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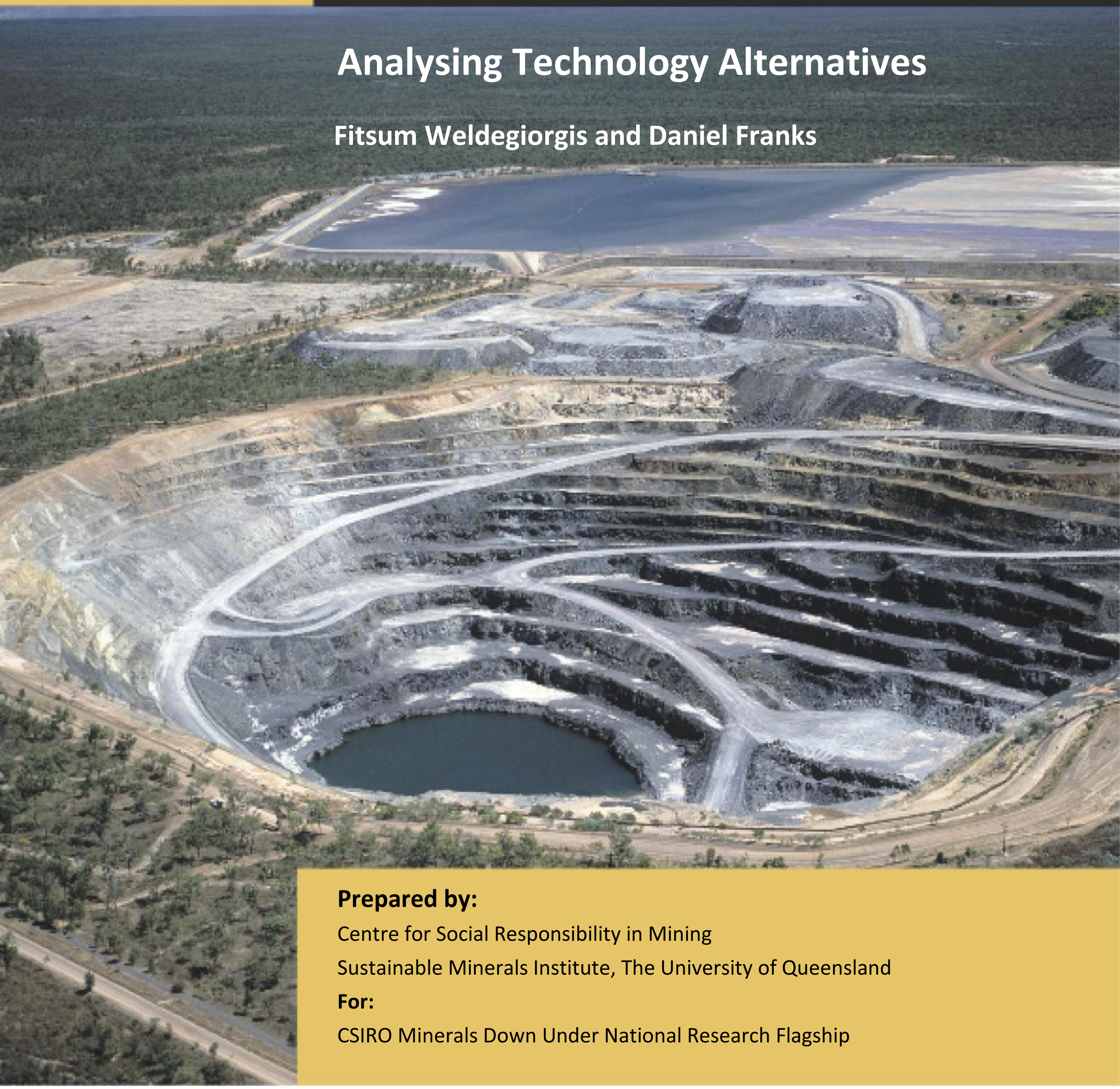
THE SOCIAL DIMENSIONS OF CHARCOAL USE IN STEELMAKING



Analysing Technology Alternatives

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For:
CSIRO Minerals Down Under National Research Flagship

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The Centre for Social Responsibility in Mining (CSRM) is a centre within the Sustainable Minerals Institute, University of Queensland, Australia. CSRM works with companies, communities and governments to respond to the socio-economic and political challenges brought about by resource extraction. The Centre's aim is to help build the capacity of these stakeholders to manage change in more effective ways. CSRM has global reach, with particular experience in Australia and the Asia-Pacific. For more information visit our website at: http://www.csrm.uq.edu.au.

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CONTENTS

EXECUTIVE SUMMARY

The increasing importance of global climatic change is driving research and development in low emissions technologies. One such technology is the potential shift from the use of metallurgical coal in steel making to renewable sources of charcoal production from biomass. This paper adapts social life cycle assessment methodologies to undertake an analysis of the social dimensions of technology alternatives in steel making. Three technology alternatives are investigated: charcoal produced from Radiata pine plantation forestry; charcoal produced from Mallee revegetation on agricultural land; and metallurgical coal.

Impact indicators analysed include land-use, employment, workplace health & safety and a qualitative analysis of identified stakeholder issues. The paper finds that no unique solution exists for optimising the social performance of the technology alternatives across all of the indicators. Biomass alternatives were found to be significant generators of direct employment at the regional level (2.9 x 10^{-3} per tonne of steel for Pine biomass and 5.41 x 10^{-4} for Mallee biomass as compared to 2.66 x 10^{-4} for metallurgical coal). However, they were also identified as having concomitantly higher rates of workplace injuries (6.28 x 10^{-5} per tonne of steel for pine compared to 3.23 x 10^{-6} per tonne of steel for coal).

The scale effects of a shift to biomass technologies on land-use are significant. When compared to metallurgical coal, Pine biomass alternatives represent a 3,840% increase in land-use (with equivalent increases required for Mallee). Production of pine plantation forestry in Australia would be required to increase by 67% to accommodate the full substitution of coal (an additional 1.35 million hectares under plantation forestry), while Mallee biomass plantation would require a full 10,176% increase on the current plantation. Land-use conflicts have been associated with plantation forestry expansion, with even revegetation projects undertaken for conservation generating local level dissatisfaction and competition with other land-use in some cases. On the other hand, local level conflicts have also manifest from the community health and amenity impacts and subsidence effects associated with metallurgical coal mining, despite the relatively small area of land impacted (5 x 10^{-3} hectares per tonne of steel). Charcoal produced from Mallee biomass planted as a conservation measure on farmland has the benefit; however, of representing a shared land-use that in turn supports farm employment through an additional revenue stream and the management of dryland salinity.

The paper was prepared as part of the Technology Futures Project, Mineral Futures Cluster Collaboration, CSIRO Minerals Down Under National Research Flagship. The project is investigating the potential use of constructive technology assessment to inform the development of transformational exploration, extraction and processing technologies within the flagship.

1. INTRODUCTION

Climate change and instances of natural resource scarcity are shifting the domain of focus for energy production to renewable energy sources. One such approach is the potential shift from the use of metallurgical coal in steel making to renewable sources of charcoal production from biomass. Biomass is believed to play an important role in partial substitution of fossil fuel in energy supply (Yu et al., 2009). In considering the use of biomass as a source of energy in the process of steel making, Life Cycle Assessment (LCA) methods could play a role in understanding the full range of the impact. Studies that have assessed the impact and benefits of a product throughout its life cycle include Biswas and Lund (2008) and Udo de Haes and Heijungs (2007). These studies have mostly emphasized the environmental dimension.

In their analysis of LCA, Reitinger et al (2011) underlined the importance of addressing impacts on societal wellbeing as well as the environment when analysing products. Social performance in the resources industries requires due attention as the social and environmental impacts associated with resource extraction and processing as they can become key community concerns. There is a general consensus that community involvement through consultation and participation in the decision making process needs to be prioritised (McMahon, 1998). However there are challenges to such involvement during the design phase of technologies (Franks and Cohen, 2012). Social Life Cycle Assessment (SLCA) is recent and there are few studies that have used a SLCA approach to analyse the performance of products in the minerals industry (Jørgensen et al., 2008), however, there has undoubtedly been an increasing interest in the area.

One component that contributes to the social impacts of a product, and is the focus of this paper, is the design of the technology employed in its production. Despite the erroneous assumption that attempts to detach the social dimension from technology, the design and planning of technology contributes to the societal impacts of products. As Asefa and Frostell (2006) pointed out, the assessment of technical systems during research and development, planning and structuring, and implementation and management phases of technological development is important for identifying and prioritising contributions to sustainability. Assessing the overall health of the technical system influences societal wellbeing. This paper applies a SLCA approach to examine the social performance of charcoal production technology in iron and steel production using biomass. The paper builds on an earlier study undertaken by

Norgate and Langberg (2009) that explored the environmental and economic aspects of the use of charcoal in steel-making.

The paper is structured as follows. Section-two presents a brief overview of technology assessment using the concept of 'social license in design'. This is followed by a review of SLCA methods in section three. This section also introduces the methodology applied in this paper. In section-four the use of biomass in iron and steel production is discussed. Section-five analyses selected social impact indicators for three technology alternatives for steel making (two biomass scenarios and one representing coal).

2. SOCIAL LICENSE IN DESIGN

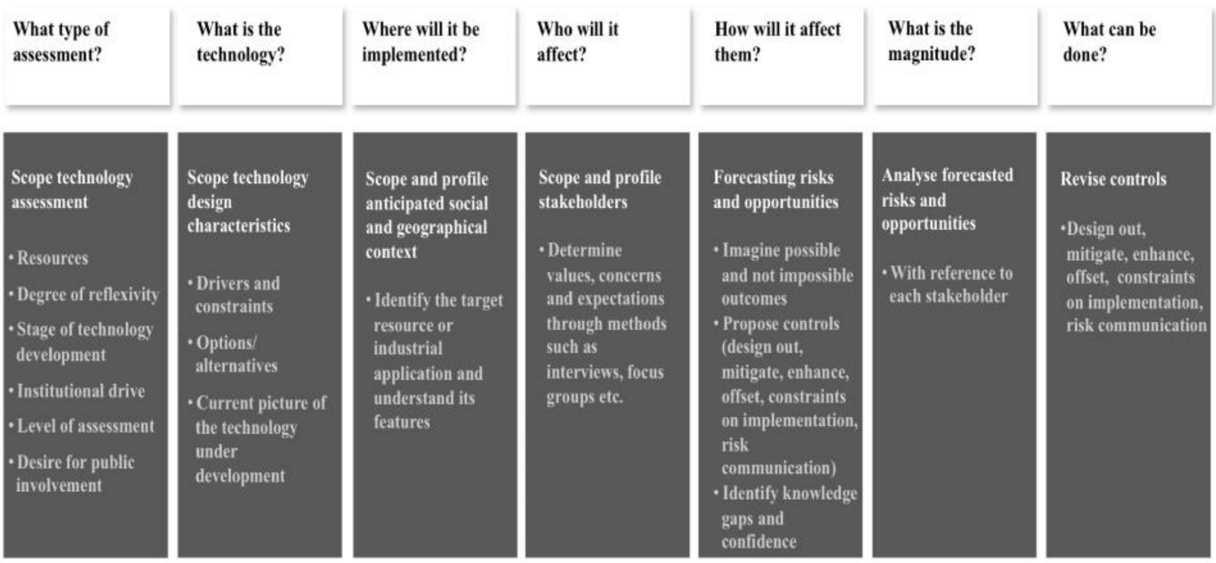
There is a growing understanding by the minerals industry about the need to reduce the social risks associated with projects and to gain social acceptance – commonly referred to as a '*social license to operate*'. Social license to operate (SLO) refers to the intangible and unwritten, tacit, contract with society, or a social group, which enables an extraction or processing operation to enter a community, start, and continue operations (Joyce and Thomson, 2000, Thomson and Boutilier, 2011). Implicit within this agreement is that participation, interaction, accountability, responsiveness, trust, respect, and credibility exist in the relationship between industry and the community.

Various approaches to Technology Assessment (TA) have emphasized the need to incorporate social context into decision-making. However, it has been argued that public participation on its own does not necessarily lead to deeper understandings of the social context (Russell et al., 2010). Constructive TA (CTA) seeks to evaluate the social effects of technological development by facilitating information sharing through dialogue and interaction between developers of technology and other relevant stakeholders. According to Schot and Rip (1997) CTA should involve co-producers of impacts including technology producers, users, and third actors such as governments and unions. Each of these actors interact during development, implementation, adoption, and wider use of technology in order to reduce the human costs associated with technology under development, anticipate potential impact, and influence decision making.

The assessment of technology during its development provides an opportunity to influence the design of the technology in a manner that social context is incorporated. Franks and Cohen (2012) developed a process of CTA, which they termed as the 'Social License in Design'. They argued that the design traits of the technologies employed to extract and process mineral resources and the interplay between these traits and their environmental and social context have a significant influence on social performance. For this reason, technology designers and decision makers should assess the operational context of the designed product beyond the user or proponent in order to reduce social hazards or minimise potential social risk and enhance benefit.

Social License in Design should be approached as an ongoing iterative process of social inquiry and reflection utilizing a multitude of assessment methods (see Figure 1). By tailoring these methods to individual circumstances of the technology under consideration, developers are encouraged to reflect and incorporate the values, perceptions and realities of the context in which the technology may be situated. In this paper we apply the Social License in Design process to assist technology developers working within CSIRO on the development of biomass technology in steel making.

Figure 1: Potential issues to be considered during an iterative Social License in Design CTA process.



3. SLCA AS A TECHNOLOGY ASSESSMENT METHODOLOGY

LCA is a widely used methodology used to determine the environmental impacts of products or processes. The Society of Environmental Toxicology and Chemistry (SETAC) is credited for the development of LCA in December 1991 (Klöpffer and Renner, 2009). LCA has since been applied extensively to assess the environmental performance of products, with the acronym widely used to refer to the assessment of the environmental dimension. More recently LCA has responded to an identified need to include the social and economic dimensions (Benoît et al., 2010) with social and socio-economic criteria in LCA signalling a paradigm shift in sustainability assessment.

One of the highlights of the progress in the LCA research is the development of instruments for the newly introduced pillars of sustainability assessment (Kloepffer, 2008, O'Brien et al., 1996). Social Life Cycle Assessment (SLCA) was developed to assess the impact areas associated with industry actions affecting social wellbeing. As defined by the United Nations Environment Programme (UNEP), SLCA broadly refers to:

> "*a social impact assessment technique that aims to assess the social and socio-economic aspects of products and their potential positive and negative impacts along their lifecycle encompassing extraction and processing of raw materials; manufacturing; distribution; use; re-use; maintenance; recycling; and final disposal*." (Benoît et al., 2009).

Accordingly, SLCA helps develop and disseminate practical tools for evaluating the opportunities, risks, and trade-offs associated with products and services over their entire lifecycle to achieve sustainable development.

Research has been undertaken to further develop the SLCA methodology. Several studies have utilised SLCA frameworks to determine damage/impact categories and category indicators (Benoît et al., 2007, Norgate, 2009, Weidema, 2006). The frameworks identify impact indicators with relevance to the different combinations of relationships among stakeholders. A different approach, known as a combined bottom-up and top-down approach, was developed by Dreyer et al (2006). The approach draws on a universal consensus document regarding social issues as well as the specific business context of companies in an effort to determine damage/impact categories and category indicators.

Recent work in the enhancement of SLCA has sought to focus on specific impact areas in relation to the product assessed. Jørgensen et al (2010b, 2010a) and Reitinger et al (2011) identified an 'area of protection' (AOP) of SLCA to refer to the concept of human wellbeing and the impact categories in SLCA. These two studies attempted to define the impact categories in SLCA to categorise the ways in which stakeholders can be affected within AOP. The authors propose a general normative framework using a capabilities approach to define AOP and the impact categories. Apart from providing a first step to understanding what is important to human life that needs protection, these studies did not address a lifecycle assessment of the impacting factor or product.

Despite the increased work on the development of the SLCA, all of the above mentioned studies acknowledged that it is still in its infancy and that further research is required. This is highlighted by some of the limitations of the SLCA methodologies developed thus far. In particular, Kloepffer (2008) reviewed SLCA literature and identifies problems such as: relating quantitatively the existing indicators to the functional unit of the system; obtaining specific data for regionalised SLCA; deciding between indicators; quantifying all impacts properly; and evaluating the results. SLCA is further complicated by ambiguity as to whether impacts are related to the type of product used or, as Dreyer et al (2006) argue, the way the company interacts with its stakeholders – a case of institutional drive.

In this paper we adapt SLCA concepts and methods for use within CTA. Application of SLCA to CTA introduces a number of further complexities. By shifting the focus of the analysis from products to technology alternatives, and from actual to hypothetical technology systems (a form of 'consequential LCA'[1]) requires some flexibility in the application of the method. Further, and consistent with the Social License in Design process outlined earlier, impact categories have the potential to be experienced differently by different social groups and therefore it is necessary to undertake an analysis from stakeholder perspectives.

The adaptation of SLCA methods used here attempts to ground hypothetical technology alternatives within the social context in which the technology alternatives are likely to be situated. The functional unit of the study is one tonne of steel – though we also consider the scale effects that are likely to be significant at different production levels. The system

[1] Consequential LCA aims at describing the effects of changes within the life cycle of technology.

boundaries of the analysis range from the production of the energy source (biomass or coal) to the blast furnace that produces steel – a form of cradle to gate study. In this paper, only selective components of the cradle (plantation establishment) stage are considered in part due to the difficulties in sourcing data for regionalised parameters. Thus transportation of the energy sources (biomass or coal) is not considered in the analysis. In the following section we introduce the potential use of biomass in steel-making.

4. BIOMASS TECHNOLOGY IN STEEL-MAKING

Steel production has predominantly involved the use of coke made from coal and blast furnace technology. Since the 1960's an alternative technology known as Direct Reduction Technology (DRI), which uses natural gas as a reducing agent emerged. However, DRI did not breakthrough as an alternative technology, mainly due to high reactivity of the solid-state direct reduced iron and the high price of natural gas (Nill, 2003). This led to a committed search for a new technology that makes use of coal resources. Since 1975, Smelting Reduction Technology (SRT) surfaced as a reliable coal-based iron making process (Luiten, 2001). According to Nill, this process allows for the reduction of iron ore to pig iron using coal instead of coke, hence providing an alternative that is less costly and has lower emissions. However, with growing concerns about the adverse impacts of green house gas (GHG) emissions, there is a need to revise the use of GHG intensive energy sources such as coal.

Steel production accounts for 4.1 percent of total world CO_2 emissions and 15 percent of all manufacturing emissions, with about 70% of these emissions coming from direct fuel use (Baumert et al., 2005). Although the contribution to CO_2 emissions is relatively moderate, the high demand for steel and the growing industrial production to satisfy that demand has increased the interest in exploring low emissions technology alternatives. According to Von Scheele (2006), the reduction and heating processes involved in the production are the two main sources of CO_2 emissions. This implies that fossil fuel based energy sources such as coke, natural gas, and coal which make an integral part of these processes are responsible for the majority of CO_2 emissions in steel making. Substitution of fossil fuel based energy sources by renewable sources such as biomass is one possible means for reducing GHG emissions.

Gupta (2003) and Lovel et al., (2007) have studied the potential for wood-char (a product of biomass) to be used in the steel industry and provided the rationale behind the viability as well as limitations of this alternative. Gupta (2003) reported that biomass can be productively generated every 5-10 years and harvested every year. In addition, wood-char is suitable as a reductant for iron-making because it is free from sulphur and contains little ash (Kumar and Gupta, 1994). Norgate and Langberg (2009) found charcoal used in steelmaking could result in greenhouse gas reductions of 4.5-5.3 CO_2e/kg steel depending on the steelmaking route, assuming 100% substitution of charcoal for coal or coke with electricity and eucalyptus oil co-product credits included for charcoal production.

However, transitioning to biomass technologies may generate further complexities. Factors such as limited availability of land for biomass plantation, competing demand for agricultural land, and lack of suitable and cost-effective biomass may also hinder progress. Given the benefits and drawbacks, it is imperative to assess the stages of the process involved in the biomass technology in order to understand the viability of this alternative.

As part of the broader aim to unlock Australia's future mineral wealth through transformational exploration, extraction and processing technologies, the Australian Commonwealth Scientific Industrial Research Organisation (CSIRO)'s Minerals Down-under Flagship has a program of research that is investigating the use of biomass within the steel industry. The carbonisation process of the technology involves thermo-chemical decomposition (pyrolysis) of biomass at low temperature in the absence of oxygen. This produces charcoal which is injected into a blast furnace and used in low emission sintering to make steel. To support the technical studies there is a need for simultaneous research on the social viability of the technology. The proceeding section presents a comparative analysis of the social sustainability of using charcoal in the steel-making industry within the Australian context.

5. ANALYSING TECHNOLOGY ALTERNATIVES FOR IRON ORE REDUCTION IN STEEL MAKING

Biomass for the production of charcoal can be sourced from timber as well as forestry residue. However, this paper has not included the potential use of residue, which would increase the productive capacity of forestry biomass for each given hectare. Three alternative scenarios are investigated for iron ore reduction in steelmaking. Regionalised scenarios have been chosen to ground the alternative technologies under investigation and are based on the most likely technology configurations in the Australian context.

The scenarios are:

A) Biomass from existing Radiata pine plantations (Macquarie Region, New South Wales)

B) Biomass from Mallee revegetation (Wheatbelt Region, Western Australia)

C) Metallurgical coal (Southern Coalfield, New South Wales)

For comparisons to be made between technology alternatives an estimate of the amount of charcoal and coal used to produce an equivalent quantity of steel is required. According to inventory data for steel production (Norgate and Langberg, 2009), 0.415 t/thm[2] of coke and 0.07 t/thm of coal are reduced in blast furnaces into hot metal. Hot metal is then converted into crude steel in Basic Oxygen Furnace (BOF) steel plants. Since 0.95 thm is required to produce 1 t of steel, the equivalent coke and coal required to make 1t of steel are 0.394t and 0.0665t, respectively (see Figure 2). In total 0.567t of coal is required to produce 1t steel, taking into consideration a coal to coke conversion rate of 1.27t coal /1t of coke.

Based on Norgate and Langberg (2009), 0.492t of solid charcoal is needed to replace coal at 100% substitution rate for the production of 1t of steel. Solid charcoal is one-third of the 100% bone-dry biomass, which also includes one-third liquid condensate and one-third gas used to run the process for energy. Therefore the equivalent oven-dry biomass required to produce charcoal is 1.476t. Freshly cut Radiata pine has 50% moisture content, and hence 2.952t of wet pine is required to produce 1t of steel. Mallee, on the other hand, is 40% wet (Enecon Pty Ltd, 2001) indicating that 2.460t of wet mallee is needed in the production of 1t of steel (see Figure 2).

[2] thm – tonne of hot metal

Figure 2: Conversion rates

Coal		
RESOURCE		STEEL
COAL	0.0665t	1t
COKE	0.394t	

Biomass				
RESOURCE	WET BIOMASS	OVEN-DRY BIOMASS	CHARCOAL	STEEL
PINE	2.952t	1.476t	0.492t	1t
MALLEE	2.460t	1.476t	0.492t	1t

Three quantitative indicators were chosen for analysis: land-use, employment and workplace health & safety. The impact indicators were chosen based on a review of literature, issues identified by stakeholder representative organisations at the local and regional scale (in published material), and the availability of regionalised data. Business and services development, impacts on land value, amenity and community health, and workforce location impacts were all considered to be important at the local and regional level but were excluded from the analysis due to data availability. Royalties and taxation returns were not included due to difficulties in data comparison across the technology scenarios and because these issues largely aggregate at the state level and are less important to regional and local stakeholders.

The quantitative categories are further supported by an analysis of identified community/stakeholder issues associated with the technology. Issues were identified through case study research of secondary data sources, and as such may not fully represent the diversity of issues in play. This data may be supplemented in the future by focus group or interview data of hypothetical or actual stakeholder groups. The combination of quantitative and qualitative indicators provides an opportunity to compare the technology alternatives from a number of perspectives. The identification of issues experienced by stakeholders is consistent with the Social License in Design technology assessment process, as described by Franks and Cohen (2012).

5.1 GROUNDING TECHNOLOGY ALTERNATIVES

This section presents an overview of the three technology alternatives grounded by geographical context. The geographic location of the technology scenarios were chosen based on their ability to represent current or likely future locations of production. A brief profiling of stakeholders affected or directly involved in the implementation of the technology is also provided to guide the qualitative identification of stakeholder issues presented in later sections.

A) Biomass from existing Radiata pine plantations: The Macquarie Region, Central Tablelands, New South Wales

The Macquarie Region is part of the Central Tablelands of NSW and comprises plantations managed by Forests NSW. The wider Macquarie Region covers approximately 1,825,871 ha. The Forests NSW estate in the Macquarie Region represents about 73,719 ha of pine forest plantation and about 79,603 ha of native forest centred around Oberon, Lithgow, Sunny Corner and Orange. The Macquarie Region's plantation grows about 1.15 million tonnes per annum of commercial timber (Forests NSW, 2008). The Australian plantation estate represented 2.02m hectares in 2009 (BRS, 2010).

The population of Central Tablelands (including Bathurst and Orange) was 129,990 in 2010 (ABS, 2010). While the biggest employers are retail and manufacturing, 10% of the total workforce in the Central Tablelands is employed in farming, forestry and fishing sector as compared to 3% at national level (Central Tablelands Landcare, 2003). This indicates the significance of forestry and its growing trend in the region and its social implication to the local community.

Key stakeholders

- **NSW Forest Products Association[3] –** While the Forest Products Association principally exists to represent the NSW hardwood timber industry at parliamentary, political and senior Government levels, it is also concerned with broader industry issues. It provides advice and assistance to branches on resource and market

[3] http://www.nswfpa.asn.au/

development as well as supplying factual forest management information to the community as required.

- **Timber Development Association**[4] **-** The Timber Development Association of New South Wales is an industry funded, not for profit organisation representing all segments of the timber industry, from manufacture to supply. It provides timber-related services to the timber industry, timber traders, tradespeople, architects, teachers, students, and the general public.
- **Australian Forest Growers**[5] **-** is the national association with branches in all states representing and promoting private forestry and commercial tree growing interests in Australia.
- **Timber Communities Australia (NSW)**[6] **-** exists to encourage multiple uses of forests. It aims to improve awareness of forest issues, provide a national voice for people associated with forestry, and support the establishment of hardwood and softwood plantations.
- **Central Tablelands Landcare Management Committee Inc**[7] – is a not-for-profit community driven organisation based in the central tablelands district of New South Wales. According to a survey by Central Tablelands Landcare, native vegetation is one of the three most important issues identified by 21% of the people, with sustainable agriculture and riparian (river systems) health being the other two (NSW Landcare, 2003). Consultation with committee officer was conducted and it was noted that the committee has not had any issues with plantation in the area. However, they are aware of the impact that large scale forestry could have on local farms.
- **Central West Catchment Management Authority (CMA)**[8] – is a NSW government body that works with regional communities to restore and improve natural resources. It includes the Macquarie, Castlereagh and Bogan river catchments, and covers a total area of 84,842 km2 (8.5 million hectares). The CMA's objective is to ensure land is best managed and biodiversity which includes 78% agricultural holdings of the total land is preserved (NSW CMA, 2008). The CMA works in partnership with landholders,

[4] http://www.tdansw.asn.au/
[5] http://www.afg.asn.au/
[6] http://www.tca.org.au/
[7] http://centraltablelands-landcare.org.au
[8] http://cw.cma.nsw.gov.au

communities, government, and industry for large-scale targeted investment in natural resources.

B) Biomass from Mallee revegetation on agricultural land (Wheatbelt Region, Western Australia)

Mallee planting in the Wheatbelt region was initiated in early 1990s to complement agriculture. The motivation behind the interest in growing Mallee has been driven by the concern over dryland salinity which is a major form of land degradation in the agricultural areas of Western Australia (Mauger and Australia, 2001). Approximately 90% of the Wheatbelt has been cleared for primary production, industry and settlements, which has caused widespread land degradation. Salinity remains one of the greatest threats to industry, the environment and broader community with more than a third of the land area of some Wheatbelt local governments at risk.

Dryland salinity can be prevented by integrating woody crops alongside agricultural farming. This farming system has the tendency to utilise resources of water, carbon dioxide, nutrients and sunlight, thereby producing greater total biomass yield (Bartle and Abadi, 2009). Furthermore, the commercial attractiveness of Mallee plantation has motivated local farmers to form an industry body called Oil Mallee Association (OMA) in 1995 in order to support and facilitate large-scale Mallee plantation (Bartle and Shea, 2002). These developments have encouraged an organised effort for a potential large-scale biomass production.

According to the *Western Australian Oil Mallee Industry Development Plan*, approximately 25.5 million Mallee trees have been planted on almost 13,000 hectares of land by 2007, mainly to prevent salinity (URS, 2009). Limited harvesting of Mallees has been made to date, mainly for purposes of distillation by Kalannie Distillers, to feed the demonstration Integrated Wood Processing (IWP) plant, and some leaf harvesting for eucalyptus oil producers. The objective of IWP plant is to produce charcoal and activated carbon, eucalyptus oil and electricity from Mallee tree biomass. While there is no Mallee forestry industry at present, there has been a growing interest from farmers through the OMA to develop a commercially viable Mallee industry.

The Wheatbelt Region has two major statistical divisions – Midlands and Upper Great Southern. It had a population of around 75,535 in 2010 (ABS, 2010). The Wheatbelt region has a total land area of approximately 15,500,070 ha. The Region has been the principal agricultural and farming region of the State comprising almost half of all agricultural production with more than a third of the community being engaged in agricultural industries (Western Australian Planning Commission, 2011). This entails the importance of agriculture as a source of livelihood not only to the wheatbelt region but also to the State of Western Australia.

Key stakeholders

- **The Oil Mallee Association (OMA)[9] –** is the peak industry body for the oil mallee industry, representing over 1,200 growers and industry participants. OMA has been coordinating oil mallee industry development activities in WA for the past 13 years. It is currently delivering a range of projects in partnership with Natural Resources Management funding programs including resource building, extension, education, and developing quality management systems. The OMA functions to promote and disseminate relevant information amongst its members, and other stakeholders.
- **Future Farm Industries CRC (Cooperative Research Centre) Ltd[10] -** is an incorporated joint venture playing a crucial role in developing new and innovative farming systems and technologies to improve the resilience of Australian broad acre agriculture to climate change, salinity, climate variability and drought while improving productivity and sustainability. Future Farm Industries CRC was established in 2007 through the Australian Government's Cooperative Research Centre Program. It plays a key role in commercialising mallee industry through projects that research and develop technologies enhancing mallee productivity and harvesting.
- **Forest Products Commission (FPC)[11] -** is a Government trading enterprise established in 2000 to develop and market Western Australia's renewable timber resources. The FPC is also working closely with local industry and Western Australian landowners and farmers to ensure land is readily available for future tree crops and plantations. The Oil Mallee Industry Development Plan is a joint project between the FPC and the OMA.

[9] URS 2009. Oil Mallee Industry Development Plan for Western Australia. URS Forestry @ http://www.oilmallee.org.au.
[10] http://www.futurefarmonline.com.au
[11] http://www.fpc.wa.gov.au

- **Plantation and Landcare Services Pty Ltd (PALS)[12] –** is a landcare contractor in Western Australia providing landcare and revegetation services in low rainfall zones. The services provided include planting native shrubs like mallee to prevent salinity, planting of carbon offset trees, and helping investors with planting and harvesting commercial trees.
- **South West Catchment Council (SWCC)[13] –** is regional natural resource management body for the South West Region of WA which receives regional funding from the Australian Government's Caring for our Country and the Government of Western Australia's State NRM Program to better protect and restore environmental assets. It Provides oil mallee seedlings to property holders to protect salinity and erosion and for commercial purposes.
- **The Growers Group Alliance (GGA)[14] -** is a non-profit, farmer driven organisation connecting grower groups, research organisations and agribusiness in a network across WA. The GGA supports farmer groups by identifying opportunities and issues of concern to the environment and farm activities.

C) Metallurgical coal (Southern Coalfield, New South Wales)

The Southern Coalfield is one of the seven major coal resources of New South Wales and a significant supplier of metallurgical coal (85% of total NSW) to Australia's domestic steel industries (NSW Department of Planning, 2008). The Southern Coalfield extends along the Illawarra Escarpment to the south of Sydney and southwest to Bargo and Berrima. The region covers approximately 830,900ha of land area. The Illawarra region had a population of 436,117 in 2010 (ABS, 2010). In addition to being the only source of metallurgical coal in NSW, the Southern Coalfield is a large residential, industrial, and agricultural area.

Illawarra Coal has a major contribution to the New South Wales economy through the supply of coal for domestic consumption and export revenue. About 60% of the saleable output from Illawarra Coal is used by the Australian steel industry's major coking plants (BHP Billiton, 2007). These include OneSteel's plant at Whyalla in South Australia and BlueScope Steel's plant at Port Kembla, which together account for the vast majority of Australia's steel production. The coal is used for the production of coke, which feeds the blast furnaces. Other

[12] http://www.palservices.com.au
[13] http://swccnrm.org.au/
[14] http://www.gga.org.au/

contributions are through significant capital and operating expenditure, which includes taxes and royalties.

Key stakeholders

- **BHP Billiton[15] –** BHP Billiton owns (100 percent) the Illawarra Coal which operates three underground coal mines in the Southern Coalfields of NSW. These mines are Appin, West Cliff, and Dendrobium. Illawarra coal also operates two coal preparation plants namely West Cliff and Dendrobium Coal preparation plants. The Port Kembla Coal Terminal is operated by Illawarra Coal on behalf of a consortium of partners (Illawarra Coal, Xstrata Coal, Peabody, Tahmoor Coal, and Centennial Coal), and leased from the New South Wales Government.
- **Xstrata[16] –** Xstrata operates the Tahmoor Colliery in the Southern Highlands region consisting of an underground mine and coal handling and preparation plant. The Colliery produces approximately two million tonnes of high quality coking coal per year.
- **New South Wales Minerals Council (NSWMC)[17] –** The NSW Minerals Council is a not for profit, peak industry association representing the State's $20 billion mining industry. It has 100 member companies, of which 40 (producers and explorers) are full members. The NSWMC works closely with government, industry groups, key stakeholders and the community to foster a dynamic, efficient and sustainable mining industry in NSW.
- **Sydney Catchment Authority (SCA)** – The SCA is a NSW Government agency created in 1999 to manage and protect Sydney's drinking water catchments and catchment infrastructure, and supply bulk water to its customers, including Sydney Water and a number of local councils(Sydney Catchment Authority). The Southern Coalfield mining occurs mainly under the Cataract, Cordeaux and Woronora dam catchments which form part of the Upper Nepean and Woronora water supply systems. SCA which sources 20% of its water supply from these catchments estimates that within the next 20 years, 91 percent of the Special Areas will have been undermined by either longwall or bord and pillar coal extraction methods(Smith, 2009).

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[15] http://www.bhpbilliton.com/home/businesses/metallurgicalcoal/Pages/default.aspx
[16] http://www.xstratacoal.com/EN/Operations/Pages/TahmoorColliery.aspx
[17] http://www.nswmin.com.au/About-Us/default.aspx

- **Southern Highlands Coal Action Group (SHCAG) – The SHCAG** is a community organisation with over 3500 members based in the Southern Highlands of NSW (Southern Highlands Coal Action Group, 2011). It was formed in August 2010 to prevent the expansion of coal mining and coal seam gas development across the Highlands which sit in the Southern Coalfield area. The Group's main concern is the impact of the Southern Coalfield mining on air, land, and water of the area in close proximity to the mines.
- **Community Action Groups–** a number of community action groups were formed in reaction to environmental issues in the Southern Coalfields that result from longwall mining around water catchments. The office of the Greens (Rhiannon, 2005) provided a report of these action groups and their issues. One of these groups, the Cataract River Action Party (CRAP), was formed by residents on the Cataract River in response to BHP Billiton's coal mining under the river. In 1998, the group successfully sued BHP Billiton for causing the cracking of the rock in the riverbed, which allowed thermal gases to vent into the river and water to drain away. Georges River Action Team (GREAT) was then formed to counter BHP Billiton's longwall mining underneath the nearby upper Georges River claiming that mining cracked the riverbed and damaged houses.

  Another community Group is Bargo River Group (BRG) which was formed in response to the cracking of the River caused by the Tarmour South Mine. Yet another Group is Nepean Action Group (NAG) which started when BHP Billiton's Illawarra Coal announced that they planned to longwall mine a 4km stretch of the Nepean River. The group held on to a strong and consistent campaign causing BHP Billiton to announce that they would no longer go underneath the river, but position their longwall panel 180m from the Nepean River. The NAG wants BHP Billiton to commit to only mining 1km from rivers and waterways.
- **Northern Illawarra Aboriginal Collective–** These are four groups responsible for raising Woronora Aboriginal issues and preserving Aboriginal heritage in the Northern Illawarra. The groups have made complaints about the lack of consultation with Aboriginal native title communities when BHP Billiton was pursuing application to destroy a rock overhang that existed on the Dendrobium 1 Site and other sites that are believed to be Aboriginal sites of major cultural significance(Rhiannon, 2005). BHP Billiton could not get approval and withdrew their application.

5.2 IMPACT INDICATORS

In this section data from the four impact indicators are presented for each technology alternative: land-use, employment, workplace health and safety, and identified stakeholder issues. For comparison indicators for each regionalised scenario are presented for 1 tonne of steel production. The scale effects are also reported for some indicators for the full substitution of coal used in steel-making.

A) Biomass from existing Radiata pine plantations: The Macquarie Region, Central Tablelands, New South Wales

Land-use

In order to be considered as an alternative to coal in steel production, charcoal would need to be produced on a large scale. Approximately 15 tonnes of wet biomass are produced per hectare per year at the end of a 30-year rotation age for Radiata pine (Norgate and Langberg, 2009). The Macquarie region grows 1.15 million tonnes of commercial timber per annum on 71,477 hectares of land, of a total land area of 1,825,871 ha (Forests NSW, 2008), thus confirming the biomass production data per hectare reported by Norgate and Langberg (2009). One hectare of Radiata pine therefore has the capacity to produce 5.08 tonnes of steel per year (1.97×10^{-1} ha/t steel). Steel production in Australia in 2009-10 totalled 6,886,000 tonnes (ABARE-BRS, 2010b), thus requiring 1.36 million hectares of plantation forestry for 100% substitution of metallurgical coal[18]. For the purposes of this analysis any use of forestry production for steel making is assumed to come from expansion of the sector, rather than displacement of other timber product use.

Plantation forestry is located across a number of Australian regions. Expansion of the sector is therefore assumed to occur relatively evenly and not preferentially within the Macquarie region. Both pine and eucalypt plantation species are assumed to contribute to biomass production for the production of charcoal. Total plantation forestry in Australia in 2009 was 2.02 million hectares (ABARE-BRS, 2010a). Full substitution of metallurgical coal by forestry

[18] Due to the recent drop in steel production in Australia the most recent figures, 2009-10, were used for this calculation

plantation biomass in Australia would therefore require an approximately 67% increase in total land under plantation.[19] Thus, full substitution would present major land-use and employment shifts in regional Australia. A shift of this magnitude in the Macquarie Region would represent an additional 47, 890 hectares under plantation.

Employment

The planted forests of the Macquarie Region support a timber industry that creates a total of 1,948 full-time equivalent jobs (Forests NSW, 2008). This comprises 940 direct jobs and 1,008 indirect jobs, implying an employment multiplier of 2.07. Assuming production for biomass would generate a similar number of jobs to current forestry use, biomass production represents 2.6×10^{-3} direct employees per tonne of steel, with 2.8×10^{-3} indirect employees (5.4×10^{-3} total employees) per tonne of steel.

Enecon (2001) reports that a fully operation charcoal production plant with a capacity of 100,000 tonne dry biomass generates 20 shift, management, administration and maintenance personnel. Charcoal production therefore represents 2.95×10^{-4} direct jobs per tonne of steel. Assuming an employment multiplier of two, an equivalent number of indirect employees would be created. Total employment for biomass and charcoal production per tonne of steel is therefore 2.9×10^{-3} direct employees and 3.1×10^{-3} indirect employees (a total of 5.95×10^{-3}).

Assuming a direct relationship between production level and the number of jobs created, employment can be projected for larger production scenarios. For the full substitution of metallurgical coal an additional 630 direct and 681 indirect jobs are generated in biomass production, 72 direct and 72 indirect jobs in charcoal production in the Macquarie region (with 17, 903 and 19, 281 direct and indirect jobs in biomass and 2031 direct and 2031 indirect jobs in charcoal production Australia wide, respectively).

Health and safety

In 2008/09, work related Lost Time Injuries (LTI) in state forestry and logging in New South Wales were reported as 122 (NSW Workers Compensation, 2008/09). The total plantation production area in NSW was 383,000 hectares in 2009 (ABARE-BRS, 2010a). Lost time injury for biomass production is therefore 6.28×10^{-5} per tonne of steel. No data for charcoal

[19] Using the forestry to biomass conversion rates for radiate pine; 15 tonne of wet biomass per hectare per year.

production are available. For full substitution of coal, biomass production in the Macquarie region would represent an additional 15 LTI per year, and 432 LTI Australia wide.

Identified stakeholder issues

As analysed in the previous section, plantation expansion brings about both positive changes and changes that can adversely affect the environment and social wellbeing. Forestry-based activities in Oberon are reported as contributing to increased economic activity for local businesses, improved employment opportunities, and higher economic activity to farming families resulting in improved health, educational and social services (Dwyer Leslie Pty. Ltd. and Powell, 1995). However, communities and interested groups are cautious in permitting large-scale forestry investment. The different stakeholders involved directly or indirectly with NSW plantations have raised concerns about the threat to the environment and the communities in the areas impacted. The *NSW Forest Products Association (FPA)* has identified social and economic impacts on local communities as important stakeholder issues for the timber sector (MacMillan, 2000). These include impacts on sustainable yield of forest products, actual values of forest utilisation, water management, cultural heritage, environmental impacts, and impacts of noise, air, roads, and traffic. Concerns have also been raised about community health and amenity issues associated with biomass production facilities, such as a charcoal production plant.

In addition to stakeholder concerns about the expansion of forestry industry, the industry lacks capacity to develop in a socially and environmentally sustainable way. The *Australian Forest Growers* underlines the lack of incentives provided to small growers, the need for a dispersed production base when environmental and social concerns are considered, and the lack of government funding for industry development and research into biomass-based renewable energy (Australian Forest Growers, 2008). Other industry stakeholders point to economic issues such as the lack of investment in expanding the plantation, underdeveloped markets for forest products, inadequate incentives for investment in private native forestry and limited/declining investment in forest research as hampering industry expansion (Montoya, 2010). These issues outline the need for a collaborative approach by the different stakeholders and in particular the government, industry, the private sector, and the community to enable the transition towards generating a renewable source of energy.

B) Biomass from Mallee revegetation on agricultural land (Wheatbelt Region, Western Australia)

The importance of Mallee in mitigating soil salinity is now recognised by a significant number of landowners who started to grow Mallee in the late 1980s. The commercial interest in growing Mallee trees is supported by research that they can be harvested on a 3-7 years cycle (Bartle and Abadi, 2009). In 2000, a feasibility study was conducted by *Enecon Pty Ltd* (2001) showing commercial viability of a Mallee industry. This led to the establishment of a 20%-scale demonstration plant at Narrogin by *Verve Energy* for the production of Mallee oil, activated carbon and electricity (URS, 2009). Following the successful operation of the plant for a period in 2006, there is now a growing interest in establishing the industry.

Land-use

Mallee used for the revegetation of agricultural land is grown in a configuration that facilitates agricultural crop production. Mallee is grown in belts with commercial agriculture practiced in between. Enecon (2001) reports that a minimum average weight of 15kg per Mallee at harvest is considered viable to ensure a sufficiently high proportion of wood in the biomass. At 15kg per Mallee and 95% survival to harvesting, a yield of 38 tonne of fresh weight biomass per hectare can be generated and harvested every 3 years (approx. 2,520 Mallee trees). This represents 12.7 tonne of wet biomass per hectare per year, or an equivalent of 5.15 tonne of steel per hectare per year (1.94×10^{-1} ha/t of steel). Mallee is a drier form of biomass, which partially compensates for the lower production of biomass per unit of land.

For full substitution of metallurgical coal 1.34 million hectares of land would be required. To date approximately 25.5 million Mallee trees have been planted in the Region on 13,000 ha of land, which are not currently harvested. An additional 1.323 million hectares would be required for the full substitution of coal. Mallee revegetation in the Wheatbelt Region as a dryland salinity measure would therefore require very significant expansion (10, 176%) if it were to represent a viable option as a replacement for metallurgical coal in Australian steel-making. The potential drivers for this transition are likely to come from the multiple benefits of the activity. According to data from the National Land and Water Resources Audit an estimated 4.3 million hectares of the southwest region of Western Australia has a high potential of developing dryland salinity in 2000 from shallow water tables; this estimate is expected to rise up to 8.8 million hectares in 2050 (Webb, 2000). Commercial benefits of a large-scale Mallee production may also be an incentive for farmers to allow greater Mallee plantation.

Employment

Estimates of employment in the harvesting of Mallee biomass must be developed from first principles in the absence of an established industry. For our other technology scenarios we have calculated employment from industry wide employment data normalised by production. Therefore the employment data calculated here could be considered as a low range estimate. An alternate approach could be to assume an equivalent employment number to biomass produced from Radiata Pine plantations. Comparison of employment data between scenarios should be cognisant of the varied methods employed within the indicator set.

Abadi et al (forthcoming) report that a mature Mallee harvesting process, operating in a similar manner to equivalent short cycle coppice crops (willow and poplar) could achieve pour rates of 60-70 wet tonnes/hour and 75,000-120,000 tonnes per harvester/year. For the purposes of this analysis we have used the mid-range scenario for a mature industry reported by Abadi et al (100,000 wet tonnes/year; 70 wet tonnes/hour; 235 days/year operation). In this configuration harvesting by a purpose built harvester is accompanied by two in-field haulouts working in rotation where loads are transferred to a road trailer for further transport. Assuming three 8 hour shifts in a 24hr cycle, 3 full-time field positions per shift, and 1 administration/management position per day, direct employment in harvesting Mallee biomass is estimated at 1×10^{-4} jobs per tonne of wet biomass or 2.46×10^{-4} jobs per tonne of steel. Assuming a multiplier of two an additional 2.46×10^{-4} indirect jobs are also created in biomass harvesting per tonne of steel.

A full operation charcoal production plant (as described above) would represent 2.95×10^{-4} direct jobs per tonne of steel, with an equivalent number of indirect employees created assuming a multiplier of 2. Total employment for biomass and charcoal production per tonne of steel is therefore 5.41×10^{-4} direct employees and 5.41×10^{-4} indirect employees (a total of 1.08×10^{-3}). It should also be noted that Mallee biomass production on farmland has the additional benefit of supporting farm jobs associated with agricultural production by providing an alternate source of farm income and improved environmental management of dryland salinity.

Assuming a direct relationship between production and the number of jobs created, a full substitution of metallurgical coal in the Western Australian Wheatbelt would create an additional 5068 direct and 5068 indirect (10136 in total) biomass and charcoal production jobs.

Health and safety

Like employment workplace health and safety data for Mallee biomass harvesting would need to be estimated from first principles or based on comparable short rotation woody crops, such as willows. Unlike employment, however, workplace health and safety outcomes are a function of both the risk profile of the activities undertaken during harvesting and the human systems developed to respond to those risks. As such, the use of cross-country comparisons of similar activities is likely to be problematic and the workplace culture of the activities difficult to predict. For these reasons we have chosen not to estimate this indicator for the Mallee biomass harvesting scenario. No data are available on workplace health and safety from trial charcoal production plants.

Identified stakeholder issues

Mallee trees in Western Australia are currently planted at a relatively small scale for the primary purpose of preventing soil salinity. So long as this purpose is served, farmers have been comfortable with the required small-scale Mallee trees that do not need harvesting. However, the opportunity to develop an industry that supplies biomass to wood and energy industries has brought some concerns from the community. The OMA which is an active promoter of Mallee trees for commercial purposes recognises community concerns in relation to large scale plantation (URS, 2009). Such concerns include the damage caused to the soil by frequent harvesting and its impact on farm land. There is also no evidence of future profitability of such an industry given the underdeveloped nature of the technology and market associated with the processing of Mallees into industrial products.

In addition to the OMA’s recognition of community concerns, other farming community groups have also raised some of the issues associated with Mallee plantation for industrial purposes. The *Growers Group Alliance (GGA)* identified issues that can arise when a shift occurs from farming to new land use systems such as Mallee production (Grower Group Alliance, 2008). These include environmental issues and community issues related to food security (whether growing carbon or food) and the threat to rural communities and family farms. As already mentioned concerns have been raised about community health and amenity issues associated with biomass production facilities, such as a charcoal production plant.

C) Metallurgical coal (Southern Coalfield, New South Wales)

Southern Coalfield is one of the seven major coalfields in NSW. The Coalfield supplies metallurgical coal, with predominantly underground long-wall mining. In 2007, the Southern Coalfield produced 10.44 mt of saleable coal for domestic supply and export, making up 85% of the coal supplied by NSW to the Australian steel industry (NSW Department of Planning, 2008). Of the 10.44mt of coal produced, approximately 4.2mt is delivered to the steel industry while the remaining 6.3mt is either exported or used in other industries. Mines in the region include, Appin, West Cliff, Dendrobium, and Metropolitan.

Land-use

According to data collected from the NSW Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS), area covered by the coal mines in the Southern Coalfield totals 245,000 hectares. This includes 96,500ha of production (mining) titles and 197,400ha of exploration titles. Considering 10.44mt of coal is produced from 96,500ha land, 108t/ha/year of coal is produced in the Southern Coalfield that can be used by the steel industry. One hectare of mining land therefore has the capacity to supply coal for the domestic production of 190.5t of steel (5×10^{-3} ha/t steel). The existing coal mines of the region reported proven and probable reserves of 785.6mt indicating that production on existing land could be sustained for around 75 years (NSW Department of Planning, 2008). While soil erosion and nutrient depletion may inhibit the longevity of plantations they are likely to represent longer-term land-use than underground coal mining.

Employment

Coal mining in the Southern Coalfield has been one of the main sources of local employment in the Illawarra Region directly employing 2,476 workers in 2007 for the production of 10.44mt of coal (NSW Department of Planning, 2008). As coal mining has expanded over the last decade, the number of people directly employed in the mines has also grown. For example, direct employment in the Southern Coalfield increased approximately 75% from 2000 (NSW DPI, 2009). According to the NSW DTRIS Division of Resources and Energy, an indirect regional employment multiplier of approximately 3 is estimated for the Southern Coalfield. The workforce is predominantly locally and regionally located in comparison to regions such as the Bowen Basin in Queensland where fly-in-fly-out and drive-in-drive out are more commonly practiced.

Rolfe et al., (2011) have calculated the economic impacts of mining employment on all local government areas in Queensland. They found the level of expenditure capture appears to be falling in mining and smaller communities with an increasing share of economic benefits going to major centres and coastal zones. These trends are associated with changes in workforce location (fly-in-fly-out and drive-in-drive out), the location of contractors, and the associated spending flows of the business supply chain. Indirect employee multipliers in mining communities ranged between 1.22 in Mt Isa, 2.08 in the Central Highlands and 4.53 in the Western Downs. Coastal and major population centres reported higher multipliers, ranging from 4.72 in Gladstone, 6.74 in Mackay, and 22.49 in Brisbane (Rolfe, 2011). This indicates that it is not the mining communities but major centres and coastal zones with more access to markets and livelihood facilities that feel the economic impact of mining that involve fly-in-fly-out and drive-in-drive out.

Based on the 2007 employment figures and using a multiplier of 3, the Southern Coalfield creates 4,952 indirect jobs in the production of 10.44mt of coal. As described earlier there are two pathways for the use of metallurgical coal in steelmaking. The first is as pure coal. The second is after conversion to coke. Direct and indirect employment for pure coal used in steel production per tonne of steel is therefore 1.58×10^{-5} and 3.16×10^{-5} respectively. For metallurgical coal that is processed into coke it is estimated that 1.27t of coal is required to produce 1t of coke (Norgate and Langberg, 2009). The number of additional jobs in coal production for use in coke making is therefore 3×10^{-4} direct and 6×10^{-4} indirect jobs per tonne of coke, which is equivalent to 1.19×10^{-4} direct and 2.38×10^{-4} indirect jobs per tonne of steel. The total number of jobs in coal production for steel making is therefore 1.34×10^{-4} (direct) and 2.7×10^{-4} (indirect) per tonne of steel.

According to data from the Illawarra Coke Company, 50 employees are involved in the production of 150,000t of coke per annum (NSW DPI, 2009). Therefore 1.3×10^{-4} direct and 1.3×10^{-4} indirect jobs are created during coking per tonne of steel (0.394t of coke) if we assume an indirect employee multiplier of 2. Total employment for coal and coke production per tonne of steel is therefore 2.66×10^{-4} direct and 4.02×10^{-4} indirect jobs (6.67×10^{-4} total).

Health and safety

Lost-time injuries per million tonnes of saleable coal production were reported as 5.7 for underground NSW mines in 2007-08 (NSW DPI, 2009), calculating to 3.23×10^{-6} lost-time injuries per tonne of steel. There were no fatalities reported in NSW coal mining (the last fatality was reported in 2003-04; (NSW DPI, 2009)). No data for coke production are available.

Identified stakeholder issues

One of the issues of underground coal mining is subsidence of the land surface. Subsidence has been identified by a number of stakeholders, in particular conservation organisations, as an environmental impact of significant concern in the Southern coalfield (NSW Department of Planning, 2008). In 2007 the NSW Government held a strategic review of the impacts of underground mining in the Southern coalfield. The inquiry found that site conditions associated with non-conventional subsidence effects are present in the Southern Coalfield; and a number of subsidence effects including valley closure, upsidence and regional far-field horizontal displacement regularly occur. One of the subsidence impacts of the Southern Coalfield mines is on water supply catchments as recognised by the NSW Minerals Council (NSW Minerals Council, 2007). Subsidence effects can adversely affect rivers, waterways and land use.

Environmental, amenity and health impacts of mining have also been of growing concern in affected communities. These include problems of noise and dust pollution, although community health issues associated with dust in coal mining are less prevalent in underground mines. Local communities around the Southern Coalfield reported damage to the Lower Cataract and Georges Rivers where nine longwall panels were mined as water has drained away, cracks in the riverbed were revealed, and methane gas began venting in the riverbed (Total Environment Centre, 2007). Damages caused by the Metropolitan underground mine on the Waratah Rivulet were also reported as cracks were found on streambed causing low levels of water flows and tilted water course resulting from subsidence and upsidence.

5.3 COMPARATIVE ANALYSIS

Table 1 provides a comparison of the quantitative and qualitative indicators analysed.

No unique solution exists for optimising the social performance of the technology alternatives across all of the indicators. Biomass alternatives were found to be significant generators of direct employment at the regional level (2.9 x 10^{-3} per tonne of steel for Pine biomass and 5.41

x 10^{-4} for Mallee biomass compared to 2.66 x 10^{-4} for metallurgical coal), however, they were also identified as having concomitantly higher rates of workplace injuries (6.28 x 10^{-5} per tonne of steel for pine compared to 3.23 x 10^{-6} per tonne of steel for coal). The lower number of direct jobs for the metallurgical coal alternative is partially substituted by higher rates of indirect employment.

The scale effects of a shift to biomass technologies on land-use are significant. When compared to metallurgical coal biomass alternatives represent a 3,840% increase in land-use (1.97 x 10^{-1} hectares per tonne of steel Pine biomass and 1.94 x 10^{-1} hectares per tonne steel for Mallee biomass compared to 5 x 10^{-3} for coal). Production of pine plantation forestry in Australia would be required to increase by 67% to accommodate the full substitution of coal (an additional 1.36 million hectares under plantation forestry), while Mallee plantations would require expansion by 10,176%. Land-use conflicts have been associated with plantation forestry expansion, with even revegetation projects undertaken for conservation generating local level dissatisfaction and competition with other land-use in some cases. On the other hand, local level conflicts have also manifested from the community health and amenity impacts, and subsidence effects associated with metallurgical coal mining, despite the relatively small area of land impacted (5 x 10^{-3} hectares/t of steel).

Charcoal produced from Mallee biomass planted as a conservation measure on farmland has the benefit of representing a shared land-use that in turn supports farm employment through an additional revenue stream and the management of dryland salinity. The indicators analysed above demonstrate that a very substantial expansion of plantation forestry or Mallee revegetation would be required if the full substitution of coal were to be realised. Future plans to establish large-scale plantations can be hampered by competition over land-use. Stakeholder support for a substantial expansion of the industry should not be taken for granted with the social license of such a measure yet to be established.

Table 1: Quantitative impact indicators for technology alternatives

PINE MACQUARIE	LAND-USE	EMPLOYMENT				HEALTH & SAFETY	QUALITATIVE
	Biomass production (hectares)	Direct Biomass	Indirect Biomass	Direct Charcoal	Indirect Charcoal	Lost time injuries (biomass)	• forest utilisation values • amenity and traffic • water management • community health & safety from charcoal plant • land values • community identity
Per tonne of steel	1.97 x 10^{-1}	2.6 x 10^{-3}	2.8 x 10^{-3}	2.95 x 10^{-4}	2.95 x 10^{-4}	6.28 x 10^{-5}	
100% substitution	1,356,542	630 (17,903 Australia wide)	681 (19,281 Australia wide)	72 (2,031 Australia wide)	72 (2,031 Australia wide)	15 (432 Australia wide)	
MALLEE WHEATBELT	LAND-USE	EMPLOYMENT				HEALTH & SAFETY	QUALITATIVE
	Biomass production (hectares)	Direct Biomass	Indirect Biomass	Direct Charcoal	Indirect Charcoal	Lost time injuries (biomass)	• investment and profitability uncertainty • soil erosion and compacting • food security • community identity • community health & safety from charcoal plant
Per tonne of steel	1.94 x 10^{-1}	2.46 x 10^{-4}	2.46 x 10^{-4}	2.95 x 10^{-4}	2.95 x 10^{-4}	NA	
100% substitution	1,327,000	1,694	1,694	2,031	2,031	NA	
COAL SOUTHERN COALFIELD	LAND-USE	EMPLOYMENT				HEALTH & SAFETY	QUALITATIVE
	Coal production (hectares)	Direct Coal	Indirect Coal	Direct Coke	Indirect Coke	Lost time injuries (coal)	• subsidence (& associated ground and surface water impacts) • amenity and community health (dust)
Per tonne of steel	5 x 10^{-3}	1.34 x 10^{-4}	2.7 x 10^{-4}	1.3 x 10^{-4}	1.3 x 10^{-4}	3.23 x 10^{-6}	

6. CONCLUSION

This paper undertook an analysis of three regionalised technology alternatives for the production of iron ore reductants for use in steel making. A number of factors can be examined in order to determine the suitability of biomass as a non-renewable energy source for steel making. In this study, we have analysed land-use, employment and workplace health and safety in an attempt to better understand the social implications of the technology alternatives. Qualitative indicators were also assessed to provide further data on the perspectives of key stakeholder groups. Data was normalised based on the production of one tonne of steel. The scale effects of biomass production as a potential replacement of metallurgical coal were also examined.

Biomass alternatives were found to be significant generators of direct employment at the regional level (2.9×10^{-3} per tonne of steel for Pine biomass and 5.41×10^{-4} for Mallee biomass as compared to 2.66×10^{-4} for metallurgical coal). There is also a potential for employment created from processing by-products such as bio-oil from eucalypts and in particular biomass residues. However, sourcing energy from biomass was identified as having concomitantly higher rates of workplace injuries (6.28×10^{-5} per tonne of steel for pine compared to 3.23×10^{-6} per tonne of steel for coal).

The scale effects of a shift to biomass technologies on land-use are significant. When compared to metallurgical coal, biomass alternatives represent a 3,840% increase in land-use. Thus, production of pine plantation forestry in Australia would be required to increase by 67% to accommodate the full substitution of coal. This means an additional 1.35 million hectares would be required on top of the current land-use for plantation forestry. The supply of land of this magnitude presents a stern challenge given land-use conflicts associated with plantation forestry expansion. However, charcoal produced from Mallee biomass planted as a conservation measure on farmland has the benefit of representing a shared land-use that in turn supports farm employment through an additional revenue stream and the management of dry-land salinity. On the other hand, local level conflicts have manifest from the community health and amenity impacts, and subsidence effects associated with metallurgical coal mining despite the relatively less significant scale of land (5×10^{-3} hectares per tonne of steel) used.

The results complement earlier studies comparing the greenhouse gas profile of charcoal and metallurgical coal technology scenarios. Norgate and Langberg (2009) found charcoal used in steelmaking could result in greenhouse gas reductions of 4.5-5.3 CO_2e/kg steel depending on the steelmaking route, assuming 100% substitution of charcoal for coal or coke with electricity and eucalyptus oil co-product credits included for charcoal production. In addition to the favourable environmental impact that Norgate and Langberg (2009) reported, the employment, workplace health and safety and land-use outcomes explored in this paper are critical in the decision making process.

Overall, the paper finds that no unique solution exists for optimising the social performance of the technology alternatives across all of the indicators. As noted, environmental issues are pointing towards the search for renewable sources of energy. The social lifecycle impact assessment presented in this paper, in conjunction with the recent environmental study, provide significant information to this search. In particular, the social aspect of technology development in the steel industry has received limited attention. As experienced in this study, there are challenges in forecasting the performance of technologies prior to implementation but useful data can be sourced to aid decision-making.

7. REFERENCES

ABADI, A., BARTLE, J. & GILES, R. forthcoming. Delivered Cost of Biomass from Short Cycle Coppiced Mallee Eucalypts. *Bioenergy.* RIRDC.

ABARE-BRS 2010a. Australian forest and wood products statistics, March and June quarters.

ABARE-BRS 2010b. Australian mineral statistics, June quarter.

ABS 2010. National Regional Profile.

ASSEFA, G. & FROSTELL, B. 2006. Social sustainability and social acceptance in technology assessment: A case study of energy technologies. *Technology in Society,* 29**,** 63-78.

AUSTRALIAN FOREST GROWERS 2008. Submission on the Garnaut Climate Change Review, Issues Paper 1: Agriculture and Forestry.

BARTLE, J. & SHEA, S. 2002. Development of mallee as a large-scale crop for the wheatbelt of WA. *URS 2009. Oil mallee industry development plan for Western Australia.*

BARTLE, J. R. & ABADI, A. 2009. Toward Sustainable Production of Second Generation Bioenergy Feedstocks†. *Energy & Fuels,* 24**,** 2-9.

BAUMERT, K. A., HERZOG, T. & PERSHING, J. 2005. Navigating the numbers: greenhouse gas data and international climate change policy. Washington, DC: World Resources Institute.

BENOÎT, C., MAZIJN, B. & (EDS) 2009. Guidelines for Social Life Cycle Assessment of Products.

BENOÎT, C., NORRIS, G. A., VALDIVIA, S., CIROTH, A., MOBERG, A., BOS, U., PRAKASH, S., UGAYA, C. & BECK, T. 2010. The guidelines for social life cycle assessment of products: just in time! *The International Journal of Life Cycle Assessment,* 15 (2)**,** 156-163.

BENOÎT, C., PARENT, J., KUENZI, I. & REVÉRET, J.-P. 2007. Developing a methodology for social life cycle assessment: the North American tomato's CSR case. *3rd International Conference on Life Cycle Management, August 27-29, Zürich, Switzerland.*

BHP BILLITON 2007. Illawarra Coal, Submission to the Independent Inquiry into NSW Southern Coalfield, July.

BISWAS, W. & LUND, C. 2008. A Review of the Application of Lifecycle Analysis to Renewable Energy Systems. *Bulletin of Science, Technology & Society,* 28**,** 200-209.

BRS 2010. Australia's plantation inventory update. Department of Agriculture, Fisheries and Forestry, Bureau of Rural Sciences.

CENTRAL TABLELANDS LANDCARE 2003. *The community of the Central Tablelands, Natural Resource Toolkit, @ www.centraltablelands-landcare.org.au/Toolkit*.

DREYER, L., SCHIERBECK, J. & HAUSCHILD, M. 2006. A Framework for Social Life Cycle Impact Assessment (10 pp). *The International Journal of Life Cycle Assessment,* 11**,** 88-97.

DWYER LESLIE PTY. LTD. & POWELL, R. 1995. Oberon: rural community development study - Final Report. Forestry commission of New South Wales, Sydney.

ENECON PTY LTD 2001. Integrated tree processing of mallee eucalypts. *Rural Industries Research and Development Corporation, Publication,* 1**,** 160.

FORESTS NSW 2008. Ecologically Sustainable Forest Management, Macquarie Region NSW.

FRANKS, D. & COHEN, T. 2012. Social License in Design: Constructive technology assessment within a mineral research and development institution. *Technology forecasting and social change,* Vol 79, No. 7**,** 1229-1240.

GROWER GROUP ALLIANCE 2008. Grower and Researcher Annual Forum: Proceedings and summary of outcomes.

GUPTA, R. C. 2003. WOODCHAR AS A SUSTAINABLE REDUCTANT FOR IRONMAKING IN THE 21ST CENTURY. *Mineral Processing and Extractive Metallurgy Review,* 24**,** 203-231.

JØRGENSEN, A., LAI, L. C. H. & HAUSCHILD, M. Z. 2010a. Assessing the validity of impact pathways for child labour and well-being in social life cycle assessment. *The International Journal of Life Cycle Assessment,* 15**,** 5-16.

JØRGENSEN, A., NAZARKINA, L., HAUSCHILD, M. & LE BOCQ, A. 2008. Methodologies for social life cycle assessment. *The International Journal of Life Cycle Assessment,* 13**,** 96-103.

JØRGENSEN, M. S., HAUSCHILD, M. Z., JØRGENSEN, A. & FINKBEINER, M. 2010b. Defining the baseline in social life cycle assessment. *The International Journal of Life Cycle Assessment,* 15**,** 376-384.

JOYCE, S. & THOMSON, I. 2000. Earning a social licence to operate: Social acceptability and resource development in Latin America. *CIM BULLETIN,* 93**,** 49-53.

KLOEPFFER, W. 2008. Life cycle sustainability assessment of products (with Comments by Helias A. Udo de Haes, p. 95). *International Journal of Life Cycle Assessment,* 13 (2)**,** 85-95.

KLÖPFFER, W. & RENNER, I. 2009. "Life-Cycle Based Sustainability Assessment of Products" in Environmental Accounting for Cleaner Production 24**,** 91-98.

KUMAR, M. & GUPTA, R. 1994. Influence of carbonization conditions and wood species on carbon dioxide reactivity of resultant wood char powder. *Fuel Processing Technology,* 38**,** 223-233.

LUITEN, E. E. M. 2001. Beyond energy efficiency: Actors, networks and government intervention in the development of industrial process technologies.

MACMILLAN, A. 2000. Assessments of Red Gum Forests in the Riverina and Cypress Forests in South-Western NSW, NSW Forest Products Association Submission.

MAUGER, G. & AUSTRALIA, W. 2001. *Salinity Situation Statement: Collie River*, Water and Rivers Commission.

MCMAHON, G. 1998. Mining and the community: Results of the Quito conference. *The World Bank Energy, Mining and Telecommunications Department***,** 1-147.

MONTOYA, D. 2010. Plantation forestry in NSW: Regulatory regimes and future prospects, Briefing paper No 12.

NILL, J. 2003. *Technological Competition, Time and Windows of Opportunity: The Case of Iron and Steel Production Technologies*, Discussion paper 58/03, IÖW.

NORGATE, T. 2009. A review of the integration of social and economic impacts into life cycle assessment, CSIRO National Research Flagships Minerals Down Under.

NORGATE, T. & LANGBERG, D. 2009. Environmental and economic aspects of charcoal use in steelmaking. *ISIJ international,* 49**,** 587-595.

NSW CMA 2008. A best management practice guide for the Central West Catchement. *In:* CENTRAL WEST CATCHMENT MANAGEMENT AUTHORITY (ed.).

NSW DEPARTMENT OF PLANNING 2008. Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield, Strategic Review, State of New South Wales through the NSW Department of Planning.

NSW DPI 2009. New South Wales Coal Industry Profile, Incorporating Coal Services Pty Limited.

NSW LANDCARE 2003. Central Tablelands Landcare Natural Resource Toolkit.

NSW MINERALS COUNCIL 2007. Submission to the Independent Expert Panel into underground mining in the Southern Coalfield.

NSW WORKERS COMPENSATION 2008/09. Statistical Bulletin @http://www.workcover.nsw.gov.au.

O'BRIEN, M., CLIFT, R. & DOIG, A. 1996. Social and environmental life cycle assessment (SELCA). *The International Journal of Life Cycle Assessment,* 1**,** 231-237.

REITINGER, C., DUMKE, M., BAROSEVCIC, M. & HILLERBRAND, R. 2011. A conceptual framework for impact assessment within SLCA. *The International Journal of Life Cycle Assessment,* 16**,** 380-388.

RHIANNON, L. 2005. NSW Coal affected communities: An overview of communities affected by coal issues. The Greens NSW.

ROLFE, J. 2011. Economic impacts of the resources sector in the Surat Basin and implications for land use. *Presentation: Mineral Futures Cluster's public forum, 31 January*.

ROLFE, J., GREGG, D., IVANOVA, G., LAWRENCE, R. & RYNNE, D. 2011. The Economic Contribution of the Resources Sector by Regional Areas in Queensland. *Economic Analysis and Policy,* 41**,** 15-36.

RUSSELL, A. W., VANCLAY, F. M. & ASLIN, H. J. 2010. Technology Assessment in Social Context: The case for a new framework for assessing and shaping technological developments *Impact Assessment and Project Appraisal,* 28(2)**,** 109-116.

SCHOT, J. & RIP, A. 1997. The past and future of constructive technology assessment. *TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE,* 54**,** 251-268.

SMITH, S. 2009. Mining and the environment, NSW Parliamentary Library Research Service, Briefing Paper No. 6/09

SOUTHERN HIGHLANDS COAL ACTION GROUP 2011. Senate standing committee on rural affairs and transport, Submission 229.

SYDNEY CATCHMENT AUTHORITY. *http://www.sca.nsw.gov.au* [Online]. [Accessed 26/03/2012.

THOMSON, I. & BOUTILIER, R. 2011. The social license to operate, in SME Mining Engineering Handbook, P. Darling, Editor. *Society for Mining, Metallurgy, and Exploration: Colorado*.

TOTAL ENVIRONMENT CENTRE 2007. Impacts of longwall coal mining on the environment in New South Wales.

UDO DE HAES, H. A. & HEIJUNGS, R. 2007. Life-cycle assessment for energy analysis and management. *Applied energy,* 84**,** 817-827.

URS 2009. Oil Mallee Industry Development Plan for Western Australia. URS Forestry @ http://www.oilmallee.org.au.

VON SCHÉELE, J. 2006. Short-term opportunities for decreasing CO 2 emissions from the steel industry. *International Journal of Green Energy,* 3**,** 139-148.

WEBB, A. 2000. Australian dryland salinity assessment, National Land and Water Resources Audit technical report.

WEIDEMA, B. Social impact categories, indicators, characterisation and damage modelling. 2006.

WESTERN AUSTRALIAN PLANNING COMMISSION 2011. Wheatbelt Regional Profile: Background and context report to support the Wheatbelt land use planning strategy, state of Western Australia.

YU, Y., BARTLE, J., LI, C. Z. & WU, H. 2009. Mallee biomass as a key bioenergy source in Western Australia: importance of biomass supply chain. *Energy & Fuels,* 23**,** 3290-3299.