

Mining and metals and the circular economy

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Foreword

This publication explores the role of mining and metals in the circular economy, an emerging concept that aims to draw the maximum value from materials. In practice this involves ensuring that materials are produced responsibly, kept in use for as long as possible through intelligent product design and application that considers recycling and disposal. It also raises fundamental questions about the structure of product value chains and how they interface with the world around them.

The concept reflects ICMM's view of how resources should be managed and life cycle extended sustainably. Indeed, one of our 10 sustainable development principles commits members to *'facilitate and support the knowledge-base and systems for responsible design, use, re-use, recycling and disposal of products containing metals and minerals'*.

This publication lays out the characteristics of a circular economy and examines the context for the growing interest in this concept. We then explore current and potential future contributions of the mining and metals industry in such an economy.

What is clear is that a circular economy will involve a shift in how we think about the use of minerals and metals from a production-disposal mentality towards on-going use and re-use. Existing examples of circularity in the mining and metals sector, such as recycling, re-use or design for disassembly, form part of the circular economy concept and lay the foundation for expansion to other products. The unique properties of metals – such as conductivity, strength, durability and recyclability – make the extension of their use vital in solving the fundamental challenges of current and future generations.

ICMM is committed to sustainable development and will remain actively involved in contributing to this conversation.



Tom Butler
Chief Executive Officer, ICMM

Introduction

The purpose of this paper is to discuss the definition and scope of the circular economy concept, and to explore the role of the mining and metals sector in such an economy.

Aspects of the circular economy have been promoted in various forms for decades, and it is now being advocated by influential organisations such as the Ellen MacArthur Foundation and the World Economic Forum. A circular economy describes production within a circular model where markets, regulations and industrial systems are optimised to design high-performance products, minimise impacts, restore or regenerate environments, and optimise material use. The ambition for the circular economy is not to replace the market economy, but rather to ensure it functions properly by providing accurate information to buyers and sellers on the full costs of production, consumption and waste.

While elements of the circular economy concept such as enhanced recycling of materials, improving resource efficiency and more sustainable design of products have been discussed, pursued and promoted by governments, leading companies and NGOs for some time, these elements have most often been discussed in a resource conservation, waste management or eco-efficiency context. Today the circular economy discussion is bringing in macro- and microeconomic considerations such as comprehensive pricing of externalities, financing mechanisms for ensuring recovery of resources, and infrastructure investments. The discussion is drawing attention to so-called megatrends in the market economy (eg population growth, rising middle class, technology advancements). The circular economy concept also calls for an economy fuelled by low-carbon energy.

When we talk about the economy, we tend to focus on it as an economic system. The website Oxford Dictionaries defines economy as “the state of a country or region in terms of the production and consumption of goods and services and the supply of money”. The circular economy also puts emphasis on a second, and older, definition of economy, which is “careful management of available resources”.¹ This definition of economy is also of direct relevance to the International Council on Mining and Metals (ICMM) and its members as they are major producers of minerals and metals, and

processors of secondary materials, as well as consumers of many types of resources such as energy, water and industrial chemicals.

The remainder of the paper is structured as follows. In Section 2 we summarise the generally agreed characteristics of a circular economy. For a more comprehensive overview of circular economy concepts, a list of key publications and online resources is provided in Appendix A. Section 3 discusses the context and drivers for a circular economy. Section 4 explores how the mining and metals industry currently contributes to a circular economy, and where there may be challenges. Section 5 identifies some areas where action is needed to further support and facilitate a circular economy, focusing on areas of particular relevance for ICMM, its members and their products. Finally, Section 6 provides some concluding thoughts.

Many thought leaders emphasise that defining and implementing a circular economy should be a significant shift from the status quo. In some of the literature discussing the circular economy, the need to rethink what we mean by the economy is an underlying, and in some cases explicit, theme. Yet, specific examples of circularity in mining and metals have clearly existed for a long time already. This is a complex area, and in this report the author does not explore the concept in depth and only seeks a high-level complement to the existing literature focusing on the potential implications for the mining and metals industry.

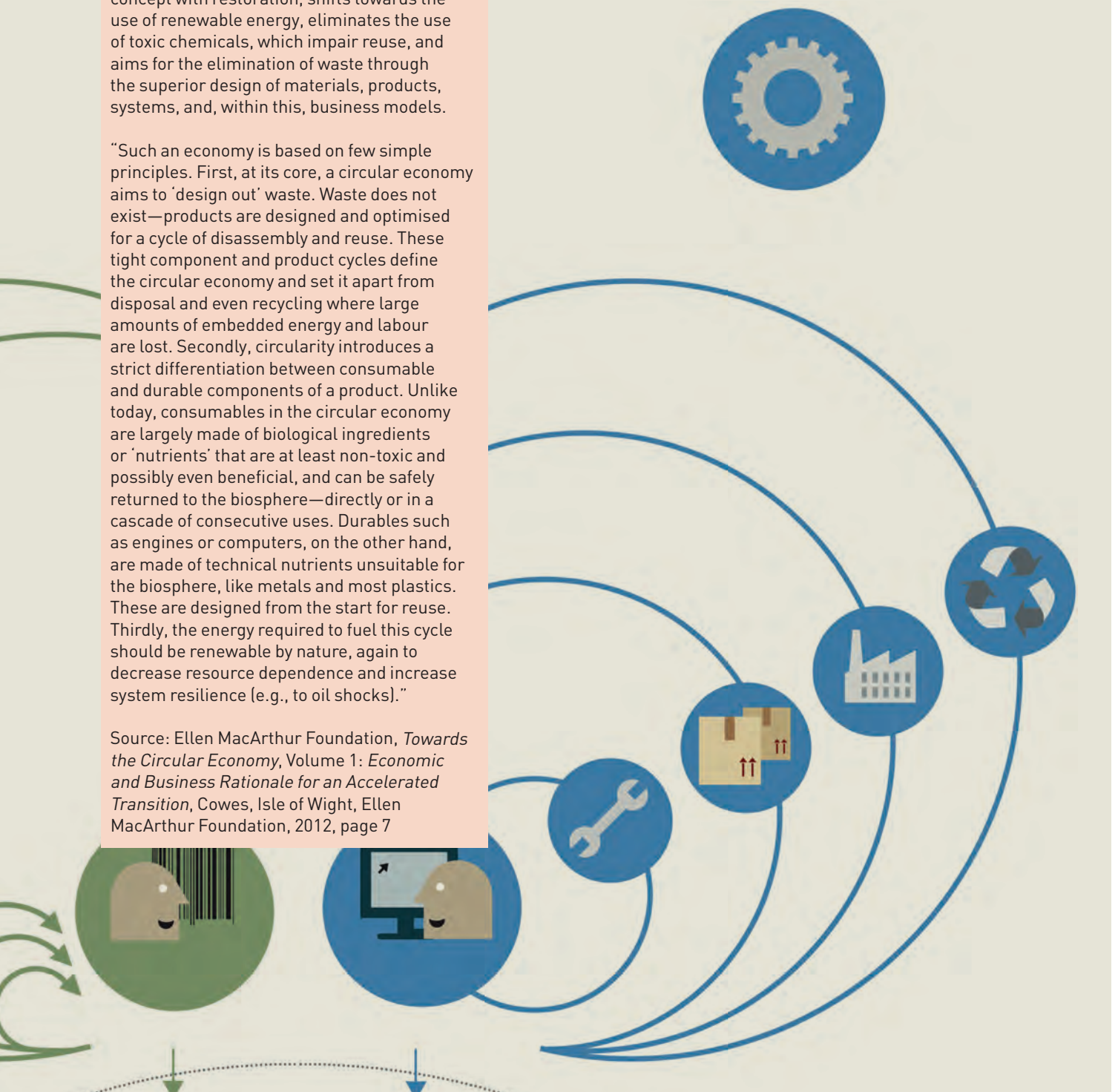
¹ www.oxforddictionaries.com/definition/english/economy?q=Economy.

Box 1. The Ellen MacArthur Foundation's vision of circular economy

"A circular economy is an industrial system that is restorative or regenerative by intention and design . . . It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models.

"Such an economy is based on few simple principles. First, at its core, a circular economy aims to 'design out' waste. Waste does not exist—products are designed and optimised for a cycle of disassembly and reuse. These tight component and product cycles define the circular economy and set it apart from disposal and even recycling where large amounts of embedded energy and labour are lost. Secondly, circularity introduces a strict differentiation between consumable and durable components of a product. Unlike today, consumables in the circular economy are largely made of biological ingredients or 'nutrients' that are at least non-toxic and possibly even beneficial, and can be safely returned to the biosphere—directly or in a cascade of consecutive uses. Durables such as engines or computers, on the other hand, are made of technical nutrients unsuitable for the biosphere, like metals and most plastics. These are designed from the start for reuse. Thirdly, the energy required to fuel this cycle should be renewable by nature, again to decrease resource dependence and increase system resilience (e.g., to oil shocks)."

Source: Ellen MacArthur Foundation, *Towards the Circular Economy*, Volume 1: *Economic and Business Rationale for an Accelerated Transition*, Cowes, Isle of Wight, Ellen MacArthur Foundation, 2012, page 7



What is a circular economy?

The circular economy concept consolidates many existing strategies and concepts (eg life cycle thinking, shifting to low-carbon energy, by-product synergy, resource productivity, recycling, reuse, design for disassembly to name a few) into an overarching model for the economic system (see Box 1 for one definition and principles).

A key feature of the circular economy is the notion of the end-of-life of materials being focused on restoration, either by returning biological materials to the earth or returning non-biological materials to the economy.

At its core the circular economy builds on the “cradle to cradle” (C2C) design paradigm developed by William McDonough and Michael Braungart.² C2C was developed in part as a response to the limitations of the eco-efficiency approach (creating more value with less impact), which McDonough and Braungart described as getting more and more efficient at drawing down natural capital. Rather than simply reducing

negative impact, cradle to cradle calls for a focus on enhancing the quality of the economy using three simple design principles:

- waste equals food (nutrients are nutrients) – which focuses on ensuring products and any by-products of production (emissions, wastes) can be returned to the earth or used as resources or inputs into similar or different product systems
- use current solar income – which calls for a focus on using renewable energy
- celebrate diversity – which considers local diversity, culture and ecology in design.

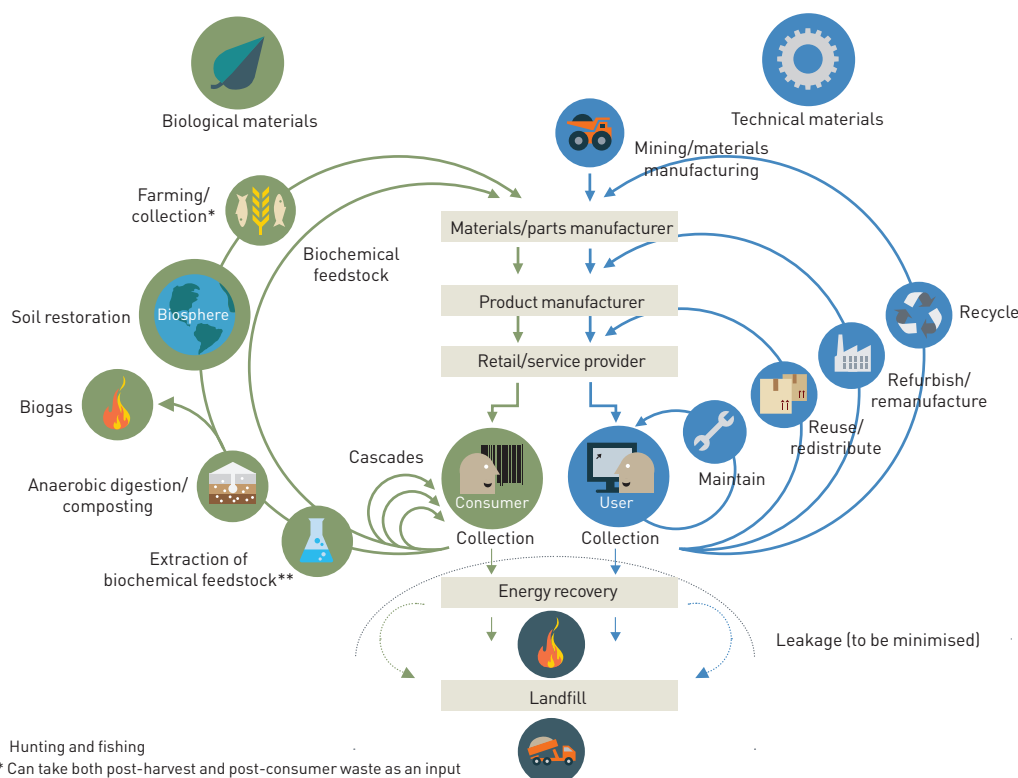
McDonough and Braungart described two types of “nutrients” that drive industrial systems:

- biological nutrients such as food, grasses, trees and other fibre sources that ultimately can return to the soil
- technical nutrients such as minerals, metals and plastics that are more suitable to be recovered, reused or recycled.

According to McDonough and Braungart, optimising the use of these nutrients requires new design approaches that will lead to more eco-effective solutions.

² William McDonough and Michael Braungart, *Cradle to Cradle: Remaking the Way We Make Things*, New York, North Point Press, 2002.

Figure 1: The circular economy



Source: Ellen MacArthur Foundation

Others have expanded on the cradle to cradle concept, merged it with other leading concepts such as natural capitalism, biomimicry, the performance economy and industrial ecology and envisioned and developed a more detailed analysis of what a circular economy looks like (see Figure 1). The centre of Figure 1 represents the traditional linear economy where materials flow from the earth through production and use phases and ultimately to some form of energy recovery or waste management scenario.

The right and left sides of Figure 1 illustrate how technical and biological materials can flow through the economy in ways that result in optimal use of these materials. Many of these cycles exist today, but Figure 1 emphasises the importance of designing product systems to optimise return loops and, as the Ellen MacArthur Foundation notes, the “power” of ensuring that:

- materials are cycled as tightly as possible, ie technical materials are maintained for their original intent, or biological materials are reused as feedstock for new or different uses
- materials cycle in the economy for as long as possible;
- materials are cascaded, where feasible, across industries into other product systems
- materials are as pure, non-toxic and easy to separate as possible to facilitate their use and reuse (see Box 2).

Using examples and extrapolations the Ellen MacArthur Foundation estimates the remaining potential for a circular business model across a variety of sectors represents hundreds of billions of dollars in materials cost savings and hundreds of thousands of new jobs. It notes that value comes from the following:

- products and materials being cycled more, and more efficiently
- costs of materials and of waste management being reduced
- creation of jobs and infrastructure to support circular economy practices related to remanufacturing, material recovery and the service economy
- innovation as actors in the value chain strive to find new ways of using materials, designing products and ensuring “circularity” (see Box 2).

It is important to note that while the circular economy may result in social benefits (eg jobs), it is not explicitly addressing the social element of sustainable development. The focus is on

materials, optimising resource use and product systems, and not explicitly on sustainable development objectives in areas such as poverty reduction, income inequality and health care. In this sense the circular economy concept is a component of a broader notion of a sustainable economy. This is an important consideration for the mining and metals industries as the upstream mining of materials imparts many benefits to, as well as impacts on, local communities. Section 3 explores the broader context for a circular economy.

Box 2. Opportunities in the circular economy

“The **power of the inner circle** refers to minimising comparative materials use vis-à-vis the linear production system. The tighter the circle, i.e. the less a product has to be changed in reuse, refurbishment and remanufacturing and the faster it returns to use, the higher the potential savings on the shares of material, labour, energy and capital still embedded in the product, and the associated externalities . . .

“The **power of circling longer** refers to maximising the number of consecutive cycles (be it repair, reuse, or full remanufacturing) and/or the time in each cycle. Each prolonged cycle avoids the material, energy and labour of creating a new product or component.

“The **power of cascaded use** refers to diversifying reuse across the value chain, as when cotton clothing is reused first as second-hand apparel, then crosses to the furniture industry as fibre-fill in upholstery, and the fibre-fill is later reused in stone wool insulation for construction—substituting for an inflow of virgin materials into the economy in each case—before the cotton fibres are safely returned to the biosphere.

“The **power of pure inputs**, finally, lies in the fact that uncontaminated material streams increase collection and redistribution efficiency while maintaining quality, particularly of technical materials, which in turn extends product longevity and thus increases material productivity.”

Source: Ellen MacArthur Foundation, *Towards the Circular Economy*, Volume 3: *Accelerating the Scale-up Across Global Supply Chains*, Cowes, Isle of Wight, Ellen MacArthur Foundation, 2014, page 16

Context for a circular economy

The circular economy discussion comes at a particularly challenging time in human history. Climate change, population growth, oil and commodity price (and general stock market) volatility, regional water shortages, other resource scarcity challenges, youth underemployment and growing concerns over income inequality are just some of the challenges affecting governments, businesses and individuals around the world.

Of all of these challenges, population growth and the impacts of increased production and consumption, in particular climate change, have become central drivers for creating a more circular economy. The United Nations Environment Programme's International Resource Panel has examined the issue of resource use and environmental impacts in depth, and in its 2014 report it notes that "The urgency for decoupling escalating resource use and environmental degradation from economic growth is now widely acknowledged by policy-makers, industry leaders and civil society."³

This urgency is reflected in the World Economic Forum's work on the circular economy where it states that in a world of close to 9 billion people expected by 2030 – including 3 billion new middle-class consumers – the challenges of expanding resource supply to meet future demand are unprecedented.⁴

Both of these observations reflect a long-standing view of the World Business Council for Sustainable Development (WBCSD), which has been calling for decoupling of human welfare from resource consumption for over a decade, through strategies such as eco-efficiency. In turn the WBCSD's position was driven in large part by government discussions going back to the World Commission on Environment and Development (Brundtland Commission) report *Our Common Future*⁵ and the deliberations at the 1992 United Nations Conference on Environment and Development in Rio de Janeiro. That conference produced Agenda 21, which noted in its discussion of unsustainable patterns

of production and consumption that "Special attention should be paid to the demand for natural resources generated by unsustainable consumption and to the efficient use of those resources."⁶

For many years governments tended to focus their response to this challenge on the downstream end of the resource value chain (ie looking at ways to minimise waste and enhance recycling). Over time it became clear that solving the waste problem required action upstream:

- enhancing the efficiency of systems of production
- enhancing the design of products
- reducing consumption.

The latter strategy is particularly challenging as most governments measure progress using gross domestic product (GDP), which is in large part a measure of consumption. As impacts of consumption have increased, however, we have seen governments, industry leaders and civil society organisations promote and adopt a variety of policies and strategies from extended producer responsibility to integrated product policy, to life cycle management, resource productivity, zero waste and many others. These policies and strategies are aimed at reducing the impacts of product systems, and to some degree they have been successful. The OECD reports that since 1980 progress in decoupling per capita consumption of material resources from economic growth has occurred. For example, Europe has reduced its resource extraction per US\$1,000 GDP from 0.83 tonnes in the 1980s to 0.46 tonnes in 2011.⁷ While this decoupling is a positive trend, the OECD also notes that environmental pressures and risks of resource scarcity will continue to intensify as greater demands are placed on the environment with, notably, the quadrupling of the population by 2050.⁸

The inability to control the increase in the overall volumes of resources being consumed has also led to a return of concerns about depletion and scarcity. For minerals and metals this is a challenging area to understand clearly, as mineral resource scarcity (or conversely availability) is tied to technological and economic factors, rather than actual natural stocks. However, for resources such as water,

3 United Nations Environment Programme's International Resource Panel, Decoupling 2: Technologies, Opportunities and Policy Options, Paris, United Nations Environment Programme, 2014.

4 www.weforum.org/projects/circular-economy.


5 United Nations, Report of the World Commission on Environment and Development: Our Common Future, New York, United Nations, 1987.

6 United Nations Sustainable Development, Agenda 21, United Nations Conference on Environment and Development, Rio de Janeiro, Brazil, June 3rd to 14th 1992.

7 www.materialflows.net/trends/analyses-1980-2011/material-intensity-by-world-region-1980-2011/.

8 www.oecd.org/greengrowth/material-resources-productivity-and-the-environment-9789264190504-en.htm.

3



“Ongoing political, economic, social, environmental and technological developments are challenging many of our underlying assumptions. Across every sector of society, decision-makers are struggling to cope with heightened complexity and uncertainty resulting from the world’s highly interconnected nature and the increasing speed of change.”

Klaus Schwab, Founder and Executive Chairman World Economic Forum, World Economic Forum, *Global Risks 2015, 10th Edition*, Geneva, World Economic Forum

stocks and flows are critical concerns in some regions. This has led to a more intense focus on decoupling, and to a variety of policies and strategies focused on greening the economy and enhancing resource productivity.

Governments (Netherlands, UK, Germany, EU, Japan and China) are beginning to create policies, laws and regulations to promote the development of a more circular economic system. In 2000 Japan enacted the Fundamental Law for Establishing a Sound Material-Cycle Society, which included a 3R policy (reduce, reuse, recycle) as well as other mechanisms to promote a circular economy. In 2008 the People's Republic of China passed the Circular Economy Promotion Law, which was formulated to promote "the development of the circular economy, improving the resource utilization efficiency, protecting and improving the environment and realizing sustainable development."⁹ In the EU the End-of-Life Vehicles Directive (2000), the Waste Electrical and Electronic Equipment Directive (2002) and the directive on ecodesign requirements for energy-using products (2005) were early examples of circular-economy-type policies. More recently, the European Commission has been developing a circular economy action plan, which was adopted in December 2015. It aims to preserve and maintain the value of products and materials in the economy for as long as possible.

The focus of these different government initiatives varies (eg some are focused on materials recycling and others place emphasis on product life cycle and design), but in general there is a clear trend towards improving the application and recovery of materials, improving product design and minimising waste generation.

There has also been a number of efforts such as the World Business Council for Sustainable Development Vision 2050 work and the World Economic Forum's Mining and Metals in a Sustainable World 2050 that have focused on imagining or envisioning a more sustainable world. These efforts include circular economy compatible strategies and goals such as enhancing recycling infrastructure and striving for zero waste. In September 2015 the UN released a new set of Sustainable Development Goals in its document Transforming Our World: The 2030 Agenda for Sustainable Development, which it calls a "plan of action for people, planet and prosperity".

The UN plan includes goals on responsible consumption and industrialisation, innovation and infrastructure that are supported by the circular economy concept. Similar to the WBCSD Vision 2050's ambitious zero-waste goal, the new UN goals call for substantially reducing waste generation through prevention, reduction, recycling and reuse by 2030. It is noteworthy that these efforts are in line with, and supported by, ICMM's ten principles for sustainable development. These support the circular economy but also go beyond it, in that they address a wide range of sustainability issues for the sector that were identified as priorities in the Mining, Minerals and Sustainable Development report (see Annex B).

⁹ www.lawinfochina.com/display.aspx?id=7025&lib=law.



“China has a large mining industry and a huge demand for mineral resources. It is also experiencing rapid industrialization and urbanization and is faced with challenges such as a large population, inadequate resources per capita as well as severe environmental pollution and degradation. For these reasons, the Chinese government is committed to sustainable development, and is making huge efforts to promote the development of a circular economy and green mining.”

Statement of the Chinese Delegation on Mining at the 18th session of the Commission on Sustainable Development 2010

How do mining, minerals and metals contribute to a circular economy?

In many senses minerals and metals are ideal technical nutrients for the circular economy.

Metals are for the most part infinitely recyclable. Many have inherent characteristics such as durability, strength and anticorrosive properties that improve the sustainability of the products in which they are used: enhancing longevity, lowering maintenance requirements and providing higher functionality. Their value enhances their recovery rates, and there is already considerable infrastructure in place to facilitate their reuse, remanufacture and recycling. Figure 2 illustrates the main life cycle stages in the minerals and metals life cycle and differentiates stewardship responsibilities related to upstream mining operations and metals production (process stewardship – highlighted in green), and stewardship responsibilities related to the product systems that minerals and metals go into (product stewardship – highlighted in blue).

Mining operations

It is well known that mining creates a considerable volume of waste (waste rock, overburden, emissions, tailings, water treatment sludge and mine water). However, there are a variety of circularity aspects that can be pursued within mining operations.¹⁰ A number of national mining associations have developed guidance and programmes to help their members meet high standards and share best practice across a range of operational activities and impacts. In Canada, for example, the Mining Association of Canada (MAC) has developed the Towards Sustainable Mining (TSM) initiative, a mandatory programme for MAC member companies, designed to drive improvements in mining operations and mine closure. TSM includes external verification of performance and requires involvement of multi-stakeholder community-of-interest panels, both in oversight of the programme and at the individual mine sites. TSM includes protocols, tools and indicators in:

- crisis management planning
- energy use and greenhouse gas (GHG) emissions management
- tailings management
- biodiversity preservation
- safety and health
- Aboriginal and community outreach.

In the TSM programme the energy and GHG protocol includes encouragement of alternative energy that can reduce emissions. The biodiversity protocol encourages the enhancement of biodiversity in areas outside of the facility's property. A leading example of low-carbon energy use in mining is Rio Tinto's Diavik diamond mine in Canada's Northwest Territories. The mine has a 9.2 MW wind farm that offsets diesel use and at the same time saves millions of dollars in fuel costs.¹¹

Box 3 provides examples of how waste from mining operations can be reused. Slags are increasingly being used as aggregate in concrete and road construction, and overburden is used for landscape contouring and revegetation during mine closure.¹² In addition, mining operations contribute to circularity through recycling of equipment (eg tyres), remanufacturing of heavy equipment and recycling key inputs such as water and reusing chemicals.

Smelting and refining

Similar to mining, the smelting and refining stages of the minerals and metals life cycle have waste streams that need to be addressed, but their main contribution to the circular economy is through the processing of residues and secondary metals. Primary smelters often use scrap in conjunction with primary concentrates, producing metals with varying amounts of recycled content. There are also secondary smelters that specialise in secondary material to ensure process control. For example, Mitsubishi Materials' Naoshima Smelter and Refinery processed approximately 80,000 short tons of metal from electronic scrap in 2015, and it is expanding that capacity to approximately 110,000 short tons in 2016. The facility produces gold, silver, copper, palladium and other valuable metals from circuit boards from the "urban mine" of discarded home appliances, personal computers, cellular and smartphones, communications servers and other digital devices.¹³ Capability to handle waste electronic products and equipment make smelters like the Naoshima Smelter and Refinery essential hubs in the circular economy.

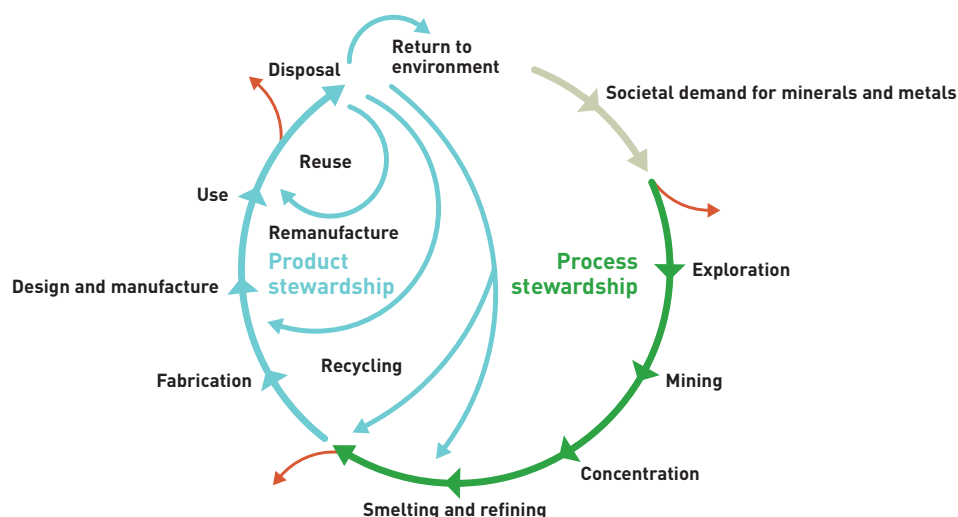
In the steel industry the two main production routes used are the blast furnace (BF), or integrated, route and the electric arc furnace (EAF) route, representing approximately 70% and 30% of world production of steel respectively. Steel produced through the EAF route is typically 88% recycled scrap but can be 100%. BF steel is typically 12% scrap but can

¹⁰ The amount of waste varies considerably by the type of mine (surface, underground, solution) and the type of deposit.

¹¹ <http://canwea.ca/wp-content/uploads/2013/12/canwea-casestudy-DiavikMine-e-web2.pdf>.

¹² See more at: www.miningfacts.org/Environment/How-are-waste-materials-managed-at-mine-sites/#sthash.NPIMcpPb.dpuf.

¹³ www.mmc.co.jp/corporate/en/news/news20150625.html.

Figure 2: Main life cycle stages for minerals and metals

Source: ICMM, Maximizing Value, London, ICMM, 2007

Box 3. Uses of mining waste

Waste rock is used as backfill, landscaping material and aggregate in road construction, or can sometimes be used as feedstock for cement and concrete or reprocessed later to extract minerals and metals.

Manganese tailings are used in agroforestry, buildings and construction materials, coatings, resin, glass and glazes.

Clay-rich tailings are used for making bricks, floor tiles and cement.

Slag is often used for road construction, and in concrete and cement.

Bauxite red mud is solid alkaline waste produced in aluminium refineries. Red mud is used as a soil amender, in wastewater treatment and as a raw material for glass, ceramics and bricks.

Mine water is used for dust suppression and mineral processing, industrial and agricultural uses, as a coolant and sometimes as a source of drinking water.

Sludge from acid rock drainage treatment, which is high in iron, is sold commercially for use in pigments.

Smelters typically include acid plants to convert sulphur dioxide to sulphuric acid, a useful industrial chemical.

Source: www.miningfacts.org/Environment/How-are-waste-materials-managed-at-mine-sites/#sthash.6lXHOVF.dpuf

be up to 35%. Currently, steel is the most recycled material in the world, with over 650 megatonnes recycled annually.¹⁴

Circularity is also enhanced at the smelting and refining stage by increasing the recovery of co-products. For example, a copper producer recovers not only copper from the ores and concentrates it processes, but also a wide range of other metals, such as molybdenum, gold, silver, selenium and others. Similarly, nickel producers often recover platinum-group metals (used in catalytic converters to reduce vehicle emissions) as well as cobalt, copper and other co-products. The capturing of these co-products helps avoid the need for additional mining processes.

Primary smelters also produce a significant share of the global sulphuric acid production through off-gas cleaning. This process turns a problem emission (acid gases) into a valuable product, and it reduces the need for additional sulphuric acid production.

¹⁴ www.worldsteel.org/dms/internetDocumentList/bookshop/2015/Steel-in-the-circular-economy---A-life-cycle-perspective_vfinal/document/Steel%20in%20the%20circular%20economy%20-%20A%20life%20cycle%20perspective.pdf

Products

As metals move from the smelter into the fabrication and product stage, the circularity benefits increase dramatically. While these stages have production impacts, it is here where the inherent characteristics of metals and their alloys such as infinite recyclability (which does not apply to dispersive uses), durability (steel, aluminium, copper), anticorrosion (zinc), conductivity (copper, aluminium) and formability can amplify the sustainability of a product. In products, the nature and properties of metals are typically not compromised and can therefore be recycled over and over again (see Box 4). Even if contaminated, they can often be cycled into a lower-value product or application.¹⁵

Some circular applications of metals in products include the following.

Low-carbon energy

Metals enable the renewable energy economy through applications in solar photovoltaic cells, wind turbines and battery technologies. Figure 3 illustrates how the use of metals in energy production has evolved over time.

Green building construction

Metals support green building construction practices where metals' strength, durability and general lack of indoor air quality impact are considered beneficial. They are used in a variety of structural (dimensional stability of steel) and technological (smart building systems) applications, and their recyclability supports sustainable building construction.

Transportation

Aluminium and ultra-lightweight galvanised steel are used to reduce weight and improve fuel efficiency of automobiles, trains, planes and light rail vehicles. Electrified railways, trams and light railways are powered through overhead copper alloy contact wires.¹⁶ Nickel, lithium, cobalt, lead and rare earth minerals are utilised in battery technologies for electric vehicles. Platinum-group metals are critical for the function of catalytic convertors that reduce tailpipe emissions.

Electronics industry

Smartphone technology is a classic example of a multifunctional product (camera, video recorder, phone and computer) that reduces the need for multiple product systems. A typical smartphone incorporates over 40 different types of metals enabling functionality that eliminates the need for separate products. Cobalt is in many types of rechargeable batteries, where it is an essential element in most nickel-cadmium, nickel-metal hydride and lithium-ion battery cells.¹⁷

Recycling

Ease of reuse and value are two reasons why some metals have been recycled for thousands of years. In many jurisdictions today the value of metals helps drive the economics of recycling programmes, and the relatively easy separation of metals from other waste-stream components leads to high recovery rates. This is particularly true for metals that are used in their pure or elemental forms such as copper, gold, lead, platinum, palladium and rhodium.¹⁸ Aluminium and steel (alloys of iron and other elements) are also highly recycled. It should be noted that metals that are alloys require more careful consideration and handling, and dissipative uses do result in losses to the environment.

In some cases environmental and human health hazards of minerals and metals need careful consideration and risk management. As Figure 3 illustrates, minerals and metals are utilised in a wide range of green technologies, including wind turbines, solar panels, catalytic convertors, electric vehicle battery systems and bicycles. Where these technologies and products contain metals that could prove hazardous, effective stewardship of the material can enable the realisation of the benefits of using the material while reducing or eliminating risks.

15 Five Winds International, *Eco-efficiency and Materials*, Ottawa, International Council on Metals and the Environment, 2001.

16 <http://copperalliance.org.uk/applications/transportation>.

17 GreenhouseGas Measurement.com (GHGm), *Social and Environmental Responsibility in Metals Supply to the Electronic Industry*, Guelph, Canada, GHGm, 2008.

18 T.E. Graedel and Lorenz Erdmann, Will Metal Scarcity Impede Routine Industrial Use? *MRS Bulletin*, 37(04) (2012), 325–31.

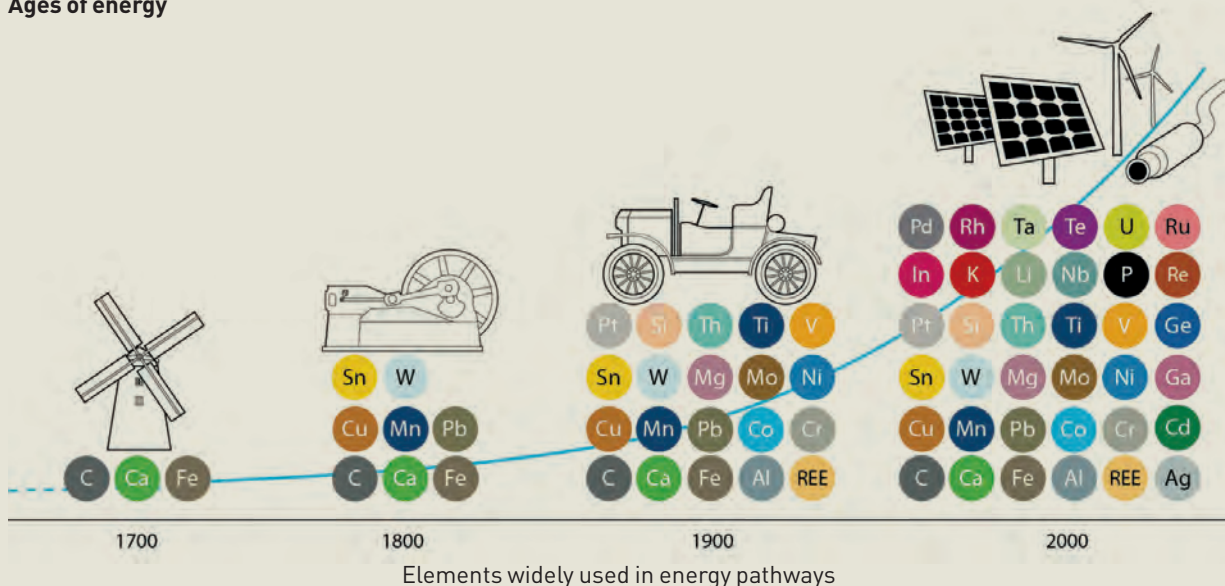
Box 4. Metals – the ultimate technical nutrient?

“Metals are elements. Their elemental nature distinguishes them from other materials and provides their basic material value. Different metals have different physical and chemical properties due to atomic-level characteristics associated with metallic bonding. Moreover, because they are elements, they cannot be destroyed and are therefore theoretically infinitely recyclable.”

Source: Five Winds International, Eco-efficiency and Materials, Ottawa, International Council on Metals and the Environment, 2001

Figure 3: Elements used in energy pathways

Ages of energy



Source: US Geological Survey, Mining for Metals in Society's Waste, The Conversation.com, October 1st 2015.
<https://theconversation.com/mining-for-metals-in-societys-waste-43766>

What more can be done to support and facilitate the circular economy?

Whatever we call it, contributing to an economy that is efficient in how it extracts, produces, consumes, recovers and recycles resources and materials will be an increasing priority in the 21st century.

Climate change, population increases, resource availability and competition, waste and other forms of pollution all point towards the need for better management of materials and increasing circularity. To meet the challenge, a number of needs have been identified, which include the following.

Sufficient awareness of related market trends and adjustments to long-term demand forecasts

Mining companies would be well advised to incorporate circular economy thinking into their assessments of long-term trends and potential shifts in demand for particular minerals and metals so that they are as well placed as possible to meet the needs of society in an accurate and timely manner. Such shifts in demand may create new opportunities through collaborative design of mining, minerals processing, and smelting and refining process flow sheets. This brings more detailed knowledge of ore bodies to those seeking to provide a broader spectrum of minerals and metals to market.

Continue improvements in mining operations and metals production

While achieving aspirational goals such as zero waste are a challenge, mining operations will need to continue innovating in response to market trends and to mitigate impacts. This may include reusing materials, supporting remanufacturing in supply chains, reducing carbon footprint, providing net benefits to host communities and restoring landscapes. Shared-use infrastructure (within or between sectors or with communities) is an example of an opportunity. Mining companies can, and do, plan and build infrastructure in collaboration with other stakeholders so that it supports project development/operations as well as having a life beyond the mine. This provides a community benefit and extends the use of the infrastructure. Companies can also do more to ensure that trace materials are not lost in tailings and other mine wastes.

More data on material flows

Many minerals and metals are used in hundreds of different product systems. Developing a better multidisciplinary and cross-sector understanding of current and future availability of resources, the flows of materials created from those resources, where stocks in the economy are located and where losses to the environment may be occurring is essential for designing policies and creating infrastructure to ensure recovery of materials wherever possible. A number of commodity associations are doing their part to collect data, but more data are needed from users of materials, and there is a need to develop a better understanding of flows, recovery rates and recycling rates, particularly for new high-tech minerals and metals. As noted by Graedel and Erdmann in their paper on metal scarcity and its potential to impede industrial use, it is also useful to look at the principal uses and recycling potentials of selected metals. They note that recycling potential can be affected by the application as well as whether the metal is used in its pure form, in a multicomponent alloy form, in a complex product assemblage or in a dispersive use.¹⁸

Enhanced recycling and recovery infrastructure

To date, the availability, and robustness, of current recovery and recycling infrastructure has been dictated by a variety of factors, including the price of materials, legislation, local/regional land use constraints or economic need. Current practices and the likelihood of more investments are complicated by differing, and sometimes conflicting, regulatory approaches to waste management, price volatility and the management approach taken to address some impurities or hazardous waste streams, which in some cases could be a potential source of materials for low-risk applications. Increased demand for minor metals, for example, may create new opportunities to develop flexible smelting and refining processes capable of recovering a broader spectrum of minerals and metals from a greater variety of concentrates. Governments need to develop a more harmonised and co-operative and proportionate approach within and between jurisdictions to provide more confidence for government and private-sector investments.

More value-chain partnerships

The Aluminium Stewardship Initiative and the National Materials Marketplace project – led by the Corporate Eco Forum, the United States Business Council for Sustainable Development and the World Business Council for Sustainable Development – are examples of the types of partnership that are likely required to further support the circular economy. Individual businesses have identified considerable opportunities through codevelopment of products, bringing more detailed knowledge of material properties to those seeking to bring particular functions to market. Creating and maintaining such initiatives requires leadership, funding, clear business models and desirable outcomes for all participants. More efforts to identify, initiate and foster these types of initiatives that reach up and down the value chain to uncover unrealised efficiencies for mutual benefit will be needed. It is also important to ensure there is a policy and public-attitude perspective that learning from challenges, and building on successes, is the way forward.

Better understanding of applications and appropriate product design

Sustainable product design is on the rise, but there are still many products being produced that are not optimal in terms of the materials used, the efficiency of their use phase, their modularity (where appropriate), their amenability to remanufacturing and the ability to recover materials at the end of their useful life. Better education of product designers and engineers is required, as are design tools that incorporate sustainability and circularity considerations and data. Enhancing the “circularity” of product design will benefit from more public-policy emphasis on life cycle thinking and product stewardship, particularly in high-footprint manufacturing sectors.

Exploration of new business models

Circular economy implementation requires a better understanding of material flows and also more control of those flows through mechanisms such as shifting from a product to a service business model. Under such a model, material suppliers might lease their materials to users and retain ownership. This would provide incentives for material suppliers to ensure better control over quality and enhanced ability to track materials, as well as incentives to ensure the ability to recover the material. It would also promote the use of less material to achieve the desired function.

Conclusions

The circular economy concept is an important contribution to our efforts to achieve sustainable development because it brings together many sustainability concepts and ideas in a logical model and strategy, including understandable objectives that can often reveal new positive business cases.

Although intuitively focusing on circular economy ambitions such as improving resource efficiency, fostering eco-innovation, optimising recycling and enhancing collaboration makes considerable sense, history has shown that achieving widespread implementation of circular economy practices has, to date, proven to be relatively slow and complicated. To accelerate the adoption of circular economy practices, more understanding, collaboration and data are needed.

The mining and metals industry has a significant role to play in a circular economy. Mining represents the initial investment that makes valuable, durable and recyclable materials available to society such that human well-being can be improved overall. Minerals and metals are ideal technical nutrients and already display a significant degree of circularity in the economy today. But more opportunities exist, and designing products, policies, buildings and infrastructure, and transportation systems with circularity in mind is critical to optimising the value of metals to society.

Finally, while it is important to focus substantive effort on building a circular economy, it is also important to keep in mind the broader goals of sustainable development and trade-offs that may occur. To this end, ICMM and its members have committed to a broad set of sustainable development principles that support the circular economy but also address other important sustainability issues that have been identified with external stakeholders as the main priorities for the sector.



“A strong move towards recycling and circularity is likely, but fundamental changes are required to support this transition, including appropriate infrastructure, regulation and legislation, and competitive cost economics.”

World Economic Forum and Boston Consulting Group, Mining and Metals in a Sustainable World 2050, Geneva, World Economic Forum, 2015

Appendix A

Resources and forums for understanding the circular economy

Websites and organisations

Circular Economy News

Primarily UK and EU focused, the Circular Economy News aggregates information and provides blogs, videos and media coverage on the circular economy.

Ellen MacArthur Foundation

Established in 2010, with the aim of accelerating the transition to the circular economy, the Ellen MacArthur Foundation is a charity that is a global thought leader, working to establish the circular economy on the agenda of decision-makers across business, government and academia. It provides background papers, case studies and tools, as well as running programmes with industry, government and academics.

Eurometaux

Eurometaux's website includes Eurometaux's position on the EU Circular Economy Package and links to a recap of Eurometaux's October 29th 2015 conference "Towards a Circular Economy: How to Maximise Europe's Resources" held in Brussels.

European Commission's circular economy website Circular Economy–Environment–European Commission

The website provides information on the European Commission's circular economy strategy as well as related policies. It also includes conference proceedings and information on public consultations.

World Economic Forum Circular Economy Initiative

The initiative has two main goals:

- Build global awareness of circular economy opportunities in key growth regions through the development of regional circular economy alliances.
- Develop and raise awareness about business solutions for "circular" asset management and financing models.

The World Economic Forum is collaborating with the Ellen MacArthur Foundation and McKinsey & Company on Project MainStream, which is an initiative "to identify and unblock the systemic stalemates that stop circular economic activity getting to scale across global value chains".

World Steel Association

The World Steel Association provides information and infographics on the circular economy and the importance of steel as a material to support the circular economy.

Books, papers and reports

Circular Construction: The Foundation Under a Renewed Sector, Amsterdam, ABN AMRO, 2014. This research paper describes "circular enterprises in the Construction and demolition sector. It describes the transition from a chain that developed in a linear fashion to a sustainable sector that is set up in a circular way."

ACEA Position Paper on Circular Economy – September 2015, Brussels, European Automobile Manufacturers' Association (ACEA), 2015.

This paper describes the European automotive industry's perspective on a policy approach needed to promote a circular economy.

A New Dynamic: Effective Business in a Circular Economy, Cowes, Isle of Wight, Ellen MacArthur Foundation, 2014.

This book "makes the contemporary case for a profound shift from throughput to 'roundput', from ownership to access. The circular economy is enabled by disruptive information technology and the design of materials and products to flow in effective cycles and at high quality – 'made to be made again'. The size of the prize is in the billions of dollars of materials cost savings per year. This volume contains contributions on understanding the model, business case studies, the performance economy, history and development and the entrepreneurial opportunities of these fluid times."

Towards the Circular Economy, Volumes 1–3, Cowes, Isle of Wight, Ellen MacArthur Foundation, 2012, 2013, 2014.

This landmark series of reports defines the circular economy concept and explores the economic and environmental opportunity. Volume 1 provides the rationale for the circular economy, Volume 2 looks specifically at the consumer goods sector and Volume 3 examines the scale-up of the circular economy across global supply chains.

Growth Within: A Circular Economy Vision for a Competitive Europe, Cowes, Isle of Wight, Ellen MacArthur Foundation, 2015, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (SUN) and McKinsey Center for Business and Environment. "The report suggests what a circular European economy could look like and compares its potential impact with the current development path."

Copper's Contribution to the EU's Circular Economy, Brussels, European Copper Institute, February 2015. The article describes copper's role in a circular economy, including a detailed infographic.

Waste to Wealth: Creating Advantage in a Circular Economy Lacy, Peter and Rutqvist, Jakob, Basingstoke and New York, Palgrave Macmillan, 2015.

Accenture's book "examines how the transition to a circular economy may be the biggest revolution and opportunity for how we organize production and consumption in our global economy in 250 years. Powered by advances in digital, it represents a huge opportunity for companies to create a circular advantage."

Material Resources, Productivity and the Environment, OECD Green Growth Studies, Paris, OECD Publishing, 2015.

The report describes the material basis for OECD economies and examines how materials flow between the environment and the economy.

The Circular Economy: A Wealth of Flows, Webster, Ken, Cowes, Isle of Wight, Ellen MacArthur Foundation, 2015.

The book explores the shift from a linear "take-make and dispose" economy towards a circular economy – "a regenerative model based around feedback-rich flows allied to new business models".

Project MainStream – a Global Collaboration to Accelerate the Transition Towards the Circular Economy: Status Update, Geneva, World Economic Forum, 2015.

"Project MainStream is an initiative to identify and unblock the systemic stalemates that stop circular economic activity getting to scale across global value chains. It is one of the World Economic Forum's global cross-industry projects [and it] brings together some of the world's leading cities, businesses and

governments to address areas where a public-private redesign of our systems and global value chains is possible."

Steel in the Circular Economy: A Life Cycle Perspective, Brussels and Beijing, World Steel Association, 2015.

This publication describes the role of steel and the steel industry in the global circular economy emphasising the importance of accounting for the full life cycle of steel products.

Appendix B

ICMM's ten principles for sustainable development

- 1 Apply ethical business practices and sound systems of corporate governance and transparency in support of sustainable development
 - 2 Integrate sustainable development considerations within corporate strategy and decision-making processes
 - 3 Respect human rights and the interests, cultures, customs and values of employees and others affected by our activities
 - 4 Implement effective risk management strategies and systems which are based on sound science and account for stakeholder perceptions of risks
 - 5 Pursue zero harm and continual improvement in our health and safety performance
 - 6 Pursue continual improvement in our environmental performance, on issues such as water stewardship and energy and climate change
 - 7 Contribute to the conservation of biodiversity and integrated approaches to land use planning
 - 8 Facilitate and support the knowledge-base and systems for responsible design, use, re-use, recycling and disposal of products containing metals and minerals
 - 9 Pursue continual improvement in social performance and contribute to the social, economic and institutional development of host countries and communities
 - 10 Proactively engage key stakeholders on sustainable development challenges and opportunities in an open and transparent manner and effectively report and independently verify progress and performance
-

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