photo courtesy of CSRP

Fly ash

Evaluating the sustainability benefits of new technologies

by Glen Corder, Ben McLellan and Stevan Green

Despite the economic downturn, worldwide demand for mineral-based products is poised for continued growth, due in particular to ongoing modernization in developing countries. Meeting this demand could strengthen economies and improve social equity by making material goods more widely available. However, there are some serious constraints. Even if production and utilization efficiencies improve amid growing demand and declining ore grades, mineral-based production will be limited by access to energy, water, allowable greenhouse gas (GHG) emissions and land for waste disposal. Given current paradigms, business growth will not be sustainable.

Changing the status quo

In a business-as-usual scenario, the Australian minerals and energy sector will emit up to 400 megatonnes of GHG by 2050, one-third more than the government's current countrywide target of 300 megatonnes. In the sustainable scenario, the minerals industry would target 50 per cent aggregate emission reductions by 2050, in line with overall targets. A pure innovation approach (i.e. with no offsets) would require 90 per cent improvement in GHG efficiency by 2050. Achieving this with forestry-based offsets would require planting 1.6 million hectares annually – approximately three per cent of Australia's arable land. Clearly, offsets cannot be the whole solution. Although no analysis has been done, it is reasonable, given similarities, to expect comparable limitations in Canada. Such scrutiny provides compelling evidence that the industry urgently needs to develop more sustainable technologies (particularly given the lead time from research outcomes to commercialization).

Sustainability benefits are a critical indicator of the "value" of research outcomes. Traditional cost benefit analysis does not recognize the need for estimating environmental and community effects. Sustainable development benefits can be quantified so that factors like carbon pricing, capital costs, legacy costs, alternative land uses, etc. are accounted for. Because these factors can strongly influence a project's viability, it is imperative to better ascertain their magnitude and impact and understand the contribution that innovative technologies or methodologies can make in improving project sustainability. Furthermore, it is desirable to examine the replicability of project outcomes, to valuate this in absolute and comparative terms. Without understanding its potential sustainability implications, one cannot determine how any new technology compares with existing or other emerging technologies that perform the same function.

Promising research

Australia's Centre for Sustainable Resource Processing (CSRP) undertakes cooperative research aimed at developing resource production methods that benefit the community, the environment and industry. Based on novelty and potential sustainable development impacts and benefits, five CSRP research projects were selected for sustainable development (SD) assessment, using methodologies developed in-house after extensive review of extant research concluded that no available methodology was suitable. The projects and their main sustainability benefits are described below.

Biomass in the iron and steel industry

This project identifies, evaluates and demonstrates opportunities for the Australian steel industry to introduce biomass-derived products into iron and steel production to reduce the industry's carbon footprint. It complements the contribution of the Australian steel industry to the International Iron and Steel Institute's CO_2 Breakthrough Program. By consolidating information on biomass use in iron and steelmaking from literature with previous research and plant reviews, the project will identify and prioritize specific opportunities for the Australian steel industry. Parallel experimental investigations aim to demonstrate the technical feasibility of using biomass in high-priority applications. Although heavily dependent on the cost of biomass (estimated to be from A$60 to A$435 per tonne), the outcomes offer potential GHG emission reductions of 27 per cent in the Australian iron and steel industry. Moreover, approximately 10 per cent of Australia's salinified agricultural land (285,000 hectares) could be rehabilitated.

Banana screen modelling demonstration

This project seeks to optimize banana screen performance by applying sophisticated discrete element modelling. Banana screens (large double-layered curved screens) are widely preferred in the iron ore industry to perform separation because of their capacity advantage over older flat-deck screens. However, their efficiency is poorly understood and optimizing screen performance is difficult, given the many operating parameters. Sophisticated modelling allows the separation efficiency, capacity and wear of screens, resulting in large improvements in industry capacity to optimize iron ore screening for increased throughput, higher value lump ore production and reduced energy use. However, the estimated sustainability benefits of banana screen performance improvements are modest. There can be no more than 0.12 kilotonnes of CO_2 reduction in GHG annually, even if there is 100 per cent uptake across Australia.

High-speed video camera

Geopolymers in mine fill

This project seeks to substitute geopolymer-based backfill products for ordinary Portland cement (OPC) in underground mine backfill. Geopolymers are formed by the reaction between an alkali and an alumino-silicate source. Their amorphous three-dimensional structure lends them fire and acid resistance, making them ideal OPC substitutes in numerous applications. Many industry by-products, including fly ash, mine tailings and bauxite residues, can serve as geopolymer feedstock. The project investigates the suitability of using mine tailings and smelter slag as feedstock for geopolymers. A suite of potential binder feedstock for use in tailings-based fills at an Australian mine site were characterized, tested and able to meet the specified mechanical properties, illustrating the technical feasibility of waste-based binders in mine backfilling. While the viability of geopolymers depends on the highly variable cost of caustic soda, geopolymers could deliver significant GHG reductions (270 kilotonnes of CO_2 per annum) if used instead of OPC at the main Australian mining operations near smelters.

Heat recovery from molten slag through dry granulation

This project substitutes dry granulation for water granulation. Historically, iron-making slag is either air cooled in large pits or water granulated. Water granulation has the advantage of producing a slag suitable as low GHG cement clinker substitute. However, its significant environmental disadvantages include high water consumption, the formation of acid mist and the need to dry the granulated slag. Dry granulation, an emerging alternative process, overcomes these disadvantages while still producing high-value slag.

Table 1. Potential Australia-wide benefits, barriers and enablers

	Benefits	Multiple pass HPGR circuit	Modelling of banana screens	Geopolymers in mine fill	Biomass in the iron and steel industry	Dry granulation of steel slag
Resource Usage	Energy (GWhpa)	620	0.65			640
Resource Usage	Water (MLpa)					19,000
Resource Usage	Ore (ktpa)		18,000			
Resource Usage	Materials (ktpa)	47 Steel grinding media	0.15 screen media	640 reduction in OPC 59 increase in NaOH	990 Coal	
Resource Usage	Land (ha)		Unquantified	Unquantified	285,000	
Emissions	Atmospheric (ktpa)					1,900
Emissions	Greenhouse (kt CO_2-eq pa)	450	0.12	270	2,700	1,700
Emissions	Aquatic (ktpa)					Unquantified
Emissions	Land (ktpa)		0.15	1,100		1,900
	Biodiversity				Unquantified	
	By-product					1,900
	Economic savings (A$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	Greenhouse incentives

* No carbon taxes or carbon credits were included. All amounts are in Australian dollars.
** Estimate based on the availability of low-cost biomass.

Previous research has demonstrated that dry granulation produces a slag suitable as cement substitute, and that the heat released from the slag can be contained in a small air volume, making the process suitable for heat recovery.

This project is further developing the technology, with emphasis on capturing the waste heat from slag cooling. It could result in GHG emissions reductions of 1.4 megatonnes of CO_2 per year in Australian concrete production, as well as a further 0.27 megatonnes of CO_2 per annum from energy savings in steel slag treatment, and a water usage reduction of 19,000 megalitres per annum.

Multiple-pass high-pressure grinding roller mill (HPGR) circuit

The objective of this project is to dry process ore to near-ball mill product to demonstrate a new HPGR flowsheet that has significant direct (through increased energy efficiency) and indirect (through reduced grinding media consumption) energy savings and reduced water usage compared with conventional semi-autogenous (SAG) milling. The concept is built on earlier work that demonstrated that while a substantial reduction in energy could be achieved by treating particles below 3.35 mm, it is also necessary to treat larger sized particles during primary comminution. Utilizing HPGR units in earlier stages should generate more fines grinding and lessen the load on the ball milling circuit. Historically, the minerals industry has not widely used HPGRs, compared with the cement industry, where more than 400 industrial units are in operation for grinding clinker. The new flowsheet could potentially reduce milling electricity usage and GHG emissions for mines using SAG mills by 30 per cent, resulting in annual reductions in electricity consumption of 620 gigawatt hours and in GHG emissions of 0.45 megatonnes of CO_2 across Australian industry. However, the capital cost for switching over to this technology would be very high.

The litmus test of sustainability

In the SD assessment of the above projects, no capital costs were included and financial benefits were based on operational impacts excluding maintenance.[1] A summary of results is presented in Table 1.

CSRP continues to apply this SD assessment to other research outcomes, and to refine and enhance this methodology in collaboration with industry partners. This methodology feeds into a collection of management tools to assist

1 Capital and maintenance costs were excluded due to the difficulty in acquiring average indicative values; these costs can be highly dependent on site location and are difficult to estimate for new or emerging technologies.

with identifying and implementing sustainable development practices in industrial operations. CSRP's system, named SUSOP® (Sustainable Operations), is analogous to HAZOP in the safety field. SUSOP® incorporates sustainability principles into the design and operation of minerals processing plants. It facilitates a structured, methodical process to identify and implement ways to use less water and energy, generate lower GHG emissions and minimize waste volume and toxicity, allowing operations to link performance imperatives to sustainability objectives.

SUSOP® helps generate ideas and assess options to produce an SD balance sheet. While SUSOP® can be incorporated into any stage of the project/production cycles, maximum benefit can be derived at the earliest stages. The concept is gaining significant traction, and several case studies are underway to further develop SUSOP® before its full deployment. This is an important contribution to industry's efforts to prepare for global constraints and to utilize opportunities presented by the sustainability agenda. CIM

About the authors

Glen Corder is a researcher at the University of Queensland's Centre for Social Responsibility in Mining (CSRM). His focus is on sustainable development methodologies and toolkits for the minerals industry, and investigating practical approaches to realizing regional synergies in heavy industrial regions.

Ben McLellan works at the Centre for Social Responsibility in Mining (CSRM) on assessing the potential sustainability benefits for Australia of the emerging minerals industry research outcomes, and on the integration of sustainability into the design and operation of minerals operations.

Stevan Green, CEO of the Centre for Sustainable Resource Processing, has a wealth of Australian and international experience and knowledge of the engineering, minerals and energy industry. He has worked for a number of major organizations, including Shell, BHP Billiton and the North West Shelf Venture.

Acknowledgments

This research was conducted at and with financial support from the Centre for Sustainable Resource Processing (www.csrp.com.au), itself supported under the Australian government's Cooperative Research Centres Program. The authors acknowledge the input of Roy Lovell (CSIRO); Phillip Bangerter (HATCH); David Brereton, Chris Moran and Robin Evans (Sustainable Minerals Institute); Mike Daniel and Marko Hilden (JKMRC); Daniel Southam (Curtin University of Technology); and Sharif Jahanshahi (CSIRO Minerals).