directives are designed to remove manufactured goods from the waste stream, to promote re-use of components and recycling of materials and thereby avoid the environmental impacts and waste which arise in earlier parts of the supply chain. The environmental benefits can be substantial (Clift and Wright, 2000) although they are not always consistent with the expressed intention of the Directives (Mayers and France, 1999). However, in the light of Figure 3, they can represent distortions to normal economic pressures in order to achieve the environmental benefits.

Ultimately, greatly expanded recovery and recycling will reduce demand for primary materials, in particular for metals. This will in turn put even more pressure onto the mining and minerals industry. If the kind of non-economic aims, embodied in Sustainable Development and starting to be expressed through instruments such as the EU Take-back Directives, are accepted more generally, then we can at least speculate as to whether the international community will recognise not only that primary resource extraction is undervalued but that meeting the challenge of Sustainable Development demands a new approach to the industry's role.

CONCLUSIONS

Applying a life cycle approach to managing the environmental and social impacts of mining and mineral processing operations can be valuable in two respects. Applying Life Cycle Assessment to the operations by examining their consumption of materials and energy and their generation of waste can lead to reductions in both cost and environmental impact. Considering the Life Cycle of a mine in time provides a way to ensure that mining contributes to Sustainable Development by building up socio-economic activities which continue after closure. This approach is being developed within the industry to derive performance indicators which can be used to set targets and monitor progress. The industry is hampered by a ratio of environmental impact to added value which is much lower than in other sectors. This can provide a basis for the industry as a whole to argue for a significantly different economic and social role.

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