WEALTH FROM WASTE

SHIFTING BUSINESS MODELS FOR A CIRCULAR ECONOMY

METALS MANAGEMENT FOR MULTI-PRODUCT-USE CYCLES

2015

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INSTITUTE FOR SUSTAINABLE FUTURES, UTS

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The Wealth from Waste Cluster is an international collaboration of research groups led by UTS, with Monash University, the University of Queensland, Swinburne University of Technology and Yale University. In partnership with CSIRO and enabled by support from the Flagship Collaboration Fund and participating universities. The Cluster is charting a pathway to enable Australia's metals and minerals industries to prosper in a future circular economy and in enabling technologies and practices for secondary resource markets.

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Rationale

There is growing awareness that current production and consumption systems are stretching the planet and people beyond their natural limits. **A radical transformation – of social, economic and technological systems – is needed to drive a new wave of responsible prosperity** that is underpinned by the sustainable use of material, energy, informational and human resources. The transformed system decouples prosperity from resource use, necessitating a redefinition of the value of resources; and, it is the need to rethink value that highlights the importance of new business models for driving the transformation.

Business model innovation is defined as innovation across the whole range of business activities that influence the creation, delivery and capture of value. This can include changes to a business value proposition, such as offering a service over a product.

Objectives

The overarching aim of this report is to explore how the Australian metals and minerals sector could embrace new business models and build on its strengths to harness new value in a global economy orientated more towards sustainable futures.

Much of the recent interest in sustainable resource management has come into focus in the context of implementing 'circular economies'. **In a circular economy, there is a strong emphasis on designing products and processes for a 'take-make-recreate' approach as opposed to the linear 'make-use-dispose' paradigm**. This means promoting an industrial ecology agenda that aims to optimise material, energy and information exchange through multiple-use-cycles for deriving new value and mitigating adverse impacts on people and the planet. A review of different conceptualisations of circular economy and the diverse approaches to implementation in China and Europe highlights the important role of new design thinking, disruptive digital technology, new collaborations between sectors and stakeholders, awareness raising and the need for better indicators and targets for appraising economic, environmental, and social outcomes. While Europe and China are engaging with circular economy concepts, it is not yet a theme of national significance and the economic drivers are very different for Australia post mining and construction boom.

In parallel with the growing interest in circular economies, and the key focus of this research, is a call for a greater focus on sustainable metals management, in particular as championed by the UNEP International Resource Panel. The expert panel strongly promote the need for greater resource use efficiency, which may be achieved by a transition from material-centric recycling to product-centric recycling. This will achieve a dramatic increase in metals recycling, which is challenged by the increasingly complex combinations of metals in modern products. The growing demand for finite metal resources, coupled with a physical and economic upper limit to recycling efficiency that is directly influenced by product complexity, highlights a need to rethink metal resource use in products and services.

Thus, in common to the ideas around implementing circular economies and the concept of product-centric recycling, is recognition that a holistic system approach is needed; incorporating new design, and new collaborations across the supply chain from advanced manufacturing to waste management. However, owing to the physical and economic limit to recycling, that includes repair, reuse and remanufacturing cycles, in order to optimise the useful service metals provide to society it is necessary to consider sufficiency as well as efficiency. On this basis, we argue that the better conceptualisations of the circular economy go further than product-centric recycling by giving consideration to the rate of metal flows within the cycle, as well as cycle efficiency. To this end, the importance of new modes of consumption and business models that address overconsumption are highlighted.

This report draws on these concepts in the Australian context to evaluate how new business models might support sustainable metals management. The specific aims of this report are threefold: (i) review progress towards implementing circular economies internationally and locally, and the relevance to the metals, waste, and products sectors; (ii) characterise contemporary business models and the policy landscape for metals recycling industries in Australia, and; (iii) evaluate potential opportunities for value creation with new business model concepts applicable to metals, and identify gaps that need addressing to realise these opportunities.

Conclusions and next steps

For Australia, many companies are at the front end of the supply chain (mining), or at the end-of-life (recycling) end. This has become more significant with the decline of local manufacturing in Australia. Whilst those companies that are the exceptions, with activities at multiple parts of the supply chain, they are not yet also in the business of ensuring flows of metals along the supply chain. Nor are they active in promoting effective design, or efficient collection–key elements in realising multi-product cycles. Considering the Australian recycling industries, we find the dominance of a small number of major players – for ferrous/non-ferrous scrap, and, also for e-waste, who are innovating within their current business models, are not looking holistically along the supply chain to shift to new business models that might be required to achieve circular economies.

By applying a framework for categorising sustainable business models we identify five archetypes that are most applicable for a driving a shift to a circular economy: (i) "Substitute renewable energy and material inputs", (ii) "create wealth from waste", (iii) "adopt a stewardship role", (iv) "maximise material and energy productivity" and (v) "deliver functionality rather than ownership". Within this framework, circular business models are defined as a subset of sustainable business models and a key distinguishing criterion is that they must be oriented towards production and consumption that promotes both efficiency and sufficiency. An analysis of 70 businesses cases from a range of sectors identified the "create wealth from waste" archetype as the most prevalent and this may be considered as an indicator for where new value opportunities have already been identified. While we acknowledge the limited number of examples that are specific to metals, our analysis demonstrates that **significant opportunities exist in looking more broadly across the value chain, in taking a focus on design for resource use intensity, in rethinking how we value waste, and in embracing new modes of consumption**. The five archetypes give particular focus to the important role of producers and manufacturer, for example through product innovation for durability, reparability and recycling. However, there is significant scope for wider engagement across the value chain, for example opportunities for new value through cooperation across industries to "maximise material and energy productivity" and "deliver functionality rather than ownership" archetypes give focus to consumers by promoting a shift from ownership to access models, like sharing assets and leasing.

Our analysis indicates that enabling new business models in the metals industries to position Australian firms to participate and potentially lead in the transition to sustainable metals management requires systemic intervention at the intersection of resources, product design, the waste industry, waste minimisation policy and use or consumption. Further research is needed to explore the range of interventions that may be leveraged by radically changing business activities towards more circular material flows across product design, disruptive technologies for manufacturing or material processing, and new consumption models such as leasing. Greater resolution in terms of different metals, products, and processes is needed to evaluate potential and to prioritise opportunities and reduce or eliminate barriers. Owing to this complexity, business model innovation requires new collaborations across the supply chain (including designers, producers, suppliers, consumers and waste industries) as an important precursor to draw on the knowledge from a range of stakeholders, including key representatives from the services sectors who can play a role in future bridging to innovation.

1 INTRODUCTION

This report examines emerging and possible future business models that can support or enable multi-product-use cycles for metals in a resource constrained future.

We contrast the contemporary structure and operation of the metals recycling industries in Australia with the dominant new business models outside the metals industries that have emerged overseas and strategies for implementing circular economies.

The research investigates and identifies the opportunities for new synergies between primary and secondary supply chains; for streamlining materials management; as well as novel modes of consumption to enable more circular material flows.

This work is part of the Wealth from Waste Cluster, a collaboration between CSIRO, University of Technology Sydney (Institute for Sustainable Futures and UTS Business School),
The University of Queensland (Centre for Social Responsibility in Mining at the Sustainable Minerals Institute); Swinburne University of Technology, Monash University and Yale University (Center for Industrial Ecology).

Specifically it is part of the P3 cluster project on business model innovation. The rationale for the work of the Cluster is that radical innovations in production systems and resource management are emerging globally; waste is now treated as a valuable resource and products, supply chains and business models are being redesigned to harness this opportunity. New wealth is being created by designing for an industrial ecology agenda, which promotes circular flows of resources. The ambition is to de-couple economic growth and resource use, and to identify new science and policies which can support the transition to circularity.

1.1 OVERVIEW OF DOCUMENT

An overview of the document is provided in Figure 1.

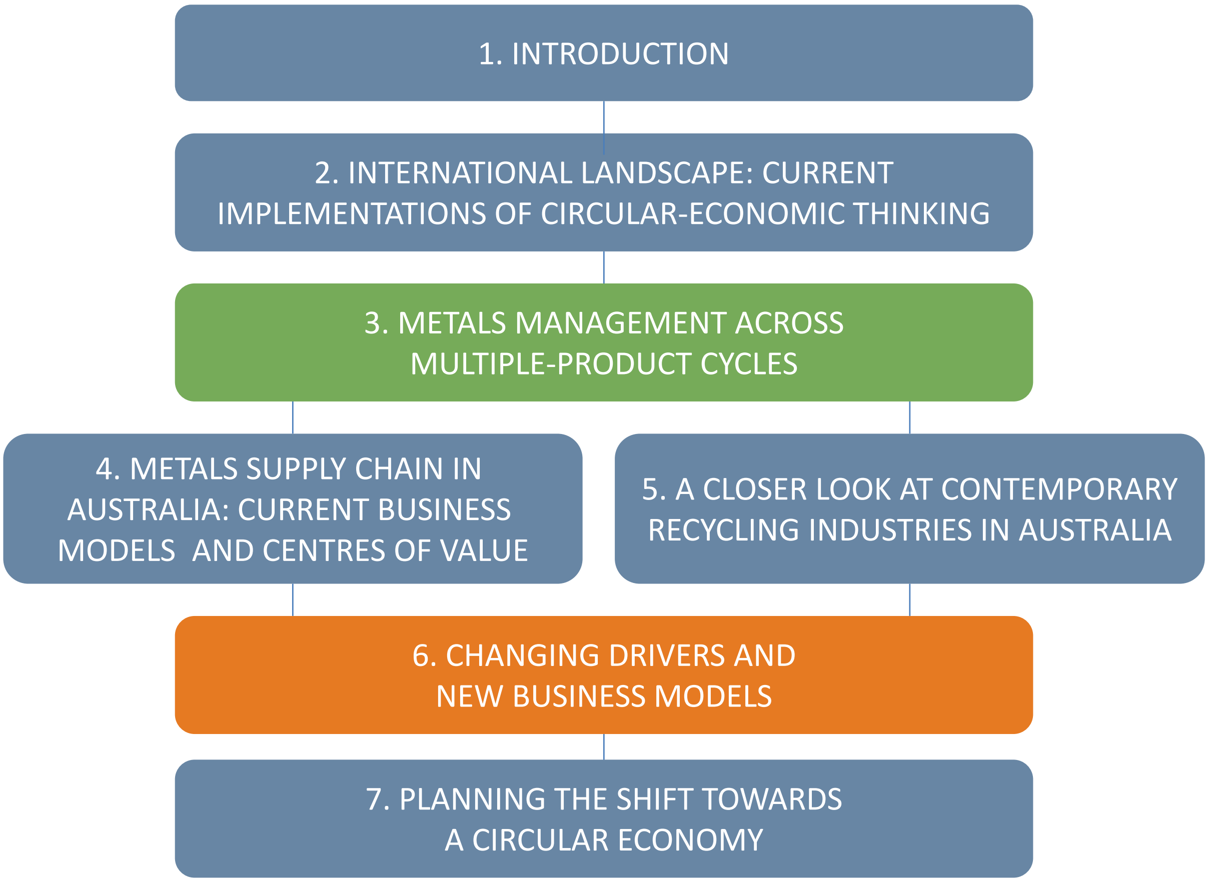

Figure 1: Overview of report

Section 1 provides an overview of this report. **Section 2** introduces the broad concept of resource productivity in the context of the increasingly prominent concept of the circular economy. This section reviews the current conceptualisations and implementations of circular economies internationally and reflects on the implications for metals. From this perspective, **Section 3** provides a greater focus on the case of metals, giving an overview of the key drivers and challenges for sustainable metals management and discussing the case for 'product-centric recycling' in line with work of the UNEP International Resource Panel. **Section 4** then provides an overview of the metals supply chain in Australia and the contemporary business models in mining and minerals processing. Reflecting on the important capacities for transitioning the Australian metals industries towards a circular economy, **Section 5** provides a closer look at the recycling industries and the policy landscape. **Section 6** presents a definition of a circular business model and highlights key characteristics by drawing on the sustainable business model literature and an analysis of 70 business model case studies from the literature across a diverse range of sectors. Based on this investigation, this section then examines in detail of two key circular business models: supply chain certification schemes and leasing. Finally, **Section 7** reflects on the opportunities for Australian businesses, considering overlap between areas of focus required for transitioning towards circular metals management and highlighting an agenda for future research.

2 INTERNATIONAL LANDSCAPE: CURRENT IMPLEMENTATIONS OF CIRCULAR-ECONOMIC THINKING

This section introduces the concept of the circular economy, which has received significant recent attention from business, government and academics. Next it presents country case studies from Europe which includes Germany, Netherlands and UK, and from China, showing the different conceptualisations and implementations of circular economies, to elucidate the key success factors, and to reflect on the relevance for metal management across multi-product-cycles.

Key points:

- **The concept of the circular economy is gaining major international traction as a framework for promoting an increase in resource productivity. This means using resources, including materials, energy, water, information and strategic relationships, more wisely to capture new economic value and to avoid adverse impacts on the planet and people**
- **The circular economy promotes a shift away from the linear 'take-make-dispose' model towards a 'take-make-recreate' model by designing for recycling, reuse and remanufacturing**
- **Different conceptualisations of circular economies emphasise the diverse benefits from reducing the material footprints of consumer products, avoiding waste to landfill, hedging against future price volatility of resources, and promoting economic diversity and growth across diverse sectors from manufacturing to renewable energy**
- **However, growing demand for constrained resources and the physical and economic upper limits to the efficiency of material cycling highlight the importance of new consumption models that decouple material use from economic growth and encourage sufficiency**
- **Key success factor and capacities for implementing circular economies include policy support, available investment capital for new infrastructure, methods and indicators for recognising natural limits and monitoring progress, and support for innovation**

2.1 THE IDEALISED CONCEPT OF A CIRCULAR ECONOMY: OBSERVING LIMITS AND FOSTERING A REGENERATIVE APPROACH

The ideal circular economy concept promotes a cyclical flow of resources (material, energy, and information, knowledge) as an alternative to the prevailing economic approach where resources are extracted from the environment, processed into products, used, and then discarded. In the circular economy, the value of materials and products is kept flowing through the economy by designing for recycling, remanufacturing, and reusing, reflecting a 'take-make-recreate' approach. The key notion is to maximise value and functionality, or rather minimise value and function loss, in every use-cycle (Figure 2).

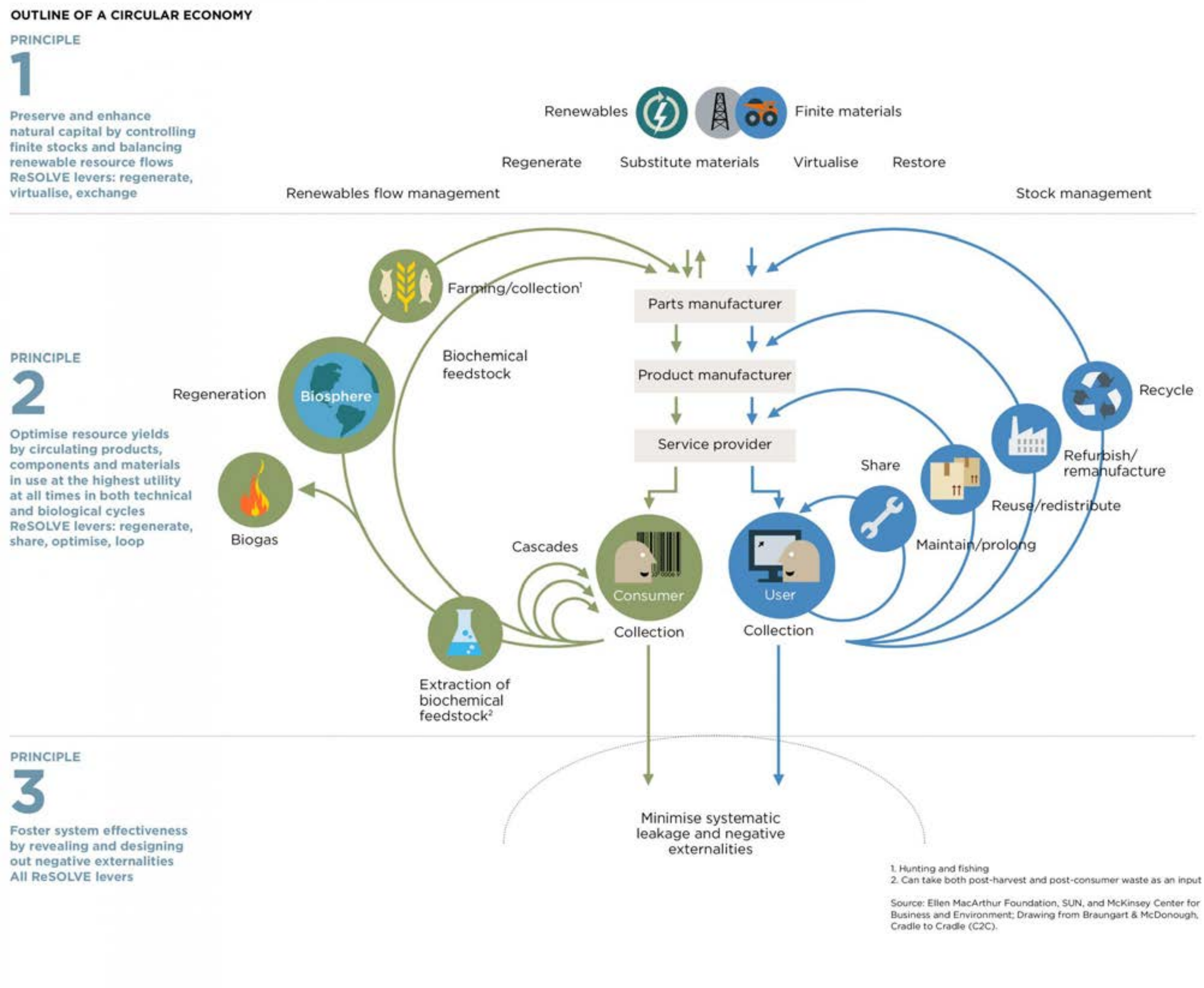

Figure 2: Circular economy for renewable and non-renewable resources (from Ellen Macarthur Foundation, 2015)

The Ellen MacArthur representation of the circular economy makes a distinction between renewable ‘bio-nutrients’ (e.g. bio-fuels, bio-products) and non-renewable ‘techni-nutrients’ (mineral resources and non-renewable energy resources). However, it is important to note that these two spheres are inextricably linked. For instance, minimising resource loss for techni-nutrients can only be maximised by substituting fossil energy resources with renewable energy resources owing to the energy intensity of reuse, remanufacturing and recycling processes. Thus, a pathway towards sustainable resource use necessarily promotes greater use of renewable feedstock and renewable energy to offset the input of non-renewables.

Considering the bio-nutrients, circular economies are likened to a living system with the potential to be restorative owing to the regenerative capacity of renewable resources. This analogy to living systems is extended by giving emphasis to the opportunities to design out waste, i.e., by conceptualising waste from one industrial process as a resource for another, which is comparable to a natural ecosystem. The analogy to living systems and the notion of symbiotic linkages between processes is not a new idea. It draws on established concepts, including bio-mimicry, sustainable product design, green manufacturing and industrial ecology. While circular economy distinguishes itself from these disciplines through a stronger focus on the economy it does not yet have the same established academic grounding and relies on many of the tools and indicators developed by the industrial ecology community (e.g. life cycle assessment, material flow analysis, input-output modelling) to rigorously appraise the environmental and social outcomes of circular economy concepts (Giurco, et al., 2014), including the observance of natural limits to resources. There has as yet been little work done on the social and cost-management features that enable the emergence of such an economy.

The circular economy concept has been criticised for not adequately engaging with unsustainable growth in demand. It is theoretically impossible to continually reuse and recycle materials without some losses or environmental impacts considering, for example, the large energy inputs required in materials recycling (Allwood, 2014). Hence, there is an upper limit in terms of the efficiency of resource cycling and increasing the efficiency alone can only deliver a reduction in demand for the input of raw materials, but not entirely eliminate the input of raw materials. Thus, in the context of continuing growth in demand, a truly sustainable model of the economy must focus on the demand-side with consideration of the natural limits to resources. This highlights the importance of new consumption models that decouple material use from economic growth and encourage sufficiency to reduce total demand. It also highlights the need to foster a regenerative approach that equates to doing more good and less bad because some impacts that are difficult to mitigate may need to be offset by other processes that can deliver positive outcomes. This shift will need significant input from industrial designers and marketing experts to change consumer behaviours. Certain products (for example, in electronics) are directed towards creative obsolescence: the design of products that are only desirable when new. Sufficiency involves consumers demanding "less, slower" and "more regional" to achieve an absolute reduction in resource use and waste generation (Wilts & Palzkill, 2015). Recent research on ethical and sustainable consumerism indicates that consumers can indeed drive change if marketing practices are appropriately setting the context of the benefits associated with such products (Irwin, 2015).

This discussion is summarised for the specific case of metals. Four main factors establish an upper limit for circular economies for metals:

1. Future reuse and recycling can only meet a part of future demand because the amount of metals in the market today is larger than the amount input yesterday whilst current economic growth trajectories continue;
2. There is a lag between the metals input to the market and when they become available (this varies from metal to metal depending on the metal's lifetime of use in products/infrastructure);
3. Based on current technological processes there are losses throughout a product's lifecycle (including dissipative losses during use such as corrosion); and,
4. Recycling activities (despite the potential energy savings compared to primary supply) require the input of energy (direct and indirect) at several stages in the supply chain.

2.1.1 DEFINING THE BENEFITS OF CIRCULAR ECONOMIES

Notwithstanding the above discussion, there are diverse benefits derived from a shift towards a circular economy that are emphasised through the different conceptualisations of circular economies.

Optimising the value of resources through recycling and reuse is important for delivering environmental benefits. These activities deliver a reduction of the material footprints of consumer and industrial products and processes, and reduce demand for continually constrained resources. Furthermore, by increasing the re-use and recycling of products and materials, waste to landfill and its associated impacts on human populations and the environment are lessened. Furthermore, full systemic change and innovations in technologies, materials, design, behaviours and policies affecting all stages of material and product lifecycles are needed to maximise these benefit (European Commission, 2014).

From an individual business perspective, there are economic benefits that may be delivered by countering rising resource prices owing to constrained supply of materials. The approach allows businesses to mitigate the risk of rising resource costs by taking ownership of their products from cradle-to-grave. Through recycling and reuse activities, businesses have more control over the full material cycle of their products and this can offset the need to hedge against future price volatility of resources (Ellen Macarthur Foundation, 2012). However, implementing systems required for effective recycling and reuse is still a barrier for some businesses particularly when compared to disposing materials and products to landfill.

In terms of economy-wide benefits, the circular economy can promote economic diversity and growth across sectors including waste and recycling management, transport and (re)manufacturing capacities and infrastructures. There are also a range of indirect benefits to the economy, including: the development of knowledge and expertise that can be exported; new incentives for the manufacturing sector, e.g., product design for reuse; new incentives for the recycling industry, e.g., introducing increasingly accurate technology for collection and separation; innovation in the logistics sector; and development of new business activity focussing on remanufacturing processes such as repair and reusing electronic products (Lacy et al., 2014).

Already there are many examples of such activities. Generic examples include recycling infrastructure for metals, glass, plastics; markets for repairs and maintenance of electronic equipment; and secondary markets for textiles. These examples clearly show that the current economic model is not necessarily linear and that many opportunities for circular material flows have already been seized. Thus there exists a realistic opportunity that is bounded by technical and economic limitations and existing activities (Figure 3). There are also increasing examples of industrial supply chains cooperating to achieve industrial symbiosis to reduce waste, water and energy, including in Australia. Key examples have been recently reviewed by Golev and Corder (2014) as part of the Wealth from Waste project.

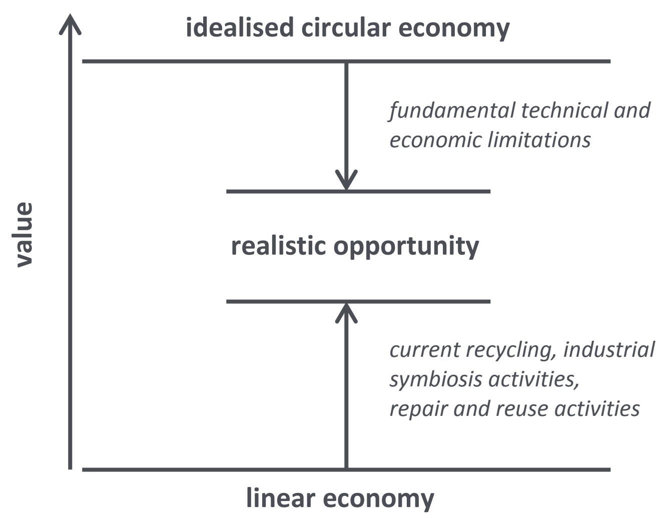

Figure 3: Realistic opportunity in moving towards a circular economy, after Bastien (2014)

2.2 IMPLEMENTING CIRCULAR ECONOMIES

Examples of approaches to implementing circular economies overseas range from those that focus on waste management and resource scarcity challenges, to more recent activities that have expanded to broader strategies that promote sustainability considering environmental, economic and social outcomes. Corresponding to this broadening of the concept is a move away from a focus on single products or material streams, to a wider systems thinking approach (Swiss Academies of Arts and Science, 2014). Recognising this range of activity, circular economy activities can be described at three levels (Yuan, et al., 2006).

1. Single product or individual firm level;
2. Symbiotic relationships between firms;
3. Between production and consumption systems at urban and regional levels.

Activities at these levels can be further classified as production, consumption and waste management activities. For example at the single firm scale this might include eco-design, green purchasing and investment in a recycling system, respectively. Symbiotic associations between firms include eco-industrial parks, renting or sharing equipment or labour resources, and waste-exchange markets. A final layer of activity includes support services, e.g., policies, legislation, management advisory and information exchange systems. These may target specific spatial levels and/or influence activities at all scales.

This range of activities is discussed in the context of circular economy activities in China, UK, Germany and the Netherlands. These countries are reviewed because there has been significant interest in the concept in China (Mathews and Tan, 2011; Yuan et al., 2006; Su et al., 2013; Ma et al., 2013), as well as in the UK; Germany is a driver of resource-use efficiency in Europe, and in the Netherlands, one of the most densely populated countries, there is a strong knowledge base in natural resource management supporting a major agriculture sector with an emphasis on transitions thinking. A comparison of the preconditions in these countries and circular economy implementation highlights are presented in Table 1. We note that this is not an exhaustive review of international circular economy activities, for instance Japan has had a long focus on the promotion of a sound material-cycle society, see e.g.,: https://www.env.go.jp/en/recycle/smcs/index.html

Table 1. Implementation strategies of circular economies overseas (Swiss Academies of Arts and Science, 2014; DEFRA, 2013; Environmental Audit Committee, 2014; WRAP., 2014; Green Alliance, 2014; Bastien et al., 2014)

COUNTRY	CHINA	GERMANY	NETHERLANDS	UK
Overview of country, context and pre-conditions	World's largest economy and centre of product manufacturing/ growing demand for metals and materials globally is driven by growth in China and the region	Driver of resource-use efficiency in Europe/ leader in international market for waste management/front runner in circular economy implementation	One of the most densely populated countries in the world/major transport hub for Europe/ strong knowledge on water management and logistics/ major agro-food sector	Major financial centre / front runner in circular economy implementation with an emphasis of business led innovation
Highlights, challenges, and contrasting conceptualisations of CE	• Circular economy is implemented through Central Government development strategy in 2002 • Shift in focus from waste management to resource use efficiency and conservation from production, distribution to consumption (it encompasses energy efficiency, conservation of natural resources • The 'Circular Economy develop Strategies and Near Term Action Plan' defines goals for industrial sectors • Academic critique of government initiatives concerns the tendency to promote new technologies, reflecting a focus on single components rather whole systems thinking • Future implementation of CE requires better implementation at industrial park and regional scales	• Circular Economy and Waste Law implemented in in 1990s reflecting the waste hierarchy • Product responsibility at core of waste policy, incentivising waste minimisation from production and use phase, maximising opportunities for high value waste recovery • Germany has decoupled waste generation from economic growth within country borders • EU Directives are driving initiatives to reduce potentially adverse effects of waste from German goods generated outside of Germany focussing on hazardous waste/ there are specific regulations for batteries, vehicles, electronic devices, PCBs. • Germany's CE and waste economy employs 250 000 people, estimated worth 50billion Euro in 2010 • New EU guidelines has led to a revision of the German CE and waste law in 2012 addressing environmental protection, climate, resource use, producer responsibility and waste as a resource	• Major drivers come from EU directives • Waste disposal is a major pillar of environmental policy but there is opportunity for greater integrated/ trans disciplinary governmental leadership • Netherlands has promoted knowledge in the area of transitions and transitions management via programmes including Sustainable Technology Development, Knowledge Network for Systems Innovations and Transitions • Integrated resource and value chain management is supported, e.g. the Nutrient Platform supports closing the phosphate cycle through the promotion of cooperation between business, universities, NGOs and government • Low processing tariffs at incineration plants viewed as major barrier for recycling • Government plan to use taxation for incentivising R&D and moving away from direct subsidies seen as a barrier to radical innovation	• Emphasis on business as the driver for CE implementation • main government initiatives (as well as EU Directives) are the LandfillTax and Producer Responsibility Regulations • There are also a number of government supported market based initiatives, e.g. Waste and Resource Action Plan supporting recycling and reuse for residential and commercial sectors by promoting partnerships • Commercial and household waste collection is the responsibility of local government authorities with 376 waste collection authorities across the UK and no standardised waste collection system • Split incentives e.g. collection authorities do not receive benefits from materials collected and so the incentive is to minimise the cost of collect that may compromise quality

While acknowledging that there are clear differences in the conceptualisations of circular economies between the countries and that these conceptualisations are also evolving, for example from a focus on waste management to a broader focus on resource use efficiency, we note some common success factors and capacities, tabulated in Table 2.

Table 2. Key Success factors and capacities for implementing circular economies

SUCCESS FACTORS FOR CE IMPLEMENTATION
• Governmental structures providing long-term and consistent support frameworks, enabling collaboration with business and NGOs
• Legal and regulatory support, e.g., performance standards for end-of-life management, product and material eco-design)
• Availability of investment capital (e.g., for new infrastructure)
• Capabilities for developing and disseminating knowledge
• Capacity for innovation and support for entrepreneurial activities
• Recognition of natural limits and systems boundaries (material, water, energy reduction)
• Methods and indicators for measuring and monitoring progress (social, economic and environmental)
• New consumption modes and lifestyles (underpinned by greater awareness)
• New business models (e.g., sharing economy models, and businesses utilising waste stream flows as process inputs)

There is an interesting contrast in the approaches between China, Germany and the UK. For China and Germany, a strong emphasis is given to governmental structure and long-term support frameworks as key success factors for driving circular economy activities. In the Netherlands too, there has been long terms support from government to develop collaborative approaches towards enabling sustainability-related transitions. By contrast, in the UK, in the absence of government structures, there is an emphasis on business as the driver for implementing circular economy, consistent with the industrial ecology literature (Golev & Corder 2014). These success factors give particular emphasis to government support through appropriate policy and regulation to drive investment in infrastructure for reverse logistics and scaling up from individual firm initiatives to system scale.

A further comparison on CE framework adoption is made between the top-down approaches in China to a market driven approach fostered in the EU in Box 1.

BOX 1:

CIRCULAR ECONOMY FRAMEWORKS IN CHINA

China's circular economy policy development is based on a broad systematic top-down approach, relying more heavily on command-and-control mechanisms implemented on a national scale rather than market based instruments. Chiefly, the development towards a circular economy has been aimed at addressing the divide between rapid economic growth, and improving productivity in response to shortages of raw materials to vital industries (for example, the chemical industry (Li, 2012)). Recently, the resource depletion and associated adverse environmental impacts have prompted Chinese decision-makers to prioritise environmental and natural resource management in state policies, and circular economy initiatives have begun to cover a broader spectrum of Chinese policy. While elements of circular economy initiatives in China are borrowed from Japan, US, and the EU, including take-back schemes, resource efficiency goals and the development of eco-industrial parks (Geng et al, 2012), China's socioeconomic and political environments provide a dramatic contrast to these economies that is reflected in how the circular economy concepts are implemented. It may be argued Chinese policy frameworks provide an ideal platform for the development of new, innovative circular economy developments in a highly regulated environment.

From the late 1970s, the Chinese economy experienced a transition from a tightly planned and controlled economy to one open to Western market forces. The result of this radical transition has been rapid economic growth over the past 30 years that has led to dramatic increases in the wealth of Chinese citizens, growth in employment, and growth in business. With these changes to the Chinese society and its economy has come tremendous environmental stress through air, land and water pollution. Resource demand in China is currently growing at more than twice the rate of the world average (Yuan, 2006), and material and resource shortages are prevalent.

In response to these pressures, in 1999 the Chinese government established the State Environmental Protection Administration (SEPA) as the first central government agency tasked with the promotion of the circular economy in China. SEPA launched a series of pilot projects and commissioned research into the applicability and possible promotion pathways to the circular economy. In 2004, the National Development and Reform Commission (NDRC) took over SEPA in the promotion of the circular economy, refocusing efforts away from energy efficiency into a three layer approach consisting of cleaner production, industrial ecology and ecological modernisation, loosely modelled on international approaches to the circular economy (Geng et al, 2013). The transition to NDRC control of promoting circular economy had a fundamental impact on the development of circular economy pathways in China. The NDRC formalised the development of circular economy as key economic development strategy.

Before 2008, the Chinese government had issued several laws that supported the circular economy, including the Cleaner Production Promotion Law (2003), amendments to the Law on Pollution Prevention and Control of Solid Waste (2005). The transition to the circular economy was formalised further in 2009 with the issuing of the Circular Economy Promotion Law, which is the current framework for the circular economy transition. This new law contains national plans for circular economy aligned municipal solid waste treatment and resource efficiency and emissions reductions. In addition to this law, the 2011 - 2015 National Economic and Social Development Plan places further emphasis on resource productivity at the enterprise level and at the macro level through continual development of circular economy aligned eco-industrial parks and cities.

Transition to the circular economy 'on the ground' generally has followed a three-layer approach (Yuan, 2006). At the enterprise level, firms are required or encouraged to conduct clean production auditing to improve environmental performance. A system of public disclosure ranks enterprises on environmental performance potentially impacting the firm’s public image. Companies are also encouraged to design more environmentally friendly products and adopt cleaner manufacturing processes. On a wider scale, the development of eco-industrial parks and networks is also growing in China, with more than 100 industrial parks throughout the country claiming to be eco-industrial parks. This extends further to the city scale, where the development of the ‘eco-city’ is one of the more prominent environmental movements in China.

CIRCULAR ECONOMY FRAMEWORKS IN EUROPE

In comparison to China, the circular economy transition in Europe is based primarily on targets and regulations applied across the European Union, and individual countries’ legislation and market based initiatives. EU Directives form the backbone of EU waste management and environmental policy, and they provide minimum requirements for adaptation by individual member states. The United Kingdom, for example, relies primarily on market based and business led initiatives to meet EU Member State and domestic obligations (Environmental Audit Committee, 2014).

Regarding metals recycling, in the EU this is well integrated and targeted within waste management and circular economy initiatives and frameworks. One of the more targeted waste streams for metal recycling is in WEEE (Waste Electrical and Electronic Equipment) (Environmental Audit Committee, 2014). Consumer electrical goods contain many metals that are valuable and becoming more expensive and difficult to procure, and can be obtained from casings, cables, magnets, coils, connections and capacitors found in

WEEE. The WEEE Directive is an EU wide directive that sets recovery and recycling targets for WEEE to reduce negative environmental effects from WEEE disposal, and to maximise material recovery from the WEEE stream. Under the WEEE Directive, EU member states have an obligation to process and recover 20kg of WEEE per capita. This target is set to change from 2019, instead targeting 65% of average weight of electrical consumer goods in the market in EU member states.

In addition to the WEEE Directive, several other EU wide regulations and strategies target metals recycling in the circular economy. The Raw Materials Initiative was launched in 2008, and establishes a strategy to boost resource efficiency through reuse and recycling best practice. The initiative has a focus on identified supply-constrained resources, including zinc, tungsten and magnesium. The End-of-Life Vehicle Directive is an example of extended producer responsibility, and aims to reduce the amount of waste generated from vehicles that reach their end-of-life, and to increase the rate of reuse and recovery. The directive applies to motor vehicles and their components, and encourages vehicle manufacturers and importers to design and manufacture vehicles enabling reuse and recycling at end-of-life. Targets for the rate of material reuse and recovery have been set for EU members, and should reach 95% of average weight per vehicle by 2015.

Considering the European policy context, which gives emphasis to business led transition to a more circular economy, the importance of business model innovation is highlighted. As well as new models of consumption that give recognition to the natural limits to resources the range of new business opportunities with particular consideration to the case of metals is discussed in detail in Chapter 6.

Next, these concepts are explored with a specific focus on metals in Section 3.

3 METALS MANAGEMENT ACROSS MULTI-PRODUCT CYCLES

Building on from the broader discussion of the circular economy concept in Section 2, this section provides specific focus on metals management. Metals use in the product cycle and constraints on metals supply is first introduced, followed by an exploration of the limitations and challenges for metals recycling. This section supports the argument for a move towards product-centric recycling as opposed to material-centric recycling to respond to some of the limitations of recycling in the metals supply chain.

Key Points:

- **There is a paucity of data for describing metals flows in society despite modern society's dependence on metals and alloys**
- **Owing to the growing demand for metals and constraints on primary supply, recycling is becoming an increasingly important source for metals in the future, yet for a large number of metals, currently no end-of-life recycling takes place**
- **Metals use in products is diverse, with a trend towards greater complexity in terms of combinations and chemistries of metals and other materials in products**
- **There is an upper limit for the efficiency of recycling, bound by economic feasibility, energy requirements, and the physical/chemical constraints inherent in separating increasingly complex material combinations**
- **The economic incentive for recycling of high value, low volume metals is missing owing to the low intrinsic value per product unit despite the potentially large value of combined mass flows**
- **To increase the upper limit for recycling, greater consideration of the complexity of metal combinations and chemistries in products at the design phase is important**
- **In addition to recycling, other activities for intensifying resource use should be considered, for example, extending the lifespan of products through maintenance and repair to enable reuse, as well as the sharing of products**
- **A level playing field between primary and secondary inputs is needed to drive investment in infrastructure to support secondary material supply chains**
- **The challenges cut across technology, organisation sectors and structures, as well as socio-economic considerations, highlighting a need for better coordination and cooperation across the supply chain and between sectors.**

3.1 METALS USE IN THE PRODUCT CYCLE

Modern society is profoundly dependent on metals and alloys, used in products and infrastructure for transport, food production, housing, water treatment, and energy generation. The different metals may be categorised on the basis of their use in society.

Metals that are used in very large quantities are referred to as 'engineering metals', e.g., aluminium for transportation and iron for structural and stainless steel. Other engineering metals include: copper, zinc and lead.

‘Specialty metals’ are used in smaller quantities compared to engineering metals and typically play an important role in high-technology manufacturing, e.g., antimony is used to harden lead for batteries. Other specialty metals include: cadmium, chromium, cobalt, magnesium, manganese, mercury, molybdenum, nickel, niobium, tin, titanium, and tungsten. A subset of this category is ‘rare earths’ (RE) that includes 17 elements (15 lanthanides, scandium and yttrium). Rare earths are not actually rare in terms of their abundance in the earth’s crust as they often occur in a variety of different minerals, however deposits that are currently economically minable are considered uncommon. Their uses are very diverse, including high-technology manufacturing applications such as for hybrid electric vehicles, wind turbines and smart phones.

‘Precious metals’ are generally characterised as scarce metals with high economic value. They are often used in relatively small quantities, e.g., palladium and platinum for catalyst technologies, including: gold, silver, platinum group metals (PGMs: palladium, platinum, rhodium, iridium, ruthenium, and osmium).

Alternative usage classifications include metals that are classified across the specialty and precious metal categories, e.g., ‘green minor metals’ which play an important role in clean technology manufacturing, such as renewable energy and energy efficient technologies, including: indium, germanium, tantalum, PGMs, tellurium, cobalt, lithium, gallium and RE.

3.1.1 CONSTRAINTS ON FUTURE AVAILABILITY OF METALS

The future availability of metals is very complex. It is dependent on geological information, environmental regulations, supply security, social licence to operate (in the case of mining activities), new technology and technical feasibility, infrastructure, as well as information on above ground metal stocks in products and infrastructure.

Considering the increasing future demand for metals and alloys for diverse and competing uses, the declining primary ore grades, and the significant energy savings when using recycled stock compared to using primary materials – it is foreseen that metals recycling and reuse will be an increasingly important source for metal supply in the future.

However given this reality, there is a significant paucity of data for describing the resource; much of the data that is available does not reflect the dynamic nature of metal flows in society from extraction, processing, use, to end-of- life; and, most information is regionally specific with very limited global estimates for metals that are used in very large quantities (zinc, chromium, manganese, nickel, tin). This is particularly the case for less developed countries (UNEP, 2010).

3.2 CHALLENGES AND BARRIERS FOR RECYCLING

Considering metal flows in society, significant uncertainties arise given the complex lifecycle of metals and metal-bearing products that is depicted in Figure 4. The figure shows a simple metals management model that is defined by four main lifecycle stages: (1) metal production and energy recovery from geological or anthropogenic stock, (2) product design, fabrication and (re)manufacturing, (3) product use, and (4) end-of-first-life. This cycle characterises the use of metals from extraction to the provision of goods and services.

The applicability of the complex interactions between the lifecycle stages for different metals varies greatly owing to a range of technical, economic and physical factors. For example, thermodynamic and/or economic limitations mean that it is not always possible or cost-efficient to un-mix metals constituents from an alloyed form, or from other product constituents. In the case of precious metals such as platinum group metals (PGMs), there are secondary processing steps that can produce pure forms, however this is not the case for nickel in stainless steels.

Figure 5 shows losses associated with every stage in the lifecycle and these are owing to a range of factors including losses during consumption. This might include retired mobile phones stored in people’s drawers, and losses associated with inefficient collection such as metals that could be economically recycled are ending up in landfill.

Certain losses are inevitable based on current product design, for example there may be 'dissipation' to the environment owing to corrosion. This type of 'loss by design' has been characterised in a recent study published by Cluster researchers (Ciacci et al., 2015) that defines four categories: (i) 'in use dissipation' that is defined as the flow of materials for which dispersion into the environment occurs by design, preventing recovery at EOL, e.g., zinc for sacrificial anodes; (ii) 'currently unrecyclable' is defined as material flows for which technological or economic barriers prevent EOL recovery, e.g., rare earth oxides used in glass polishing powders; (iii) 'potentially recyclable' defined as the flow of materials where today's technology could but isn't currently used for recovery, e.g., alloying elements; and (iv) 'unspecified' are material flows that were not categorised owing to a lack of available data. The figure shows that most of the material losses may be categorised as 'potentially recyclable' and 'currently unrecyclable'.

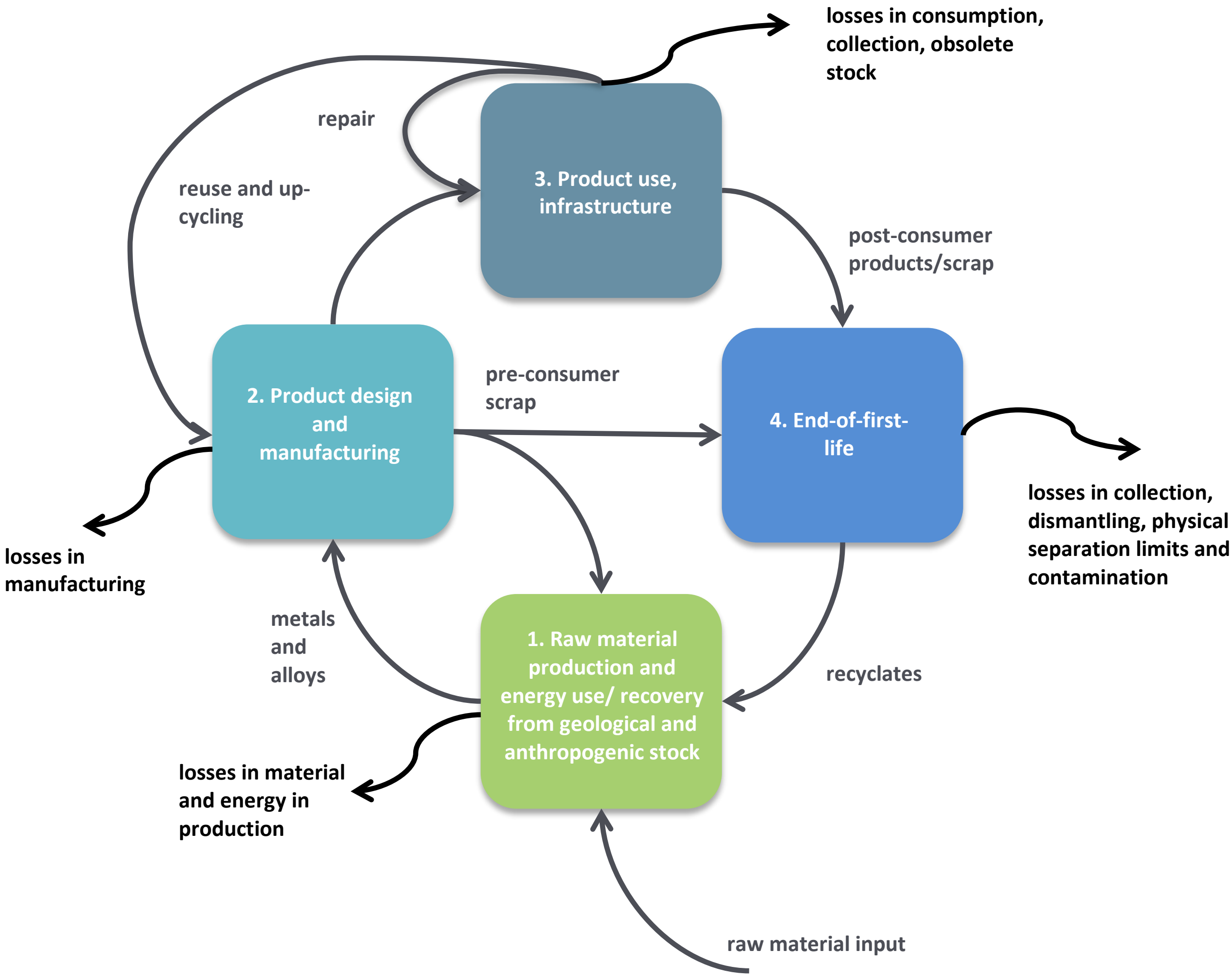

Figure 4: Lifecycle of metals and metal bearing products (after UNEP 2011)

Figure 5: Distribution (%) of metal elements 'lost by design' according to four categories: (i) 'in use dissipation' that is defined as the flow of materials for which dispersion into the environment occurs by design preventing any form of recovery at EOL as, e.g., zinc for sacrificial anodes; (ii) 'currently unrecyclable' is defined as material flows for which technological or economic barriers prevent EOL recovery, e.g., rare earth oxides used in glass polishing powders; (iii) 'potentially recyclable' defined as the flow of materials where today's technology could but isn't currently used for recovery, e.g., alloying elements; and (iv) 'unspecified' are material flows that were not categorised owing to a lack of available data. (from Ciacci et al., 2015)

Considering these complex material flows, the percentage of recycled metal as a portion of total supply that are available to be brought back into the economy has been estimated for 60 different metals (see Figure 6) (UNEP, 2011). Only in a three cases – lead, niobium, ruthenium– does recycled metal comprise more than 50 % of total supply. These metals range across the major use categories, i.e., engineering, specialty and precious metals, respectively. For a large number of metals, little or no end-of-life recycling is taking place, either because it is not economical, or the technology does not exist.

It is important to note that there are significant uncertainties in these estimates that are influenced by the quality of the data, as well as the maturity and scale of recycling activities. For those metals where greater than average recycling content is estimated this may be owing to very efficient pre-consumer recycling where the flow is typically of a high concentration, and therefore relatively easy to recycle, e.g., this is the case for precious metals used in the industrial manufacturing of jewellery. The general advantages of pre-consumer scrap in terms of their potential to recycle, include:

- high concentrations;
- typically well characterised (quality and quantity);
- supply is continuous, or at least predictable; and
- the volumes tend to be relatively high compared to other metal waste generation leading to economies of scale (UNEP, 2009) .

By contrast, post-consumer recycling is often more challenging owing to:

- low concentrations per unit;
- metals are often the minor component in complex material matrix;

- limited transparency in location and ownership of many metal bearing products (automotive or electronic and electrical equipment, EEE);
- there is a lack of infrastructure or systems for collection; and
- dissipative effects (by design and/or use).

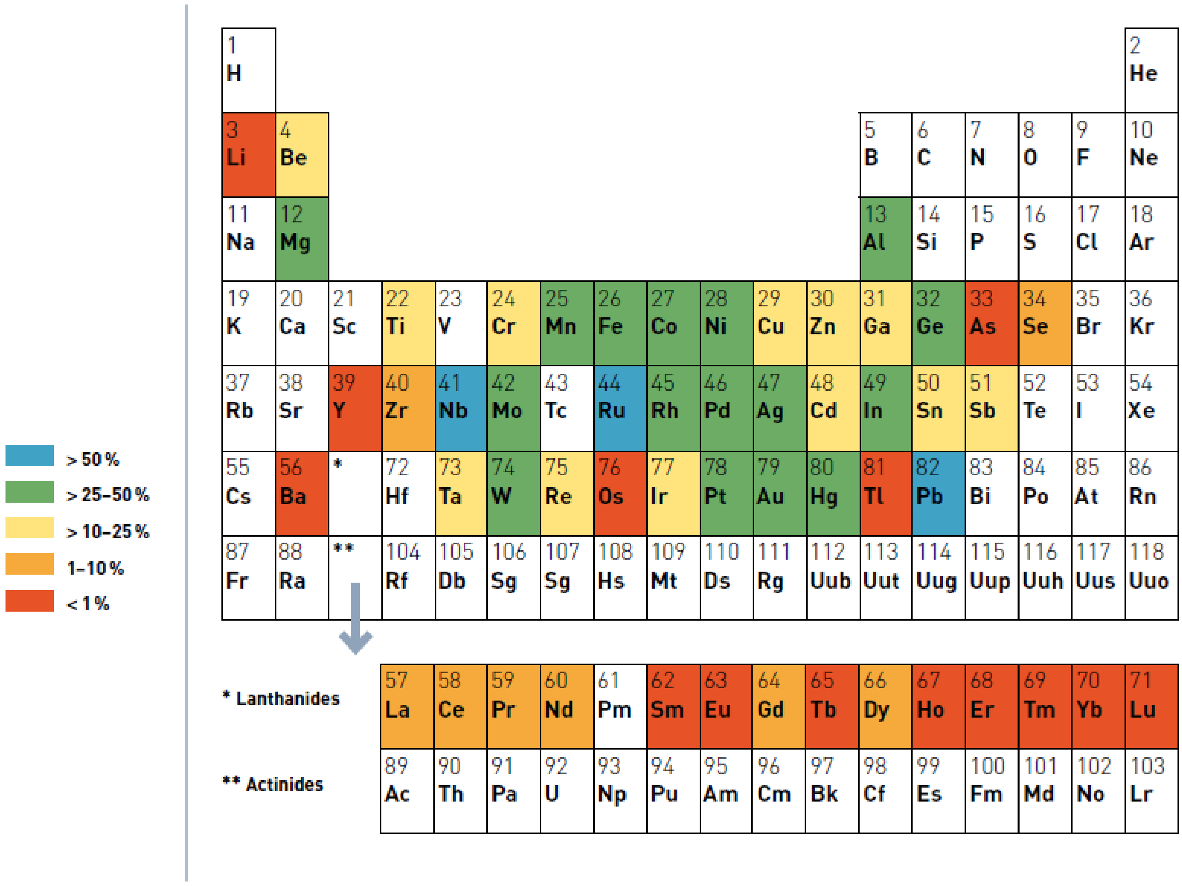

Figure 6: Global average recycling content (fraction of secondary/scrap metal in the total metal input to metal production) (UNEP, 2011)

The broad range of challenges affecting the percentage of recycled metals are categorised in Table 3. It is clear that there is cross over between technical, economic and organisational categories that reflect the complexity of the challenges and the need for better coordination and cooperation between stakeholders throughout the whole product lifecycle. This includes better interregional stakeholder cooperation given the lack of transparency in location and ownership.

Table 3. Economic, technical, organisational and policy challenges, barriers and opportunities for increasing material efficiency (after UNEP 2011, 2013)

ECONOMIC	TECHNOLOGICAL	ORGANISATIONAL	POLICY
• Recovery of post-consumer material resources contributing to supply security and price stability • Missing economic recycling incentive owing to low intrinsic value per product unit despite potentially large impact of combined mass flows	• Increasing complexity of products with new mixes and concentrations of metals and associated limits of recycling technologies to manage complex and diverse products • Product design that make disassembly difficult, or impossible • Lack of recycling infrastructure (particularly in developing countries) • Greater digitalisation of the recycling chain (ID tags, sensors, design tools)	• Managing fast growing streams of discarded products • Lost opportunities when metal bearing products hibernate in people's drawers • High mobility of products and multiple owners	• Need for a level playing field between primary and secondary inputs (e.g. by internalising environmental costs such as carbon emissions) • Recycling targets to capture efficiency of metals recovery from post-consumer products • Provisions for cross-border coordination

3.2.1 UPPER LIMITS TO RECYCLING: THE CASE FOR PRODUCT-CENTRIC RECYCLING

If the metal has sufficient value, and the technology and infrastructure for recycling exists, then it will be recycled. A key consideration is that metal bearing products lose their functionality during recycling activities and so the economics of recycling are driven by the material value that has to pay for collection, sorting, dismantling and physical separation. For engineering metals, e.g., iron and copper, which are used in large amounts in relatively simple applications, recycling is a mature industry with an established business model characterised by high-volume, but low value through-put. However, this driver is missing for high value low volume metals owing to the low intrinsic value per unit product despite potentially large impact of combined mass flows.

A challenge highlighted in Table 3 limiting metal recycling is the growing complexity of products and the diverse and competing uses leading to complex streams of materials. Material complexities in metal products is also highlighted in Figure 7. This is particularly relevant to minor metals including precious metals used in electronic equipment. Because metals are almost always mixed with other metals and materials the value is affected by the purity of the metal that influences the costs of separation and processing. There are also physical and chemical limitations that can limit separation. That is, for certain metal combinations and concentrations, separation is impossible, not yet feasible (without technology development), or not economically viable. When the concentration is very low the collection rate may need to be very high to achieve viable economies of scale.

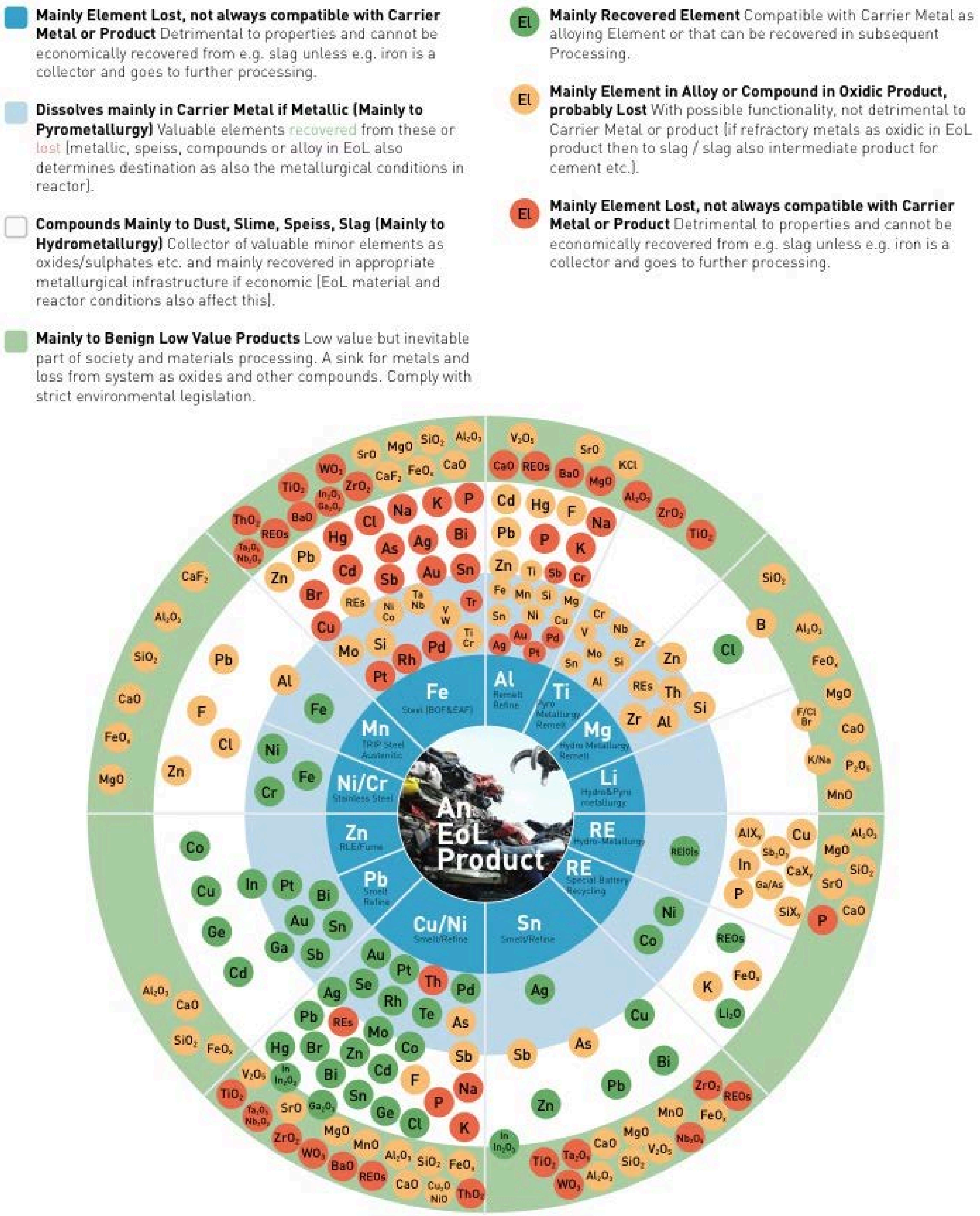

Figure 7: The "Metal Wheel", highlighting material complexity and material losses in End of Life products (UNEP, 2013)

This discussion highlights the importance of design, and/or redesign, to avoid certain combinations of metals and to use components that can be easily separated at the end-of-first-life, i.e., reflecting a change in approach from a material-centric to a product-centric recycling (UNEP, 2013; Reuter and Schaik 2015).

While there is great scope to increase recycling rates, there exists an upper limit (physical and economic) and this also underlines the importance of alternate activities for intensifying resource use. These may include, for example, reuse, extending the lifespan of products through maintenance and repair, and the sharing of products increases resource use intensity. These activities can be facilitated by redesigning products, e.g., where less durable components can be replaced and recycled; such developments require a broader focus involving a range of stakeholders across the supply chain, including consumers. Other key enabling factors and capacities for a circular economy transition influencing production and consumptions systems will be discussed in the context of new business models in Section 6. The next section focuses specifically on the metal supply chain in Australia.

4 METALS SUPPLY CHAIN IN AUSTRALIA: CURRENT BUSINESS MODELS AND CENTRES OF VALUE

The focus of the report herein is to evaluate opportunities for implementing circular material flows in the Australian metals industries with a particular focus on new business models. We begin by providing a contemporary overview of the Australian metals supply chain. Reflecting on the discussion in Sections 2 and 3, there is clearly great scope to leverage Australia's technical and technological know-how in primary production to support and grow emerging secondary market.

Key Points:

- **Mining was the largest exports value-adding sector in Australia in 2012-13**
- **The expertise acquired from Australian mining operations has led to the growth of a world leading Mining Equipment, Technology and Services (METS) sector, contributing over $90-billion per annum to the Australian economy**
- **The technical and technological know-how in the METS sector can potentially be exploited for delivering new value from above ground metal waste streams and unconventional resources. International companies such as Outotec in Finland are already looking to these opportunities**
- **Securing access to specialty metals could reverse the trend away from vertical integration towards 'core business' such that one company has control of both mining and processing, or above ground mining and reprocessing**
- **Currently, all Australian and most global actors in primary metals mining and processing are not also active in secondary metals; Boliden in Sweden is an exception; the emergence of a secondary metals market in China underscores the importance in looking towards this emerging market**
- **Australian metals manufacturing is subject to intense competition from foreign manufacturers and innovation is needed that incorporates new circular thinking, including integrating renewable energy and unconventional inputs, as well as better understanding of appropriate management systems and policies ; Australia's access to abundant natural resources and integration with technologies including additive manufacturing could provide a competitive advantage by offering high-value responsible products and overcoming traditional barriers associated with distance to market and scale**
- **Rapid professionalisation in the recycling sector from small uncompetitive operations towards national and international aggregation has resulted in a recycling industry in Australia with pockets of capability, but not necessarily proper economies of scale.**
- **Remanufacturing is emerging in niche areas, supported by corporate-led sustainability policies such as at Fuji Xerox Australia, with significant opportunity for growth.**

4.1 MINING

Mining was the largest exports value-adding sector in Australia in 2012-13. Over the last decade the structure and business models of mining companies have also changed, with increased mergers and consolidations, fewer mid-tier national companies (FMG would be an exception) and fewer multi-commodity companies. Mergers by major international companies are shown in Figure 8. Some companies have sought to turn unprofitable mines to profit through improved operating practices and cost reductions.

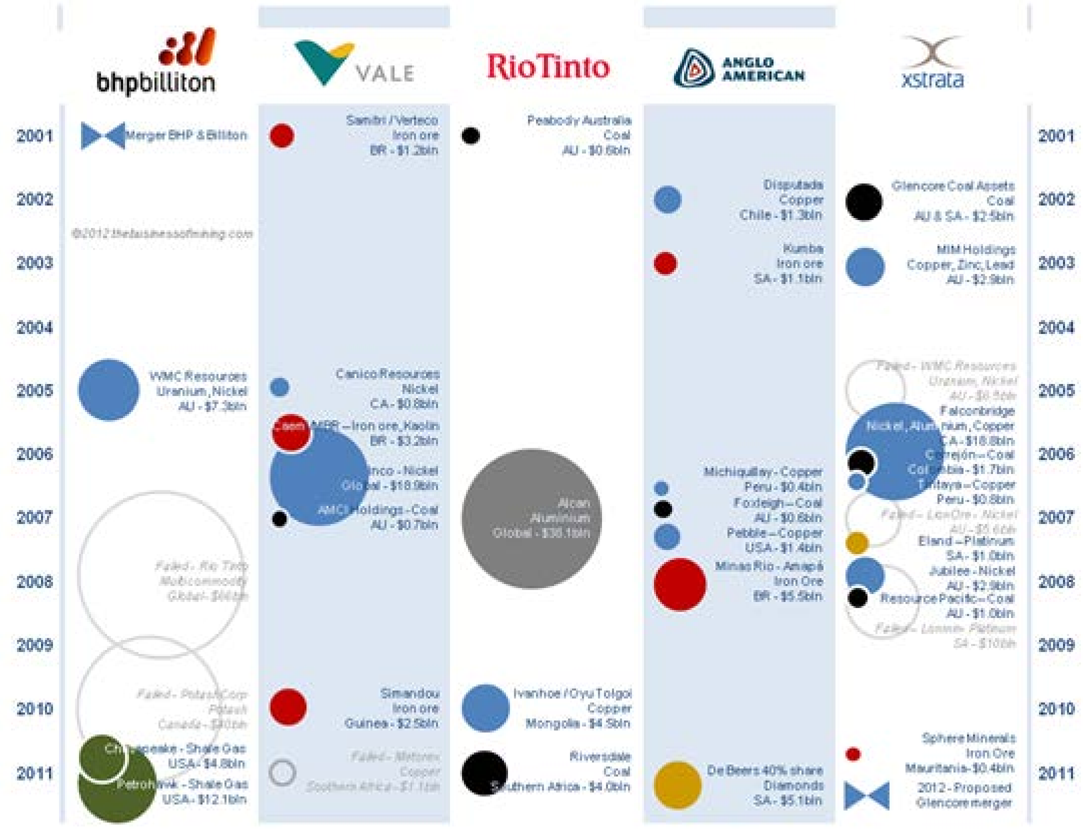

Figure 8: Mergers in major mining companies. [Key: circle size = value; open circles = failed mergers; colours = commodity: black = coal, blue = nickel, yellow = platinum/diamond, grey = aluminium, red = iron ore] (Source: thebusinessofmining.com)

A generic contemporary mining business model is shown in Figure 9. It shows the profit or loss is dependent on sale price and volumes, as well as operating costs. Influencing factors are also identified and the declining quality and accessibility of existing (and often even newly discovered) ores is putting pressure on mining costs – including due to the energy costs in Australia. The central node shows that the mining may be operated at site by the owner or contracted. The evolution of the drivers and business models associated with contract mining is on-going (Dunlop, 2004) and may be expected to continue as global moves towards the circular economy develop.

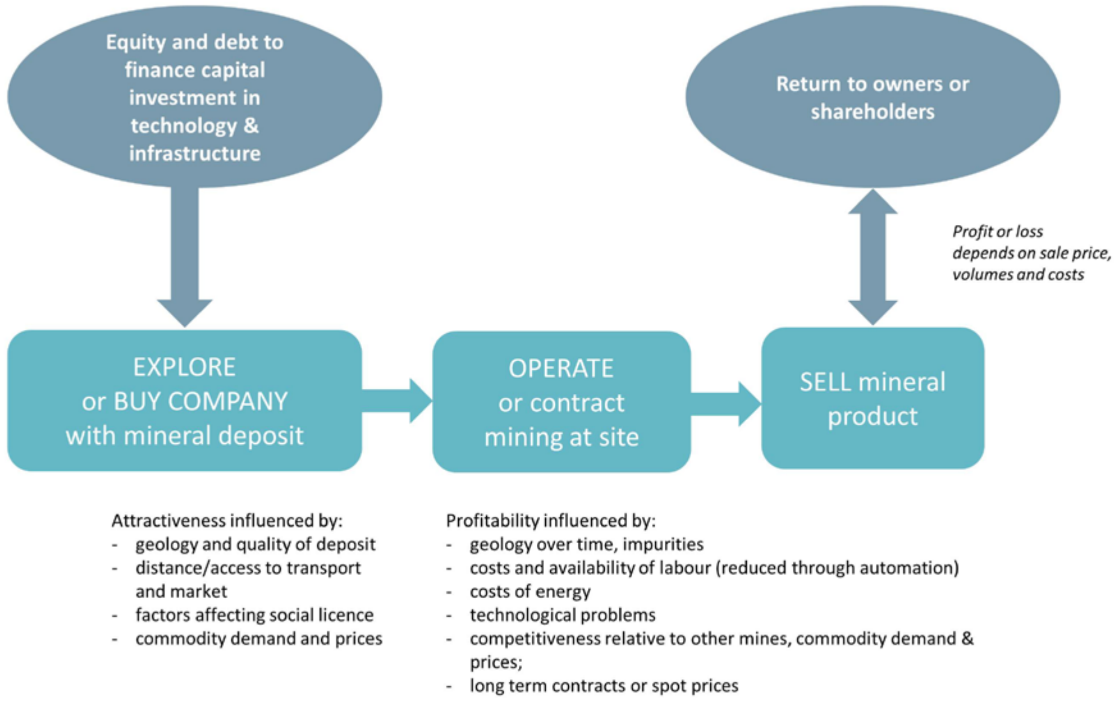

Figure 9: Overview of mining business model

4.1.1 THE MINING EQUIPMENT, TECHNOLOGY AND SERVICES SECTOR

The commodity boom in minerals in Australia has built a large and reputable mining equipment, technology and services (METS) sector locally that fosters exploration, mining, metallurgical and managerial innovation. The expertise acquired from Australian mining operations has underpinned the development of the local METS sector (Tedsco and Curtotti, 2005) which has become a key driver for Australia's export economy worth over $90-billion in annual revenue (Austmine, 2014). Australia is recognised a global leader in providing advanced mining services and the sector is one of Australia's largest export sectors on its own, as well as supporting the growth and development of the mining sector itself.

The METS sector in Australia can be broadly defined to comprise technology and service based businesses that service the mining industry. This covers a wide breadth of services, including:

- Core engineering and design services
- Core mining and general equipment
- Consulting services (i.e., mining and geological consultation)
- Information technology equipment and related services (i.e., information management systems and automation)
- Specialised technology (i.e. analytical laboratories, and mining instrumentation)
- Water management and environmental rehabilitation
- Mineral processing

Growth in the METS sector is characterised by the evolution of upstream supply sectors responding to growing demand from further down the supply chain. The METS sector story in Australia is analogous to the evolution of other technology and equipment supply sectors internationally. One particular example is the forestry sector in Finland, evolving from a lumber supply industry, to providing diverse range of milled lumber, pulp and paper, to specialised equipment and chemicals (Fuchslocher, 2007). This evolution is shown in Figure 10.

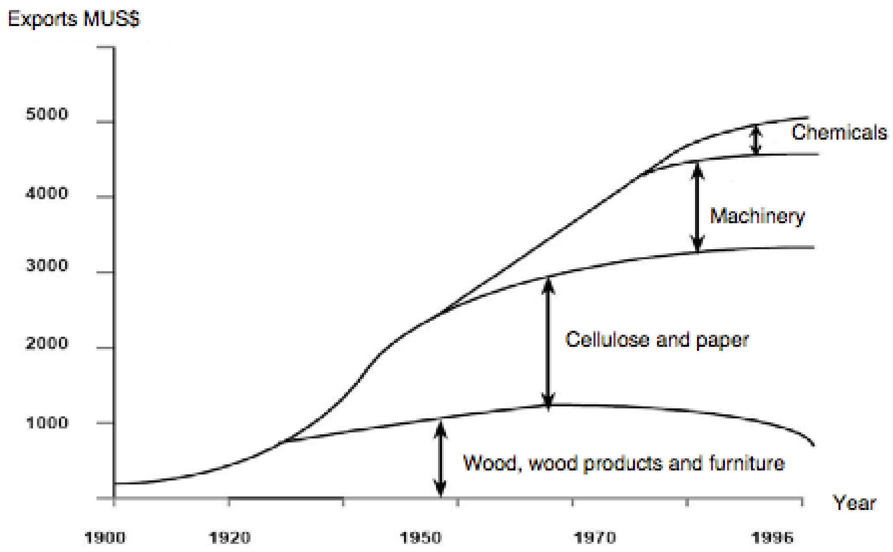

Figure 10: Evolution over time of a technological intensive industry (Finnish lumber) from raw material supply, to supplying complex products, equipment and services (Fuchslocher, 2007)

Figure 10 exhibits parallels with the evolution of the METS sector; with core mining operations (ore extraction for example) evolving (to varying degrees) into vertically integrated operations (e.g., mining, smelting and refining), and on into the mining equipment export sector, and mining services and expertise. Continual focus on exporting mining equipment will mean the METS sector will be metals intense, however if more focus is placed on the exportation of mining services and expertise (Chavan & Agarwal, 2015) , metals use in this sector might de-intensify.

The technical and technological know-how in the METs sector can be exploited for delivering new value from above ground metal waste streams and unconventional resources.

4.2 MILLING, SMELTING, REFINING

Vertical integration (e.g. as in BHP steel 30 years ago, Alcoa more recently up until the closure of recycling in 2014) where a company would own a mine and smelter has often been overturned in favour of a focus on 'core business', for example, with steelmaking (by BlueScope steel) separated from mining (by BHP Billiton). The exception to this general trend has been in some specialty minerals, where securing supply for the product has involved a direct arrangement with the mine, for example Galaxy Resources Limited constructed a lithium carbonate processing facility in China for producing battery-grade lithium (recently sold) (http://www.galaxyresources.com.au/), or in alumina mining and aluminium smelting where Alcoa or Rio Tinto Alcan would own both.

The continuation of mergers, however, is also creating mega-integrated companies (Glencore Xstrata) as shown in Figure 11. It has been proposed that this will mean integrated companies think more about the customer (via flexible schedules) and align output with demand, including just-in-time production where feasible. It also improves supplier power (as well as reducing costs from eliminating the trading department) (TheBusinessofMining.com, 2014).

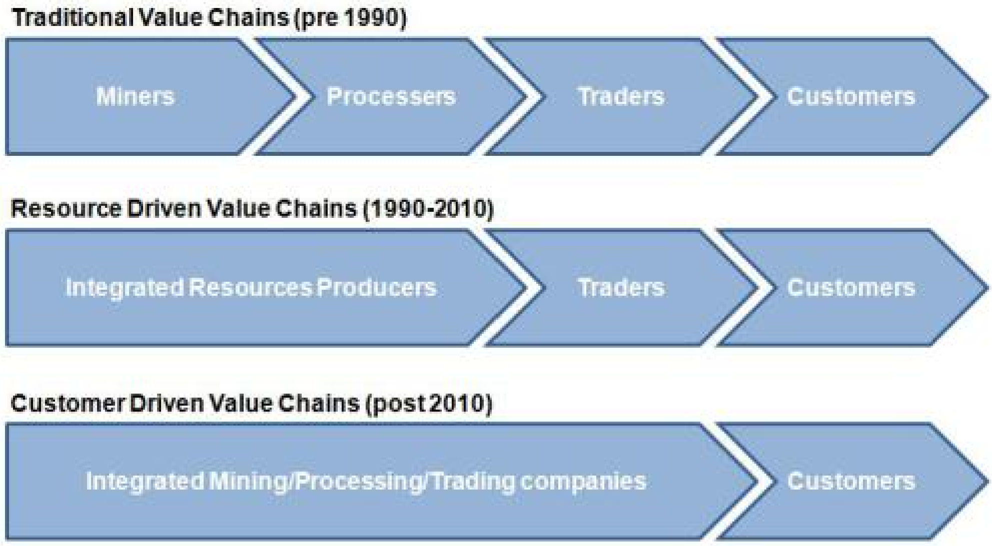

Figure 11: Integration over time (Source: thebusinessofmining.com)

Currently, most of these global actors in primary metals mining and refining are not also active in secondary metals, however there are exceptions overseas, such as Boliden in Sweden. Typical business models for smelting / refining in Australia are characterised by the purchase of ore by a smelter operator at an agreed specification from a vendor. The smelter operator then sells the refined metal. Toll refining, that is less common in Australia, although Ausmelt was involved with toll smelting zinc (Australian Mines Atlas, 2014), is when the smelter operator is paid by the vendor for the delivery of a smelting service.

Of particular note is Nyrstar's planned redevelopment of the Port Pirie smelter to a 'multi-metals processing and recovery facility'. The upgrade represents a shift in business model away from a primary focus on lead smelting to a broader focus on high value metals, including precious metals from diverse metal bearing feedstock including waste (http://www.nyrstar.com/investors/en/Pages/Port-Pirie-Redevelopment.aspx).

4.3 MANUFACTURING IN AUSTRALIA

The manufacturing sector in Australia can best be characterised as a sector under continual pressure from both internal and external factors (Agarwal et al, 2014). Locally, Australian manufacturing has been hampered by the high cost of energy, and a high Australian dollar – driven primarily by the commodity boom in minerals in response to strong demand for raw materials from rapidly industrialising economies (Jacks, 2013). The high Australian dollar (leading to higher export prices), and the industrial sector's focus on low to medium technology manufacturing, has rendered traditional low-cost manufacturing uncompetitive in the face of immense pressure from lower-cost international competition (i.e., China) (Green & Roos, 2012; Green et al, 2014). The impacts on the local manufacturing industry in Australia have been severe, with recent closures of car manufacturing plants and the cessation of all car assembly in Australia by 2018 represents a major blow to the local manufacturing sector.

Figure 12 shows the percentage share of the manufacturing industry and metals manufacturing to Australia's gross domestic product from 1984 to 2014. The manufacturing sector's share of GDP in 1984 was 31% of national GDP, contrasted by a share of 6.2% in 2014 – an approximately 80% reduction in total share of GDP in a 30 year period. This is despite a growth in value in manufacturing goods over this same period (Green, 2015). The reduction in metal manufacturing's (including metal product fabrication) share is similar to the broader manufacturing sector, with a 5% share of GDP in 1984 compared to approximately 1% in 2014.

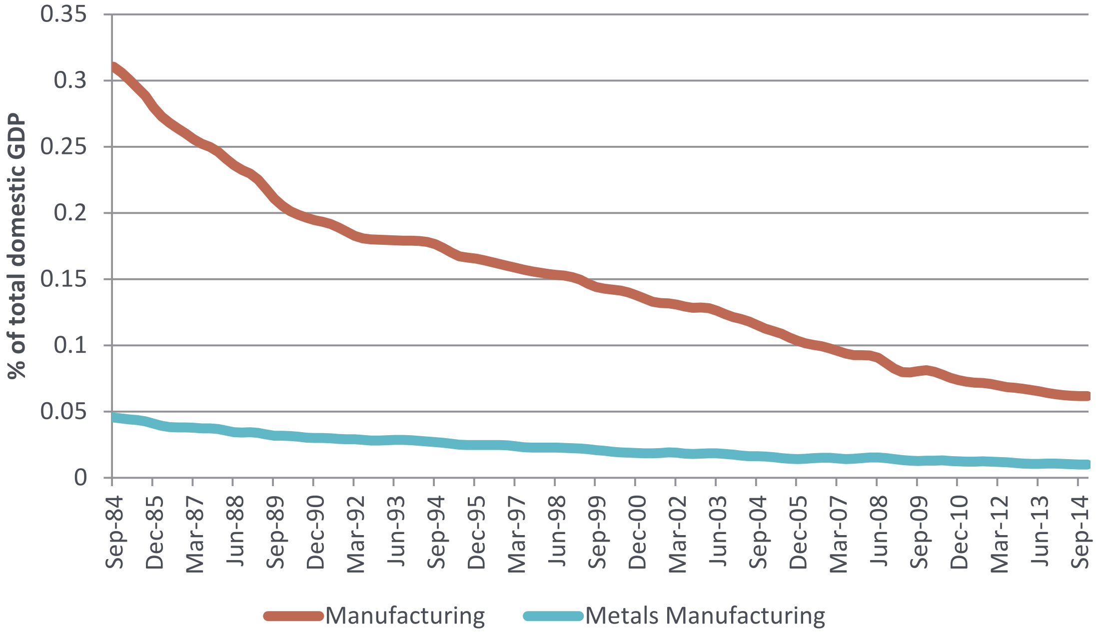

Figure 12: Percentage share of GDP for the manufacturing sector in Australia (trend) (ABS, 2014)

Metals manufacturing in Australia is subject to intense competition from foreign manufacturers owing to cheap overseas imports of fabricated metal products, and a saturated consumer market. Metals manufacturers from overseas (namely China) are able to operate at lower operational costs than in Australia (IBISWorld, 2015). In addition, slow rates of product development and high levels of product standardisation among low value-added products have resulted in an influx of cheaper overseas imports into the Australian consumer market. Weak activity in downstream markets (for example, car manufacturing and assembly) has also restricted demand for a range of products from metals manufacturing,impacting on local metals manufacturing firms.

While depreciation of the Australian dollar is expected, local manufacturing firms will continue to struggle to compete with overseas manufacturing from China and elsewhere. Metal substitutes (including carbon fibre) may also provide further pressure on the metals manufacturing sector in Australia. Ignoring macroeconomic conditions, innovation is necessary to provide competitive advantage to Australian manufacturing to compete within this high-cost environment. Innovative manufacturing must incorporate new thinking with alternative/renewable materials inputs, while providing high-value products at low costs. There are unique opportunities for innovation in (metals) manufacturing in Australia, due to access to abundant natural resources (Green & Roos, 2012), and integration with technologies including additive manufacturing could provide competitive advantage for Australian manufacturing firms.

4.3.1 ADDITIVE MANUFACTURING

While manufacturing is in decline, the industry is of a very different composition and output than the past (Green, 2015), and must innovate to meet the challenges of a resource-constrained future. Additive manufacturing (AM) exemplifies the features of advanced manufacturing, and enables manufacturing with reduced material and energy inputs and waste outputs relative to subtractive manufacturing through the 3D printing of materials. Initially limited to plastics for rapid prototyping of products, AM is now being utilised in the manufacture of metal parts across a range of industries (Giurco et al, 2014). AM can provide scalability and distributed production – with a mix of localised and global production/shipping, redefining the geographies of production and consumption, and enabling mineral rich economies to create value-adding products (Giurco et al, 2014). AM also has significance in the design and manufacture of products that can be adapted and personalised so they acquire a higher-value of their own for the user (Ashby, 2013). Whilst AM does not necessarily lead to resource productivity, the thoughtful application of AM within the circular economy may be characterised in the following scenarios (Giurco et al, 2014):

- **Extension of product lifetimes:** through the affordable manufacturing of replacement parts. Products repaired by consumers will ultimately be driven by cost and convenience factors;
- **Mass customisation, targeted production:** with less of a one size fits all approach typical of today's manufacturing, there is potential for a reduction in the stock of superfluous products;
- **Consumer assembly, design for disassembly:** may drive the design of products to be readily assembled and disassembled by consumers, which in turns greatly aids materials recovery;
- **Enabler of local recycling:** AM could foster the recovery of metals and materials locally, and provide a feedstock of recyclables for production utilising AM
- **Rapid prototyping**: Reducing the timeframe of prototyping could accelerate the time and reduce the costs associated with the commercialisation of new products and technologies

4.4 RECYCLING

A generic overview of the contemporary recycling business model is shown in Figure 13.

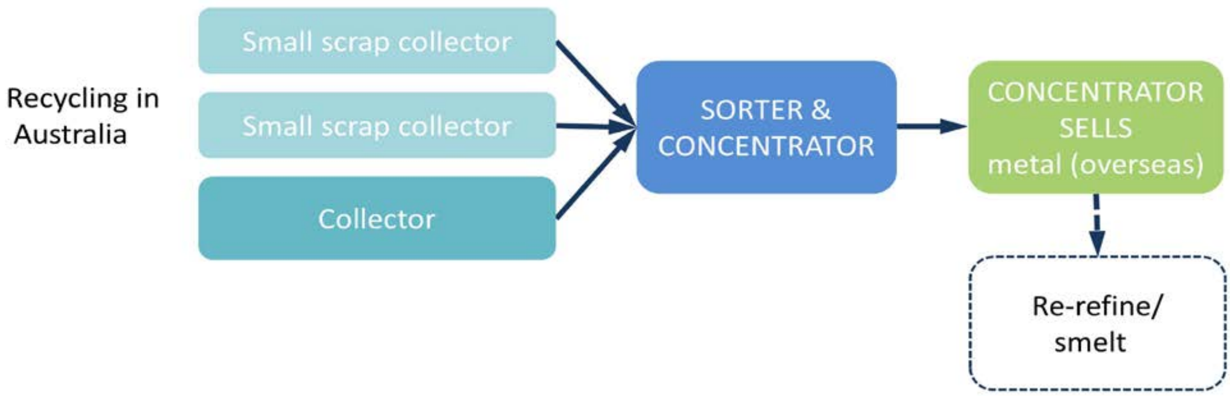

Figure 13: Overview of recycling business model

The industry is mature and concentrated (small number of major players). It is still innovating through the acquisition of new technology, but not by actively looking upstream along the supply chain to work with product designers on design-for-recycling.

As shown in Figure 13, larger companies are fed by many smaller players. There has been a rapid drive to professionalise from small uncompetitive operations due to small margins, to bigger groups with the potential for national and international aggregation (B. Edwards, *pers. com*. 2014). This leaves an industry in Australia with pockets of capability, but not necessarily proper economies of scale. A more detailed evaluation of the metal recycling industries is given in Chapter 5

Estimated metal tonnages in and values are represented in Figure 14.

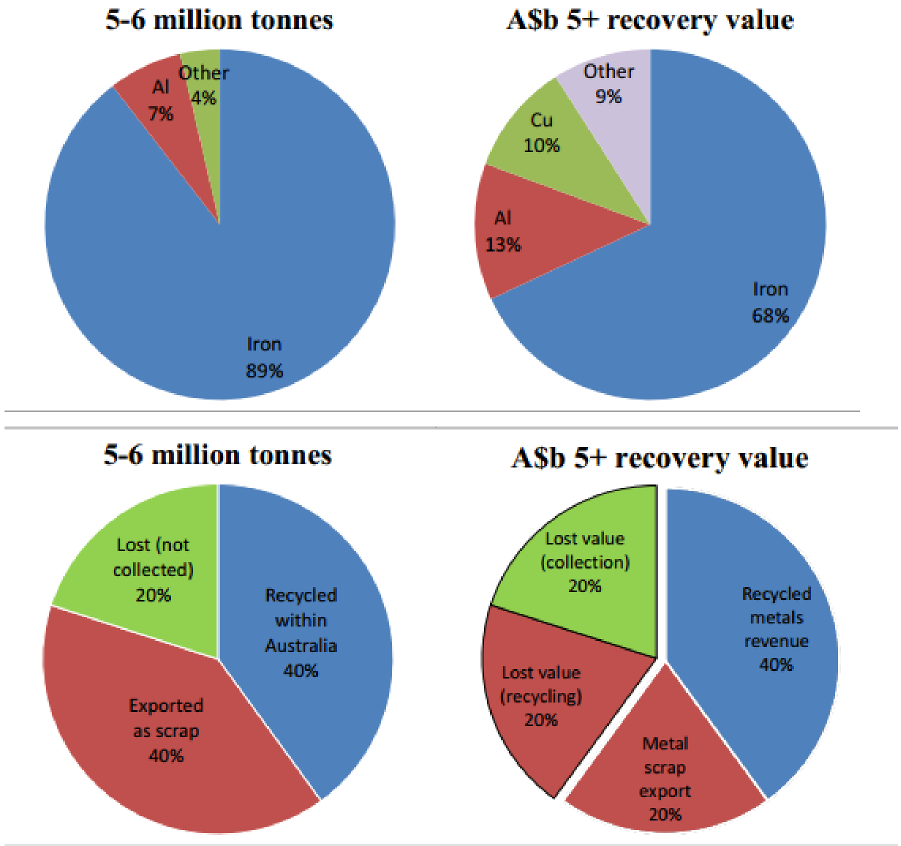

Figure 14: Estimated metal waste streams in Australia (2012/13) (Golev & Corder, 2014)

Considering steel scrap, whilst some steel is re-smelted locally (Arrium handles about one million tonnes across the globe, including in Australia), much is exported as shown in Figure 15, with key destinations being Vietnam, Indonesia, Malaysia and Thailand. These are not necessarily the final destinations of the metal.

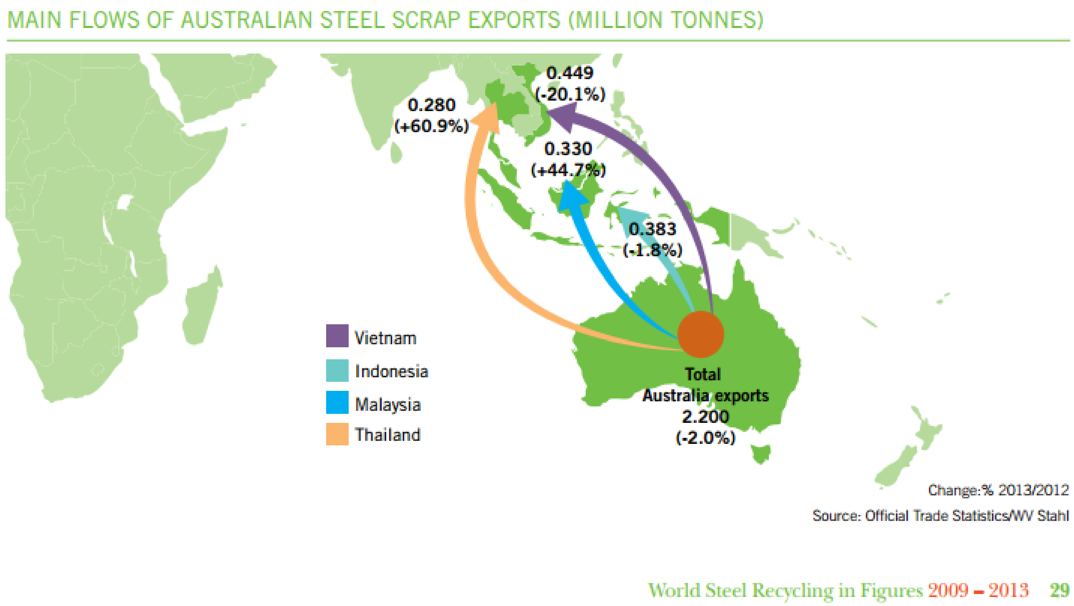

Figure 15: Destination of steel scrap exports from Australia (Bureau of International Recycling, 2013)

4.5 REMANUFACTURING

Remanufacturing is the process of restoring used products to like-new performance, for resale on the market. These remanufactured goods go by multiple names including refurbished, reconditioned, rebuilt, recertified, and others (Abbey et al, 2015), indicating revitalisation of dormant usefulness that many discarded objects hold. Remanufacturing has gained significance recently as a strategy for companies to recover value from end-of-life products, and also to address increasing corporate and product sustainability legislation (Subramoniam et al, 2010). More to this, remanufacturing is an embodiment of product-centric recycling—key to circular economies.

The remanufacturing process is similar across different products, materials and supply-chains: (1) products are delivered to a remanufacturing entity, through product returns, waste collection, or closed-loop supply chains; (2) the remanufacturer disassembles and cleans the products; (3) all missing, defective, worn or broken parts are replaced; (3) the product is then reassembled and tested, ensuring performance of the remanufactured product is comparable to a similar new product, and; (4) the product is returned to the market for resale (Lund, 1984). Remanufacturing is distinct from recycling, in that the form of the product is retained, whereas recycling results in the destruction of the product form to break down products into their constituent components. This places remanufacturing higher on the waste-hierarchy than recycling, but lower than product reuse, which does not go through the process of replacing faulty parts and ensuring as-new functionality.

The market for remanufactured products is large, estimated at over $100-billion per year (Abbey et al, 2015). Market share of remanufactured products is highest in the transportation industry, and other industries with high investment capital products (Lee et al, 2001), such manufacturing, construction and energy generation. In these sectors, products (for example, aircrafts) go through regular maintenance where component parts are replaced routinely. In the case of aircraft, airframes originally manufactured decades ago are still in operation, with new engines, new cabins, and new airframe components. Likewise, industrial machinery over the course of many years could have all of its original parts replaced, yet still retains its original purpose. In these capital-intensive sectors, remanufacturing is a cost-effective way of keeping products and capital operational.

On a smaller, consumer scale, remanufacturing is well placed for closed-loop supply chains. Producer responsibility and product take-back schemes can provide opportunities for product manufacturers to remanufacture goods passed their first end-of-service-life period. Replacing defective components allows manufacturers to resell used products, ensuring continued market share with reduced material demand. More to this, third-party manufacturers are well placed to procure used products, and remanufacturer them for resale—in the process creating new supply chains of collection and distribution.

With Australia's dwindling manufacturing capacity, opportunities may be present for Australia's past manufacturing expertise to be utilised in remanufacturing as a growing end-of-life market. Australian remanufacturers could act as third party agents for global product suppliers; such is the case with Australia's large automotive aftermarket parts industry (AAAA, 2013). Leveraging on Australia's past automotive manufacturing expertise, this sector has experienced growth due to the growth in ownership of foreign and locally manufactured vehicles.

Fuji Xerox Australia's Eco Manufacturing centre is another example of remanufacturing in Australia. As part of its producer responsibility obligations, Fuji Xerox operates its Eco Manufacturing centre which remanufacturers approximately 150,000 parts and subassemblies annually, and accounts for 30% of Fuji Xerox Australia's spare parts[1]. Not only does this lead to reduction in environmental footprint from diversion from landfill and negating the need for new resources, it leads to significant cost savings also, by embodying the wealth from waste concept.

Remanufacturing is not a new concept, however is a response to sustainable materials management that is more energy efficient, and perhaps more pragmatic in some cases, to recycling. With Australia's

[1] http://www.fxasustainability.com.au/eco_about.php

diminishing manufacturing assets and its reliance on imports, remanufacturing in the future may also offer Australia some security in its product supply, and the creation of new value centres. Remanufacturing can also be highly dependent upon a technically skilled workforce, hence playing to one of Australia's key advantages.

4.6 A NOTE ON MARKETS AND TRADING

In addition to the physical infrastructure for mining, processing, using and recycling metals,the systems that include the exchange and trading of metals are also a powerful influence on the landscape.

PRIMARY MARKETS

The London Metals Exchange conducts more than 80% of non-ferrous business. The fact that many contracts are for three-month futures stems from the time it took copper to arrive in London from Chile over one hundred years ago. This shows the importance of cultural and institutional arrangements in enabling or constraining new business models.

For example, the rise of digital trading has been a disruptive force for booksellers via Amazon, but also for metals traders and the potential for B2B exchanges. As shown in Figure 16, the initial advent of digital trading did not align with users' expectations, including inadequately capturing the social and cultural relations present in existing trading situations (Cousins and Robey, 2005). The onset of the digital economy will be a strong force in the management of metals, including through the potential to better locate urban stocks of metals and to understand their composition.

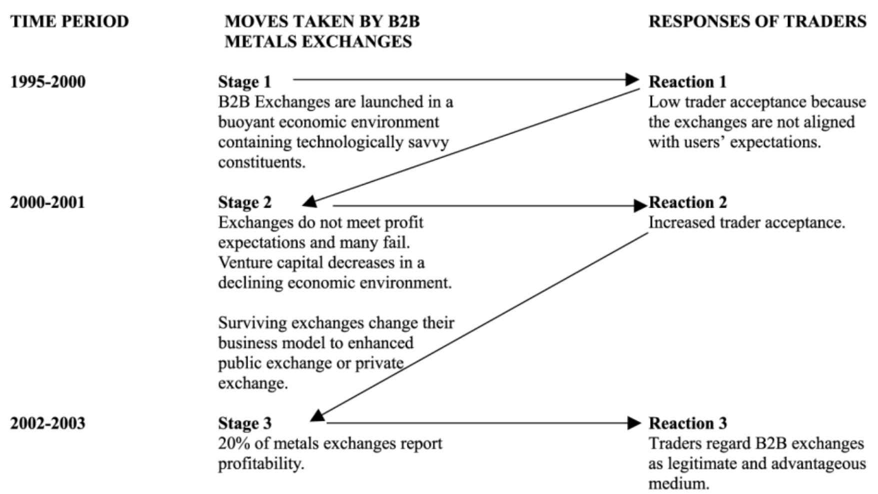

Figure 16: Evolution of digital metals exchanges (Cousins & Robey, 2005)

SECONDARY AND END-OF-LIFE MARKETS

Following a three month trial in 2014, Shanghai Metals Market (in cooperation with China Nonferrous Metals Industry Association Recycling Metal Branch (CMRA)) launched a secondary metal pricing platform to publish prices for over eighty distinct categories of secondary copper, lead, aluminium and tin (www.smm.cn/secondary/index.php). This underscores the importance that China sees in secondary metals trading. China is the world's largest importer of secondary metals and in 2013 "China's production of secondary copper, aluminium, lead and zinc totalled 10.73 million tonnes", representing an annual increase of 3.3% (SMM, 2014).

In other sectors, e.g. tyres, the Australian Government is looking at developing secondary markets: connecting, aggregating, end of life markets and this experience could inform the evolution of other secondary markets here. Currently lead and gold, steel, copper and aluminium have developed secondary markets and can be considered useful examples for exploring extension to other commodities.

In summary, this Section has described an overview of the current business models active in the metals supply chain, the next section provides elaborated detail with a focus on the recycling industries.

5 A CLOSER LOOK AT CONTEMPORY RECYCLING INDUSTRIES IN AUSTRALIA

Key capacities and capabilities for circular metal flows exist in the waste management and recycling industries. Hence this section provides a closer look at the recycling industries and initiatives in Australia. A broad view of recycling is taken recognising reuse, remanufacturing and reverse logistics. First, an overview of the local recycling sector is given, including key businesses. This is followed by an evaluation of the current disconnects in the landscape, and a brief overview of the local policy. When viewed in the context of sustainable metals management, Australia has ample opportunities for growth in metals recycling, with a mature industry, and accommodating policies such as the *National Waste Act*.

Key Points:

- **The industry of sorting and concentrating of scrap metals, most destined for overseas, is mature with high barriers to entry for reputable operators, due to the capital intensity of the sector; increases in the demand for metals product will increase profits in the sector, but it also remains vulnerable to global commodity prices and demand**
- **E-waste is a fast growing waste type identified as a major environmental concern. A key driver for local recycling in this sector has been the Product Stewardship Act 2011 that is currently under review**
- **Increasing sophistication of the sector requires collaboration and network linkages across disparate components of industrial activities**
- **Analogous to the identification of resources in below ground stocks of metals that is facilitated by Geoscience Australia, reinstating the ABS "Waste Account" would go part-way to assisting in the characterisation and evaluation of the profitability of urban mining activities**
- **Some progress is being made with EPR policy, the National Waste Act, and state-based recycling policies making impacts. Further policy coordination, such as container deposit legislation could justify further recycling infrastructure.**
- **Opportunities for circular material flows are not on the radar for the Australian metal industries, with the focus of recycling in Australia being material-centric and efforts largely aimed at avoiding waste to landfill, and not sufficiently focussed on reducing waste generation that continues to increase**
- **Innovations in the way products are consumed and how materials are used is required to move towards product-centric recycling, and to extend the product-centric recycling agenda up the supply chain to design sufficiency-based consumption models**

5.1 CHARACTERISING THE RECYCLING SECTOR

The recycling sector is made up of all companies that are involved in the collection, transfer, sorting and processing of materials for use in the place of raw materials in the manufacture of the same or similar non-waste product (NetBalance, 2012). Recycling is not just an activity carried out by recycling-only companies, many companies who contribute significantly to the recycling sector, have activities such as manufacturing or logistics as their core business. This makes analysis of the recycling industry from official statistics challenging as a significant proportion of the firms involved in the recycling value chain are listed under various data collection categories.

The highly integrated nature of metals recycling and reuse industrial activity makes it difficult to use existing data sources for industrial analysis. This data gap is one of the central drivers behind the primary data collection on the industry proposed to be undertaken in the subsequent phase of the Wealth from Waste project. However through analysis of a number of industrial sub-sectors it is possible to get a picture of the current activity in Australia. These sub-sectors include scrap metal recycling and e-waste collection and processing. These sub-sectors really only cover the collection, transfer and processing of materials, and in a limited sense the remanufacturing (usually into simple form). More complex remanufacturing and niche or specialised collection and processing, and going even further up the supply chain to design and consumption models (e.g. leasing activities) are not possible to analyse from these data sources.

5.2 OVERVIEW OF THE MAIN METALS RECYCLING AND REUSE BUSINESSES IN AUSTRALIA

A brief sector overview of scrap metal recycling and e-waste collection and processing is provided below.

Major metals recyclers (and non-metal recyclers) are represented by the Australian Council of Recyclers (ACOR). The remit of this industry association is:

- "Lobbying governments for policies and regulations that support the recycling and resource recovery industry
- Representing businesses in the supply and value chain of recycling and resource recovery
- Raising the calibre of resource recovery and recycling debate in Australia in order to achieve commercial solutions for members" (ACOR website, 2014)

- A secondary industry association is AMRIA, the Australian Metal Recycling Industry Association.

Taking the members of the ACOR membership base who are concerned with metals, these companies and their position on the supply chain was mapped to provide a contemporary picture of the Australian sector and is shown in Figure 17.

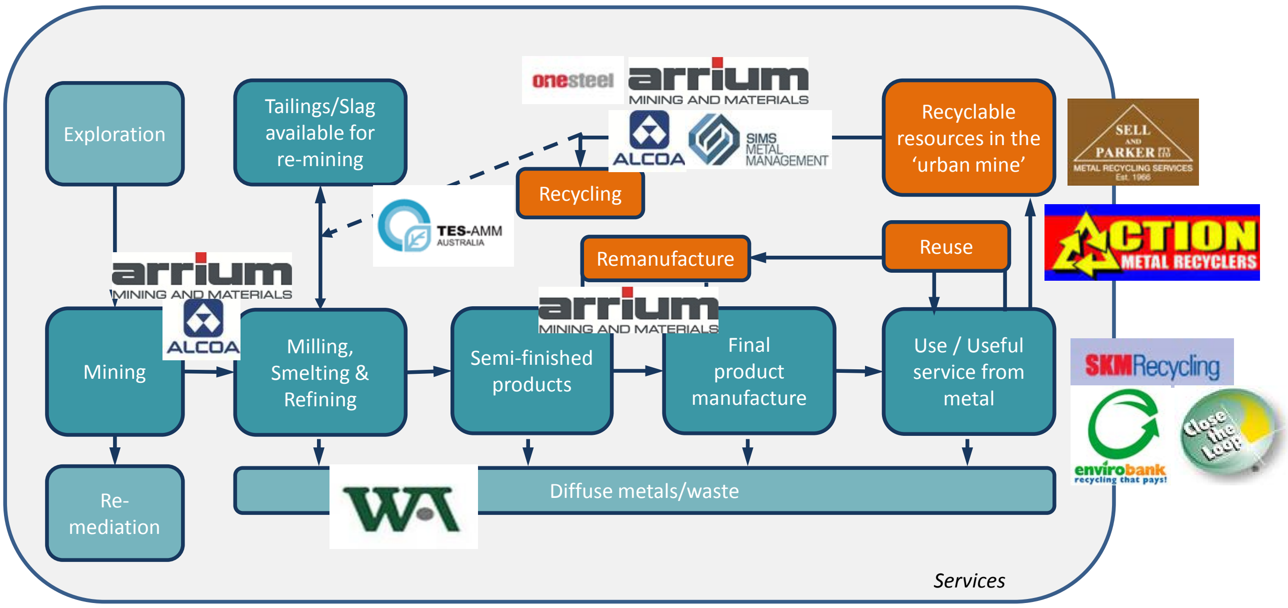

Figure 17: Overview of metal-related businesses in Australia who are members of ACOR

Whilst the companies who are members of ACOR are not an exhaustive list, they could be considered to be amongst the more progressive players in the industry. Interestingly as shown in Figure 17, only two companies (Alcoa and Arrium) have a presence in recycling and mining / smelting (and Alcoa has since closed its recycling facility at Yennora). Sims is a comprehensive recycler and Tess-Amm has a hydrometallurgical/pyrometallurgical process for e-waste. Sell & Parker (NSW) and Action (Qld) are scrap recyclers, but do not operate secondary refineries. Envirobank is reverse vending (incl. aluminium and steel cans) and SKM recycling offers collection services to councils. The vast majority of the collected and concentrated scrap is exported overseas.

5.2.1 SCRAP METAL RECYCLING IN AUSTRALIA

The sector and firm level data discussed in the following sections are drawn from the IBIS World Australian database. Firms in this sector are engaged in the secondary recovery of recycled scrap metal and its reprocessing into new materials. The most commonly recycled materials include steel and titanium. This industry is defined as mature, and has high barriers to entry due to the capital intensity of the sector and the highly concentrated ownership of firms; the top three firms in the industry account for over 70% of market share, as illustrated by Figure 18. The sector is also highly vulnerable to global commodity prices and demand, the volatility of which in recent years has seen the industry contract by 2.6% since 2008.

Increasing market concentration and some recovery in profit margins as a result of an increase in demand for metal products are expected in the next five years. The dominant business model in this sector will one of extracting slim profit margins by increasing economies of scale (and vertical integration) providing cost savings.

Figure 18: Major players by market share in the scrap metal recycling sector (IBISWorld, 2013). Note that CMA Corporation went into administration in August 2013

Sims Metal Management Limited

According to their website, “Sims Metal Management is the world’s, as well as Australasia’s and North America’s, largest metals and electronics recycler. Today, Sims Metal Management has over 270 locations on five continents, and more than 6,600 employees”

In Australia the business processes 1.5 trillion tonnes of metals and materials and it is the largest operator in the scrap metal sector with 37.5% of market share (IbisWorld, 2013). The company’s Australasian arm processes metals across all states in Australia (as well as New Zealand and PNG).

Arrium Limited

Arrium Limited, formerly One Steel, is a mining and materials business with three main divisions: mining, consumables and steel and recycling. It is notable for its connections to both primary and secondary parts of the value chain. In this latter category of secondary recycling the company has 26.1% of the market share in Australia, and processes more than 1.2 million tonnes of ferrous scrap. Arrium operates 36 recycling locations in Australia and a further 39 locations worldwide. The recycled materials are sold to steel mills, foundries and other related manufacturing industries (IbisWorld, 2013).

Sell & Parker

Sell & Parker is Australia’s largest privately owned scrap metal recycler, comprising 8 facilities across NSW, Port Hedland (WA) and Darwin (NT). They employ two hundred and fifty people with an annual turnover of $250 million. The company collects and processes scrap (including using high power shredders, mobile shears and plasma cutters) to recycle items ranging from aeroplanes, cars and trains to building and landfill scrap, production offcuts and also the aluminium casings of Nespresso capsules (via a subsidy). (Sell & Parker, 2014).

Other firms

- CMA Corporation was a significant player with 17 recycling facilities, but eight years after listing on the ASX, went into administration in August 2013. A downturn in Australian construction and manufacturing plus lower imports into China were cited as contributing factors (BRW, 2013)
- Pacific Metal Group is one of the largest collectors and processors of scrap metal in Victoria.
- Dodd & Dodd are one of the largest operators in Western Australia.
- P.F. Metals are a large operator servicing most of southern Australia and New Zealand.

5.2.2 E-WASTE COLLECTION AND PROCESSING

E-waste is defined as computers, televisions, refrigerators, batteries, household appliances and electronic equipment. E-waste is one of the fastest growing waste types and has been defined as a major environmental concern as e-waste contains a number of toxic chemicals and metals which can leak into ground water and soil if sent to landfill (ABS, 2013).

A key driver of industrial activity in this sector has been the National Television and Computer Product Stewardship Scheme (NTCRS) under the *Product Stewardship Act 2011*. The introduction of the Act has increased the amount of e-waste recycling by 25% per annum (although this rate could be higher due to the switch over from analogue to digital television generating higher TV replacements). E-waste companies retrieve metals and plastics and sell these to metal refining and plastics companies to be reused in other goods. E-waste also contains precious metals such as gold, silver and palladium.

The sector is a growth sector, experiencing annualized growth rates of nearly 9% for much of the past five years (IBISWorld 2014). The growth trajectory is expected to continue as the NTCRS embeds and the demand for computer and domestic appliances continues to grow.

E-waste business models are dependent a variety of revenue sources including receiving revenue from councils for providing e-waste collection and processing services, from businesses to collect and transport their redundant waste, from the sale of discarded electrical goods to repair and refurbishment companies, and from the sale of discarded e-waste. Industry profitability depends upon contract wins, service costs, wage levels, the price of second-hand electrical and electronic goods, and metals prices.

In Australia there are an estimated 142 firms operating in this sector (IBISWorld, 2014) and this is expected to increase in coming years as the NTCRS is targeting 80% of e-waste to recycling (from the current 30%). The sector is also expected to concentrate in coming years as well as volume increases the need for operations to professionalise and gain economies of scale in order to maintain revenues. Figure 19 shows the major firms involved in this sector in Australia.

Figure 19: Major players by market share in the e-waste collection and processing sector (IBISWorld, 2013)

SIMS METALS MANAGEMENT LIMITED

Sims plays a dominant role in the e-waste collection and processing sector with 15.5% market share, the highest of any firm operating in this area. Sims e-Recycling division provides e-waste collection, processing and recycling services for computer equipment, TVs, mobile phones and other electrical equipment. These processes include the collection, dismantling and recycling of e-waste at facilities around Australia.

This business division was established as a joint venture with Veolia Environmental Services in 2005, with Sims being the majority stakeholder. The company's Australasian e-waste recycling solutions division includes four facilities in Australia, and a further six in New Zealand, Singapore, India, Dubai, and South Africa. Ibis World (2014) estimates that Sims will generated $20m of revenue from its Australian operations in 2013-14, and revenue has been growing at more than 10% over the past five years. The revenue growth is attributed to Sims expansion of e-waste facilitates over this time, which has allowed it to increase market share.

VEOLIA ENVIRONMENTAL SERVICES (AUSTRALIA) PTY LTD

Veolia Environmental Services is a major waste collection and processing company with revenues in excess of $1b (2012) and over 100 sites and 2,900 employees (IBISWorld, 2014). The main wastes Veolia process are general solid, liquid, and construction waste services. E-waste is a smaller waste stream for the company, and the resource recovery services division in a joint venture with Sims Metal Management provides collection, processing and recycling services for e-waste. In the JV, Veolia provides the logistical services including the provision of collection bins to business customers, the collection of these bins delivery of e-waste to Sims facilitates and the dismantling and processes of some e-waste goods.

Ibis World (2014) estimates that the e-waste component of Veolia provides $15m of revenue per annum, and has grown by 13.4% per annum over the past five years. The strength of the JV in place with Sims and opportunity to increase market share over the coming years as the e-waste market consolidates will provide further growth opportunities for Veolia in this area.

SEMBSITA AUSTRALIA PTY LIMITED

SembSITA Australia Pty Limited is the parent company of SITA Australia (SITA) and is a 60:40 joint venture between SUEZ Environment and Sembcorp Industries. In 2012, SITA provided waste management services to over 56,000 commercial and industrial customers and about 3.7 million household residents (IBIS World, 2014). SITA also provides a range of e-waste services including single e-waste collections from customers, through to the provision of dedicated on-site e-waste bins and crates for regular collections. In the e-waste collection and processing sector SITA has about 10% market share and revenues of $13m (2013-14).

SITA sorts and processes collected e-waste, diverting retrieved metals and plastics to other manufacturers for reuse into other products. The company also has a nationwide battery-recycling program and can recycle fluorescent light tubes.

Other relevant businesses identified by IBISWorld (2014):

- Tox Free Solutions Limited (Estimated market share: 4.7%), WA based waste management company provides recovery and recycling services for electronic and electrical goods. E-waste revenues approximately $5m per annum.
- PGM Refiners (Estimated market share: 2.7%), Melbourne based, receive e-waste for processing and refining at its facilities. The company specialises in processing and recycling CRT tubes, printed circuit boards, computers, TVs and plastics. Retrieved metals and plastics are then sold to metal refining and other manufacturers for re-use in other goods. Estimated revenues of $3.5 million in 2013-14.

5.3 KEY DISCONNECTS IN CURRENT LANDSCAPE

The recycling sector is differentiated from other industrial sectors by the fact that it does not start with primary industries, and aside from resources required to reprocess materials such as energy and water, the recycling sector does not directly deplete natural resources to produce its outputs.

Market demand and commodity prices have significantly impacted on the rate of resource consumption and recovery of products and materials in Australia (HyderConsulting, 2009). Recovery levels tend to be higher and more stable when the price of recycled material compares favourably to: the price of virgin material; profit to be made from the recycling process (including collection and reprocessing), low levels of contamination in the recycled material and strong market demand for the recycled product. Factors that reduce recovery levels on the other hand include: limited and varied demand for the recycled product, and when the price of the recycled product does not compare favourably with virgin material, the sale price for the recycled materials is less than the cost of collection and reprocessing meaning subsidies are necessary to fund the gap.

Viability is also affected both in terms of knowledge and access to the volume of material available for recycling, but also the cost of collecting supply. Despite the criticality of this information, strong supply chain links only exist in very specific geographical areas and for specific materials. This is a significant barrier to further uptake of recycling and reuse activities, and the general viability of the sector.

A further unique and complex aspect of the recycling sector is its integration with other sectors of the economy. The recycling sector is simultaneously providing a collection service to waste generators and producing and marketing recovered products that are on-sold as inputs into manufacturing processes (NetBalance 2012). These characteristics mean that collaborations and connections along the supply chain are essential to the viability of collection, processing and resale of recycled materials.

The increasing sophistication of recycling processes requires collaboration and network linkages across disparate components of industrial activities. Value and supply chains are changing their orientation from linear chains to networked systems. This requires collaboration from businesses and organisations that would not usually have cause to partner. Networked or closed loop supply chains are rarely considered as value-creating systems in the strategic sense, but rather their focus is on the operational issues (Guide et al., 2003). Moving to such business models will require firms to have a deep understanding of their business practices and the benefits of these practices and to cultivate more sophisticated relationships with key stakeholders such as customers, suppliers and partners (Tsvetkova and Gustafsson, 2012).

Customer demand can be an important source of value creation in the supply chain, and increasingly this value is being configured in more intangible ways than costs and market for recycled materials. Recycling and e-use activities are closely tied to corporate social responsibility (CSR) activities for global and increasingly large national firms. The reputational value of CSR activities provides additional demand for recycling and reuse services and for the increased professionalization of these services. The demand for these services may help balance other economic factors that currently underpin recycling activities (costs and volume) or at least make global firms invest more heavily in innovating solutions that overcome these economic factors.

BOX 2: RADICAL INNOVATION AND THE REORGANISATION OF PRODUCTION AND CONSUMPTION SYSTEMS

The need for collaborations and innovations that encompass entire supply chains also means an increased focus on radical changes. The term ‘radical’ and ‘incremental’ have typically been attached to technological innovation, but increasingly radical innovation applies to system-wide reorganisation of entire production and consumption systems.

Radical innovation is assessed at three levels: new to the firm, new to the country and new to the world (Ettlie et al., 1984; Grover et al., 2007; Utterback, 1996). It is also associated with disruptive effects for both customers and manufacturers. These innovations are often the result of a much larger group of researchers, scientists and specialists across multiple organisations both public and private. They are also unlikely to have lead users or internal champions and therefore struggle to develop the essential feedback loops needed for successful exploitation. On the positive side radical innovation is associated with irreversible industrial change, new phenomena and the potential for new industrial creation and the resulting employment and export growth of these new industries.

The pathway to success for radical innovations is often longer and more complex than for incremental innovations. This is largely due to uncertainty, and a series of ‘unknowns’- how and when these discoveries will transfer into applications is unknown (Pavitt, 1991) as is how they will change industrial composition and competitiveness (Tijssen, 2002) and who will benefit from any resulting wealth creation (Kassicieh et al., 2000). The functions and advantages of radical innovations are unfamiliar to customers (Freeman and Soete, 1997). Market feedback in the early stages of commercialisation of these innovations is not available to guide the commercialisation process in the same way as exhibited in other areas of new product and service development. This can result in mismatched technology and market development, which is a further risk to the innovation process.

This is where public support for radical innovation is needed - to structure and incentivise a wider group of stakeholders and economic actors to investigate the potential for value creation.

5.4 OVERVIEW OF AUSTRALIAN POLICY LANDSCAPE

This section provides a high level overview of the policy landscape in Australia in the waste and recycling arena.

As was reviewed in Chapter 3, circular economy and resource-use efficiency is increasingly recognised in policy frameworks internationally. The new European Commission Strategy, Europe 2020, sees improvements in resource efficiency as critical to delivering both Europe's emissions reduction targets but also on economic development and job generation as well. As the strategy notes,

"…increasing resource efficiency will be key to securing growth and jobs for Europe. It will bring major economic opportunities, improve productivity, drive down costs and boost competitiveness. It is necessary to develop new products and services and find new ways to reduce inputs, minimise waste, improve management and business methods, and improve logistics. This will help stimulate technological innovation, boost employment in the fast developing 'green technology' sector, sustain EU trade, including by opening up new export markets, and benefits consumers through more sustainable products" (Europe 2020).

In Australia the National Waste Policy and Act provide the main framework for public policy activity in Australia. This policy was developed from environmental policy objectives (as shown in Box 3: Relevant Sections of National Waste Act), but has broadened to encompass the economic and productivity advantages of resource efficiency. The fact that such policy coordination is sitting within the environment department (rather than industry) may limit the perceptions of its relevance to the innovation potential connected with the circular economy.

All Australian Governments have endorsed the National Waste Policy through COAG (August 2010) and the policy provides a nationally consistent framework for developing product stewardship and extended producer responsibility schemes.

Regarding resources along the supply chain, the identification of resources in below ground stocks of metals is facilitated by Geoscience Australia, yet for above ground stocks of resources data are less established. Reinstating the ABS "Waste Account" that was trialled would go part-way to assisting in this regard, as will the compilation of a GIS database on above ground stocks of selected metals in Australia by the Wealth from Waste Cluster (led by Monash University http://wfw-atlas.monash.edu/apps/atlas/).

BOX 3: THE NATIONAL WASTE ACT

Section 4 of the Act states that,
"(1) It is an object of this Act to reduce the impact:
(a) that products have on the environment, throughout their lives; and
(b) that substances contained in products have on the environment, and on the health and safety of human beings, throughout the lives of those products.
(2) It is Parliament's intention that this object be achieved by encouraging or requiring manufacturers, importers, distributors and other persons to take responsibility for those products, including by taking action that relates to the following:
(a) avoiding generating waste from products;
(b) reducing or eliminating the amount of waste from products to be disposed of;

(c) reducing or eliminating hazardous substances in products and in waste from products;

(d) managing waste from products as a resource;

(e) ensuring that products and waste from products are reused, recycled, recovered, treated and disposed of in a safe, scientific and environmentally sound way.

Other objects

(3) The following are also objects of this Act:

(a) to contribute to Australia meeting its international obligations concerning the impacts referred to in subsection (1);

(b) to contribute to reducing the amount of greenhouse gases emitted, energy used and water consumed in connection with products and waste from products."

Section 5 of the Act contains product stewardship criteria that are satisfied in relation to a class of products if:

a) the products are in a national market

b) at least one of the following applies in relation to the products in the class:

i. the products contain hazardous substances;

ii. there is the potential to significantly increase the conservation of materials used in the products, or the recovery of resources (including materials and energy) from waste from the products;

iii. there is the potential to significantly reduce the impact that the products have on the environment, or that substances in the products have on the environment, or on the health or safety of human beings.

5.4.1 EXTENDED PRODUCER RESPONSIBILITY

Extended Producer Responsibility (EPR) is an environmental policy approach that requires the producer or supplier of a product to take greater responsibility for managing the environmental impacts of their products throughout the product life-cycle. By making a producer responsible for a product after the consumer stage of a product lifecycle there is, in theory, an incentive to minimise the amount of material that ends up as waste, to use less resources, to use more recycled resources, and to minimise the use of toxic ingredients.

EPR schemes implemented around the world tend to focuses on new products, product groups and/or waste management (http://www.oecd.org/env/tools-evaluation/extendedproducerresponsibility.htm). In Australia there is a strong focus on waste management. For example, the National Television and Computer Recycling Scheme targets the collection and recycling of waste televisions, computers, printers and computer products. The scheme is funded and run by industry and regulated by the Australian Government under the *Product Stewardship Act 2011* and the *Product Stewardship Regulations 2011*. Under the scheme, manufacturers of products (over a certain volume) are required to join an approved 'co-regulatory arrangement' that is responsible for the collection and recycling of products. A recent operational review of the scheme resulted in an increase in the recycling target to 50 % of the available e-waste in the 2015-16 financial year and increasing to 80 % by 2026-27. These target changes are expected to allow the scheme to deal with legacy waste sooner. A 'waste arising scaling factor' has also been introduced to reflect higher trends in the export of computers compared to other products targeted under the scheme.

The companies delivering services under co-regulatory arrangements are:

- DHL Supply Chain (www.dropzone.org.au),
- E-Cycle Solutions Pty Ltd. (www.ecyclesolutions.net.au),
- Australia and New Zealand Recycling Platform Limited (www.techcollect.com.au),
- Electronics Product Stewardship Australasia (Product.Stewardship@simsmm.com) and
- Reverse E-waste (www.reverseewaste.com.au).

While different approaches are taken, these approaches allow free drop-off and typically aim to build up existing recycling services.

6 CHANGING DRIVERS AND NEW BUSINESS MODELS

Building on the overview of the recycling industry and policy in Australia, this section explores how changing drivers and business models in the circular economy could affect sustainable metals management. New business models are identified to demonstrate the opportunity for the Australian metals industries in a global market – however, further research will be required to rank the market potential, barriers and enablers for different models.

Key Points:

- **Circular business models are defined as a subset of sustainable business models and a key distinguishing criterion is that they must be oriented towards consumption, or production and consumption, to promote both efficiency and sufficiency**
- **A categorisation framework developed by Bocken et al (2014) that aligns business model examples to key archetypes was modified for the purpose of analysing new business models for the circular economy. The five archetypes selected were: "Substitute renewable energy and material inputs", "Create wealth from waste", "Adopt a stewardship role", "Maximise material and energy productivity" and "Deliver functionality rather than ownership"**
- **Based on an analysis of 70 new businesses models from the literature, "Wealth from waste" models, that is those that derive value through the utilisation or exchange of waste products and by-products (e.g. closed-loop production, re-materialisation, and utilisation of idle assets), make up the highest proportion of categorised business models**
- **The analysis demonstrates the significant opportunity for (re) design of products and services, and rethinking how products are used for transitioning business models for a circular economy**
- **Certification schemes may be important for developing circular economies by promoting better communication across the supply chain, increased understanding and awareness of sector-wide benefits of material efficiencies, and for developing consistent data acquisition and interpretation protocols**
- **The leasing model provides a strong driver for circular material flows because ownership is retained with a producer and thus there is a strong driver for recycling and monitoring material flows in the economy. However, the limited examples of metal leasing for metal bearing consumer products makes a detailed appraisal for metals difficult**

6.1 CHARACTERISING NEW BUSINESS MODEL CONCEPTS

Whilst there is an extensive literature available on Business Model Innovation, in the context of this report, we use Bocken et al.'s (2014) definition for Business Model Innovations for sustainability, defined as:

> Innovations that create significant positive and/or significantly reduced negative impacts for the environment and/or society, through changes in the way the organisation and its value-network create, deliver value and capture value (i.e. create economic value) or change their value propositions.(p. 44).

Underpinning this definition are three main business model elements: value proposition, value creation and delivery, and value capture (Teece, 2010) Figure 20.

VALUE PROPOSITION	VALUE CREATION	VALUE CAPTURE
product, service or information offering to generate value, incl.: economic, ecological value, social value	e.g., activities, resources (material, energy, knowledge), enabling technology, partnerships (formal and informal)	revenue model (e.g., leasing) and revenue streams

Figure 20: Three main business model elements (adapted from Osterwalder and Pigneur, 2005; Teece, 2010; Bocken et al, 2014)

To introduce change in the business model requires transformation that will likely influence all three business model elements. In order to maximise societal and environmental benefits, and not just economic gains, it is important to note that any change arising from business model innovations for sustainability may not be economically viable upfront, however, due to regulatory or institutional changes overtime, realisation of value creation and value capture is possible in the long run. In light of this, the defensive, accommodative, and proactive business model innovation typologies proposed by Schaltegger et al.'s (2012) are to be considered when proposing business model innovation strategies for the metal sector. Whilst the first two strategies allow for incremental adjustments driven by the need for compliance and include some consideration of environmental or social objectives through improvement and integration of internal processes, the proactive strategy fundamentally reforms and redesigns the core business logic of the firm in an attempt for sustainable development. With this backdrop, we next discuss the possible new business models that may suit Australian industry. Other business models similarly group sustainable business models into compliance, efficiency or more proactive approaches where sustainability is embedded in core business practices (Benn et al, 2014). This discussion is elaborated elsewhere in a recent publication from Benn et al. (2015) as well as in Sharpe and Agarwal (2014).

6.1.1 CIRCUALR BIUSINESS MODELS AS A SUBSET OF SUSTAINABLE BUSINESS MODELS

Bocken et al (2014) define 8 sustainable business model archetypes based on a very comprehensive review of literature (academic and grey literature) and business practice. These include: (1) maximise material and energy efficiency, (2) create value from waste, (3) substitute with renewable and natural processes, (4) deliver functionality rather than ownership, (5) adopt stewardship role, (6) encourage sufficiency, (7) repurpose for society and the environment, and (8) develop scale-up solutions.

For our evaluation of business practice from the literature, with a focus on business models for circular material flows, we have selected a subset of five business model archetypes. We argue that the three additional archetypes identified by Bocken et al (archetypes (6), (7), and (8)) may be usefully conceived as necessary precursors, or enablers, for delivering sustainable outcomes in a circular economy. That is, business activities that encourage sufficiency (6), e.g., by promoting a new mode of consumption to alleviate demand for a raw material, are essential for achieving truly sustainable outcomes. Similarly, whilst acknowledging that some business activities may be redirected for delivering positive social outcomes (7) this may be considered as an overarching objective for sustainability, but may be independent to the achievement of circular material flows. Finally, we would argue that new business models are scalable is essential for delivering meaningful change (Figure 21).

The five business model archetypes selected for this work are outlined in Figure 21 that also includes examples of new business models that are identified as most relevant to the metals industries. These are defined below and their applicability to sectors and stakeholders are discussed:

(1) **Substitute renewable energy and material inputs** explicitly acknowledge natural ecological limits by promoting the use of renewable energy and material inputs as alternatives to fossil derived inputs. An example is substituting metals with natural fibres, or utilising solar energy for minerals processing.

Environmental value is derived from addressing resource constraints and mitigating adverse impacts of resource extraction. The focus of these models is on production and manufacturing through process innovation, however there is scope for wider changes across the value chain. For example, technology innovation and manufacturing efficiencies have led to cost reductions in PV technology allowing consumers to become producers and feed electricity to the grid.

(2) **Create wealth from waste** models reconceptualise waste as a resource. This category is distinct from 'maximise material and energy productivity' because there is a focus on finding new value from waste rather than seeking to minimise waste generation (Bocken et al., 2014). Closing material loops when waste is used as feedstock for other production systems reduces the environmental impact of industry. These activities also reduce demand for raw materials and economic drivers promote positive environmental outcomes. The concept of industrial symbiosis is an example of utilising a material waste stream as a feedstock; other business model examples take advantage of idle resources, space or time. The focus of these models is on product design and manufacturing facilitating reuse, repair, remanufacturing or recycling with new opportunities across industries. There is also significant opportunity for the waste and recycling industries owing the logistical challenges associated with collection and sorting.

(3) **Adopt a stewardship role** are models that explicitly engage with all sectors and stakeholders in a product value chain to promote sustainable outcomes. These business models can contribute to environmental and social outcomes, for example reducing the use of toxic substances that may cause environmental and human health problems at the EOL phase (upstream stewardship). These models frequently adopt a third party certification scheme to differentiate from other products and secure market share. Downstream stewardship models include consumer choice-editing whereby a retailer can directly influence consumer behaviour by eliminating the availability of certain products (Bocken and Allwoood, 2012). The broad focus of these models requires new collaborations and partnerships across the value chain from production to consumption and EOL.

(4) **Maximise material and energy productivity** models promote doing more with less resources and generating less waste, or pollution. These models align environmental objectives with economic objectives however where resource use productivity leads to significant cost reductions there is potential for a 'rebound effect' whereby lower prices can incentivise higher rates of consumption. Productivity improvements, e.g., efficiencies realised by the automation of mines, has also resulted in reductions in employment opportunities. The focus of these models is on production and manufacturing through process innovation, however there is scope for wider changes across the value chain including through resource or sharing that requires direct engagement with consumers.

(5) **Deliver functionality rather than ownership** is about the provision of a service (product function and benefit) that a customer demands rather than the provision of the physical product. This archetype includes the concept of Product Service Systems (PSS) and servicisation. Tukker (2013) categorises PSS in terms of product-oriented, user-oriented, result-oriented reflecting a trend in decreasing material or product importance. These models better align the user's needs with the producer and this can potentially reduce resource consumption. Because the producer maintains ownership there is greater motivation to manage products across the value chain. Significantly, these models decouple the link between profit and production volume. Revenue is generated (e.g., by a rental or leasing fee) that exceeds the cost of production and maintenance across a product lifecycle. Evaluating the environmental impacts of the use phase is important for determining potential environmental benefit (van Beers et al., 2014). These models promote (re)design to incentivise durability, reparability, upgradability and traceability. There is also scope for more direct consumer engagement including the need to address a cultural preference for ownership.

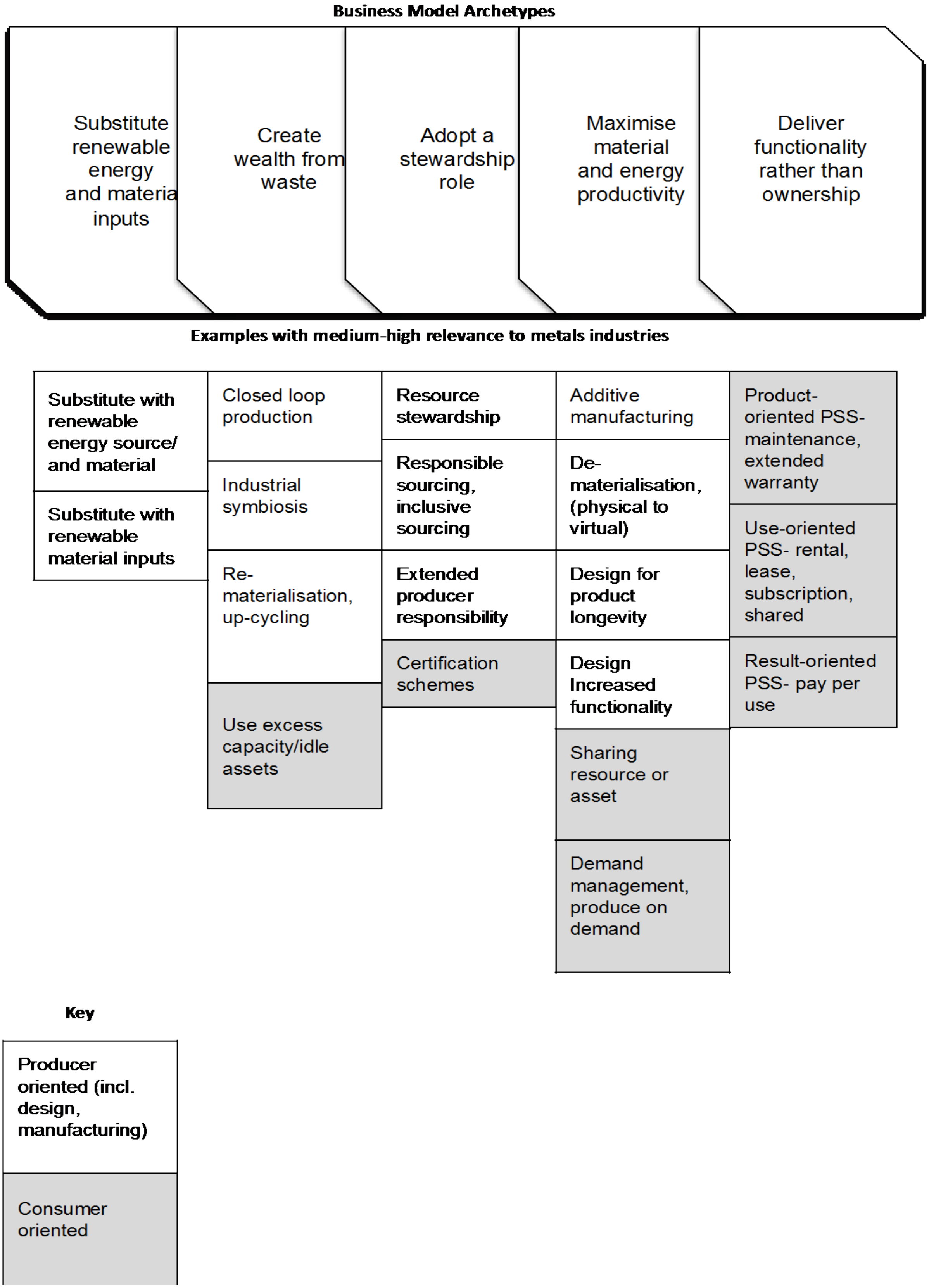

Figure 21: Categorisation of business model archetypes for circular material flows, after Bocken et al, 2014

Considering this categorisation of business models it is apparent that business activities cannot be pigeon holed in one category and that the framework is most useful when viewed as a palette for characterising different types of business activities to support sustainable metals management. For example, metals recycling industries utilising new technology that increases the accuracy of collection and separation, such as a recycling process that uses robots for sorting, or the use of novel x-ray analysis to separate metals from waste streams, are easily assigned to the 'create wealth from waste' archetype. However, the extent to which these business models may deliver circular outcomes is limited without the additional effort to substitute energy inputs with a renewable energy source during the reprocessing steps, or the promotion of material and energy efficiency in the re-production phase. Thus, while it is clear how recycling efficiency improvements may create value relative to standard recycling practice, if fossil energy is used or if there are 'rebound effects' then the environmental and social benefit may be undermined and the metals management is sub-optimal (Bocken et al., 2014).

Conversely, while it is expected that novel technologies will play an important role in future supply and demand (Giurco et al., 2014), technology innovation that is strongly focussed on increasing the resource base, including reprocessing and recycling technologies, cannot deliver sustainable outcomes in isolation. For example, while recycling efficiencies of > 95 % are achievable for platinum group metal containing materials, this is only possible if these materials reach the state-of-the-art facilities. In many instances it is not the technical recyclability of a material but stakeholder interactions (e.g. collection and delivery systems) within the material life cycle that is the limiting factor (Hagelüken, 2012). This does not discount the importance of technology, for example: the potential of 3D printing to both reduce material intensity and enable the development of distributed production/manufacturing systems; and, advances in digital technology as an enabler for tracing material flows in secondary cycles to monitor quality and efficiency, and assign value.

Thus new business model concepts for metals management in a circular world requires a synergy between different business model concepts outlined in Figure 21. Furthermore, recognising the complexity of the metals recycling sector, and the complexity of metal bearing products, significant advances likely necessitates new collaborations across the supply chain, involving appropriate management systems and approaches as well new modes of consumption. Those business model examples that are aligned with consumers are shaded, while those that are more aligned with changes to design and manufacturing processes are clear boxes. In order to improve the efficiency of material flows and encourage efficiency it is likely necessary that new circular business models cut across both production and consumption oriented categories. On this basis we suggest that circular business models are a subset of sustainable business models and a key distinguishing criterion is that that must be oriented towards consumption, or production and consumption, to promote both efficiency and sufficiency. As will be discussed below with reference to a compendium of new business models from the literature, many new business models reviewed fall outside of this definition highlighting the challenge of characterising the circular business model.

6.2 INNOVATION IN BUSINESS MODELS

Recognising that business model innovation will not necessarily be derived from within the metals industries, in this section we look more broadly at new business models across a range of sectors. A compendium of 68 international business case studies spanning a wide range of scales and sectors was assembled based on case studies appearing in the literature and company websites. The compendium and references to individual case studies can be found in Appendix 1. The purpose of the compendium is to identify underlining business model traits of international case studies to evaluate applicability to business activity in the Australian metals sector. The case studies compiled for the compendium represent a limited exploration of international sustainable business models from the reviewed literature, and cover case studies and business activity that is not necessarily 'circular'.

Case studies in the compendium were qualitatively categorised by business model archetypes (Figure 21), points of intervention in the product supply chain (design, inputs, production, transport, use, end-of-life disposal, and return), and orientation of the business model (consumer, producer, and consumer/producer). Categorisation was done based on aligning categories with descriptions of the business models and business activities found in the literature and from company websites and profiles. For the categorisation by archetype, some case studies were associated with more than one archetype (for example, "wealth from waste" and "adopt a stewardship role"), highlighting business models that have reached across several revenue streams and supply chains. Primary and secondary archetypes were classified to cover cases where a case study was associated with several archetypes. Where in the product/material/service life cycle that the case study business models targeted was also categorised for analysis.

6.2.1 CATEGORISATION OF INNOVATIVE BUSINESS MODELS BY ARCHETYPE

Our analysis of this categorisation exercise identifies key traits and opportunities. Figure 22 shows a percentage breakdown of business model classification. "Create wealth from waste" classified models, those that derive value through the utilisation or exchange of waste products and by-products (e.g. closed-loop production, re-materialisation, industrial symbiosis and utilisation of idle assets), make up the highest proportion of categorised business models at 35% of the total number reviewed in the compendium. Half of these business models classified as "create wealth from waste" were models focused on re-materialisation and up-cycling of waste and by-products. Examples of these businesses include the extraction of metals and valuable fats, oils and grease (FOG) from wastewater, and the use of industrial residuals (including from the agricultural and metals sectors) for the production of bio-fuels, process additives, and recycled materials. Industrial symbiosis was another important exemplary business model within the "create wealth from waste" archetype, including eco-park models. The use of idle assets, while making up a small proportion of "create wealth from waste" models (approximately 17%), is still an important aspect of the "create wealth from waste" archetype, with businesses such as Sendle (Australian example) providing innovative solutions in a growing digital markets. Finally, waste exchange was another mechanism of the "create wealth from waste" archetype characterised in the sample, and includes inter-firm as well as collaborative consumption models.

"Maximise material and energy productivity" was the second highest classified archetype (22% of sample), however it was the archetype that had relevance across nearly all business models. While we choose to define this as an archetype (for example, businesses that aimed at implementing resource or energy efficiency may be classified under this archetype), it is important to recognise that it is a cross-cutting (or underlying) theme with relevance across many case studies (for example, de-materialisation as a requirement for product certification in stewardship aligned business case studies), and a driver for circular economy transition.

"Substitute renewable energy and material inputs", "Deliver functionality rather than ownership", and "Adopt a stewardship role" make up the remaining proportion of classified business models (19%, 13% and 10% respectively). "Substitute renewable energy and material inputs" include primarily case studies where material and energy inputs have been replaced by sustainable alternatives, including natural ingredients/components/processes, renewable energy, and bio-chemicals. This archetype is particularly relevant for industrial and manufacturing sectors, and transportation.

"Deliver functionality rather than ownership" includes leasing, and collaborative consumption and sharing models (the significance of leasing has been noted elsewhere in this report), and are typically enabled by digital technology (internet communication, for example), highlighting the significance of digital technology as an enabling factor for circular economy business models. "Adopt a stewardship role" includes product and resource stewardship models, in addition to certification schemes. These models include responsible production/design models as well as extended producer responsibility into the end-of-life disposal cycle.

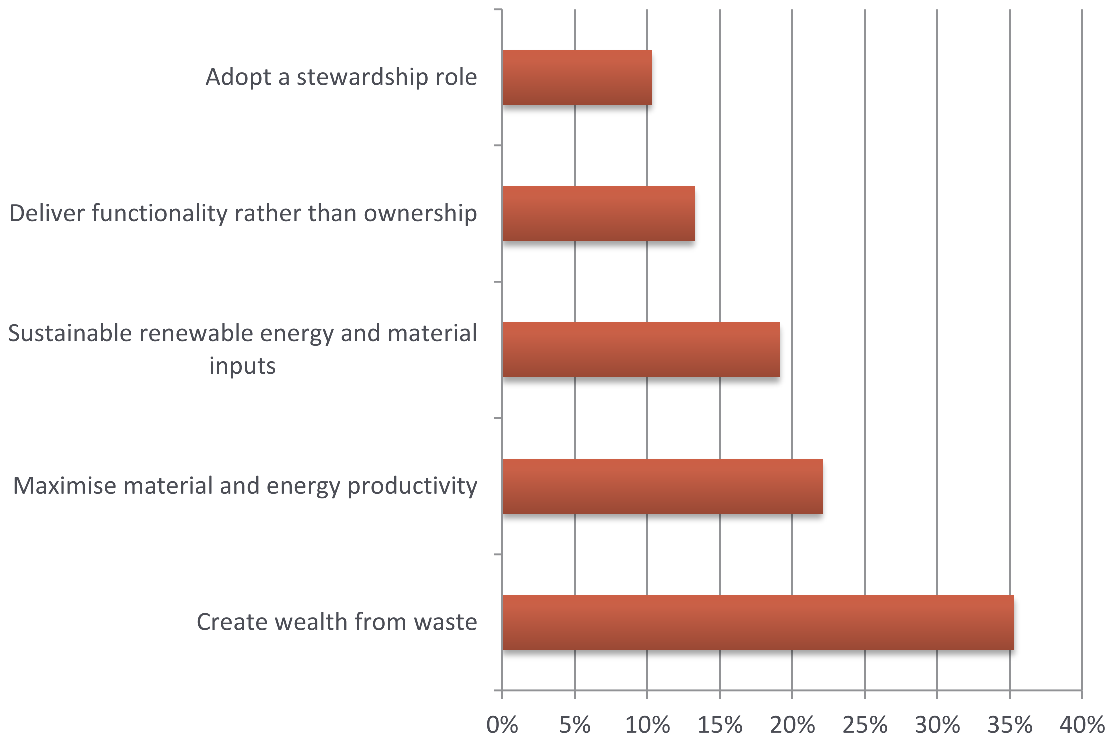

Figure 22: Summary of classified compendium case studies by business model archetype

6.2.2 POINTS OF INTERVENTION IN THE PRODUCT, MATERIAL OR SERVICE LIFECYCLE

In addition to the categorisation of the business case studies by archetype, case studies were also classified according to where in the product, material or service lifecycle the business model is targeted to identify key points for intervention in the material lifecycle for improving material productivity.

Figure 23 shows the percentage breakdown of this analysis. Design and use were the most targeted points of intervention in the product life cycle (22% and 21%) based on our evaluation. This preliminary analysis demonstrates the significant opportunity for (re) design of products and services, and rethinking how products are used for transitioning business models for a circular economy. The return phase or ‘reverse logistics’ (i.e. post use and disposal stages) is also very important (19%) that highlights the importance of the logistics and waste industries. This classification is specifically relevant to “Create wealth from waste” business models archetypes, which are predominantly active in the return lifecycle phases.

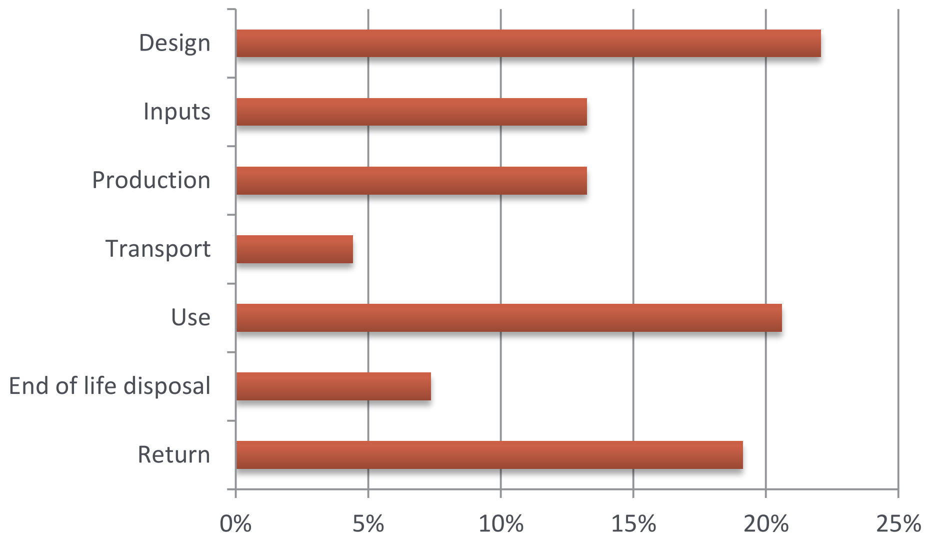

Figure 23: Summary of product/service life cycle phases targeted

Further, by mapping where in the product/material or service life cycle the archetypal business models are important offers some insight into where new value centres exist and/or where future opportunity may exist (Figure 24). "Maximise material and energy productivity" and "Create wealth from waste" are more active across the entire product/service life cycle, targeting the largest number of product/service cycle phases. This is in contrast with the "Deliver functionality rather than ownership" archetype, where many of the case studies evaluated were assigned to the use phase only.

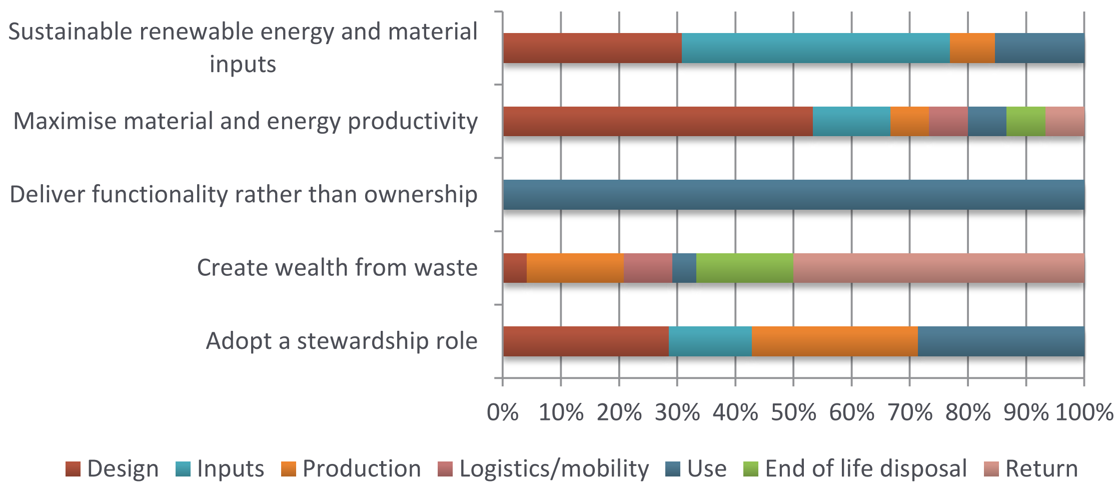

Figure 24: Breakdown of product/service cycle phase targeted by business model archetype

"Create wealth from waste" predominately targets the return phase of the product cycle (46%), where waste items and material are up-cycled or used as inputs for processes. Examples of "Create wealth from waste" models targeting the use phase are models aimed at utilising idle/excess capacity. Design is targeted by approximately 4% of the "Create wealth from waste" case studies, which are focussed on eco-designed products utilising waste items demonstrating significant scope for a greater emphasis on this phase.

By contrast, the significant proportion of "Maximise material and energy productivity" models (57%) target the design phase, indicating the significance of de-materialisation and designing for increased functionality/longevity in the design phase of eco-products and services within this sample.

The design, production and use phases are evenly targeted within the “Adopt a stewardship role” models. This is consistent with the differences between production and resource stewardship and certification schemes, which are core to the stewardship principle and it also reflects the whole supply chain approach that under pins these business activities

Further research is needed to validate the relevance of these insights for the Australian metals industries.

6.2.3 ORIENTATION OF BUSINESS MODELS

A final categorisation of business models was done based on the orientation of the business model towards consumer orientated, producer orientated, or where both consumers and producers are targeted. Figure 25 shows a percentage breakdown of case study business model, showing that almost 70% of the collected case studies were producer orientated business models. This reflects the sample of case studies analysed, which are ‘sustainable business models’ and not necessarily circular. Producer orientated business models are largely aimed at substituting renewable resources in the production cycle, and encouraging resource efficiency in production. An orientation towards consumers is necessary to promote sufficiency. This analysis supports the definition of circular business models as a subset of sustainable business models. Further research using a more comprehensive set of business model examples would provide further insight into the determination of circular business model characteristics.

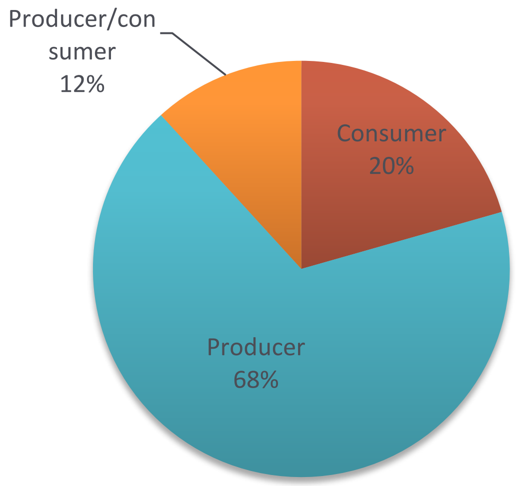

Figure 25: Breakdown of business model orientation in the compendium case studies

Figure 26 shows the breakdown of business model orientation by business model archetype. The “maximise material and energy productivity”, “create wealth from waste” and “adopt a stewardship role” archetypes have business models orientated towards all three orientations, indicating that business models that promote both resource efficiency and consumption sufficiency in the compiled compendium are potentially found within these archetypes. The “deliver functionality rather than ownership” archetype is targeted towards consumers only, reflecting the core nature of this archetype. Conversely, the “sustainable renewable energy and material” archetype is orientated 100% towards producers, again reflecting the core nature of this archetype in replacing non-renewable resources in the production cycle with renewable options.

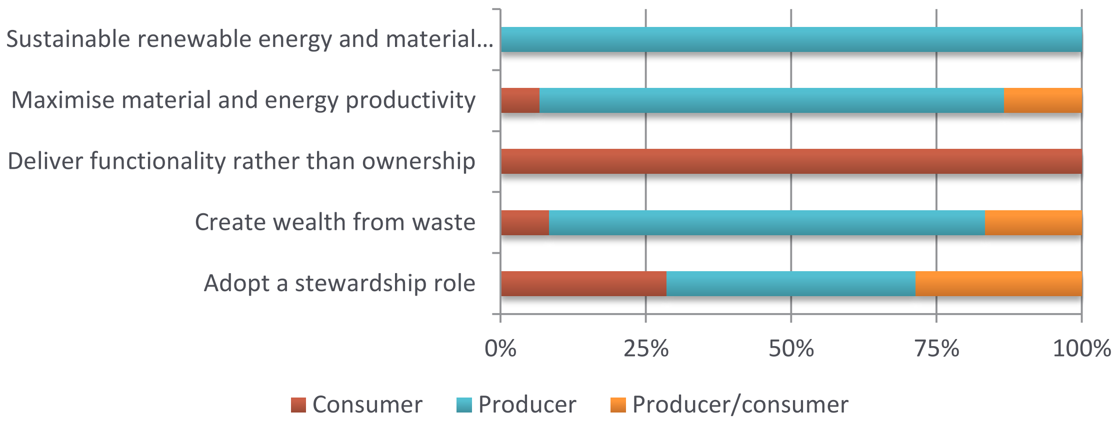

Figure 26: Breakdown of business model orientation by business model archetype

6.3 IMAGINING CIRCULAR BUSINESS MODELS FOR METALS

Notwithstanding the important advances in technology that have the potential to improve material cycling efficiencies, in the remainder of this section we look in more detail at new business models that have the potential to improve efficiency as well as sufficiency. Owing to the importance of collaboration across the supply chain for accessing new value, and the importance of engaging produces and consumers, below we examine certification schemes and the leasing models, categorised as "Adopt a stewardship role" and "Deliver functionality rather than ownership" archetypes respectively. Both of these models satisfy the criterion for circular business models by being oriented towards producers and consumers. Herein we discuss the applicability to metals.

6.3.1 A CLOSER LOOK AT SUPPLY CHAIN CERTIFICATION SCHEMES

A range of supply-chain certification schemes have been developed in recent years for metals with the aim to derive a competitive advantage by differentiating metals/ metal products on the basis of superior environmental and social impacts across the whole life cycle. The importance of this type of approach is apparent considering that engagement with environmental impacts across the whole lifecycle of materials or products is frequently overlooked, e.g., the majority of emissions from value chains are not currently measured (Carbon Disclosure Project, 2012). This is most relevant to metals given the energy intensity of production and reprocessing.

Summaries of examples are provided below in Table 4 they are intended to give a snap shot of what the schemes aim to do and how they work.

ENABLING FACTORS

Managing risk is seen as a major driver, including legal and health and safety issues, e.g., for miners this is about maintaining a 'social license to operate' avoiding disruption from protests, changing worker safety conditions, or adverse environmental releases. Benn et al. (2014) also observe an emerging phenomenon of a 'social license to market'. For example, the ARM recognises that customers want gold that they buy is produced without adverse impacts on people or the environment.

This demonstrates that supply chain certification schemes are being pursued as a proactive strategy to secure market advantage, i.e., where opportunities for value creation arise from consumers being willing to pay a premium. That said, the added-value of Australian 'Responsible Steel' for example may be limited given that global demand is driven by consumers in developing countries who may not have the same consumption preferences and priorities (Benn et al., 2014).

Scheme	Responsible Steel (Steel Stewardship Forum (SSF), n.d.)	Chain-of-Custody Certification for Precious Metals (Responsible Jewellery Council, 2014)	Fairmined Mining Certification (Alliance for Responsible Mining, 2014)	Aluminium Stewardship Initiative (Aluminium Stewardship Initiative, 2014)
Description	The Steel Stewardship Forum (SSF) aims to facilitate stewardship (environmental and social) across the entire steel product life cycle	Developed by the Responsible Jewellery Council (RJC) this scheme is a not-for-profit, standards setting and certification organization consisting > 500 Member companies across the jewellery supply chain from mine to retail. RJC defines responsibly sourced as: • conflict-free as a minimum, and • responsibly produced at each step of the supply chain.	Fairmined is a standard, developed by the Alliance for Responsible Mining (ARM), for sound environmental, labor, formalization and traceability practices amongst artisanal and small-scale miners of gold and associated precious metals.	The Aluminium Stewardship Initiative (ASI) was launched in 2012 to foster greater sustainability and transparency throughout the aluminium industry. The ASI's main goal is to develop a global standard for aluminium sustainability by the end of 2014, in order to foster responsible resource management of aluminium throughout the entire value chain.
How it works	• Still under development, a pilot scheme (introduced initially for mining and steel manufacturing over a 12-18 month period) will be fully expanded across the steel value chain within five years) providing information, knowledge, leading practice	• The RJC developed a Code of Practices with auditable standards of ethical, social and environmental practices,e.g., the Chain-of-Custody (CoC) for precious metals (published in 2012). It includes standards for human rights, labour, environmental impact, and business ethics. • Companies throughout the supply chain – mine to retail – can be certified against the CoC Standard, using third party, RJC-accredited auditors.	• Inspectors from a third party independent certification body audit compliance with these requirements. If the miners' organization complies with all the requirements of the Fairmined standard, it obtains Fairmined certification.	• The Standard will define principles and performance criteria in the areas of governance, environmental and social practices. It will be applicable for all stages of aluminium production and transformation bauxite mining, alumina refining, primary aluminium production, semi-fabrication (rolling, extrusion, forging and foundry), conversion, and refining and re-melting of recycled scrap. • To support the credibility of the ASI Standard, the members of the ASI have committed to follow the ISEAL Standard-Setting Code (V5.0) (ISEAL Alliance, 2014), that applies to all standards that promote improvement in social and environmental practices.

Table 4. Summary of supply chain certification schemes

IMPLICATIONS AND CHALLENGES FOR CIRCULAR MATERIAL FLOWS

For the SFF, the first activity has been the mapping of commodity flows and emission intensities across the supply chain with data voluntarily supplied by the companies involved. Currently much of the scrap in Australia is melted down to be used in low-grade products and this is unlikely to incentivise an increase in the share of recycled materials relative to demand (Benn et al., 2014).

In the case of Fair-mined Mining certification, the main benefits are for the mining communities and the establishment of an international network such that certified miners are provided with direct access to markets and responsible supply chains, and thereby greater profits as intermediaries are by-passed

Thus, while the extent to which these initiatives will increase circular material flows may be as yet unclear, the promotion of better communication across the supply chain, increased understanding and awareness of sector-wide benefits of material efficiencies, and development of consistent data acquisition and interpretation protocols are important precursors towards creating value for secondary material flows.

The development of certification schemes for engineering and precious metal classes demonstrate a broad applicability. New capabilities to tag metals sourced from sustainably supply chains may be needed to extend the applicability to a broader range of metal bearing consumer products. Whilst the current focus has been on inputs there is a need for a greater focus on secondary material flows, for example via programs such as the Sustainable Electronics Recycling International (SERI) R2 Standard that provides a common set of processes and practices for business that repair and recycle electronics (https://sustainableelectronics.org/). Such a shift may also be facilitated through new consumption models, such as leasing, discussed in detail below.

6.3.2 A CLOSER LOOK AT LEASING

The concept of metals leasing is a relatively novel idea that has received limited critical reflection (Morrison & Giurco, 2011; Prior et al 2013.). The concept has been explored in more detail in the context of the chemical industry (Lozano et al., 2014). For example, the Global Chemical Leasing Program was launched in 2005 in the context of the UNEP Strategic approach for International Chemicals Management (SAICM) (UNIDO, 2011). According to UNIDO, the leasing model is defined as “a service-oriented business model that shifts the focus from increasing sales volumes of chemicals, towards a value-added approach”(UNIDO, 2011). More efficient resource use may be promoted because value is no longer linked to volume of sale/production, instead a miner or producer might generate value from the service that the metal provides. There are likely benefits in terms of encouraging resource sufficiency and quality.

ENABLING FACTORS

Metals that may be most applicable for leasing have a high capacity for recovery and a high price as opposed to products with a low value or a low capacity for recovery. Certain metals streams (gold, copper, platinum group) are ideal candidates for leasing with enablers for leasing including a high value, a high concentration in the waste stream, and the capacity for a high percentage of recovery (e.g. greater than 75% has been suggested by (Lozano et al., 2014).

A key factor is collaboration, including the requirement of companies to share information and engage in long-term cooperative activities with producers/suppliers.

IMPLICATIONS AND CHALLENGES FOR CIRCULAR MATERIAL FLOWS

The leasing model provides a strong driver for circular material flows. For example, if ownership is retained with a producer then there is a strong driver for recycling and monitoring material flows in the economy. There are limited examples of metal leasing, e.g., recovery of nickel and iron in electroplating (Schwager & Moser, 2006), platinum recovery from fuel cell vehicles has been evaluated (Kromer, et al., 2009), it has been proposed for lithium (Prior et al., 2013) and Morrison & Giurco (2011) discuss metal leasing as an alternate taxation strategy.

Further research is required to identify which types of metals may be most suitable for leasing, considering: recycling efficiency, proximity of producer and user, and reasonable durations for leasing arrangements (Lozano et al., 2014). This necessitates better data acquisition to measure the efficiency of use and percentage of recovery, which is critical for apportioning value (for materials, services, labour, and energy). There are further questions in terms of what type (and size) of companies may be most suited, and how to establish new collaborations and interactions in the supply chain, including the changing role of producer to service provider as well as new customer expectations (Lozano et al., 2014).

7 PLANNING THE SHIFT TOWARDS A CIRCUALR ECONOMY

7.1 OPPORTUNITIES FOR AUSTRALIAN BUSINESSES

In recent decades, economic growth driven by global demand and high prices for Australia's natural resources has allowed the country to prosper. However, our national focus on productivity has slipped and many businesses operate with great uncertainty about the future. This report, in the context of the metals industries, discusses the broad opportunities and challenges for Australian governments and industry in increasing resource productivity in the circular economy.

A circular economy means promoting a shift away from the linear 'take-make-dispose' model towards a 'take-make-recreate' model by designing for recycling, reuse and remanufacturing. In Section 2 we reviewed different conceptualisations of circular economies that highlighted the diverse benefits and opportunities from reducing the material footprints of consumer products, avoiding waste to landfill, hedging against future price volatility of resources, and promoting economic diversity and growth across diverse sectors from manufacturing to renewable energy. Significantly, the critical importance of new consumption models that decouple material use from economic growth and encourage sufficiency was highlighted. Based on a review of international strategies for implementing circular economies in Section 2 it is clear that our primary trade partners in Europe and China are already pursuing new opportunities to accelerate resource productivity. If Australia is to be competitive in a future circular world then resource productivity and innovation must be prioritised as a topic of national significance.

Considering the case of metals, because of growing and competing demands for metals and alloys, circular flows are becoming an increasingly important source for future metal supply. However, as discussed in Section 3, at the moment there is a paucity of data for describing metals flows in society and for a large number of metals no end-of-life recycling taking place. In part, this is because the economic incentive is missing and/or physical-chemical constraints inherent in separating increasingly complex material combinations make it very difficult if not impossible to reprocess. To push this upper limit for recycling, greater consideration of the complexity of metal combinations and chemistries in products at the design phase is important, as well as other activities for intensifying resource use. These changes require better coordination and technological and business model innovation.

Section 4 discussed the great opportunity for post-mining and construction boom Australia to leverage existing technical and technological know-how in the METs sector for creating and capturing new value from above ground metal waste streams and unconventional resources. Currently, all Australian and most global actors in primary metals mining and processing are not also active in secondary metals; however the emergence of secondary metals markets, including the fastest growing market for e-waste, underscores the importance in looking towards these new value pools. Today, the Australian metals manufacturing and the manufacturing sector more broadly is subject to intense competition from foreign companies and new circular thinking, including integrating Australia's abundant renewable energy resource could provide a competitive advantage. Remanufacturing also offers an opportunity for sector growth as exemplified by niche business activities.

Planning for these new opportunities requires a shift in thinking and there is great scope for the recycling industries to adapt to opportunities in design and manufacturing, however, as discussed in Section 5, the Australian metal industries are not yet looking across the supply chain for new value and there remains a strong focus on material-centric recycling. There is a lack of data to justify investment in new infrastructure. As was mentioned above, reinstating the ABS "Waste Account" would go partway to assisting in the characterisation and evaluation of the profitability of urban mining activities

As well as re-framing the perceptions of value, there is a unique opportunity for Australian businesses to be the vehicles for coordinating production and consumption system innovation, but this requires reconceptualising the function of business. Notwithstanding the importance of disruptive technologies, innovation is business models is central to driving a shift towards the circular economy**.** New business models can allow businesses to diversify their revenue streams, engage with new emerging markets and de-risk in the context of resource constraints. Section 6 discussed how new value is being created through five archetypal new sustainable business models: “Substitute renewable energy and material inputs”, “Create wealth from waste”, “Adopt a stewardship role”, “Maximise material and energy productivity” and “Deliver functionality rather than ownership”. Circular business models were identified within these archetypes and defined as a subset of sustainable business models; a key distinguishing criterion is that that must be oriented towards consumption, or production and consumption, to promote both efficiency and sufficiency. Based on an analysis of 70 new businesses cases from the literature (not limited to metals), “wealth from waste” models, that are those that derive value through the utilisation or exchange of waste products and by-products (e.g. closed-loop production, re-materialisation, and utilisation of idle assets), make up the highest proportion of categorised business models. The analysis demonstrates the significant opportunity **for** design of products and services, and rethinking how products are used for transitioning business models for a circular economy. However, the limited examples for metals highlight the opportunities for future research to appraise the specific opportunities for the metals industries in Australia.

7.2 FUTURE RESEARCH

Adapting to a new era of resource productivity requires new collaborations at the frontier between traditional sectors. By bringing together business, research, technology, policy and social and cultural change Australia can deliver the skills, products and services needed to increase resource productivity in a circular economy.

Further research in this program, and within the Cluster, will explore potential pathways that might be adopted in the Australian industry and policy context that intersect with the potential of new business models for circular economies. As depicted in Figure 27, we have identified a range of transition pathways that may be leveraged by key stakeholders and the matrix provides a first attempt at determining the points of intersection across policy, disruptive technologies, new consumption models, and new business models.

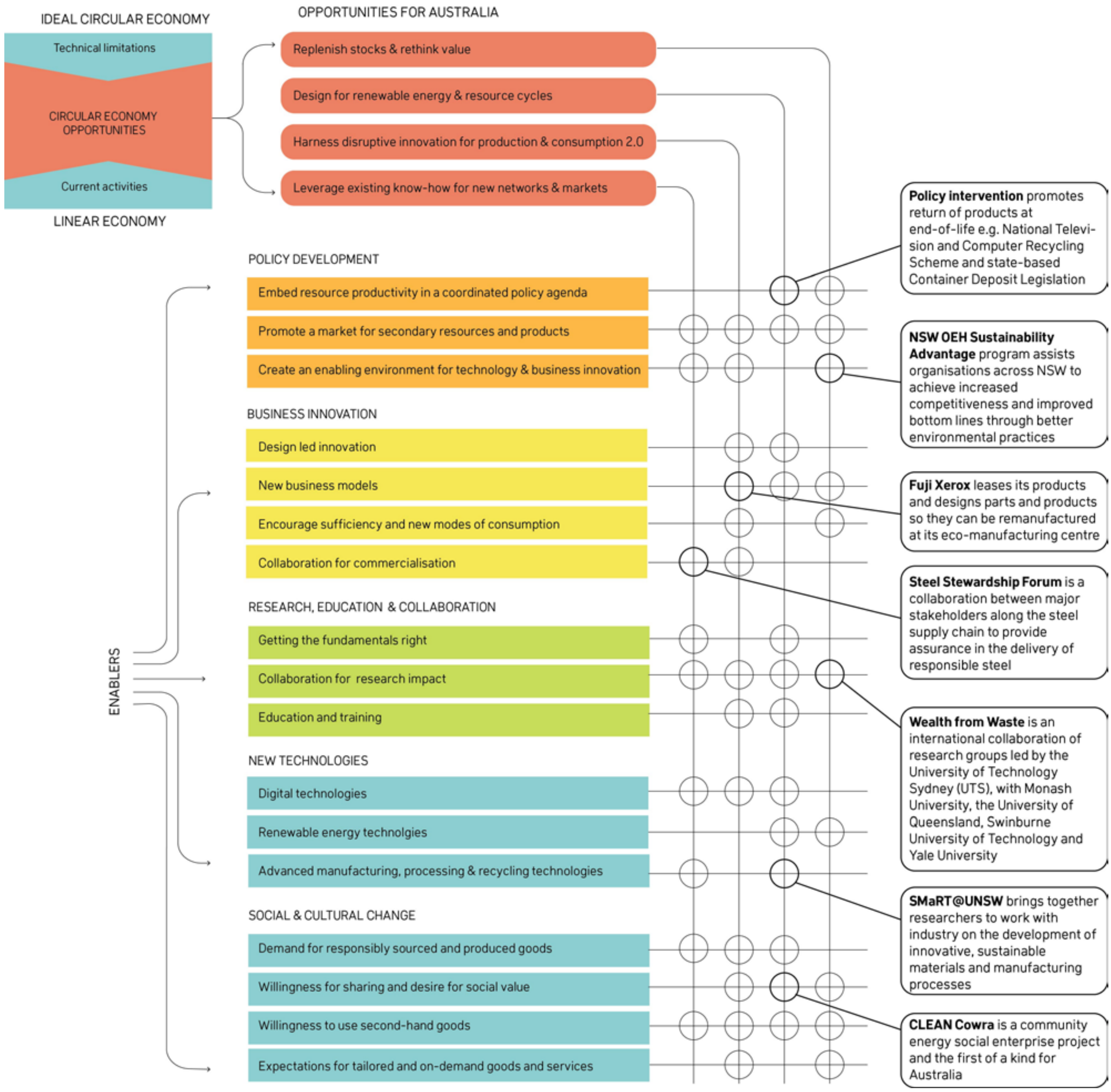

Figure 27: Characterising business, technology, policy and social enablers for a circular economy in Australia (Florin et al., 2015)

The figure emphasises the importance of new connections between stakeholders and sectors and the nodes identify opportunities that are already being seized, as well as those that are likely to be significant for seizing opportunities for Australia. Whilst the emphasis in this work is on metals, this research can be used to demonstrate the potential of innovation opportunity within the circular economy more broadly.

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9 APPENDIX

A1 EXEMPLARY CASE STUDIES

Below are three examples of innovative local business models that, while outside the metals sector, have attributes that may be applicable to metal supply chains and sustainable metals management in the near future. These cases studies are based on more in depth cases studies available written by Tamzyn Dorfling and available online at: http://sustainability.edu.au/about-sustainability/material/teaching-materials/

Fuji Xerox Australia

Fuji Xerox Pty Ltd was founded in the 1960s as a Japanese-American partnership that reproduced paper information. Today the company has transformed to delivering communications and image processing technologies that integrate paper with electronic data and cloud services.

Fuji Xerox Australia has grown from being a small sales office to a prominent company operating in Asia-Pacific. Remanufacturing is the flagship initiative at the Sydney-based Eco Manufacturing Centre that was established in 2000. The facility has returned $240 million on a $22-million investment by offering a range of remanufacturing and recycling initiatives targeting the recovery of end-of-life equipment and affiliated product throughout the value chain.

The recycling and remanufacturing efforts reflect a shift in thinking about waste as an asset or productive resource. From as early as 1989 the parent company began to sell newly manufactured copiers that contained recycled parts, whilst in 1991 they introduced recycled paper into the Australian market, and in 1993 they began recycling parts and consumables. In 1994 they began remanufacturing end-of-life machines, and this culminated in the opening of a dedicated Eco Manufacturing Centre at Rosehill, Sydney.

At Rosehill, they take back products, parts and toner cartridges returned by customers for remanufacturing, or it is sent to domestic third party recyclers depending on which kind of product is being recycled achieving a zero landfill target by 2013. Taking products back at end-of-life is not only related to responsible waste management; remanufacturing and reusing parts allows the company to reduce new resource input and to minimise the carbon footprint of new product manufacture. From a remanufacturing and recycling perspective, things have been made easier as the parent company introduced product designs comprising fewer parts so machines could be more quickly dismantled and the 'waste' can be more easily separated in to pure material streams. Including the Sydney facility, there are four dedicated state-of the-art remanufacturing, re-use and recycling facilities in operation in Japan, Thailand, and China which achieve 99% resource recovery from their products at end-of-life. Fuji Xerox Pty Ltd also look to influence their stakeholders and management of the supply chain is prioritised, covering initiatives such as responsible procurement and sourcing of paper, and managing carbon emissions with logistics providers. Product design effecting the use phase is also an important part of the company's approach, with their latest office equipment ranges being amongst the most energy efficient devices of their category on the market.

Sendle

Sendle is an online door-to-door parcel delivery service providing a convenient mechanism that links up new markets within the circular economy model by moving waste to a place where it becomes a valued resource This successful start-up enterprise has grown quickly since its inception in 2014. Founder and CEO James Moody developed Sendle as a way to make his other online enterprise, TUShare, financially viable. TuShare allows clients to give unwanted items directly to recievers through an online sharing platform. Thus, Sendle came into being, first as the logistics mechanism embedded in the TuShare sharing network, but now it is a stand-alone entity and provides a way in which items can be delivered affordably and conveniently from door-to-door.

Courier and other parcel delivery services operate in an extremely competitive environment with companies trying to position themselves to provide a service at the lowest cost in the least possible timeframe. A range of parcel delivery providers have emerged due to growing local demand for local delivery services driven by international e-commerce sites that rely on local delivery, as well it is expected that this demand will continue to rise with on-line shopping predicted to grow twice as fast as the total retail market in the future.

Recognising that couriers possessed significant idle capacity in terms of their road vehicles already delivering and picking up items country-wide, Moody realised that they were well positioned to take on new business at a competitive rate.

Linked to TuShare, Sendle allows givers to easily send their unwanted items through the courier network and receivers pay the small transport fee to receive the gifted item for free at their door. All that givers are required to do was ensure their unwanted item was appropriately packaged. Once a receiver requested an item Sendle takes care of the exchange.

As well as reducing the amount of waste that went to landfill when people disposed their unwanted items in household bins, by making use of the idle capacity of the couriers, the 'reverse logistics' solution plays a part in offsetting the resource and environmental pressures of transporting items from door-to-door in terms of the increased 'carbon miles'.

In the eight months since inception, Sendle had performed well beyond expectations experiencing 35% growth in deliveries. More and more customers from outside of the TuShare network are taking advantage of the affordable and environmentally neutral service. The performance of each courier company is tracked through the use of an electronic assessment system, and with a user-rating tool, Sendle is dedicated to continually improve the parcel pick-up experience.

Clean Cowra's community-based decentralised biomass-to-energy initiative

Clean Cowra is a first-of-a-kind for Australia community bio energy initiative that is poised to become a reality having funding recently been approved funding to undertake a business case.

As a bioenergy project, various waste (feedstock) generated through agricultural, industrial and local government activities will be used to produce a renewable fuel gas. This in turn could generate power for the community as an alternative to the energy generated through using traditional fossil fuels and there are also by-products that are invaluable to the local agricultural community, such as organic fertilizer.

The community social enterprise project model will also deliver two other vital outcomes making it unique to Australia: community involvement and regional regeneration.

Known as the 'Centre of the Central West', Cowra is the largest population centre and council seat for the Cowra Shire, with a population of 12,574. It is a major agribusiness hub, with agriculture, forestry and fishing operating being the most significant economic sector in employment terms, and abattoirs, cereal crops and wool generating the most income within this sector. However, just as in many other regional areas in NSW Australia, Cowra is in decline, with transport nodes such as train stations and the regional airport having closed down.

Through collaboration of various local Cowra stakeholders from local government, agriculture and industrial communities, the Cowra biomass-to-energy project will involve feeding at least nine key local waste products (feedstock) into a system to produce heat and power. The waste includes: sludge from the waste treatment plant, green matter from municipal green waste, horticultural waste generated by greenhouse or horticultural production, waste from food processing plants and the abattoirs, and intensive farming such as piggeries, poultry, and dairies Two key technologies are planned for converting the waste to energy: one through an anaerobic digestion (AD) process and the other through a pyrolysis process. The two systems are highly complementary, with the first one producing methane gas and the second, commodities which are in demand amongst the local farming community including high value fertilizers which could be customised to suit specific soil types. The second system is also able to produce energy through a thermal process. Farmers are attracted to the idea not only because their waste becomes valuable, but because they reduce their energy costs and can use the fertilising commodities.

There were five phases planned for the project implementation, with the first one focused on delivering a concrete working model. The first phase would involve only AD technology, whilst the second pyrolysis process would follow soon after as it was complementary but less complicated in terms of technology integration. The plan is for phase 1 to generate 2 megawatts of energy, but because the process is only limited by the supply of biomass it is expected that this would then be scaled up to another 4 megawatts and then to 8 or 10. The energy that will be generated is planned for use on an industrial estate that includes the Council's waste treatment plants, and any other entity in proximity to the locale. The town already has a decentralised energy model, and the aim is to make use of an already existing micro-grid.

Looking ahead, according to the project champion Dylan Gower, the main challenge is not about the technology, that will be purchased from a vendor, but around managing broader community engagement. For, example, how to approach issues such as ownership and co-operation aspects regarding the project with the broader community.

A2 COMPENDIUM OF SUSTAINABLE BUSINESS CASES

Company	Scale of activity	Sector	Primary archetype	Secondary archetype	Orientation	Point of intervention	Business Model Characterisation	Description	Source
IKEA	Multinational	Furnishings	Maximise material and energy productivity		Producer/ consumer	Logistics/mobility	Green supply chain management (IWAY)	Value proposition is to supply affordable and resource efficient home furnishings. The design stage of a product begins with the product price, based on which the design, manufacturing and logistics are conceived. Sustainable and ethical materials are sourced and sustainability standards are systemised	Henriksen et al, 2012
Schüco International KG	Multinational	Construction	Maximise material and energy productivity	Sustainable renewable energy and material inputs	Producer	Design	Eco-housing incorporating energy generation and energy storage	Value proposition is to provide housing solutions that save, produce and store energy; main materials produced from recycled aluminium, glass, silicon	Henriksen et al, 2012
Trimo	Multinational	Construction	Maximise material and energy productivity		Producer	Design	Low-carbon buildings	Value proposition is low carbon steel housing. The company provides complete customised solutions covering all stages of the product cycle, from design to production and maintenance. The organisation offers consultation services to customers to reduce environmental impact of their buildings	Henriksen et al, 2012
NatureWorks	Multinational	Manufacturing	Sustainable renewable energy and material inputs		Producer	Design	Bio-polymers from renewable, non-fossil sources	Value proposition is providing customers a renewable based product to substitute fossil fuel derived products; value creation from patented fermentation technology to produce polymers from bioproducts (corn, sugar cane); company charges higher price than fossil fuel but offers more stable	Henriksen et al, 2012

								price allowing customers to hedge against oil price uncertainty	
Elvis&Kresse	Multinational	Manufacturing	Create wealth from waste		Producer	Design	Production of life-style accessories from waste	This business model uses waste as a resource in the manufacture of lifestyle products that would otherwise end up in landfill, saving money for waste generators. The BM solves niche waste problems (e.g.belts made from london firebrigae hoses, bags from coffee bean sacks in collab with Costa Coffee)	Henriksen et al, 2012
Trigema	Multinational	Manufacturing	Adopt a stewardship role	Maximise material and energy productivity	Producer	Design	Environmentally friendly production of cradle-cradle clothing products	The organisation is a privately owned textile company, owning much of supply chain with all operations in Germany. The business model is the manufacture of environmentally friendly clothing products, with cradle-to-cradle product certifcation. Profits are invested in water saving and renewable enrgy process technology locally	Henriksen et al, 2012
Maersk Line	Multinational	Transportation	Adopt a stewardship role	Maximise material and energy productivity	Producer/ consumer	Production	Triple-E container ships and responsible dismantling	Maersk Line provides environmentally, efficient and responsible transport services. Triple-E ships are a new class of efficient and environmentally improved container vessels. Maersk Line has also introduced responsible ship dismatling and recycling, developing a cradle-to-cradle passport system that is used to communicate information about sustainable ship design, for example, to identify that ship is made from high quality recycled steel necessary to avoid contamination with low-quality steel during dismantling	Henriksen et al, 2012

Desso	Multinational	Manufacturing	Adopt a stewardship role	Maximise material and energy productivity	Consumer	Inputs	Cradle-to-cradle certified textile products	Organisation provides products that support customer sustainability policies, with many products cradle-to-cradle certified. Desso sells floor covering by the square-metre, and offers a take-back program at the end of life (including competitors products). Products also have positive effect on environment, for example cleaning the air, or light reflecting qualities that reduce lighting demand	Henriksen et al, 2012
Van Gansewinkel	Multinational	Waste management/ treatment	Create wealth from waste		Producer	Return	Closed-loop re-use of waste materials	Van Gansewinkel has evolved from a waste collection company to sustainable waste management. It coordinates production cycles with collaborative partneships, produces products from waste material, and organises extracting raw materials from waste, for example, providing secondary glass to bottle manufacturers.	Henriksen et al, 2012
SafeChem Europe (subsidiary of DOW)	Multinational	Cleaning products	Adopt a stewardship role		Producer	Use	Sustainable future-orientated use of solvents in surface cleaning	The company offers a range of cleaning services based on their value-added 'SAFE-TAINER' product, utilising double-walled safety steel containers that allow safer handling of fresh solvents. The technology allows the take back of chemicals for recycling or thermal treatment for energy generation. The company offers a range of services including chemical leasing. Within the Chemical Leasing business model, a monthly leasing fee is invoiced to the customer for the entire solution. The fee is calculated on the basis of product performance (e.g. chemicals used per square metre or per time unit) instead of materials used. The revenue therefore shifts from being based on the volume of sold solvents to the performance of the	Henriksen et al, 2012

								complete chemical product service solution .	
Car2Go	Multinational	Transportation	Deliver functionality rather than ownership		Consumer	Use	Vehicle sharing model	Car2Go offers customers a flexible mobility solution - the novelty is a car sharing service with no fixed drop off points. Customers pick up conveniently located cars based on location using a smartphone app, with information of cleanliness, fuel/charge of the vehicle. Drop off can be any public space in defined zone; users must be members and there is a membership fee but no monthly subscription. The revenue model is 'pay per usage', and a fee per minute is calculated based on fuel, taxes, maintenance, insurance (thus parking during use reduces usage fee). There are additional fees based on maximum hour/day rates, km limits and rewards associated with refueling/recharge	Henriksen et al, 2012
Phillips	Multinational	Diversified technology	Deliver functionality rather than ownership		Consumer	Use	"Pay per lux" product as a service model	Business model follows a cradle-to-cradle philosophy, offering a closed-loop lighting service where lighting is delivered/installed, used, taken back for better product and environmental performance. The service includes monitoring consumption, closer relationship with customers and a new revenue model based on continuing payment	Henriksen et al, 2012

EastexMaterial Exchange	Multinational	Waste exchange	Create wealth from waste	Maximise material and energy productivity	Producer/ consumer	End of life disposal	Web-based waste exchange	Web-based material exchange to reduce the cost of raw materials for SMEs - revenue is generated by selling the platform to local council regions. There are currently 1200 members, and enough profits are generated to be self sustaining (other revenue streams may be found through advertising)	Henriksen et al, 2012
Rantasalmi	Scandinavia	Eco-parks	Create wealth from waste	Maximise material and energy productivity	Producer/ consumer	Logistics/mobility	Eco-industrial park	Rantasalmi commune eco-industry park in Finland comprises wood processing, transport, blade maintenance services. Rather than focussing on waste exchange and sharing raw material, the commune collaborates on exchanging labour, and sharing of equipment, logistics and storage	Henriksen et al, 2012
EoN	Multinational	Eco-parks	Create wealth from waste	Maximise material and energy productivity	Producer/ consumer	Return	Eco-industrial park	Low-cost and environmentally friendly energy from waste (household and industrial, eg. from paper production and sawmill) for heating and raising steam (reduces cost on inputs and revenues from production while promoting a green image)	Henriksen et al, 2012
Yalumba (Samuale Smith and Son)	Multinational	Food and beverage	Adopt a stewardship role	Maximise material and energy productivity	Producer	Production	Sustainable supply chain management	The company monitors lifecycle impacts, and has developed a sustainable wine making program that promotes land stewardship, product stewardship, waste management and climate change adaption. The company works closesly with suppliers and encourages adoption of clean technology, and has developed LCA that is used as standard in New World Wine industry.	Henriksen et al, 2012
Biototal AB	Scandinavia	Agriculture	Create wealth from waste	Sustainable renewable energy and	Producer	Return	Upcycling of agricultural/forestry waste	The business model is the upcycling of waste and by-products from agriculture/forestry for bio-	Henriksen et al, 2012

				material inputs				fertilisers. The company acts as a link between waste generators (often municipalities) and users (farmers) that need nutrients. The organisation has good knowledge of local customers needs and prioritisse exchanges that minimise transportation costs.	
ChargeStorm AB	Scandinavia	Transportation	Maximise material and energy productivity		Producer/ consumer	Use	Intelligent charge stations for electric vehicles	The organisation incorporates knowledge about telecom technology, and data communication network which underpins e-vehicle charging infrastructure. Infrastructure can be used by energy companies and enterprises providing charging spaces for e-vehicles	Henriksen et al, 2012
Econova AB	Scandinavia	Construction	Create wealth from waste	Sustainable renewable energy and material inputs	Producer	Return	Upcycling of agricultural wasts	The business model processes secondary/residual products and waste from industry and society into useful products such as bio-fuel or soil (compost) for municipalities and agricultural/horticultural companies	Henriksen et al, 2012
Envac Optibag AB	Scandinavia	Waste management/ treatment	Maximise material and energy productivity		Producer	End of life disposal	Improved sorting of household waste	The business model is an in-house development of optical sorting technology for source-separated household waste. System simplifies households to source separate waste which leads to increased efficiency and higher quality material than achieved with current methods of waste sorting	Henriksen et al, 2012
Plantagon International AB	Multinational	Urban gardens	Maximise material and energy productivity	Adopt a stewardship role	Producer	Inputs	Urban Vertical Farming Technologies	This company develops innovative solutions to meet the rising demand for fresh food in urban areas. Urban farming and vertical gardens can deliver fresh produce directly to urban consumers at lower prices and with reduced environmental impacts.	Henriksen et al, 2012

PolyPlank AB	Multinational	Construction	Create wealth from waste		Producer	Production	Recycled materials for the manufacture of composite boards for the construction industry	The company was founded on a process technology developed in-house for the development of its own unique composite. The composite which is used in their products is derived from recycled wood fibre waste from the sawmilling industry, and recycled plastics derived from packaging and other waste products.	Henriksen et al, 2012
Qlean Scandinavia AB	Scandinavia	Cleaning products	Sustainable renewable energy and material inputs	Maximise material and energy productivity	Producer	Use	Non chemical based cleaning products for the energy and industrial sectors	The company provides safe cleaning solutions and products designed to keep costs low and reduce environmental impacts. Qlean products are not chemical based (pure-water) therefore limits environmental impacts. Products specifically targetted towards the power generation and industrial sectors, where algae, mold, dirt and oil problems are prevalent. Currently operating in Sweden, moving towards operation in Norway and Germany and in talks with possible partners abroad.	Henriksen et al, 2012
Svensk Biogas I Linkoping AB	Sweden	Alternative energy	Create wealth from waste	Sustainable renewable energy and material inputs	Producer/ consumer	Return	Biogas production and distribution through local business network	The business model focus is to operate existing biogas production facilities and to establish new production and distribution networks in the region (Linkoping), and surrounding areas. Organistaion has partnerships with local meat industry, local wastewater treatment plants and other collaborators/stakeholds including local bus depots. The company is paid to collect organic waste and residues from local industry and households for biogas production. Waste material from biogas production is sold as certified bio-fertilizer to local farmers	Henriksen et al, 2012

Islensk Matorka ehf.	Scandinavia	Food and beverage	Sustainable renewable energy and material inputs	Create wealth from waste	Producer	Inputs	Utilisation of waste from geothermal energy generation for aquaculture	The business model is focused on sustainable aquaculture (fish farming) taking advantage of waste water from local geothermal power plants. Another aspect of the business model is sustainable fish feed used, sourced from local renewable sources. The goal of the business is to produce fish products that do not leave any negative impact on the environment	Henriksen et al, 2012
Hopbilar	Iceland	Transportation	Adopt a stewardship role		Consumer	Use	Providing ISO14001 certified transportation	Hopbilar is the only transportation company in Iceland providing passenger services that are certified under ISO14001. All coaches are run on diesel fuel, supply chain has been reduced (only company refueling stations are used), and all drivers have completed eco-driving courses aimed at driving to help reduce fuel consumption.	Henriksen et al, 2012
Scandinavian Business Seating	Scandinavia	Furnishings	Maximise material and energy productivity	Adopt a stewardship role	Producer	Design	Green supply chain management and cradle-to-cradle production	The business model is a hybrid lifecycle model, green supply chain management and cradle-to-cradle model. Ergonomics and sustainability are the key drivers of office chair design and production for the company. Environmental Product Declariation Certification, documenting the carbon footprint of products is attached to SBS products. Supply chain must align with SBS sustainability goals, and partnerships with suppliers has been a major contributor to improving environmental performance of products	Henriksen et al, 2012
Netcycler Oy	Multinational	Waste management/ treatment	Create wealth from waste		Consumer	Use	Web-platform for collaborative consumption	Netcycler is a model of collaborative consumption, offering a web-platform where users offer unwanted goods for re-use to other users. In this model, users are the	Henriksen et al, 2012

								suppliers and customers of the supply chain.	
Roltex	Multinational	Food and beverage	Sustainable renewable energy and material inputs	Create wealth from waste	Producer	Design	Ecological products	Roltex has developed the "Earth Tray" made from recycled and FSC certified cardboard, and organic phenol resin obtained from bio-waste, to replace standard plastic food trays used in the food service industry. Roltex wants to reduce waste by partnering with fast food chains to exchange end of life service trays for ecological processing	Beltramello et al, 2013
INTEMAN	Multinational	Cleaning products	Sustainable renewable energy and material inputs		Producer	Inputs	Ecological products	The company has developed and manufactured biological, non-contaminating and safer cleaning products, specifically targetted at the the food industry. The food industry is regulated increasingly by Hazard Analysis Cricial Control Point (a preventative approach to food safety addressing physical, biological and chemical hazards). INTEMAN has developed networks with the food industry in Spain, and is now looking at expanding its network into Europe	Beltramello et al, 2013
Sekisui Chemical Co. Ltd.	Multinational	Construction	Create wealth from waste		Producer	Production	Reuse housing system	Sekisui Chemical Co. uses a construction method for modular housing where pre-constructed housing 'units' can be reused, refurbished or remodelled for new housing. The system is based on extended lifespan metal used in the structural frame of the modular units, ensuring structural integrity over many 'reuses' of the modular units. Pre-constructed modular housing is disassembled and remodelled before being erected in the construction of a new dwelling	Beltramello et al, 2013

Orana	Multinational	Manufacturing	Maximise material and energy productivity		Producer	Design	Net0lift - Research project/consortium focusing on sustainable passenger lift systems	Orana leads consortium of stakeholder companies in a research project that aims to develop new concepts to produce zero energy passenger lift systems. Consortium has partnerships with product suppliers and technological developers. Sustainability indicators are used to assess new technological concepts including application of smart energy systems and the waste hierarchy in lift design and construction. Innovations resulting from the consortium have already been implemented in new lift products on the market	Beltramello et al, 2013
3M	Multinational	Diversified technology	Adopt a stewardship role		Producer/ consumer	Design	Pollution Prevention Pays (3P) benchmarking program/employee engagement	The 3P programs benefits from 3M corporate culture of employee based engagement in innovation strategies. The 3P program seeks to reduce pollution and waste at the source (product design and manufacturing) through innovation. The 3P program has lead to innovation in water-based adhesives and hot-melt tape products, which have measurable pollution, energy and waste reduction. 3M have partnered with the US EPA and DOE to continue to develop sustainability benchmarks for their products	Beltramello et al, 2013
Refrigerants, Naturally!	Multinational	Chemical production	Sustainable renewable energy and material inputs		Producer	Inputs	Development of natural refrigerants and alternative refrigeration technologies	The Refrigerants, Naturally! Initiative was launched by a collaboration of The Coca-Cola Company, Unilever and McDonalds to combat ozone layer depletion by the replacement of F-gases, CFCs, HFCs and HCFCs in refrigeration with natural refrigerants. The initiative is supported by Greenpeace and UNEP, and member companies work with suppliers and manufacturers to develop and test new technologies	Beltramello et al, 2013

								using natural refrigerants. New partnerships are expected to contribute to the development of further innovations in natural refrigerants and alternative refrigeration technologies	
Alcoa	Multinational	Metals processing	Create wealth from waste		Producer	Return	Enhancing the value of bauxite residue	Alcoa produces 3-4 million tonnes of bauxite residue as a by-product of alumina production. Alcoa is developing ways to process this residue for a number of applications including in cement manufacturing, road building, and top-soil dressing.	Beltramello et al, 2013
Grundfos	Multinational	Waste management/ treatment	Maximise material and energy productivity		Producer	Production	Biological wastewater treatment innovation	BioBooster is a biological wastewater treatment innovation that has a smaller footprint compared to other treatment technologies for the same volume of water treated due to decreased infrastructure and energy requirements	Beltramello et al, 2013

Humolea	Multinational	Agriculture	Create wealth from waste		Producer	Return	Upcycling of olive oil production wastes	Humolea uses residues from the olive oil production process to produce a high-quality soil conditioner for agriculture. Olive oil processing produces toxic solid and liquid waste. Traditionally this waste is processed through aerobic/anaerobic biological treatment or incineration. Humolea reconfigures the value of the waste by upgrading it to a valuable product (soil conditioner) thus creating a new value chain	Beltramello et al, 2013
Brisa	Multinational	Construction	Create wealth from waste		Producer	Return	LIFE ECOVIA - recycling for infrastructure construction	Brisa is a Portuguese motorway operator, The LIFE ECOVIA project aims to create new material from cardboard food packaging, rubber from used tires, and mixed plastic residues, to be used for various motorway items (barriers, pathways, protectors etc). Brisa seeks to use existing recycling infrastructure around Europe for manufacturing its products	Beltramello et al, 2013
TECMACAL	Multinational	Manufacturing	Create wealth from waste		Producer	Return	CARRE - recycling of leather waste	TECMACAL is a market leader of the sale of machinery for the leather and footware industries. TECMACAL have developed new machinery that produces prepared leather "blankets" from leather waste products, to be used again in the creation of other leather products	Beltramello et al, 2013
Ecoera	Multinational	Agriculture	Create wealth from waste	Sustainable renewable energy and material inputs	Producer	Return	Biochar - upcycling of agriculture by-products	Agricultural residues are blended and undergo pyrolysis to produce biochar for carbon sequestration, soil conditioning and heat generation for farming. Business model provides link between agricultural soil carbon and Carbon Accounting Systems	Beltramello et al, 2013

Preseco Oy	Finland	Waste management/ treatment	Sustainable renewable energy and material inputs		Producer	Production	Bio-carbon - equipment licensing; bio-waste refining for energy	Preseco delivers facilities and equipment for water, wastewater and bio-waste treatment and refining. Bio-carbon is a product produced by this equipment which can be used as a replacement for coal. The technology is licensed to other companies who use the technology to transfer organic waste into bio-carbon	Beltramello et al, 2013
Brite Hellas	Greece	Alternative energy	Deliver functionality rather than ownership	Sustainable renewable energy and material inputs	Consumer	Use	Solar windows	Brite Hellas is a start-up from Greece that has introduced solar windows into the market. The business model is based on selling an innovative product that reduces fossil-fuel derived energy consumption	Beltramello et al, 2013
Solray Energy Ltd	Multinational	Chemical production	Sustainable renewable energy and material inputs	Maximise material and energy productivity	Producer	Inputs	Super critical water reactor	Solray applies super critical water technology to the production of commodity chemicals, using bio-mass as feedstocks. The business model is targeted at organisations that are harvesting algae through wastewater, facilities that have an abundance of saw-dust and fibre, and eutrophic lakes.	Beltramello et al, 2013
Waste Solutions	Multinational	Waste management/ treatment	Deliver functionality rather than ownership	Create wealth from waste	Consumer	Use	Cigar Biogas Reactor	Waste solutions has developed the Cigar Biogas Reactor as a low capital cost option for regions where land is not at a premium. The BM builds water treatment installations at low cost, and investment is returned through the selling of produced energy	Beltramello et al, 2013
LanzaTech	Multinational	Waste management/ treatment	Create wealth from waste	Sustainable renewable energy and material inputs	Producer	Production	Microbial gas fermenatation process - ethanol from steel industry waste	LanzaTech have developed a microbial gas fermentation process to produce ethanol fuels and other chemicals (for use in the plastic/polymer markets). Feedstock gas contains carbon and hydrogen, and can come from a number of sources, with the focus thus far	Beltramello et al, 2013

								being on waste gases from the steel industry.	
Frito Lay	Multinational	Food and beverage	Create wealth from waste	Maximise material and energy productivity	Producer	Production	Net-Zero Plant	Business model is the transition of a Casa Grande Frito-Lay plant to Net-Zero. Goal of the plant is to run on 100% renewable power and recycled water, and all waste recovered on site through reuse/recycling and bioenergy feedstock	Beltramello et al, 2013
Cowell	Taiwan	Lighting	Deliver functionality rather than ownership	Maximise material and energy productivity	Consumer	Use	LED lighting rental service	BM response to high customer demand for rental service over a short period of LED lighting products. The company subcontract rental of lighting to external rental companies while ownership is maintained. Main customers are stores, and the business replaces older halogen lighting with LEDs. BM also includes extended product warranties	Beltramello et al, 2013
Danfoss Solutions	Multinational	Energy	Deliver functionality rather than ownership		Consumer	Use	ESCO solutions	An ESCO solution is a commercial service where the energy service company (ESCO) performs analysis on a client's production processes and routines and offers recommendations for the reduction of energy, and financing. Savings are guaranteed by the ESCO, and the ESCO is paid a proportion of the energy savings achieved. Danfoss targets the industrial and food processing sectors, and extends ESCO recommendations beyond technological solutions to include behavioural aspects and people engagement	Beltramello et al, 2013

National Technical University of Athens	Greece	Transportation	Maximise material and energy productivity		Producer	Design	Zero Vehicle - lightweight, safety orientated vehicle	NTUA has developed an ultra-light vehicle for cities focused on driver and pedestrian safety. The vehicle has an external energy absorbing layer to reduce pedestrian injury in the event of a collision, and travels at a slower speed. Due to its lightweight construction, the vehicle has low energy consumption, low construction cost, and is partly constructed from recycled materials, while achieving higher safety standards when compared to other European "city" cars	Beltramello et al, 2013
Better Place	Multinational	Transportation	Deliver functionality rather than ownership	Sustainable renewable energy and material inputs	Consumer	Use	Better Place battery ownership model	Better place delivers a network of services that promotes use of electric vehicles. Battery and vehicle ownership is separated, with the battery remaining the property of the service provider	Beltramello et al, 2013
Ulsan Eco-Industrial Park	South Korea	Eco-parks	Create wealth from waste		Producer	Return	Facilitation of industrial symbiosis networks	Korea has launched an eco-industrial park initiative with the aim that all Korean industrial parks will become eco-industrial parks. Ulsan promotes development of designed symbiosis networks in Ulsan industrial complexes, assisted by stakeholders including the Korean Industrial Complex Corporation and the Korean Ministry of Knowledge Economy. The adoption of industrial symbiosis projects in Ulsan thus far has resulted in approximately $70-million in economic benefit, and approximately $2-million in R&D support	Beltramello et al, 2013
Active House Alliance	Multinational	Sustainable Housing	Sustainable renewable energy and material inputs	Maximise material and energy productivity	Producer	Design	Active housing - energy efficient and renewable energy housing	Active House Alliance - includes architects, engineers, developers, scientists - share and developed the active house principles/vision. Based on open source knowledge sharing,	Beltramello et al, 2013

								specification and demonstration, and communication of efficient housing princples. Active House Specification is one outcome which is intended to be used as a guideline for construction and design industries at an international level to innovate approaches of architectural design, environmental performance and energy efficiency	
BB Architects	Spain	Sustainable Housing	Maximise material and energy productivity	Sustainable renewable energy and material inputs	Producer	Design	Torrelles Public Housing in Torrelles de Llobregat - traditional knowledge and local resources influencing design	BBArchitects have developed an eco-housing project for public housing near Barcelona which incorporates traditional knowledge, local resources and the envionment into housing design. The project utilises local resources and systems to better integrate housing into the environment, and feature such measures as recycled water and distributed generation to meet environmental performance goals. The housing project meets a need for economical shelter in the area.	Beltramello et al, 2013

DigiEcoCity	Finland	Sustainable Housing	Maximise material and energy productivity		Producer	Design	DigiEcoCity - walkable city; ecological principles with ICT innovations	DigiEcoCity is a Nordic city combining ecological principles with innovations in ICT. The objective of the approach is to combine elements of a walkable city with a digitally integrated 'smart-city' that is energy and resource efficient. The model city will be diverse, and resistent to changing social and economic conditions.	Beltramello et al, 2013
Raidis Architecture		Urban gardens	Maximise material and energy productivity		Producer	Inputs	Integrated sustainability solutions in urban dwellings	The Eco System service provided by Raidis Architecture provides eco-solutions and energy savings in an urban context - specifically focused on apartments. The approach is specified to local characteristics including weather and local materials. Solutions include energy efficiency measures and integration of environmental services with the building, as well as green roofs which promote local agriculture activities and supports social interactions.	Beltramello et al, 2013
Panasonic	Japan	Sustainable Housing	Sustainable renewable energy and material inputs	Maximise material and energy productivity	Producer	Design	Smart town in Fujisawa	Panasonic is leading a collaboration of organisations (including construction, car-sharing, banking) to develop a 1,000 household town in Japan. The aim of the project is to create a new type of town development and services through the collaborators' solutions, focused on day-to-day life. Services include energy management systems, EV infrastructure, solar power and battery storage	Beltramello et al, 2013
Endesa	Spain	Sustainable Housing	Sustainable renewable energy and material inputs	Maximise material and energy productivity	Producer	Inputs	Smartcity Malaga	Consortium of 11 companies and 14 research centres have created a 'living lab' where new technologies (smart metering, communications, alternative generation etc) are tested in a small area of Malaga.	Beltramello et al, 2013

								Living lab allows testing in real conditions, and individual companies in the consortium support and share knowledge development. End-users are active participants. Project partners benefit from new business models and opportunities	
Michelin	Multinational	Transportation	Deliver functionality rather than ownership	Maximise material and energy productivity	Consumer	Use	Tire leasing	Michelin offers customised tire leasing programs for fleet customers in the transit, public transport, refuse, and all types of trucking fleets. Customers pay a lease on an agreed upon cost per km/mile. 'Pay as you go' for tire users offers the advantage of reducing capital expenditure. Tire leasing benefits Michelin through being able to maintain control over the tires throughout their use. Michelin is able to easily collect them at the end of lease, and can extend their technical life through repair, or introdruce material components into inputs for other products/processes	Accenture, 2014
Incom Recycle	China	Waste management/ treatment	Create wealth from waste	Maximise material and energy productivity	Producer	End of life disposal	Intelligent solid waste recovery and recycling in China	Incom Recycling is the leading operator of intelligent waste management systems in Beijing, using digital technology and innovating sorting and collection methods to develop an intelligent recycling network in Beijing and further afield. Incom's Reverse Vending Machines are a principal product of Incom. Incom's RVM products integrate internet and digital technology to provide intelligent recycling systems for urban locales. RVMs developed for different scales (including for beverage bottles and batteries), and are marketed globally. RVMs include data collection and provides data for policy formulation at government	http://incomrecycle.com/

								level	
FogBusters	USA	Waste management/ treatment	Create wealth from waste		Producer	End of life disposal	Removing fat, oil and grease from wastewater	FogBusters is a eco-friendly technology for removing fat, oil and grease (FOG) from wastewater. The novel system works in conjunction with current typical wastewater treatment systems to recover FOG from wastewater without the use of chemicals. Recovered FOG can then be sold for revenue or used in other applications (e.g., biodiesel)	http://www.fogbustersinc.com/
Tusaar	Multinational	Waste management/ treatment	Create wealth from waste		Producer	End of life disposal	Sequestering toxic, hazardous, and metals from wastewater	Tusaar has developed novel waste treatment technology for sequestering toxic, radioactive and precious metals from wastewater. Tusaar's process involves surface treatment and permeation of granulated activated carbon with other eco-friendly compounds. The process targets over 45 different metals, and can isolate these metals from a single source allowing sequestered material to be recovered	http://tusaar.com/
British Sugar	UK	Food and beverage	Create wealth from waste	Maximise material and energy productivity	Producer	Return	Industrial ecology and business model innovation	Over the last 30 years, British Sugar has sought ways to adapt their business model to turn waste and emissions outputs from their core production processes into useful and positive inputs to new products. The core business model has not changed (sugar production), but has been supplemented with animal feed production, electricity generation, and bioethanol production.	Short et al, 2014

Hepburn Wind Farm	Australia	Alternative energy	Sustainable renewable energy and material inputs		Producer	Inputs	Local cooperative model	Hepburn Wind has been set up as a co-operative that owns and operates Hepburn Community Wind Park - Australia's first community owned wind farm. Through the community partnership model, members of the community can invest in the wind farm, and revenue is generated through the sale of electricity to the local energy network	APEC, 2009
SunEdison	USA	Alternative energy	Deliver functionality rather than ownership		Consumer	Use	Solar power purchase agreement model	Walmart Stores and SunEdison have entered into a solar power services agreement where SunEdison finances, builds, operates, and maintains photovoltaic systems installed at Walmart stores. Walmart purchases the power under a long term agreement from SunEdison, who retains ownership of the system	APEC, 2009
Earth Energy Utility Copr.		Alternative energy	Sustainable renewable energy and material inputs		Producer	Use	Geothermal Heat Pumps Energy Service Model	Earth Energy Utility Corp provides geoexchange technology for heating and cooling for owners of large-scale developments. Owners enter into a contract and agree to pay a fixed monthly fee equal to their current utility bill and is guaranteed for 50 years	APEC, 2009
Google		Manufacturing	Maximise material and energy productivity		Producer	Design	Project Ara Initiative	Project Ara initiative focuses on reinventing the smartphone by breaking it down into replaceable modules that can be assembled and customised according to user requirements. Customisation allows the phone to remain technologically relevant for a longer period of time and to repair the phone more easily/inexepensively	Accenture, 2014
Tushare	Australia	Waste exchange	Maximise material and		Consumer	Return	Sharing platform	Tushare was designed to allow users to share unwanted items directly	https://www.tushare.com/

			energy productivity					through an online sharing platform. Key driver is reducing amount of waste to landfill through disposal of unwanted household items	
Sendle	Australia	Logistics	Create wealth from waste		Consumer	Logistics/mobility	Reverse logistics courier service	Sendle is a reverse logistics delivery mechanism for users of TuShare. The driver behind this business model was a cheap and efficient courier service that would ensure TuShare's use by making it easier for users to exchange items than to dispose them as household waste. The BM utilises the excess capacity of couriers for parcel delivery	https://www.sendle.com/

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