Assessing the Benefits of Sustainable Processing Research in the Minerals Industry

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Abstract

There is a growing demand to evaluate the sustainability benefits of innovative technologies for the minerals industry. Applying traditional cost-benefit analysis to ascertain the 'value' of these technologies excludes the increasing need to assess other critical factors related to environmental and community benefits and long term economic benefits. Such factors are vital in determining the true value and viability of a new project using new innovative technology, and the role this technology can play in enhancing the sustainability of new, existing or expanding operations.

Much of the work of the Co-operative Research Centre for Sustainable Resource Processing (CSRP) has environmental, community and wider economic benefits, over and above direct financial benefits. If these research outcomes are widey implemented, they will contribute significantly to sustainable development in the mineral and related industries. This paper presents the results of applying a developed assessment methodology to quantify the sustainability benefits of innovative research outcomes from CSRP.

A review of existing public-domain sustainability frameworks and assessment methodologies was used as a basis to develop a sustainability assessment methodology specifically for minerals processing project, but potentially applicable to other industry sectors. The methodology has a four-stage approach of first characterising a project's key sustainability components followed by the application of suitable tools to evaluate and where possible quantify the benefits. Results of applying the methodology to key CSRP research projects in the areas of comminution, geo-polymers and biomass are presented. Using these results, the paper then postulates the potential sustainable development benefits from CSRP research outcomes at various levels of adoption throughout the Australian minerals industry.

1. INTRODUCTION

Extensive research is currently being undertaken in the minerals industry that claims to improve sustainability. However, much of the benefit has not been assessed using a standardized framework. Most of the sustainability frameworks developed to date examine the sustainability of broader scale activities – such as whole industries or countries (Fiksel, Garvin et al. 2002; IISD 2002; ICMM 2003) – rather than examining the immediate sustainability implications of individual projects. Recently this deficiency has been noted, and some initial methodologies posited for the development of appropriate measures (George 1999; Evans and Joy 2003; Rodrigues, Campanhola et al. 2003; Basu and Kumar 2004; Brent and Labuschagne 2004).

The Co-operative Research Centre for Sustainable Resource Processing (CSRP) undertakes research to create methods to produce minerals and metals in a way that benefits the community, the environment and industry. Estimating the sustainability value of key CSRP projects is critical to determining the importance of these projects. The traditional method of applying a cost-benefit analysis to determine the ‘value’ of minerals industry projects does not include the growing need to measure and evaluate other critical factors related to environment and community impacts and benefits. As these factors can have a major bearing on a project’s viability, there is a need to not only better understand their magnitude and impact but also the role that innovative new technologies or methodologies can play in improving the sustainability of an operation. Furthermore, it is desirable to examine the potential for widespread application of the project outcomes within the Australian context, to valuate this in absolute and comparative terms.

The problem is framed in the context of CSRP objectives, vision and mission (www.csrp.com.au) from which it is apparent that CSRP is currently focused primarily on the environmental or ecological impacts of the minerals industry, rather than the social impacts. This focus is reflected in the projects included within CSRP, and justifies an approach to sustainability based heavily on the environmental pillar of the triple bottom line.

An initial review of the literature surrounding sustainability (particularly in the minerals industry) found that no “off-the-shelf” framework could be adapted for the assessment of project-level sustainability. As a result, a methodology was developed to fulfil the particular needs of this application. The desired outcomes from applying this methodology were to:

- identify key sustainability categories relevant to CSRP projects
- estimate the benefits of CSRP project outcomes compared with a suitable benchmark
- estimate the potential total sustainability benefits of uptake across the Australian industry
- value the benefits in monetary and non-monetary terms

2. METHODOLOGY

The methodology developed consists of four steps, as illustrated in Figure 1. The characterisation step compares the project outcomes against a variety of sustainability categories to identify where the sustainability contributions lie, and to reduce the scope of further assessment to the categories of importance. The second step is the quantification of the sustainability contributions in terms of the smallest applicable unit. Extrapolation of these contributions to different levels of potential uptake, incorporating parameters bounding the applicability, is the third step in the methodology. Finally, these potential contributions are valued in monetary and non-monetary terms, for the sake of decision makers.

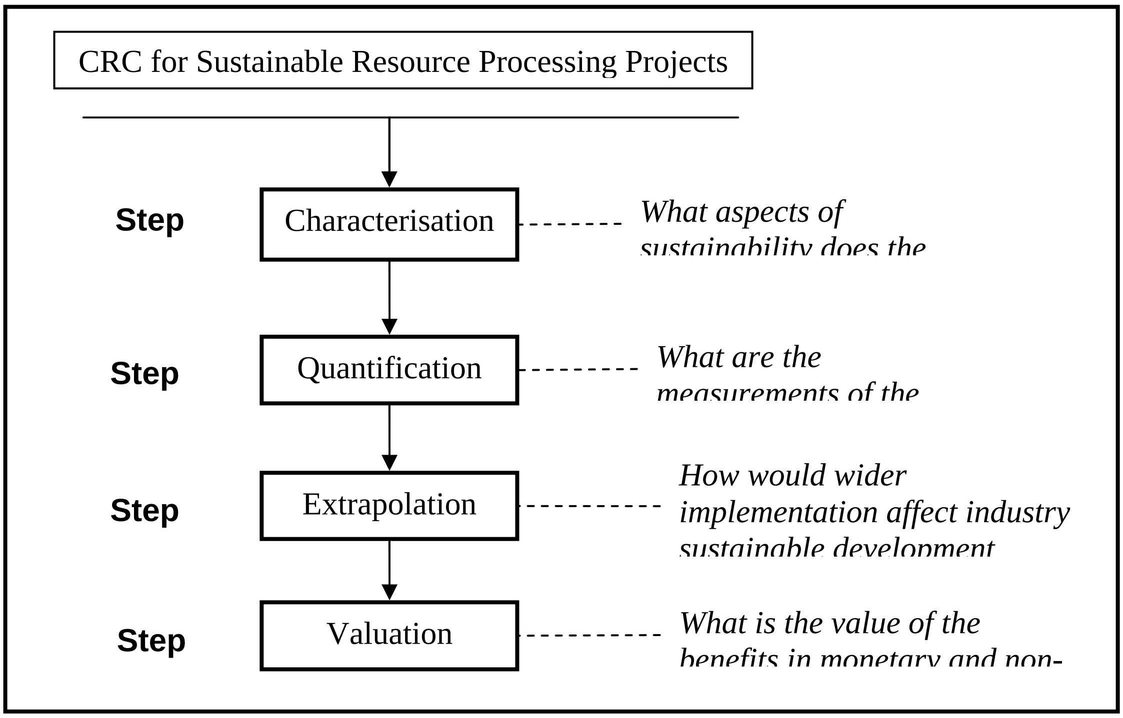


Figure 1: Schematic of the Sustainability Contribution Assessment Methodology

The methodology uses sets of questions to prompt research project leaders to identify the areas in which sustainability is addressed by their projects, quantify the benefits or impacts and give guidance around the applicability of research outcomes within the Australian context.

2.1. Step I – Characterisation

The first step in the process of project sustainability contribution assessment is to *identify the impact categories to which the project contributes*. An initial set of categories was based on the Institution of Chemical Engineers sustainability metrics (Azapagic, Howard et al. 2003) as per the benefits column of Table 1, with an additional social category. By characterising the projects in this manner initially, it is possible to reduce the assessment time and gives an obvious indication of where potential project benefits lie.

The characterisation step is intended as a broad overview of the intended or expected contributions of the project rather than a comprehensive assessment. Full scale life cycle assessment (LCA) would be required to obtain a detailed picture of the sustainability contributions, but that is often not feasible at the project development stage due to time, data and budget constraints.

2.2. Step II – Quantification

The aim of the second stage of the methodology is to *assess the lowest-unit-level change in impact to each category identified in the characterisation step.* This entails determining the change in relevant performance parameters at the level of implementation, and significant flow-on effects in other processing units.

To ease the way for extrapolation of potential benefits, it is important that the units of measurement of parameters are chosen appropriately. Perhaps the most appropriate units are change per unit product output, (e.g. X kWh/t for energy savings) as this can be translated directly to an operation of any size.

The quantification in this methodology must be based on the available data, or estimation from the project team, as a full LCA is often impractical due to time, data and budget constraints. One desired outcome from this project would be the development of factors allowing a simple LCA to be done as a first-run approximation. An LCA of this kind would enable better estimation of project benefits and impacts. For example, estimates on the embedded energy in grinding media could give an insight into off-site impacts.

It is important to include a description of the standard process against which the project is being compared. This description should include values of standard performance, and an idea of the range of values in current practice. The methodology also identifies any barriers to implementation, such as high capital costs.

2.3. Step III – Extrapolation

The third step in the methodology is to *extrapolate the results from the lowest-unit-level to the highest potential for implementation.* Here, the Australian industry levels are taken as the highest level of implementation.

The first step in extrapolation is to expand the process unit improvement to the site level, and express the improvement or contribution on a per tonne of product basis (if not completed earlier in Step 2). This is made more complex by the uniqueness of each ore body and processing plant (Stewart and Petrie 2006).

Ultimately, the desired result of this step is to know the level of implementation possible across Australia. To assist in determining this result, the following questions are posed:

1. Which mine or minerals processing sites across Australia could the project outcomes be applied to?
2. What is the total capacity in terms of ore throughput or production?
3. What is the total extrapolated effect of the project?

4. What is the uncertainty in this figure?

2.3.1. Range of Applicability

To allow a more meaningful and realistic extrapolation of the potential for impact of project outcomes, the range of applicability must be specified. The following are a guide to a range of applicability criteria (not necessarily an exhaustive list):

1. What type of minerals can the project outcomes be applied to?
2. What type and grade of ore can the project outcomes be applied to?
3. What mining configurations can the project outcomes be applied to?
4. Are there any process constraints on applying project outcomes?
5. Are there any environmental constraints to application?

2.3.2. Contextualisation

Various aspects of the local environment will affect the level of sustainability benefit – for instance, water conservation is not as high a priority in areas of high annual rainfall. This section asks whether the plant in question and the industry in general are situated in locations where significant environmental parameters may affect sustainability.

2.3.3. Extrapolation

Extrapolation forms the key third step in the process of assessing the sustainability benefits of CSRP projects. Once unit or site level project benefits have been quantified, they can be extrapolated to the Australian level. At the extrapolation stage, the unit benefits are expanded under the limitations set by the range of applicability, using industry level production data.

2.4. Step IV – Valuation

The valuation step derives the final summary figures for the assessment process, which are the key output from the methodology. Non-monetary sustainability benefits resulting from the previous 3 steps may be summarised for the extrapolated values.

2.4.1. Monetary Valuation

In terms of monetary valuation, a variety of methods exist for calculating the economic or financial value of a project. Fundamentally, however, the current assessment methodology requires the understanding of 3 main points:

1. What was the cost of the project?
2. Are there cost changes resulting from the project?
3. Is there changed revenue due to the project?

Internalisation of environmental sustainability benefits for determining the monetary value of externalities is not recommended, as the data for Australia is not available, and conversion from overseas factors is intrinsically inaccurate due to societal and environmental differences. In addition, converting environmental impacts to monetary values encourages the combination into a single figure summary, which does not offer a true picture of the sustainability benefits and costs.

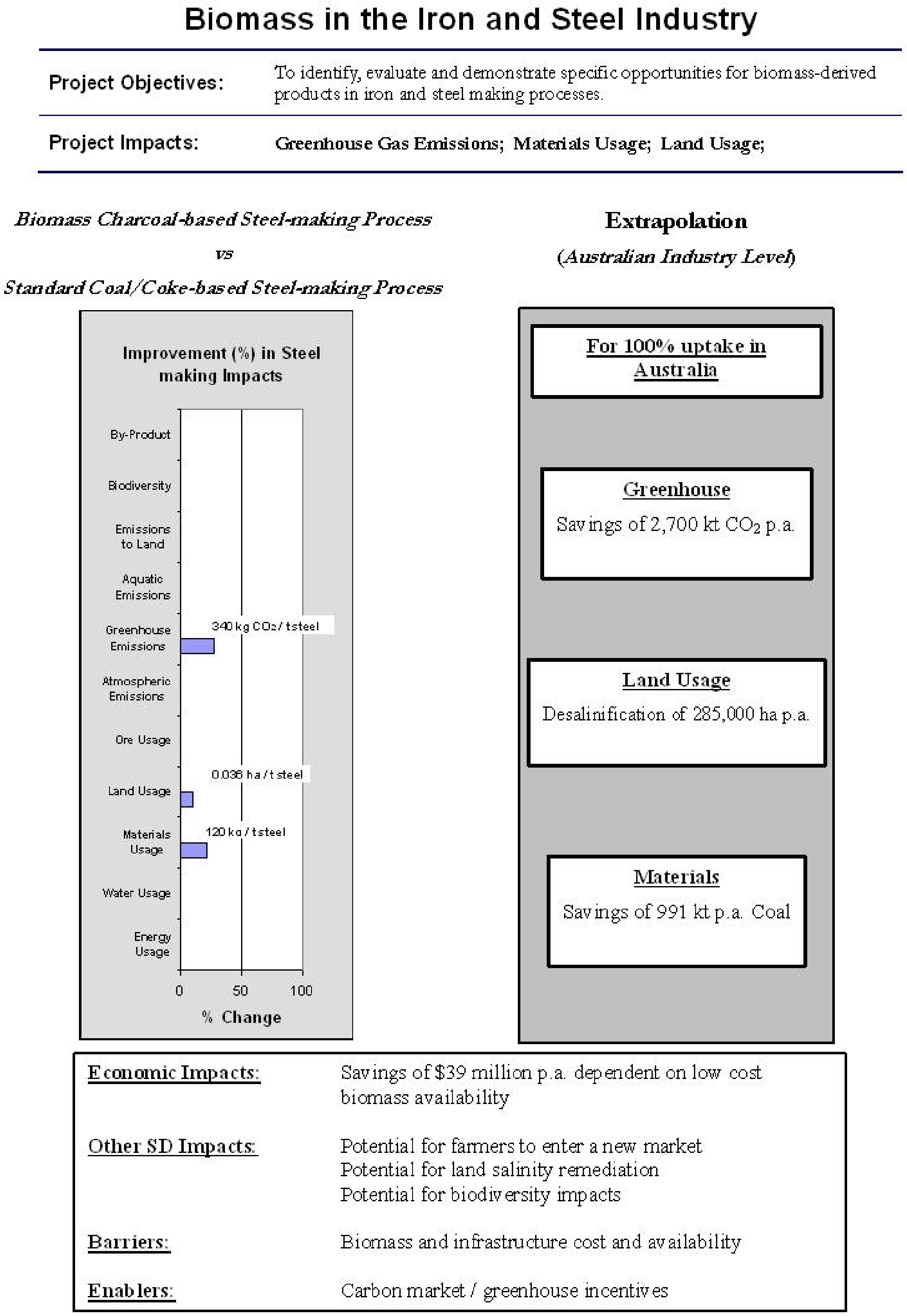
Therefore the current methodology has applied a simple analysis of the variation in operational costs due to raw materials and energy usage changes, and increases in revenue, with the exclusion of capital costs and maintenance costs, due to the lack of availability of the appropriate data on each project. Some projects may be able to clarify the capital cost requirements, and these could be included in an NPV analysis.

2.4.2. Non-Monetary Valuation

Non-monetary valuation is performed to provide a greater level of understanding of the relevance of the sustainability benefits. For example, the reduction in output of greenhouse gases may be translated into a percentage of the total Australian emissions or the total industry emissions. One complexity of non-monetary valuation is obtaining an appropriate basis for comparison of every one of the impacts, and the allocation of cross-industry impacts, as illustrated in some of the case studies in the next section

3. CASE STUDIES

The methodology was applied to five projects as a demonstration, and to identify areas where further development or adaptation was required. Projects were selected based on their novelty, variety of impacts and perceived opportunity to have widespread sustainable development impacts. Complete project descriptions can be found on CSRP website (www.csrp.com.au). No carbon credits or taxes were used, and financial benefits are based purely on operational impacts excluding maintenance. A summary of overall potential impact of CSRP projects is given in Table 1. The outcome of each of the assessment steps was summarised in a one-page display for each project (e.g. Figure 2). Assessment data was obtained from the project leaders and industry reports (full assessment and framework given in (McLellan, Corder et al. 2007)).



Biomass in the Iron and Steel Industry

Project Objectives:	To identify, evaluate and demonstrate specific opportunities for biomass-derived products in iron and steel making processes.
Project Impacts:	**Greenhouse Gas Emissions; Materials Usage; Land Usage;**

Biomass Charcoal-based Steel-making Process

vs

Standard Coal/Coke-based Steel-making Process

Extrapolation

(Australian Industry Level)

For 100% uptake in Australia

Greenhouse
Savings of 2,700 kt CO_2 p.a.

Land Usage
Desalinification of 285,000 ha p.a.

Materials
Savings of 991 kt p.a. Coal

Economic Impacts:	Savings of $39 million p.a. dependent on low cost biomass availability
Other SD Impacts:	Potential for farmers to enter a new market Potential for land salinity remediation Potential for biodiversity impacts
Barriers:	Biomass and infrastructure cost and availability
Enablers:	Carbon market / greenhouse incentives

Figure 2: Example of the one page summary for display of Results

3.1. Biomass in the Iron and Steel Industry

This project is identifying, evaluating and demonstrating specific opportunities to introduce biomass derived products into iron and steel making processes. It will be a component of the contribution of the Australian steel industry to the CO_2 Breakthrough Program of the International Iron and Steel Institute (IISI). Assessment of this project was based largely on LCA work in which the project leader was involved (Langberg, Norgate et al. 2006; Norgate and Jahanshahi 2006).

The outcomes of this project offer potential reductions of Australian Iron and Steel industry greenhouse gas emissions by 27% (approximately 2.7 Mt CO_2 p.a.). It also offers potential to rehabilitate approximately 10% of Australia's salinified agricultural land (285,000 ha). However, the financial benefits of this project rely heavily on the cost of biomass, with estimates from the WA government ($60 / t) being much more favourable than other figures ($435 / t). Best-case scenario cost savings would be around $40 million p.a.

3.2. Triple Pass High Pressure Grinding Roller Mill (HPGR) Circuit Concept

The main aim of this project is to dry process ore to near ball mill product size and to accurately determine the energy to achieve this. The project's objectives include:

- To demonstrate a new HPGR flowsheet that has significant direct energy (through increased energy efficiency) and indirect energy (through reduced grinding media consumption) savings.
- To demonstrate a new dry preparation comminution circuit that could potentially reduce processing water requirements.

The outcomes from this project could potentially reduce milling electricity usage and greenhouse gas emissions for mines utilising SAG mills by 30%. Across the Australian industry, this would equate to 620 GWh p.a. and 0.45 Mt CO_2 p.a. respectively. Furthermore, the HPGR concept offers the potential to reduce steel usage in grinding media by 0.047 Mt p.a. Altogether, these savings would lead to a financial benefit of $120 million p.a. to the Australian industry. This technology is, however, potentially expensive in capital terms. This project aims to verify these benefits, and any potential costs, on the industrial scale.

3.3. Demonstration of Banana Screen Modelling Capabilities

Large double-layer curved screens (often referred to as banana screens) are widely used in the iron ore industry to perform separation because of their high capacity over the older-style flat-deck screens. Banana screen efficiency is poorly understood and it is difficult to optimise screen performance because of the large number of operating parameters. Using sophisticated modelling capabilities, screen performance can be optimised in terms of separation efficiency, capacity and wear. This improvement in performance can result in very large benefits given the high capacity nature of the equipment. This project will deliver an improvement in the industry's capability to optimise screening of iron ore for increased throughput and production of higher value lump ore and reduced energy use.

The outcomes from this project could lead to potential benefits of 0.12 kt CO_2 p.a. reduction in greenhouse gases (0.5% of the crushing emissions from the Australian Iron Industry) from 100% uptake across Australia. However, the major benefits of this project are financial – with a potential increase of $320 million p.a. in revenue. Some savings in screen waste materials of approximately 150 t p.a. could also result.

3.4. Geopolymers in Mine Fill

The project is investigating the potential for geopolymer-based backfill products to substitute Ordinary Portland cement (OPC) in underground mine backfill. The suitability of using mine tailings and smelter slag as feedstock for geopolymers is being investigated and geopolymer-based back fill products are subsequently being developed and tested, to demonstrate technical feasibility, economic viability and sustainability/greenhouse gas benefits.

The outcomes from this project would result in reduction of greenhouse gas emissions by approximately 4% of Australian cement industry emissions (270 kt CO_2 p.a.) from the substitution of Ordinary Portland Cement (OPC) with geopolymers based on smelter slag in backfill for the main Australian mining operations near smelters. The direct impact of this application is the usage of 77% of smelter slag (1.1 Mt p.a.) in the geopolymer binder which produces a useful by-product as well as reducing waste emissions to landfill. Cost savings and feasibility of the application are dependent on the highly variable cost of NaOH. Potential savings of $40 million p.a. to $110 million p.a. are possible, dependent on the costs of NaOH and OPC.

3.5. Heat Recovery from Molten Slags through Dry Granulation

Dry granulation is emerging as an alternative process that overcomes the environmental disadvantages of water granulation (such as high water consumption, formation of acid mist, and need to dry the granulated slag). Previous research has demonstrated at laboratory and pilot scale that dry granulation using a rotating disc atomiser produces a slag suitable as cement substitute. This project is further developing dry granulation technology, with particular emphasis on using it to capture the waste heat released from slag cooling.

The outcome from this project could result in a 21% (1.4 Mt CO_2 p.a.) reduction in greenhouse gas emissions from Australian concrete production, given utilisation of all steel-making slag instead of Ordinary Portland Cement (OPC), as well as a further 0.27 Mt CO_2 p.a. from energy savings in the steel slag treatment process (2% of Australian steel industry impacts). Furthermore, reductions in water usage equivalent to 10% of the metal products manufacturing industry (19,000 ML p.a.) and in land required for slag storage, are possible. Estimates show a potential $340 million p.a. in savings and new revenue from the new slag by-product.

Table 1: Potential Australia-wide Benefits, Barriers and Enablers for the Case Study Projects

Benefits		**Triple Pass HPGR Circuit**	**Modelling of Banana Screens**	**Geopolymers in Mine Fill**	**Biomass in the Iron and Steel Industry**	**Dry Granulation of Steel Slags**
Resource Usage	**Energy (GWhpa)**	620	0.65			640
	Water (MLpa)					19,000
	Ore (ktpa)		18,000			
	Materials (ktpa)	47 Steel grinding media	0.15 screen media	640 reduction in OPC 59 increase in NaOH	990 Coal	
	Land (ha)		UQ[1]	UQ	285,000	
Emissions	**Atmospheric (ktpa)**					1,900
	Greenhouse (ktpa)	450	0.12	270	2,700	1,700
	Aquatic (ktpa)				UQ	
	Land (ktpa)		0.15	1,100		1,900
Biodiversity						UQ
By-product						1,900
Economic ($M p.a.)*		120	320	40 – 110	39 **	340
Social					New market for farmers	
Barriers		HPGR Capital Cost	-	High NaOH cost	Biomass & infrastructure cost & availability	-
Enablers		Greenhouse incentives	-	High OPC cost Greenhouse incentives	New product for farmers Possibility of salinified land rehabilitation Greenhouse incentives	Greenhouse incentives

** no carbon taxes or carbon credits were included in this assessment*

*** estimate is based on the availability of low cost biomass*

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[1] UQ = unquantified

4. CONCLUSIONS

A methodology has been developed for the assessment of minerals industry research projects, with particular emphasis on sustainability benefits. Five CSRP projects were chosen as case studies, and assessed utilising this methodology. Significant sustainability impacts were apparent in a number of areas with most of projects in the categories of greenhouse gas abatement and energy savings, with some impacts in other categories. The outcomes from all five projects would provide both good sustainability and cost saving benefits, even without the consideration of a carbon tax or credit scheme. The application of this methodology is as yet not fully standardized, and some advances can be made in the clarity and ease of application by collating relevant minerals industry data. However, the analysis presented in this paper has demonstrated the advantages of summarizing the full range of potential benefits (that is environmental, social and economic) associated with the application of innovative research outcomes for the minerals industry.

5. ACKNOWLEDGMENTS

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