

# EVOLUTION OF A SUSTAINABLE DEVELOPMENT PROGRAM FOR THE MINERAL PROCESSING INDUSTRY

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## ABSTRACT

The CRC for Sustainable Resource Processing (CSRP) is developing an integrated suite of research activities that will deliver a toolkit for incorporating sustainability considerations into the design and operation of minerals processing plants. The toolkit will facilitate a structured, methodical process to identify and implement ways to use less water and energy, generate lower greenhouse gas emissions and minimise waste volume and toxicity, allowing operations to link performance imperatives to sustainability objectives. The project outcomes will help form a strong basis for expanding a similar theme of research leading to structured business practices for sustainable operations and development in the future.

The paper presents a commentary on the evolution of this program of work, possible directions for the future and key outcomes to date including:

- Quantification of the benefits of CSRP technical research outcomes from the development and application of an SD assessment methodology
- Preparation of ‘issues papers’ that identify the critical future aspects for water and energy in the minerals industry
- Application of industrial ecology principles to produce practical sustainability benefits across industrial regions
- Development and application of a quantitative methodology for sustainable management of bauxite residue areas

## INTRODUCTION

Sustainable Development (SD) is a concept of ever-growing importance in the modern world. The minerals industry has been particularly quick to embrace this concept, and has made significant efforts in addressing sustainability issues. Much of this has been driven by a “compliance” approach or the desire to maintain “License to Operate”, and has concentrated on community relations, energy and water efficiencies. However, there is a need for a broader focus on new technologies and wider social and environmental impacts. Understanding the potential benefits of these technologies, and where possible

quantifying these benefits, is an important consideration in determining the most suitable sustainability solutions for the minerals industry.

The Co-operative Research Centre for Sustainable Resource Processing (CSRP – [www.csrp.com.au](http://www.csrp.com.au)) undertakes research to create methods to produce minerals and metals in a way that benefits the community, the environment and industry. These benefits can significantly affect the viability of an industrial development, and as such there is a need to better understand the contribution that innovative new technologies or methodologies can make in improving the sustainability of an operation. To address this, the CSRP has embarked on an integrated suite of research activities that will deliver a toolkit for incorporating sustainability considerations into the design and operation of minerals processing plants. This paper presents and discusses the key research outcomes to date and future directions of this program.

## **QUANTIFICATION ASSESSMENT OF CSRP TECHNICAL RESEARCH OUTCOMES**

The CSRP's research projects have been based on opportunities in the areas of energy-efficient liberation, greenhouse emissions reduction, waste/by-product usage and water. All of these have important sustainability contributions, and there is a strong need to quantify the potential benefits to gauge their likely degree of uptake across the industry. By assessing these projects at the early stages of development, it is possible to estimate their potential for impact at the local level, or on the industry as a whole. This analysis provides an indication of the possible SD benefits (e.g. reduction in water or energy use, or waste generation) of the research outcomes if they were widely adopted by the minerals industry.

To estimate these SD benefits the CSRP developed a methodology previously described in detail elsewhere (McLellan et al. 2007). This methodology has been further refined (refer to Fig. 1) and incorporated into a spreadsheet tool, with the aim of increasing the ease of application of the methodology, and allowing some standardisation for presenting the "SD case" for new projects. The ultimate purpose of the tool, known as the SD Contributions Assessment Tool, is to provide indicative estimates of potential SD contributions of new technologies or research outcomes to the Australia minerals industry.

A recent application of the SD Contributions Assessment Tool has been on the re-use of mineral sands industry waste (known as ReSand™) as road base material instead of standard aggregate<sup>1</sup>. The basis for the assessment was 5000 tonnes of the material for the construction of 300-500m of road base. The preparation process for ReSand™ and the quarried aggregate is illustrated in Fig. 2. A key difference was the need to transport the ReSand™ material 20 kilometres to the aggregate crusher.

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<sup>1</sup> The CSRP has registered a generic trade mark, ReSand™, to collectively describe minerals processing by-product material that comprises coarser, sand-sized particles (e.g. bauxite residue, copper ore waste rock, mineral sands by-products and gold processing wastes) which have potential value as useful by-products for various commercial applications.

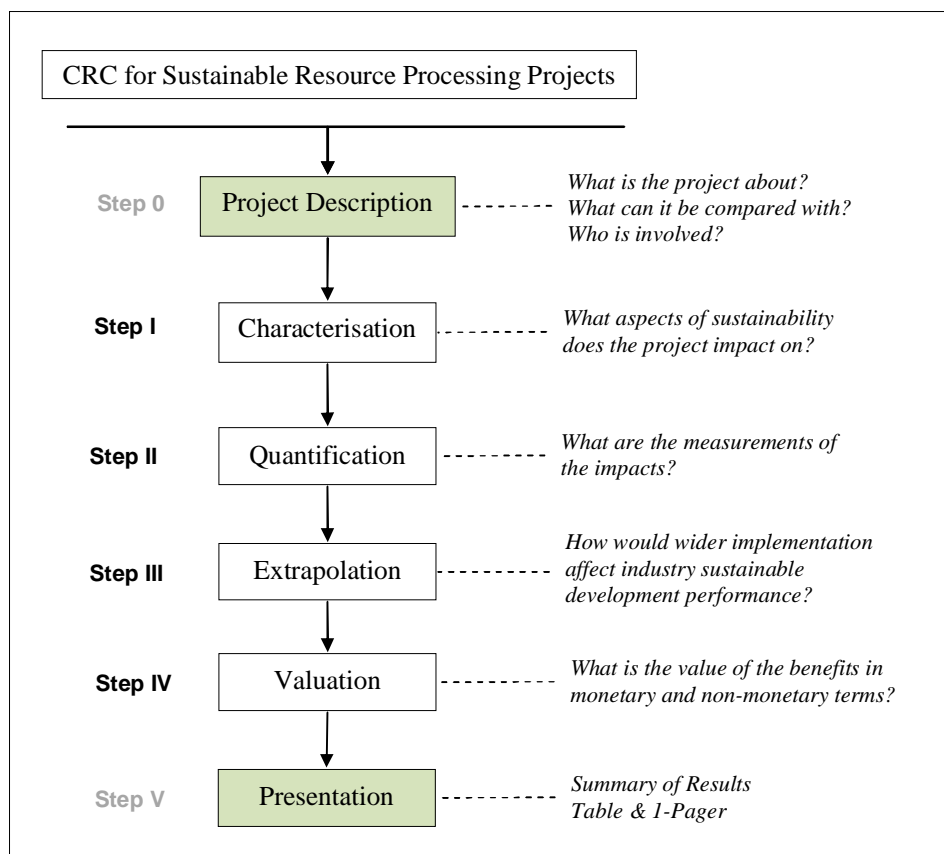


Fig. 1 Methodology for CSRP Project Benefits Sustainability Assessment

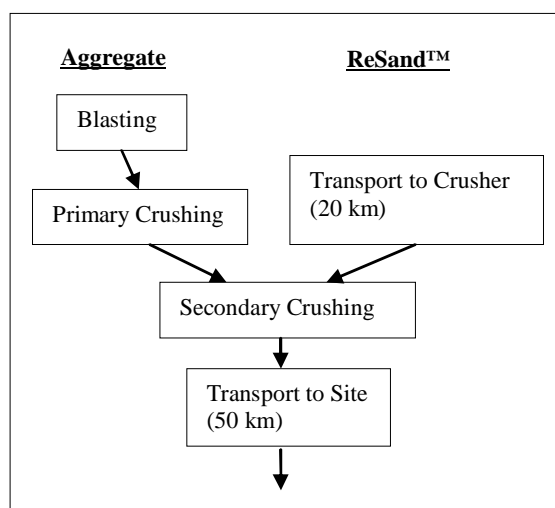


Fig. 2 Operations involved in production of road base

The assessment results from this case study showed that re-using ReSand™ would reduce greenhouse emissions by approximately one third, reduce other atmospheric emissions (dust, etc.) by approximately 60%, but increase energy usage by approximately

one quarter due to the additional transportation requirement compared with standard aggregate. The reduction in greenhouse emissions was due to the elimination of the need to use explosives for blasting virgin rock when using ReSand™ - the production of ammonium nitrate used to create the explosives is a significant contributor to life cycle greenhouse gas emissions. Further reductions in greenhouse emissions, improvement in energy usage and profit margins all relied heavily on the transport distance of the mineral sands waste to the aggregate crusher. This assessment demonstrated that while re-using by-products can bring good environmental benefits there can also be adverse environmental impacts if the by-product requires significant transportation to its place of re-use. In the case presented here, the ReSand™ would need to be within 2.5 kilometres of the crusher for it to have better overall energy use than standard aggregate.

## **FUTURE CRITICAL ASPECTS OF WATER AND ENERGY**

Water and energy are two critical aspects for the minerals industry in Australia. Recent drought conditions throughout much of Australia and the implications of energy use, particularly from the greenhouse gas perspective, are key concerns for the minerals industry at present. An important role of the CSRP is to identify the critical future aspects related to sustainability issues, such as water and energy, that the industry could conceivably face into the near to medium term. The CSRP 'issues' papers for both water and energy aim specifically to address this by examining the current 'state of play' and current key trends as well as identifying the significant challenges and constraints from a sustainability perspective for both these 'utilities'.

### **Water**

Even though the minerals industry accounts for only 2-3% of Australia's water use and supplies about 90% of its needs through its own infrastructure, many of its operations are in regions where water is scarce. Consequently, the actions of the industry in relation to water can significantly affect the surrounding environment and community. A key finding from the *water issues paper* is that a variety of approaches for water management exist and that reduction targets across different companies and industry sectors are highly variable. The typical trend of mining companies is to report water use production ratios, but these are highly variable and offer little insight into how well water is being managed. Similarly, financial production ratios (\$/ML) provided little insight as they do not take account of the different cost structures within the companies (Cote et al. 2007). To address the inconsistency in approaches, the water issues paper proposed a hierarchical conceptual model that would integrate activities from the level of individual unit operations in a plant to linked sites in an industrial ecology context with clear sustainability and operational water management objectives. This should help relieve a major issue with water management in the industry, as it would link corporate and government imperatives to daily operational performance pressures. To complement this hierarchy, the papers also highlighted the need to design, implement and test tools that will link operational/technical performance imperatives for water management to sustainability objectives, including consideration of energy needs/efficiency and chemical interactions (Cote et al. 2007). The CSRP are developing a research agenda based on the key findings from the water issues paper, and one of the initial projects will investigate the balance between water and energy use at the site level.

## Energy

The need to address energy issues related to greenhouse gas emissions and the likely adoption of a carbon pricing scheme dominated the *energy issues paper*. The minerals industry in Australia is a moderate contributor to Australia's greenhouse gas emissions, with aluminium and steel being the biggest users, generating over 40 Mt CO<sub>2</sub>e/yr and nearly 15 Mt CO<sub>2</sub>e/yr respectively (Lund et al. 2008). However, with decreasing ore grades into the future even more energy would be required to produce the same tonnes of metals using current technology. Added to this is the forecast increases in the productions over the foreseeable future further increasing the energy demands of the industry. Hence, approaches to reduce greenhouse gas emissions are of utmost importance and are driving the need for step-wise technology changes. Technologies highlighted in the paper to reduce greenhouse gas footprints include process efficiencies and modifications; fuel switching; waste process heat utilisation; alternative energy sources; biomass feedstock; geo-sequestration; and bio-sequestration. For example, capturing and re-using heat generated in cooling a typical blast furnace slag to ambient temperature (about 1.2 GJ/t of slag), could result in up to a 1-2% reduction in greenhouse gas emission in a steel making (Norgate and Jahanshahi 2006). Longer term, life cycle assessment research has shown that it might be possible to reduce greenhouse gas emissions by up 55% by using charcoal in the integrated steel making route in place of coke. Given the lead times for adopting new technology, there is a sense of urgency in promoting further research and development into low greenhouse gas technologies for energy generation. The key finding from the energy issue paper is that the most economically sensible time to act to reduce greenhouse gas emissions is now, as delaying will most likely result in more expensive outcomes in a more uncertain carbon-constrained environment (Lund et al. 2008).

## SUSTAINABILITY BENEFITS FROM INDUSTRIAL ECOLOGY PRINCIPLES

Where there is a high concentration of large industries in close geographic proximity, there is the potential to deliver sustainability benefits from applying industrial ecology principles. Industrial ecology is both 'industrial' and 'ecological' (Lifset and Graedel 2002) and attempts to apply the principles of natural ecological systems, which are extremely effective in recycling of resources, into an industrial context, where the source of resources and the sinks for wastes are part of the greater eco-system. One of the most practical applications of industrial ecology is regional synergies, where by-products (materials, water, energy) from one industry are re-used by one or more industries in the region. Realising the contribution that regional synergies can make towards sustainable minerals processing, the CSRP began in 2004 supporting research into the development of practical tools for enabling of regional synergies, and supported research projects to further develop and implement industrial synergies in Australian intense industrial regions (e.g. Kwinana and Gladstone). The main aim of these projects was to demonstrate through a more systematic and rigorous approach that there was potential to realise more synergies across industrial regions resulting in greater sustainability benefits.

## **Practical Facilitation with Industrial Regions**

The specific aims of these practical ‘hands-on’ projects were to support the companies in the Kwinana and Gladstone industrial areas, both major heavy industrial regions in Australia, to develop, evaluate and implement regional synergy opportunities. In both regions, several opportunities were identified (over 90 possible opportunities in Kwinana and over 20 opportunities in Gladstone) with the respective projects providing the support and facilitation to realise these opportunities. Examples of these opportunities included water recycling, alternative fuels from wastes with calorific value, energy recovery from flue gases and initiatives to re-use large waste streams such as bauxite residue and fly ash as substitutes for conventional construction materials (Corder et al. 2006; van Beers et al. 2007a; van Beers et al. 2007b). A number of spin-off projects have resulted from the initial Kwinana facilitation project, including a research project to find solutions for utilising large volume inorganic by-products, and the identification of synergy opportunities around a proposed integrated gasification combined cycle (IGCC) plant (CSRP 2008)

## **Regional Synergies Toolkit**

An initial detailed review of best practices of regional synergy development from around the world revealed that regional resources synergies have so far primarily developed opportunistically in the absence of specific methods for synergy option generation (Bossilkov et al. 2005). This highlighted the need for a toolkit that could both identify potential synergy opportunities and provide guidance on the relevant technologies to realise any identified opportunities. The CSRP, in response to this finding, developed a practically orientated toolkit suitable for use by engineers or technologists in intense industrial regions. This toolkit comprises two key components:

- Regional Synergy Opportunity Tool, which identifies potential synergy opportunities in an industrial region; and
- Technology Assessment Tool, which assesses the technology needs and opportunities for selected regional synergies.

## **Regional Synergy Opportunity Tool**

This tool enhances and facilitates the identification and development of synergy opportunities within an industrial region through a three-stage process. Firstly, a scanning assessment is conducted using a generic database, which has input and output flows for most major industries, to generate a list of potential regional synergies. Secondly, a more detailed analysis is performed on the promising opportunities resulting in ranked listings of potential synergies in the three areas: water, energy and material by-products. Finally, a screening analysis is conducted to gauge the potential contribution the synergies could make to the sustainable development of the region.

Application of this tool on the Kwinana and Gladstone regions demonstrated that it can assist with the synergy identification process and complement the more time-consuming manual approach adopted in these ‘hands-on’ projects. In fact, the tool generated a greater potential synergy list of potential synergy opportunities, including collective initiatives for purchasing materials and recycling (like sulphuric acid and caustic soda) and potential alternative fuels by-products, such as spent solvents, tyres, biomass, and

plastics – refer to Tab. 1. The scanning assessment has also been applied to other industrial regions in Australia, Geelong, Victoria and Wagga Wagga, New South Wales (Bossilkov and Corder 2006; Corder and Bossilkov 2006). More recently, the tool was used to identify potential opportunities for a possible new industrial initiative in Kwinana Industrial Area, an integrated gasification combined cycle (IGCC) plant with carbon capture and storage. In this case, the tool importantly identified of all four specific water sources. Outside Australia, the tool in the process of being used to investigate synergy opportunities between the key platinum producers and near-by industries in other sectors in the Rustenburg region (South Africa).

Tab. 1 – Results from Applying Preliminary Assessment Tool to Kwinana and Gladstone Regions - from (Bossilkov 2006)

Kwinana	Gladstone
Various wastewater streams exchanged between different operations	Various wastewater streams exchanged between different operations
The following resources as alternative feedstock, mainly in cement production:	The following resources as alternative feedstock, mainly in cement production:
§ baghouse waste/dust	§ baghouse waste/dust
§ slag	§ metals
§ gypsum	§ gypsum
§ sludge	§ metal oxides
§ fly/bottom ash	§ fly/bottom ash
	§ filter dust
The following resources as alternative fuel:	The following resources as alternative fuel:
§ hydrogen	§ hydrogen
§ methane	§ spent pot lining
§ spent oils/grease	§ spent oils/grease
§ fuel gas	
Potential for reuse of the following resources:	Potential for reuse of the following resources:
§ carbon dioxide	§ lime
§ lime	§ diluted sulphuric acid
§ lime sand	§ steel and other metals
§ spent caustic	
§ garnet and sand	
§ sulphur	
§ diluted sulphuric acid	
§ hydrochloric acid	
§ steam	

### Technology Assessment Tool

The Technology Assessment Tool aids the user in the selection of the most suitable transport and technology components in the implementation of the identified synergy opportunities. Constructed around an analytic framework, the tool analyses potential synergy opportunities in three components, capture, recovery/management and utilisation, and in by-product categories of water and energy. It attempts to provide a list of potential technologies (e.g. viable water or recycling technologies) only ‘knocking-out’ those that have very poor return on investment. Application of this tool is limited at present as it is still currently under development.

## Global Synergies Database

The CSRP have also developed a compendium of regional synergy examples, the Global Synergies Database, to promote existing regional synergy examples from around the world and encourage other industrial regions to develop similar synergy initiatives. This database includes examples from Kwinana, Gladstone, Forth Valley, Puerto Rico, Kalundborg, Tampico, Humberside and Quebec and is publicly-available at [www.csrp.com.au/database/index.html](http://www.csrp.com.au/database/index.html).

## SUSTAINABLE MANAGEMENT OF BAUXITE RESIDUE AREAS

In some cases, not all of a by-product can be re-used for regional synergies and thus requires storage or disposal. One such example is bauxite residue from the alumina industry. In these cases, management of a bauxite residue area should be done in the most sustainable manner possible to ensure minimal impact to local environment and community. The CSRP have developed and tested a methodology for sustainable bauxite residue management that provides both a framework for evaluating the sustainability of bauxite residue storages and a practical tool to assist with sustainability assessments.

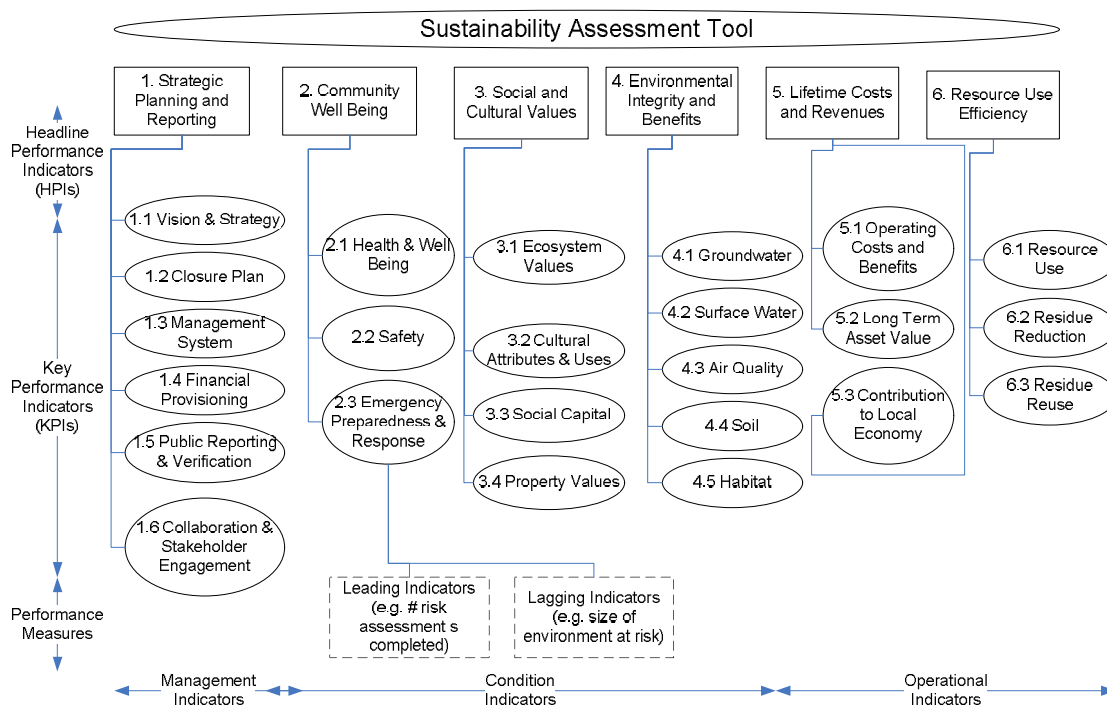


Fig. 3 Structure of Indicators in Methodology for Sustainable Bauxite Residue Management – from (van Berkel and Power 2007)

The management of the residue area is monitored against a series of indicators that are categorised into three hierarchical levels. These levels comprise respectively six Headline Performance Indicators (e.g. strategic planning and reporting, community well-being, social and cultural values, environmental integrity and benefits, lifetime costs and revenue, resource use efficiency), 24 Key Performance Indicators and a number, which is case-dependent, of Performance Measures – refer to Fig. 3. For each indicator, ideal and best reasonable targets are set and management performance is assessed by monitoring

progress towards these targets. The integrated quantitative manner in which the methodology considers the environmental, social and technical performance of bauxite residue storage systems over their lifetime and beyond allows a uniform approach in monitoring progress to the desired targets at a single site or across a range of sites (van Berkel and Power 2007). To apply the methodology, a Sustainable Assessment Tool was developed using Microsoft Office™ applications and trialled at Alcoa's Kwinana (Western Australia) Residue Storage Facility. This trial provided a useful complement to the existing environmental, social and economic audit protocols (van Berkel and Power 2007).

## **FUTURE WORK**

The CSRP research activities and their associated outcomes presented in this paper demonstrate the need to have multiple approaches for evaluating sustainability benefits and addressing sustainability issues that could affect minerals industry operations. The ranges of approaches from identifying critical future aspects for the industry through the 'issues' papers to the development of a structured and uniform quantitative methodology for the sustainable management of large by-product storage areas ultimately need to be part of an overall structured business Sustainable Development approach.

A current major CSRP research activity is the development of SUSOP® (Sustainable Operations), which will comprise a collection of management tools to assist with identifying and implementing Sustainable Development practices in the design and operation of industrial operations. SUSOP® is the Sustainable Development analogy to HAZOP in the safety field, and will assist operations and organisations in Sustainable Development based decision-making both in the project development phase and the production phase. There are SUSOP® tools available through CSRP and its Partners for various stages from initial concept through design and operation of projects and sites. SUSOP® is still in the development phase. By carrying out a number of industry-based case studies CSRP will further develop the SUSOP® technique.

## **ACKNOWLEDGMENTS**

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## **BRIEF BIOGRAPHY OF PRESENTER**

Glen Corder is a chemical engineer and has over 20 years experience in the resource industries, including 13 years at the Julius Kruttschnitt Mineral Research Centre at the University of Queensland, Australia. During this period he was involved in minerals processing and process control consultancy, and presentations of training courses. More recently he has worked on sustainable development research projects at the Sustainable Minerals Institute at the University of Queensland, include investigating approaches for realising industrial regional synergies and developing and applying sustainable development methodologies and toolkits for the minerals industry.