Minerals Engineering 76 (2015) 2–9

Contents lists available at ScienceDirect

Minerals Engineering

journal homepage: www.elsevier.com/locate/mineng

"Wealth from metal waste": Translating global knowledge on industrial ecology to metals recycling in Australia

G.D. Corder [a,*], A. Golev [a], D. Giurco [b]

[a] Centre for Social Responsibility in Mining, Sustainable Minerals Institute, The University of Queensland, Brisbane, QLD 4072, Australia
[b] Institute for Sustainable Futures, University of Technology, Sydney, PO Box 123, Broadway, NSW 2007, Australia

ARTICLE INFO

Article history:
Received 31 July 2014
Revised 3 November 2014
Accepted 5 November 2014
Available online 2 January 2015

Keywords:
Industrial ecology
Metals recycling
Urban waste

ABSTRACT

Australia's rich stocks of mineral resources have been the source of national wealth and competitive advantage in the past. However, the security of this wealth is not guaranteed into the future, and what were once considered waste materials from mining, infrastructure and products are now becoming accessible and valuable as 'above-ground' mineral resources. Globally there is growing capacity and innovation in recycling, closed-loop supply chains and Australia's role as a global leader in primary production must anticipate and adapt to the implications of a rise in the importance of recycling. However, both at a global level and in Australia, there are a broad range of factors and local influences affecting the successful application and implementation of industrial ecology beyond technical re-use solutions. This paper presents the initial outcomes from a major collaborative research project (Wealth from Waste Cluster), funded by the CSIRO Flagship Collaboration Fund and partner universities, focused on identifying viable options to 'mine' metals contained in discarded urban infrastructure, manufactured products and consumer goods. This paper presents initial estimates of the mass and current worth of metals in end-of-life products. Results from this analysis have identified that the value of metals in end-of-life products is more than AUD6 billion per year, and assuming existing recovery rates, the estimated potential for recovering metals from "waste" or end-of-life products is of the order of AUD2 billion per year. In addition a metal flow analysis of the Australian economy identified that approximately half the scrap metal collected in Australia (approximately 2.5 million tonnes per year) is currently being transported overseas which potentially could be recycled in Australia if suitable technology were available.

1. Introduction

Australia's rich stocks of mineral resources have in recent years been the source of national wealth and competitive advantage. The security of this wealth is not necessarily guaranteed into the future and therefore Australia as a nation needs to seek alternative sources of revenue generation and competitive advantage. Waste materials, which were once considered of little or no value, are now becoming accessible and valuable as 'above-ground' mineral resources. Globally there is growing capacity and innovation in recycling, and closed-loop supply chains (World Economic Forum, 2014).

The increase in recycling (and reuse and remanufacturing) is driven by a number of factors – for instance, recycling or secondary production of metals has in general a significantly lower energy footprint compared with producing metals from virgin ores (Grimes et al., 2008), which results in minimising environmental impacts and supporting sustainable development through the efficient use of resources. Other factors include the lack of available natural resources in certain counties such as those in the European Union and Japan where the closed loop economy model is actively promoted. However, the world demand for metals is still mostly met by primary production.

The closed loop economy presupposes predominantly cyclical use of metals within the system, yet it is economically impractical to limit the system to national or regional borders, and it should be rather justified and achievable at the global scale. This means that while some countries still play the role of net providers of primary (mined) material resources at the global level, there should be the initiative to develop and implement effective collection, reuse and recycling systems internally for end-of-life products.

Australia needs to balance its interest in raw materials exports with Australian leadership in stewardship, which is consistent with a resource efficient economy across the entire value chain. Achieving this balance will offer the potential to expand the

* Corresponding author.
E-mail address: g.corder@smi.uq.edu.au (G.D. Corder).

http://dx.doi.org/10.1016/j.mineng.2014.11.004
0892-6875/

resource base available to Australian operations and build new niche manufacturing and services companies based on recycling and re-use. Realising this potential requires an ability to analyse, explore, and conceptualise new business models and understand the linkages along the value chain and between supplier networks. Australia currently has significant expertise in mining and metallurgy and this provides a window of opportunity to build on this foundation and develop expertise in the distinct thermodynamics associated with 'urban' ores and secondary processing.

This paper presents the initial outcomes from a major collaborative research project (Wealth from Waste Cluster), funded by the CSIRO Flagship Collaboration Fund and partner universities, focused on identifying viable options to 'mine' metals contained in discarded manufactured products and consumer goods. An important initial focus of this research has been on understanding the current status of industrial ecology both globally and at a national level as well as producing quantitative estimates of the potential for metals recycling from end-of-life products.

2. Wealth from waste cluster

The Wealth from Waste Cluster is a three-year research program that aims to identify viable options for recycling metals from Australian products (CSIRO, 2014). It is focused on identifying viable options for 'mining' above ground resources, which are the metals contained in collections of discarded manufactured products and consumer goods (end-of-life products). The key focus of the Cluster is to address the pathways that will help Australia realise the above-mentioned potential for expanding its resource base to be both a primary and secondary metal producing nation. While technological solutions form an important part of this progress, a resource efficient circular economy requires more than technological solutions alone. Understanding what other factors – including the operation of collection systems, legislative constraints and market drivers – are required to underpin recycling economics is a key objective of the Cluster. The Cluster commenced in mid-2013 and builds on work undertaken by the Mineral Futures Collaboration Cluster that ran from 2009 to 2012 (CSIRO, 2013).

The research program is supported through CSIRO's Minerals Resources and Manufacturing flagships and partner universities, including:

- University of Technology (UTS), Sydney, Australia.
- Monash University, Melbourne, Australia.
- University of Queensland, Brisbane, Australia.
- Swinburne University of Technology, Melbourne, Australia.
- Yale University, New Haven, USA.

Teams drawn from the different universities and disciplines are undertaking four distinct, but interconnected, research programs to develop a better understanding of this complex landscape and possible pathways for change:

- Program 1: Recycling systems: barriers and enablers for industrial ecology in Australia.
- Program 2: Future resource value: characterising stocks and mapping impacts.
- Program 3: Developing business models for future value chains.
- Program 4: Transition pathways for leadership in resource stewardship.

Embarking on a long-term research project of this nature means that there are expectations that the research outcomes will make a major contribution in creating a paradigm shift in the way that the Australian economy considers sources of metal stocks. However, to begin with it is important to understand the outcomes from related research and practical activities on a global scale in industrial ecology and synthesise this knowledge to help progress the uptake of metals re-use and recycling within the Australian context (Section 3). In addition, the expected outcomes from this research need to be underpinned by a baseline analysis to determine the levels and justification for increasing recycling rates and uptake within the Australian context. This analysis compares Australia's primary metal producing capacity with an estimation of metals consumption in Australia and the estimated available metals in waste streams (Section 4).

3. Global knowledge on industrial ecology

3.1. Growing importance

The term industrial ecology was popularised 25 years ago by Frosch and Gallopoulos (1989). Using nature as a metaphor, industrial ecology aims to optimise the total material cycle from virgin material to product and to ultimate disposal, and closely examines the opportunities to reuse and recycle different waste streams arising in industrial and consumer activities, as well as reorganising the industrial systems to ensure resource efficiency and resilience.

The field of industrial ecology is becoming increasingly important for some countries and regions in the world. This is illustrated by the growing trend for mining development activity over the last 50 years from, in broad terms, countries that both produce and consume metals to countries that produce metals, which are then exported to metal consuming countries. Humphreys (2013) demonstrated this trend by examining the world in two groups – metal consuming regions (North America, Western Europe, Japan, China and the Former Soviet Union) and metal producing regions (Asia less China and Japan, Africa, Latin America and Oceania). This analysis showed that from 1960 to 2010 countries which both mined and consumed copper, supply dropped from 55% to 25% and similar changes have also occurred for bauxite, iron ore and nickel (Humphreys, 2013). This illustrates that some of the metal consuming countries now rely more heavily on metal producing countries for their supply of metals and minerals which in turn has led to a greater emphasis on seeking alternative sources for metals and minerals including their own stocks in end-of-life products. This has created significant activities for industrial ecology initiatives centred on the circular economy (World Economic Forum, 2014).

3.2. Global initiatives

Although industrial ecology can take on a product-based systems perspective or a geographically defined local–regional industrial ecosystem approach (Korhonen, 2002), the primary interest for this work is on utilising the industrial ecology concept to identify the pathways for higher levels of metals recycling in Australia. Due to their nature, metals are highly amenable to the industrial ecology model as – given sufficiently available energy and technology – they can be reused without losing their physical properties (Ayers, 1997) and can be used at various levels such as high volumes for example with iron and steel, aluminium, and copper, to critical and precious metals usually used in minor quantities, e.g. gold, PGMs, and rare earths. Others have pointed out that the recyclability of metals from non-dissipative uses, given appropriate energy inputs and technology availability, should focus attention on the operation of the value chain and less on the issue of resource scarcity within the value chain (Stewart and Weidema, 2005).