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Resource efficiency, the circular economy, sustainable materials management and trade in metals and minerals

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Resource Efficiency, the Circular Economy, Sustainable Materials Management and Trade in Metals and Minerals

Paulo de Sa and Jane Korinek

A more resource efficient and circular economy will help to decouple global economic growth from natural resource use, decrease environmental degradation and improve energy efficiency. Existing circular economy policies have been largely focused at the national level. However, trade policies can promote greater resource efficiency and circularity by enabling economies of scale in recycling; by ensuring regulatory coherence between different frameworks for recyclable material; and by helping to address the problem of exports to countries without adequate recycling facilities.

The vast majority of trade in end-of-life material – waste and scrap – is in metallic material. Recycling metallic waste and scrap means less mining of non-renewable resources, and producing the most commonly used metals from recycled material uses 60-97% less energy than producing them from mined material. Moreover, demand for some minor metals and minerals, such as lithium, cobalt and rare earth elements (REE) used in energy storage, wind turbines and other environmental goods is projected to increase sharply as the global economy strives to become more carbon-neutral. Recycling these low-volume minerals will become urgent. Trade in these recovered materials will be particularly important in order to allow economies of scale for recycling operations as technologies evolve.

Keywords: Recycling, waste and scrap, raw materials, energy storage, export restrictions, lithium, cobalt, rare earth elements (REE)

JEL Codes: Q01, Q02, Q37, Q38, Q56

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Key messages

- A more resource efficient and circular economy can support the aim of decoupling global economic growth from natural resource use and help to decrease environmental degradation and improve energy efficiency.
- Trade in metallic waste and scrap accounts for about 80% of the value and over half of the volume of total trade in waste and scrap. Recycling these materials has the greatest potential to be economically viable given their high unit values, which means less primary raw material extraction. And producing the most commonly used metals from recycled material uses 60-97% less energy.
- Trade policies can promote greater resource efficiency and circularity by enabling economies of scale in recycling, ensuring regulatory coherence between different waste frameworks, and tackling problems of exports to countries with inadequate recycling facilities.
- Export restrictions, affecting 40% of traded copper waste and scrap, 30% of aluminium, and 20% of iron and steel waste and scrap negatively impact trade in waste and scrap. Meant to safeguard domestic supply, they can provide a disincentive for further collection of end-of-life products by lowering prices for domestic downstream users.
- Concerns about exports of waste and scrap, including e-waste from discarded end of-life electric and electronic products, to countries that do not have adequate recycling facilities can be addressed through strengthened international cooperation.

Executive Summary

In the transition toward a more resource efficient and circular economy, resources used to produce goods are minimized and kept in use as long as efficiently possible and waste is diminished. Greater circularity can also contribute to decoupling economic growth from the consumption of finite resources. One of the main global benefits of the transition to a resource efficient and circular economy is an expected reduction in environmental pressures, including less reliance on primary resources and more efficient energy use. Trade policies can impact the potential for achieving a more resource efficient and circular economy, while greater circularity in turn will impact trade flows.

Thus far, the transition to a resource efficient and circular economy has yet to be realized. Recycled material accounts for no more than 30% of steel and aluminium production. Some reuse and remanufacturing business models have experienced rapid growth recently, but they are limited to a few niche sectors and represent no more than 5-10% of output. Remanufacturing has generally taken place on large and costly equipment and investment goods, such as engines and other vehicle parts, photocopiers and medical equipment.

Existing circular economy policies have largely focused on closing, extending and narrowing material loops at the national level. They generally encourage waste management and material recovery to take place domestically using instruments such as extended producer responsibility programmes (EPR), landfill taxes, and industrial partnerships to encourage product design for circularity.

Trade and circular economy policies share a broad interface. This paper focuses on trade in end-of-life and refurbished and remanufactured goods with metallic content. Trade in metallic waste and scrap has grown substantially since the early 2000s and currently accounts for about 80% of the value and over half of the volume of total trade in waste and scrap. Not only is metallic waste and scrap the most traded of all types of waste material, but recycling these materials has the greatest potential to be economically viable given their high unit values. Exports of metal scrap amounted to USD 82 billion in 2017 up from USD 22 billion in 2002, representing 27% of the value of exports of primary metals. Most trade takes place in a few products: iron and steel, aluminium, copper and gold, with all other metallic waste and scrap accounting for less than 20% of the value of exports. About 70% of metal waste and scrap exports by value originate in the EU-28, Japan, and the United States.

While import restrictions on metallic waste and scrap are not prevalent (70% of such materials encounter zero import tariff), export restrictions are used more than on any other segment of primary material production, affecting 40% of traded copper waste and scrap, 30% of aluminium, and 20% of iron and steel waste and scrap.

Lowering trade barriers and increasing availability of metallic waste and scrap on global markets would contribute to closing material loops and enable production of metals using less energy. Ensuring that trade in recovered minor metals, i.e., those that are available in small quantities, takes place will be particularly important as technologies evolve, in order to allow economies of scale for recycling operations of these low-volume materials.

Despite agreements that ban or restrict cross border shipments of hazardous and other waste, illicit trade in waste often bypasses regulations that impose obligations to export waste only upon consent of importing and transit countries so that such waste can be managed in an environmentally sound manner. This is particularly important as regards e-waste, which is discarded electrical and electronic equipment, and is the fastest growing global waste stream. Concerns about the exports of waste and scrap, including e-waste, to countries without adequate capabilities for managing this type of waste, and the negative environmental consequences they entail, will need to be further addressed.

Notwithstanding its potential contribution to supporting resource efficient and circular economy outcomes, global trade in remanufactured products is constrained by regulatory barriers, import bans, unfavourable consumer perception, and the lack of common definitions. Critical issues to the proper functioning of these markets include distinguishing trade in second-hand goods from products that are exported for remanufacturing or for recycling; agreeing upon, disseminating and observing international quality standards for their collection, processing and reuse; and clarifying collection and recycling programmes, such as EPR, in a global context.

Governments can play a greater role in creating a policy environment that supports resource efficient and circular business models by engaging with firms to promote responsible stewardship throughout the lifespan of their products, supporting the introduction of new technologies that prolong the useful life of products and parts, and promoting re-use, re-manufacture and the recycling of waste and end-of-life final goods.

Trade policies can play a role in encouraging more resource efficient and circular outcomes through greater trade in reused and remanufactured products, secondary materials and scrap. As a first step, measurement systems could be improved to better reflect the differences between new, used and remanufactured products, and different categories of waste and scrap. Barriers to trade in metallic waste and scrap should be lowered to allow economies of scale in recycling and increase incentives for collection of such materials

Standards for waste recovery, in particular e-waste, are lacking in some areas, as is information on recycling operations and the streamlined organization of exports to such facilities. International treaties and agreements such as the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal and the 2001 OECD Decision of the Council on the Control of Transboundary Movements of Wastes Destined for Recovery Operations could be strengthened to ensure they accurately address flows of hazardous waste and scrap amidst changing trade patterns. One model for gathering information in order to manage trade flows of waste and scrap is the OECD Database of Transboundary Movements of Wastes, which collects information regarding recycling facilities and the types of waste they accept, and institutes a procedure for exporting waste to pre-consent recovery facilities.

Technological improvements can aid in internationalizing closure of material loops, such as sensors that establish material composition of waste and scrap in order to better sort waste types and blockchain technologies that track products through their lifecycle. In order to diffuse these technologies widely, they should not be subjected to unnecessary barriers to their trade. An enabling trade and investment environment regarding services will be necessary to support the increased services that result from a transition to a more circular economy.

As the paper demonstrates, trade frameworks, i.e., classifications, standards, trade rules and practices, for waste, scrap and secondary materials could be adapted to better address and support the transition to a circular economy. Safely and effectively managing trade in waste and scrap is a complex task that requires international collaboration and agreement between stakeholders in order to contribute to the transition to a circular economy. Global partnerships will need to be forged, to agree and enforce trade rules, to combat illicit exports and ensure waste is not exported to countries without adequate treatment capabilities, and to contribute to closing global material loops by ensuring waste, scrap and secondary materials are available for reuse, remanufacture and recycling in the most efficient and sustainable way possible. Preferential trade agreements can also be leveraged to enhance circularity, *inter alia* through sustainable trade in used and remanufactured goods, waste, scrap and secondary materials.

1. Introduction

Production has traditionally taken place according to a linear model of “take-make-consume-dispose” where resources are extracted, processed using energy and labour, sold as goods and discarded at the end of their lives. More recently, however, countries and consumers have become aware of the unsustainability of this model and the benefits derived from the extension of the useful lives of assets and resources.

The circular economy is a concept based on changes in consumer behaviour, technologies and business models that give priority to longevity, reuse, repair, refurbishment, sharing, leasing, and recycling of products and materials to achieve a more efficient use of resources by closing, redesigning, extending and narrowing loops of material flows. Similarly, the concept of sustainable materials management (SMM) is a systemic approach to using and reusing materials more productively over their entire life cycles.

How our society uses materials is fundamental to our economic and environmental future. Global competition for finite resources will intensify as world population and economies grow. More productive and less impactful use of materials helps economies remain competitive, contributes to our prosperity and protects the environment in a resource-constrained future.

The basic principle of approaches such as the circular economy, resource efficiency and SMM is that economic growth can be accomplished without equivalent increases in resource extraction and the environmental degradation that often goes with it through the more efficient use of resources.

Central to the concepts of resource efficiency, circular economy and sustainable materials management[1] is the incentive to minimize the extraction of primary resources and the flows of materials that go to waste thereby ultimately "decoupling" primary raw materials consumption from economic growth. The concept of decoupling resource use from economic growth is central to the achievement of the Sustainable Development Goals (UN Environment, 2019). Estimates suggest that material use will double by 2060, and use of metals will triple over that period in a "business as usual" scenario (OECD, 2018d).

Much work has been done on resource efficiency, its impacts, and policies that support the aim of decoupling growth from resource use. Recently, OECD has been active in the G20 resource efficiency group, and in the G7 group on plastics. Many OECD and some non-OECD countries have implemented policies to support greater resource efficiency that aim to better price the value of end-of-life disposal of materials through policies such as landfill taxes; extended producer responsibility programmes; by reducing or removing harmful subsidies; fostering the trade and production of products produced using resources more efficiently and more easily reparable and recyclable; and promoting greater consumer awareness. Recent policies by Japan, Finland among other countries, for example, have focused on reducing the use of plastics and increasing their potential for recycling.

Less thought has been given to the interaction of trade and the circular economy, and how to better align trade policies with resource efficient outcomes. A full examination of the link between circular economy and trade policy could require an assessment of a wide range of topics such as services (e.g. recycling and waste treatment services), innovation (e.g. waste treatment technologies, extraction of secondary materials from scrap) and investment (such as restrictions on cross-border investment in recycling and related sectors). This paper will focus on selected aspects of trade, in particular those that most directly affect trade in goods with metallic content, which will be necessary to close material loops and maximize the re-use and re-manufacture of materials, and recycling of waste. The particular problem of e-waste being exported to countries that do not have adequate recycling facilities is one issue that requires a solution both in terms of trade and resource efficiency policies.

The strong growth in trade in waste and scrap over the last decade, from levels close to zero, has posed new challenges to existing trade frameworks. The ban on Chinese imports of certain types of waste and scrap since January 2018 has brought the issue of trade in waste and scrap to public attention.[2] Until the ban was implemented, much of the waste and scrap that was exported ended up in the People's Republic of China (hereafter "China"). For countries that have been exporting their plastics waste and scrap, the Chinese import ban has led to growing domestic waste stockpiles and diversion of material into other export markets. Waste management firms in most of these countries appeared to be responding through

[1] These ideas have grown since the late 1970s, building on schools of thought such as Cradle to Cradle, the Blue Economy, the Performance Economy, Industrial Ecology or Industrial Symbiosis and Biomimicry. See Circle Economy (2018).

[2] Recently China has submitted three notifications to the WTO's Committee on Technical Barriers to Trade relating to imports of solid waste or secondary materials. Two of these WTO notifications were made in 2017 establishing a list of 24 solid wastes items to be prohibited for imports, and setting maximum levels of contamination for 11 items. In April 2018, China announced import prohibitions on a further 32 categories of solid waste, including plastic waste and scrap from industrial sources, to take effect in December 2019 at the latest (BIR, 2018). China's justification to the WTO for these regulations was the protection of the environment or of human health (WTO, 2017). The General Office of the State Council of China also suggests imports of waste and scrap are to be substituted with increased collection of domestic waste and scrap and increased recovery of materials included in electric and electronic goods and automobiles (General Office of the State Council of China, 2017). Organisations such as the US Trade Representative office, the Bureau of International Recycling and the Institute of Scrap Recycling Industries suggest that thresholds for carried waste included in imports of recyclable and scrap products are more stringent than China's domestic ones, which may constitute a form of trade discrimination [see for example USTR(2021) and BIR(2017)].

a mix of increased disposal and a search for alternative export markets, mostly in Asia (OECD, 2018b). The Chinese ban has impacted the ability of some OECD countries to meet their recycling targets and to close material loops: the time required to develop new recycling facilities means that the policy has yet to result in new domestic recycling capacity in those countries.

Acknowledging that there are a variety of approaches countries can pursue to manage the transition to a circular economy, this paper explores some of the issues and interactions between resource efficient and circular economy approaches and trade policies and outcomes. It explores the issues that link trade in goods with greater resource efficiency and the circular economy, in particular as they impact goods with metallic content. Waste and scrap from end-of-life metallic products is the most traded type of waste and scrap both in terms of value and volume. Moreover, the high price of these materials suggests that recycling of metallic waste and scrap may be more economically viable than recycling of some other types of waste and scrap. This aspect has motivated the focus of this paper on the circular economy and trade in metals and minerals.

The paper starts by outlining some of the key concepts and policies surrounding resource efficiency and the circular economy, and some of the key policies that have been implemented. It suggests three misconceptions present in the circular economy literature that are particularly important when assessing circularity in metals. Subsequent sections outline the issues surrounding trade and the circular economy and examine how these policies interact to produce outcomes that may be mutually reinforcing or counter-productive. Trade flows in metallic waste and scrap and trade policies affecting them are also documented. The particular question of electronic waste, the fastest growing type of waste, is considered in the following section. The paper concludes with some policy considerations and recommendations for countries, and for the international community, as issues affecting both trade and the circular economy demand global solutions.

2. Resource efficiency and the circular economy: Key concepts

Since 1990, the global use of materials has grown slightly slower than global GDP, a trend known as relative decoupling. Several structural factors have contributed to this, including the increased share of the less material-intensive services sector in OECD economies. Innovation and technological change also played a role, while volatile and relatively high resource prices, and reduced demand in many countries due to the global financial crisis were short-term factors accentuating the trend. Despite the apparent decoupling of GDP from resource use in OECD countries, global resource productivity has started to decline since 2000 because of the transfer of production of globally traded goods to countries with lower average resource productivity.

Global demand for raw materials will continue to increase due to growing populations with higher incomes. Production and consumption are shifting towards emerging and developing economies, which on average have higher materials intensity. Looking forward to 2060, despite projections of lower material intensity, the use of metals is forecast to increase 1-1/2 times in OECD countries, triple in BRIICS countries and multiply by 4 in all other countries (OECD, 2018d). The use of metals is projected to grow faster than any other consumable material. Recycling of metallic metals, however, is projected to grow faster than mining (OECD, 2018d).

The McKinsey Center for Business and Environment (2016) has identified the following pathways to reaching decoupling of resource use from economic growth and development:[3]

- reducing the extraction of non-renewable resources and mainstreaming the use of renewable sources
- optimizing materials yields in the manufacturing and recycling processes
- circulating products, components, and materials already in use to the highest possible levels
- minimising the negative environmental externalities associated with the use of these resources and materials.

A number of different frameworks of reference exist to describe the transition to greater resource efficiency throughout the lifecycle of products. Many of these frameworks are overlapping, and in some cases competing definitions exist. Resource efficiency, the circular economy and sustainable materials management are three of these frameworks. They all involve fundamental changes to production and consumption systems. This entails designing products with extended lifespan and with their end-of-life in mind. Although the extension of consumer products' lifespan can contribute to decreasing both manufacturing and post-consumption, end-of-life waste, product lifespan has generally declined since the late 1980s, possibly in order to encourage purchase of replacement products (Circle Economy, 2018, and EMAF, 2013a).[4]

Indicators of resource efficiency commonly cover both measures of resource productivity and resource intensity. In particular, productivity indicators reflect the production of a given output produced by given inputs; intensity indicators reflect the use of natural resources or materials inputs necessary to produce a given output. Intensity indicators are the inverse of productivity indicators. (See OECD, 2016a, p. 23-5 and UN Environment and IRP, 2017, p. 37-44 for a full discussion of definitions and metrics). Resource efficiency emphasises that individual units should be produced in a more efficient, less resource intensive way, therefore reducing resource consumption per unit of production. However, there is not one clearly accepted definition of resource efficiency, which has led to some confusion in the literature (European Parliament, 2012, p. 9, UN Environment and IRP, 2017, p. 37, and OECD, 2016a, p. 23).

Several definitions of the circular economy exist (McCarthy et al., 2018, p. 11). According to the European Academies Science Advisor Council, a circular economy aims to maximise the value added of products and services in the economic value chain, both to minimise residual waste and to ensure that resources remain in use for longer (European Academies Science Advisory Council, 2015). The World Economic Forum and the Ellen MacArthur Foundation assert that a circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and

[3] A complementary framework for describing the functioning of a circular economy is ReSOLVE: https://makewealthhistory.org/2016/09/12/the-resolve-framework-for-a-circular-economy/.

[4] Several measures to increase durability and product lifespan have been proposed, such as including all relevant resource-efficiency features among the mandatory requirements for product design, establishing product labelling with details about product durability and expected lifetime, providing technical standardization to the benefit of the consumer, and guaranteeing a minimum lifetime for purchased products. In July 2017, the European Parliament approved a resolution that recommended, among others, establishing minimum criteria for durability, upgradeability and reparability for every product category from the design stage; extending product guarantees to match potential repair times; and providing spare parts for the lifetime of the product at a reasonable price (European Parliament, 2017). Some countries have made use of legal approaches to fight planned obsolescence such as longer consumer warranties and measures to incentivize the availability of spare parts. For example, France introduced a definition of planned obsolescence into its legislation in 2015, making it a punishable offence.

return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems and business models (World Economic Forum, 2014; Ellen MacArthur Foundation, 2015). Pathways to achieving circular economy objectives include a focus on improving material efficiency (i.e., reducing waste through material reuse and recycling), broader resource efficiency and industrial ecology approaches, durable consumer goods, renewable energy, increased energy efficiency and elements of the shared economy (IISD/Sitra, 2018). The circular economy concept considers products that have reached the end of their traditional function to be the starting point of a new cycle (hence 'cradle-to-cradle'). It emphasises the finite nature of resources and therefore their reuse, aiming at stabilising or reducing the overall consumption of resources.

Three main mechanisms for reduced demand for natural resources are often highlighted (Bocken et al., 2016; OECD, 2018e). *Creating material loops* involves the substitution of secondary materials, and second-hand, repaired, or remanufactured products for their virgin or new equivalents. *Slowing material flows* involves the emergence of products which remain in use for a longer period of time, usually due to more durable product design. *Narrowing material flows* refers to a more efficient use of natural resources, materials, and products, either through the development and diffusion of new production technologies, the increased utilisation of existing assets, or shifts in consumption behaviour away from material intensive goods and services. The rise of the 'sharing economy' is an example of the latter mechanism.

Closing and narrowing material loops requires the promotion of repair, reuse, refurbishment[5] and remanufacturing[6] of end-of-life products and incentives to the development of product-service systems and global reverse networks. Through remanufacturing, non-renewable resources remain in circulation for multiple lifetimes, conserving significant volumes of the raw materials, labour, and embodied energy in the product.[7]

The sustainable materials management (SMM) framework is a systemic approach to using and reusing materials more productively over their entire life cycles. SMM has been defined as "an approach to promote sustainable materials use, integrating actions targeted at reducing negative environmental impacts and preserving natural capital throughout the life-cycle of materials, taking into account economic efficiency and social equity" (OECD, 2010). By examining how materials are used throughout their life cycle, an SMM approach seeks to:[8]

- use materials in the most productive way with an emphasis on using less
- reduce toxic chemicals and environmental impacts throughout the material life cycle
- ensure sufficient resources are available to meet today's needs and those of the future.

[5] Refurbishment refers to returning a used product to acceptable working condition, with limited restoration of product functionality, by rebuilding or repairing major components, even before fault (Taylor et al., 2016).

[6] Remanufacturing is a process of disassembly and recovery of an asset at a product and component level, involving the restoration of the used product to its original level of functionality. Products suited for remanufacturing generally have long product life cycles and a modular design for easy disassembly and repair, like capital intensive and durable goods. Functioning, reusable parts are taken out of a used product and rebuilt into another, with a warranty that is comparable to that which was provided with the original part. Remanufacturing of automobile parts is currently the largest remanufacturing sector globally (EMAF, 2016).

[7] On average, remanufacturing achieves energy savings of 50% and material savings of 80% compared with new production (UN Environment, 2013).

[8] https://www.epa.gov/smm/sustainable-materials-management-basics.

By looking at a product's entire life cycle, opportunities arise to reduce environmental impacts, conserve resources and reduce costs. The recycling value chain encompasses a sequence of operations including collection, preparation, physical dismantling and manual or mechanical sorting of constituent materials, and material recovery, which consists of chemical, physical and/or metallurgical operations transforming the sorted waste material into finished material, but not including incineration for energy recovery and the reprocessing into materials that can used as fuel. The collection of waste streams can involve complicated logistics with multiple stakeholders and materials and relies on consumer awareness and participation. Geographic dispersion, material complexity (e.g. metals that are combined to make alloys) and product complexity (combination of many different materials, some in very small quantities, to make up products) provide challenges to recycling and introduce leakages[9] that prevent fully “closed loop recycling”.

Even if they have sometimes been successful,[10] recycling policies are not sufficient. Redesign, reuse, repair, remanufacturing and refurbishment strategies are increasingly being perceived as having higher benefits, because of losses during collection and processing, and degradation of material quality during recycling. Remanufactured or refurbished products often realise resource savings per material of between 80% to 95% for the first life extension compared to a new product (European Union, 2017). Each component goes through its own number of life cycles, which can vary from two to nine. However, after a certain number of cycles, remanufacturing becomes economically unviable.

A widely agreed “waste hierarchy” represents a system of ranking of best treatment options for producers and consumers (OECD, 2018c). The very best option is waste avoidance and reduction, followed by re-use, re-manufacturing, then recycling followed by incineration with energy recovery. The environmental attractiveness of different solid waste management options is embedded in the concept of a waste hierarchy. In this framework, waste prevention is preferable to waste disposal because the environmental pressures associated with the extraction of materials are avoided, and so are losses during collection and processing, as well as degradation of material quality during recycling. Thus, from an environmental perspective, redesign, reuse, remanufacturing and refurbishing are always preferable to recycling, because product life extension business models have the potential to reduce the amount of waste generated. In contrast, the influence of resource recovery business models tends to be limited to diverting already existing waste towards material and energy recovery facilities.

A fully closed-loop economy where no materials are wasted is not possible to achieve however, as there is always loss of material quantity or quality in the processes of manufacturing and recycling.[11] The Circle Economy (2018) estimates that the global economy is currently only 9.1% circular,[12] leaving a massive circularity gap.[13] Prevailing recycling processes are typically ‘loose’ with long cycles that reduce material

[9] Leakage refers to the loss of materials, energy, and labour as products, components, and materials are not or cannot be reused, refurbished/remanufactured, and recycled (WEF, 2015).

[10] For example, the number of countries reporting the use of landfill taxes increased significantly in the past 15 years, leading to the diversion of waste away from landfills into material and energy recovery (OECD, 2016a).

[11] Additionally in some cases it is not economically viable to recuperate all materials that make up products at the end of life; and in some instances trade-offs exist between a longer first lifespan of products and the ease and viability of recuperation of constituent materials.

[12] Of the 19.4 billion tonnes of materials classified as waste, only 8.4 billion tonnes or 9.1% of total material use of society is cycled, with the remainder incinerated, landfilled, or dispersed into the environment (Circle Economy, 2018).

[13] On the other hand, waste disposal is declining, and materials recovery is increasing in some OECD countries. For example, between 2004 and 2012 waste generation from manufacturing and services sectors in the European Union and Norway declined by 25% and 23% respectively, despite respective increases of 7% and 13% in sector economic output. Meanwhile, total municipal waste generation in EU countries declined by 2%, despite a 7% increase in real

utility to lower levels, the lowest of which being the incineration of waste. Apart from the automotive industry, few industries achieve today a collection rate of end of life products reaching 25% (EMAF, 2013a).

Global benefits of the transition to a resource efficient and circular economy include a reduction in the environmental pressures caused by current systems of production and consumption. Synergies between increased circularity and low carbon economies also arise from the shift in the use of primary to secondary raw materials – which require less energy intensive production processes – that could lead to a reduction in carbon emissions. In addition, for resource importing countries, the circular economy could serve as a potential hedge against raw material supply shocks caused both by price volatility and disruptions in the access to raw materials, particularly in the context of uncertain trade environments.

Despite its strong potential, to date the transition to a more resource efficient and circular economy has been slower than expected (EMAF, 2016). Recycling is still a relatively small factor in most segments, responding in the best case, for about 30% of total steel production. Reuse and remanufacturing business models usually represent 5-10% of output in most sectors and although some of them have recently experienced rapid growth, they come from a low base and are still limited to a few economic niches (OECD, 2018a). Remanufacturing[14] generally takes place on large equipment goods. The focus of many capital equipment manufacturers is to take back their finished products at end of life. Philips Corporation reports that 11% of its turnover is from circular solutions. It plans to take back all its medical equipment by 2020 and by 2025 aims to be fully circular across all products.[15]

Circularity could be greatly enhanced by digital innovations, namely by the rapid increase in the number of “intelligent assets”, capable of sensing, storing and communicating information about their location, condition, and material composition. Recycling can be significantly improved when products 'know' what materials they contain, who manufactured them, as well as other information that facilitates their reuse and the recycling of their components and materials. More knowledge-intensive products make it possible to optimise the use of resources, including energy, during the product life-cycle and allow 'predictive maintenance', whereby potential operational failures can be detected and communicated. In addition, information regarding product recycling, reuse and remanufacture could be effectively made available to product designers, while traceability in logistics can enable optimal stock utilisation, thus reducing material waste and transport costs (European Environmental Agency, 2017).

Although asset tracking has been standard practice in the logistics sector for decades, new technologies supporting reverse logistics programmes – the inbound flow and storage of assets and related information – are still used on a very limited scale. Similar developments are emerging in waste management where, in addition to real-time waste collection route optimisation, new systems sort and recycle multiple types of materials as well as monitor and incentivise waste disposal behaviour (EMAF, 2016).

household expenditure. Notwithstanding, 2.5 billion tonnes of waste (or about 5 tonnes per capita) are still generated each year in the European Union (EPRS, 2016).

[14] The global market for remanufactured goods is around USD 120 billion. The United States was the world’s largest remanufacturing pole in 2011, with around USD 43 billion in output. In the European Union and the United States, remanufacturing generally accounts for no more than 4% of the output from any given sector, with aerospace, heavy duty and off-road equipment, medical equipment, and tyres being the most established sectors (OECD, 2018a).

[15] Intervention by Philips representative at panel on the 4th Industrial Revolution Technologies for accelerating the Circular Economy, World Circular Economy Forum (WCEF), Yokohama, Japan, 22-24 October 2018.

3. Addressing three frequent misconceptions

Some discussions on the transition to a circular economy have been influenced by three perceptions regarding the use of materials, especially metals, that have misrepresented what actually happens. These are i) that metals can be infinitely recycled, ii) that recyclable material will soon replace primary resource extraction, and iii) that the world is running short of primary materials. The first two of these misconceptions have had the effect among some minerals and metals producers, in particular some that rely heavily on the mining sector for a substantial part of their economic activity, to question the validity of a transition to a circular economy. The latter issue underlines the difficulty in estimating reserves of non-renewable resources.

Contamination: Metals cannot be infinitely recycled

In recent circular economy literature,[16] metals like steel and aluminium have been described as 100% infinitely recyclable at the end of its life without loss of quality. In principle, metals are indeed infinitely recyclable but in practice recycling is mostly inefficient because of limits imposed by social behaviour, product design, recycling technologies and processes, and the thermodynamics of separation.

The economic feasibility of materials recirculation depends on the capacity to retain their value over the lifecycle, producing high-quality secondary materials that can replace primary ones. Currently, all metallic products require a minimum of primary metal flowing into the chain to compensate for losses over the cycle, and secondary metals (i.e., metals produced at least in part from recycled scrap) usually need to be mixed with primary metals to reach a level of purity required for new uses (UN Environment, 2013).

Steel has a high global recycling rate, with around 80% of end-of-life steel collected for recycling, but overall losses are still large (Material Economics, 2018). Steel scrap potentially available for recycling can be classified in three main categories (Bowyer et al., 2015).

- *Home scrap* in the form of trimmings or rejects generated during the production of iron and steel has known physical properties and chemical composition, so is usually quickly reprocessed in the steel mill. It is estimated to account for approximately 20% of all scrap recycled.[17]
- *New scrap*, also known as prompt scrap, is generated in the manufacturing of steel products and is often returned directly to the steel mill, usually within weeks or months. It is clean with a chemical composition generally well known and is estimated to account for about 20% of total scrap recycled.
- *Old scrap*, also known as obsolete scrap, is steel that has been discarded at the end of product life. The greatest volume is composed of junk vehicles, old appliances and machinery, old railroad tracks, and steel from demolished buildings. It also includes cans and other containers as well as a variety of discarded consumer products. Because chemical composition and physical characteristics are usually not well known, old scrap is more difficult and more costly to recycle. Treatment includes cleaning, sorting, removal of coatings, and other preparation. It accounts for approximately 60% of all scrap recycled.

[16] See, for example, Ellen MacArthur Foundation (2013a) and WEF (2014).

[17] The measurement of home scrap and new scrap, in particular, is extremely difficult so these are rough estimates.

An important problem is the loss of quality of the collected and traded scrap through contamination, especially with copper,[18] resulting in a difference in quality between steel made from primary and secondary raw materials, preventing the use of some steel made from recycled material for anything other than basic construction steel.[19] Copper enters steel scrap when products containing both steel and copper are dismantled. To keep the quality of the steel stock, products must be dismantled carefully at end-of-life (EoL), to improve sorting and to separate high-copper scrap from less contaminated varieties. Currently, it is routine for recycling facilities to use magnetic, eddy current, and gravity assisted systems for sorting between steel, aluminium, plastic and paper goods. Yet, automated sorting is not completely effective for more complex products where a concentration of many individual components, each with similar physical properties, limits the ability of sensors to distinguish between different alloys.

Another major source of contamination of steel scrap is the steelmaking process itself, as there are many different grades of steel with diverse physical and chemical properties made by adding various metals in the form of alloying elements. Each time scrap steel is recirculated, the concentration of residuals rises, making processing more difficult. Efforts need to be made to keep alloys separate so that the properties of the scrap can be retained after re-melting, avoiding downgrading.

Similarly, although aluminium can technically be re-melted indefinitely, the metal is rarely used in its pure form. It is usually alloyed with a range of other elements to attain the desired properties that often depend on keeping alloying composition within a tight range, as even small deviations can undermine the quality for a specific purpose. There are many different types of alloys, but they can be roughly classified in two broad groups, with wrought alloys containing in general much smaller quantities of alloying elements than casting alloys. Wrought alloys with lower alloying content can generally be recycled into casting alloys, but this cannot be reversed as most alloying elements cannot be removed once they have been added. Overall, a large share of aluminium recycling today involves turning EoL aluminium from a range of sectors into casting alloys used in the automotive sector. Only around 20% of EoL scrap is turned into wrought aluminium, even though wrought products account for two-thirds of all aluminium in use.

Until now, growth in the demand for casting alloys has absorbed available post-consumer scrap, but in some countries the market for some applications is saturated. The European Union and North America have already reached the point where available scrap exceeds domestic needs of cast aluminium. This scrap has therefore been exported to other regions. Over the next decades, a continuation of downgrading of aluminium threatens to undermine the scalability of recycling unless additional flows of aluminium are kept in 'closed loops', so that metal can be recycled and used for the same purpose repeatedly, like that for used beverage cans. Beverage cans are recycled in a 'closed loop' in the context of producer responsibility programmes, allowing for the same metal to be used repeatedly for the same purpose.

Aluminium recycling can be further increased by reducing losses of new scrap, which now amount to 25-30%; by increasing collection rates of post-consumer scrap; and by improving recycling practices that mix different qualities of metal thereby causing irreversible downgrading that in time will become an obstacle to recycling. For example, current processes for dismantling of cars and buildings lead to significant materials degradation. Reverting this will require changes in product design enabling separation of

[18] Even low levels of copper – 0.15% or less – can result in the permanent and long-term downgrading of steel. The copper content of scrap in most OECD countries is around 0.2-0.25%, a level that exceeds the requirements for many product categories except rebar (Material Economics, 2018).

[19] The Electric Arc Furnace (EAF) steelmaking process removes many contaminants in the re-melting process but not all, limiting the use of steel produced by this process to large structural shapes. In Basic Oxygen Furnaces (BOF) steelmaking, contaminant removal is even more difficult, a problem that is dealt with by strictly limiting the volume of old scrap mixed with pig iron. With contaminants minimized, BOF plants can produce flat products and rolled steel sheets where their presence would have presented significant problems (Bowyer et al., 2015).

individual qualities, more developed dismantling of products at EoL, advanced sorting technology, and additional deposit schemes.

Scaling up metals recycling to 100% cannot be achieved soon

OECD countries have accumulated large stocks of used metals and the flow of old scrap emerging from in-use stocks is the key source for secondary metal production. From the mid-1970s, the proportion of secondary steel and aluminium in total output increased steadily in these countries. However, at a global level, the penetration of secondary metals in world supply fell during the last 15 years – from around 34% to 26% for steel and 25% to 16% for aluminium – due to strong increase in demand and the lifespan of many goods with metallic content. New supply resulted mostly from investments in the construction of additional primary capacity in China.[20]

The share of secondary metal production is expected to increase as mining conditions become more difficult (because of lower ore grades, more complexity, greater depths, etc.), the stock of end-of-life products continues to grow in non-OECD countries, and the quantity and quality of scrap increases. This does not necessarily translate to 100% recycling for all metals, as technical and economical limits continue to affect the scalability of metal recycling. In the case of aluminium, the benefits could be large, as re-melting requires just 5% of the energy of new production. However, recycled material from end-of-life products covers only 20% of total global demand.

Data on scrap collection is difficult to obtain but it is widely understood that it depends on three factors: availability, treatment costs (including transportation), and price. The supply of old scrap depends on the volume that can be collected from the stock of material from products historically used in the economy.[21]

Supply is also a function of the economics of collecting, processing, and transporting old scrap, which together determine the minimum scrap price the recycling industry needs for viability. Scrap supply is inelastic below a certain price dictated by treatment and transportation costs: when prices drop below that threshold, collectors only recover scrap that can be easily extracted. Above that threshold, supply tends to increase with scrap prices which are strongly correlated with primary metal costs. For example, the consumption of steel scrap is driven by the price differential between scrap and iron ore and coking coal used to produce pig iron, as scrap is essentially a substitute for them (McKinsey & Company, 2017). Secondary aluminium is cheaper to process than primary metal because of much lower energy requirements, but the cost differential can be eroded by scrap collection costs, which can be very high, and scrap prices that are driven by the price of primary metal. Therefore, the prices of secondary metals are not determined by the cost of scrap collection and treatment alone but are also influenced by price competition with their immediate substitutes (in the case of secondary aluminium, the price of primary metal). Scrap collection is inhibited in periods of low primary metal prices, while scrap prices can rise steeply during periods of high primary metal prices.

One of the major limitations to scaling up lies in the need to achieve high output volumes from individual recycling operations to repay the large investments in equipment. Another challenge is the recovery of valuable and rare elements that are present in products in quantities that are too small to justify their economic recovery. This is the case, for example, of rare earth elements (REE) where the volume found in EoL goods such as solar panels and batteries is often too small to justify their recovery and processing.

[20] For example, steel production grew by 40% over the last 10 years, with nearly 95% of this growth in China alone.

[21] For example, the stock of steel in industrialised countries is typically 10-14 tonnes per capita, but in non-OECD countries, the average per capita stock is just 2 tonnes (Material Economics, 2018).

Although the need for currently scarce elements is projected to grow significantly in the future, iron, aluminium, copper, tin, titanium and chromium still represent the largest metal-recycling volumes. The proportion of metal derived from scrap in total metal production is less than 25% for all widely used industrial metals and less than 10% for most speciality metals (UN Environment, 2013).

In 2012, the average European used 16 tonnes of materials; only 40% of that was recycled or reused. However, material recycling and waste-based energy recovery capture only a small portion of the original value of the raw material. Even recycling success stories such as steel, polyethylene terephthalate (PET), and paper involve the loss of 30-75% of the value of the materials during the first use cycle. And use cycles are short: the average manufactured asset (excluding buildings) lasts only nine years (EMAF, 2015).

Constraints on the supply of high-volume primary metals are economic rather than geological[22]

Metallic minerals constitute one-fifth of global raw material consumption; steel, aluminium, and copper currently account for around 80% of the production of the most widely used metals. Iron ore, manganese, nickel, and zinc are used to manufacture steel, which is used extensively across a range of industries; aluminium is essential for the transport sector; and copper allows the efficient transmission of energy. Metallic materials are also essential components in key sustainable innovations, such as low-carbon transport, renewable energies and digital communications.

As the production of most minerals and metals showed strong growth over the past two decades, mineral deposits became more complex and difficult to process. Today, the average grade of extracted minerals is much lower than in the past, with this decline expected to continue. Up until now, this trend has been offset by huge economies of scale in the excavation of hard rock that, since the mid-twentieth century, caused a major shift from underground to open pit mining in minerals such as coal, iron ore, gold and nickel. This has led to an exponential increase in the waste rock excavated per unit of ore processed, and this ratio continues to increase over time.

Although growing production continues to put pressure on known resources, forcing a gradual shift to lower quality deposits, economic reserves of minerals and base metals have kept increasing, challenging their perception as non-renewable resources (Mudd, 2010). Conventional wisdom tends to see mineral resources as a fixed stock of reserves, relying on physical measures of availability to conclude that growing demand must eventually consume the available supply of finite resources, making mining inherently non-sustainable[23] over the long run. However, believing that there is a given quantity of a resource available in the Earth crust is a misleading indicator of resource availability.

An alternative way to look at mineral depletion, presented by Tilton (2009), is to assess resource availability by estimating how much society must pay to produce another unit of a mineral commodity, i.e. its opportunity cost. While over time depletion tends to drive the opportunity cost of mineral production up, new technology and other forces can offset this upward pressure. The threat then is not physical depletion, where the world would literally run out of mineral resources, but economic depletion, where the costs of producing and using mineral commodities rise to the point where they are no longer affordable. Long before the last barrel of oil or the last tonne of zinc were to be hoisted from the earth's crust, costs would rise dramatically. This would first curtail and then eventually eliminate demand and trigger substitution.

[22] This section refers to primary, high-volume metals and minerals such as raw materials for making steel and aluminium products. Minor metals, specialty metals and small-volume minerals including critical raw materials are not the focus of this section.

[23] For example, experts have calculated that without a rethink of the use of materials in the linear economy, minerals such as gold, silver, indium, iridium, tungsten and many others could be depleted within five to fifty years (WEF, 2014).

Although potential depletion can be measured by the increase of production costs or the value of mineral reserves in the ground, the most readily available indicator is long-term price trends.

The need to exploit lower grade, more remote, and more difficult to process mineral deposits tends to raise the costs and prices of commodities over time, new technology can offset this upward pressure. Therefore, over the long-run, the supply of mineral commodities is determined by two opposing effects: the cost-increasing impacts of depletion and the cost-decreasing effects of new technology. Until now, this competition has largely been won by technology, as the long-run trends in real prices for most mineral commodities have either declined or remained stable.

Although few metals are currently facing physical depletion, the increasing costs of energy and of managing socio-environmental impacts of resource extraction can raise barriers to the economic viability of their production and usage. Therefore, according to Mudd (2010), the fundamental question is not whether mineral resources are ‘finite’ but rather what are the future conditions under which mineral resources are likely to be considered ‘economic’.

Another factor contributing to the misconception is that “reserves” as reported by mining companies generally include only those portions of mineral deposits which have been measured, usually by costly drilling and chemical analyses, and can be economically exploited using current technologies and at the prevailing prices. They are thus a highly dynamic quantity, which depends on changing market prices and advances in technology.

4. Main types of policies used to further resource efficiency and the circular economy

Most OECD countries have well-established laws, regulations, standards and institutions with responsibility for policy development and regulatory oversight of solid waste management. Some have also developed legislation establishing guidelines, performance targets and operational and environmental standards that promote the transition to a circular economy. The European Union is probably the most advanced in this area and some of its policies are outlined in Box 1. China, Finland, France, India, and the Netherlands have also adopted national circular economy roadmaps and implementation plans. Following are some of the policies adopted to promote the transition to a circular economy.[24] Notably, many policies that support circular economy outcomes include developing new services sectors, or leveraging existing services sectors in new ways.

- Support for innovative forms of collaborative consumption (the “sharing economy”). The transition to a circular economy involves different attitudes to consumption, more innovative sharing, leasing and rental contracts, and the introduction of insurance schemes that cover repaired goods and products containing used parts. By changing the way in which goods and services are produced – e.g. using vendor take-back strategies or reverse logistics – the sharing economy can optimize the use of resource inputs and energy.

[24] This is a subset of all the policies used for sustainable materials management. It serves to highlight many of the policies that are most relevant to the transition to a more resource efficient and circular economy but should not be considered in any way comprehensive. Conversely, no one country has implemented far-reaching policies in all of the areas outlined.

- Support for innovative product design aims to develop longer-lived products[25] that can be disassembled at the end of life and parts can be individually reused, considering the environmental impact of materials used. Policies can be implemented through product group specific regulations to promote the reparability, durability and enhanced recycling of products and improve their environmental performance (such as minimum mandatory requirements for energy efficiency), supporting solutions with the least life-cycle costs. Mandatory energy labelling regulations may complement eco-design requirements.
- Extended Producer Responsibility (EPR) systems – in which the cost for the final recycling or disposal of materials is borne by the producer of the good – are increasingly recognised as an efficient way to improve recycling and reduce landfilling of products and materials. Most OECD countries have implemented EPR policies in sectors such as packaging, batteries, tyres, end-of-life vehicles, and electrical and electronic equipment. EPRs started with coverage limited to specific geography areas usually located close to the production site but are quickly becoming global under product-service systems and global reverse networks. However, their expansion is constrained by several trade barriers. As EPRs are particularly pertinent for end-of-life products that include metallic material, this policy is further outlined below.
- Landfill taxes, or similar tax instruments for waste sent to landfills have been introduced in many OECD countries. They are typically levied in units of currency per unit of volume or weight of non-recycled waste and imply an additional payment for sending waste to landfill.[26] Landfill taxes have been successful in providing incentives for more sustainable ways of waste disposal, contributing to mitigate environmental impacts such as contamination of groundwater or soil and methane emissions from decaying organic waste.[27] Landfill and similar environmental taxes are quite straightforward to administer and appear to contribute effectively to diverting waste away from landfills.[28]
- Mandated recycling targets can facilitate the creation of markets for secondary raw materials when associated with mandatory quality standards for recycling, for example of electronic waste, however their efficiency depends on how well programmes are implemented.
- Adopting green public procurement establishing resource efficiency criteria for public purchases can stimulate innovation and increase demand for green products, based on objectives building on lifecycle analysis (see, for example, UN Environment, 2018).

[25] There seems to be a trade-off between products that last longer and potential technological improvements that take place over time. Replacing products sooner than expected with new products leads to indirect price increases for consumers. In addition, there are non-direct economic losses related to time spent organising replacement products. A number of studies in Austria suggest that consumers would wish products to last considerably longer (BEUC, 2015). However, increasingly, new products include additional technological improvements that can range from ease of use to greater energy efficiency.

[26] Alternatively, Kinnaman et al. (2014) suggest that landfill taxes on non-recycled waste could be complemented with subsidies for recyclable materials.

[27] An estimated 1.6 billion tonnes of carbon dioxide–equivalent greenhouse gas emissions were generated from solid waste management in 2016. This is about 5% of global emissions (World Bank, 2018).

[28] For example, the UK landfill tax was introduced in 1996 in order both to reduce the overall levels of waste produced and to send less waste to landfill. Annual revenues have risen from GBP 400 million in 1997/98 to a peak of GBP 1.2 billion in 2013/14, while revenues in 2015/16 were GBP 900 million. The continuously increasing tax level has had a significant impact on the quantity of waste sent to landfill: in 2001/02, 50 million tonnes (Mt) annually were sent to landfill. In 2015/16, the same figure was around 12 Mt (Elliott, 2016).

- Strengthening local government coordination: often, local governments are responsible for adopting regulations for managing and disposing of waste in their areas of influence and allocating physical and financial resources as well as cost recovery. Successful policies have encouraged cooperation in recycling, collection and waste treatment services to make them more scalable, by standardising recycling programmes to increase compliance and improving municipal data reporting thereby facilitating the emergence of efficient recycling hubs.
- Promoting information instruments, such as eco-labelling, supply chain reporting, sustainability reporting, consumer advice services, and information centres.

Extended Producer Responsibility and voluntary stewardship programmes

Extended Producer Responsibility (EPR) programmes are increasingly being adopted, committing producers to take financial and/or organisational responsibility for collecting or taking back, sorting and treating end-of-life products for eventual recycling. Since the early 1990s, many countries started promoting EPR programmes in sectors such as packaging, electric and electronic equipment, batteries and vehicles, obtaining significant increases in recycling rates and public spending reductions on waste management. [29] In general, EPR programmes have emerged as a way to promote collective producer responsibility in order to foster economies of scale, greater risk-sharing among participants and to reduce administrative burdens for consumers, retailers and municipalities (OECD, 2016b). In some cases, individual producer responsibility have emerged where individual producers are responsible for the recovery and recycling of their own products. Generally, individual producer responsibility programmes are thought to provide a stronger incentive for design changes, as the feedback loop is more directly linked to individual brands, whereas collective producer responsibility programmes are often more cost-effective to implement (Watkins et al., 2017). Collective producer responsibility programmes are the more common type of EPR scheme (European Environment Agency, 2017).

Rather than a single policy, EPR can be described as a framework or a mix of four broad categories of instruments that can be implemented concurrently (OECD, 2014; 2016b):

- Product take-back requirements setting recycling and collection targets for producers or retailers regarding their products or materials at the post-consumer stage.
- Incentives to bring used products back to the selling point, including deposit-refund schemes, Advanced Disposal Fees, and material taxes.
- Regulations and performance standards that can be mandatory or applied voluntarily by the industry.
- Accompanying information requirements to raise public awareness, such as reporting requirements, labelling of products and components, communicating to consumers about producer responsibility and waste separation, and informing recyclers about the materials used in products.

Although EPR programmes are mandatory requirements imposed by government, similar programmes have also been established through a voluntary agreement with the industry (OECD, 2016b, p. 53).

[29] Small consumer electronics are the most prevalent product covered under EPRs globally, followed by packaging (including beverage containers), tires, vehicles and lead-acid batteries. All EU Member States have implemented EPR schemes on the four waste streams for which EU Directives recommends them, i.e. packaging, batteries, end-of-life vehicles and electrical and electronic equipment (OECD, 2014).

Initiatives under which producers operate voluntarily are often referred to as “stewardship programmes”.[30] Materials stewardship programmes are being increasingly developed by industry[31] or by third-party organizations or government agencies. They gradually introduce improvements in materials lifecycles to reduce energy and natural resource usage and waste, by focusing on the way materials are sourced, processed, manufactured into products, maintained through the product lifecycle and redirected at the end of their lives. Producers often organize and finance collective Producer Responsibility Organizations (PROs) that carry out the collection and/or recycling of end-of-life products on behalf of their members. One successful example of collection and recycling in the metals industry is that of aluminium cans.[32]

Overall, mandatory or voluntary targets for recycling have encouraged EPR programmes to organise cost-efficient collection systems to increase the recyclability of their products, diminish the amount of material used in production and reduce waste. However, they have been less effective in stimulating other product circularity options as part of the waste management chain (EEA, 2017). Furthermore, exports of waste and scrap and used products create “leakages” in EPR and stewardship programmes whereby goods further consumed abroad are no longer recycled under the programme. As transport becomes cheaper and some environmental and legal requirements become more stringent, these exports can reduce the efficiency of EPR and stewardship programmes.

Box 1. Circular economy policies in the European Union

The European Union has one of the most highly developed and integrated circular economy policy frameworks in the world. In 2010, the European Commission published the “Roadmap to a Resource Efficient Europe”, giving long-term policy guidance on increasing resource productivity and decoupling growth from resource use, while considering environmental impacts. The analysis, part of the “Europe 2020 Strategy”, concluded that greater efficiency in the use of resources was critical not just for environmental reasons but also for competitiveness, employment and resource security. A high-level European Resource Efficiency Platform was established, bringing together selected governments, businesses and civil society organizations.

Part of the 2015 revised Circular Economy Package, the EU Action Plan for the Circular Economy presented several actions covering product lifecycles, from production and consumption to waste management and secondary materials markets. Regarding production, the Plan aimed to improve product design by promoting the reparability, durability and enhanced recycling of products through the Ecodesign Directive and EPR programmes. It fostered resource efficiency and facilitated industrial symbiosis. Regarding consumption, it promoted the sustainability of products through labelling, encouraged innovative forms of consumption, and integrated circular economy requirements in 'green' public procurement. The plan also aimed to create markets for secondary raw materials, for example by setting quality standards for materials recovered from waste, like standards for recycling of electronic waste and batteries, and proposed a monitoring framework building on existing indicators.

[30] See OECD (2014), page 7, for a complete discussion on the design of EPR programmes.

[31] The International Council for Minerals and Metals (ICMM) for example has adopted since 2006 a metals stewardship policy (ICMM, 2006).

[32] Another successful example of collection and recycling is that of spent lead acid batteries in North America which is close to 100%. See http://www3.cec.org/islandora/en/item/11665-environmentally-sound-management-spent-lead-acid-batteries-in-north-america-en.pdf

The current regulatory framework in the European Union for the management of waste of electrical and electronic equipment (WEEE) includes a series of applicable definitions in this area, establishes collection rates, as well as goals for the preparation of reuse, recycling, and recovery of waste, thus standardizing the implementation of collective systems of extended producer responsibility at the level of the EU market (Directive 2012/19/EU).

In 2018 the European Union adopted a new set of measures that support the implementation of the Action Plan and the European Union's vision of a circular economy, as well as a revised legislative framework on waste that sets new targets for the reduction of waste and establishes a long-term path for waste management and recycling. Key aspects include: i) an EU Strategy for Plastics in the Circular Economy to transform the way plastics and plastic products are designed, produced, used and recycled; ii) integrated legislation on waste, consumer products, and chemicals; iii) a Monitoring Framework on progress towards a circular economy at European Union and national levels; and iv) a Report on Critical Raw Materials and the circular economy that focuses on making the use of the 27 critical materials more sustainable.

Several legislative proposals – including the Waste Framework Directive, the Landfilling Directive, and the Packaging Waste Directive – set new waste management targets to be met by 2030 that increase the share of municipal waste prepared for reuse and recycling to 65% and the share of packaging waste prepared for reuse and recycling to 75% (with specific targets for various materials used in packaging). In addition, they set minimum requirements for EPR programmes and differentiated the contribution paid by producers based on the costs necessary to treat their products at the end of their life. Moreover, by 2030, EU Member States will send no more than 10% of municipal waste to landfill. This objective is supported by a ban on the landfilling of waste to be collected separately (glass, plastics, metal, paper and, in future, biowaste). The EC is also stepping up the enforcement of the revised Waste Shipment Regulation through an implementing act adopted in 2016 setting out correlation between customs and waste codes.

Regarding the sustainable consumption of metals and minerals in particular, the European Commission adopted a Raw Materials Initiative in 2008, renewed in 2011, to address the need for sustainable access to raw materials within and outside the European Union, and for resource efficiency and recycling of secondary raw materials. The EU raw materials policy contributes to many of the priorities of its 2050 strategy for climate neutral Europe. Moreover, in 2011, the Commission published a list of critical raw materials, updated in 2014 and in 2017, that combines raw materials of high importance to the EU's economy and of high risk associated with their supply. The Raw Materials Information System is a comprehensive online repository of information on policies, activities and data related to the European raw materials sector (http://rmis.jrc.ec.europa.eu/).

The European Innovation Partnership on Raw Materials (EIP), launched in 2013, brings together all relevant stakeholders to promote innovation in the entire value chain of raw materials – exploration, extraction, processing, recycling and substitution. The EIP's Raw Materials Scoreboard monitors progress every two years.

The EU's Horizon 2020 programme provides funding to realize the full potential of primary and secondary raw materials and to boost the innovation capacity of the EU raw materials sector.

5. Circular economy and trade

Trade policies affect the potential for achieving circular economy outcomes. As stated at the outset, this paper focuses on a subset of the trade policy aspects relevant to a transition to a circular economy. It focuses on a subset of trade policies that are most directly relevant including trade in used manufactured goods, trade in refurbished and remanufactured goods, trade in primary and secondary raw materials, and trade in waste for material and energy recovery.

In the short term, the impact of increased circularity on the flows of primary raw materials will probably be modest. Increases in the demand for commodities will essentially come from non-OECD countries, and primary raw materials will probably continue to be a main driver of global supply. This may give resource-rich countries the time necessary to adjust and implement measures to increase their resilience to future external shocks in specific commodities.

The composition of trade flows could change in the medium-to-long term, since the share of secondary materials in global demand is expected to grow, as the expanded stock of used metals at the global level will increase the quantity and quality of recoverable scrap. However, the shift will be complex and full of uncertainties. Without substantial improvements in the collection and processing of scrap, contamination could increasingly force the downgrading of secondary materials, limiting their demand in OECD countries and increasing the potential volumes available for export, as outlined in Section 3 above. Moreover, the expected reduction in the materials intensity in OECD countries and the possible extension of product lifespan could impact trade flows. Trade volumes of primary products should decrease and contribute to a reduction in post-production manufacturing and end-of-life scrap and their corresponding trade flows, which will in turn reduce market share gains of secondary materials in global consumption. On the other hand, trade in used and remanufactured goods should rise.

So far, current policies have generally encouraged waste management and material recovery to take place domestically. They have largely focused on closing, extending and narrowing material loops at the national level, using instruments such as EPR programmes, landfill taxes, and industrial partnerships to encourage design for circularity, as outlined in Section 4 above. In some cases, geographically closed supply loops with materials and components returning from where they were used to the point of manufacture can increase resource productivity because of the known quality of the products.

The proximity principle, adopted as a guiding principle in some countries, suggests that waste and scrap should be treated and disposed of closely as possible to the point of generation. This principle is closely related to that of self-sufficiency in waste management in the European Union whereby countries are required to move toward developing their own waste disposal facilities wherever practical. In the European Union, where mandatory recycling and energy recovery targets are in place, the proximity principle is combined with the objective that shipment of waste is only allowed when the receiving country can guarantee recycling, treatment and disposal according to environmental requirements equivalent to those that apply in the European Union (Handbook on the Implementation of EC Environmental Legislation, p. 399; UK Management Plan for Exports and Imports of Waste).

The proximity principle has also been applied in situations where differences in jurisdictions' regulations create dis-incentives to dispose of waste locally. In Australia, for example, lower landfill taxes in Queensland compared with New South Wales generated an increase in trade in waste between the two states in favour of Queensland. In order to avoid "waste dumping" in the cheaper jurisdiction, the government of New South Wales instituted a ban in 2014 on waste transported more than 150 kilometres from its area of collection.[33]

In most if not all cases, caveats exist to the proximity principle to cover the cases where adequate recycling facilities do not exist close to waste collection sites (e.g. Australia), or where "it may not be feasible or practical to treat certain wastes (e.g. special or hazardous wastes) close to its source of arising or within the region in which it is generated".[34]

As volumes of recyclable material increase, and a significant part of the recycling value chain, especially manual sorting and processing, is located in non-OECD countries, there will increasingly be a trade-off between costs of local sorting, processing and conversion, and economies of scale and comparative advantage in activities along the recycling value chain. Substantial investments in equipment and infrastructure are required to recycle some metallic waste and scrap and cannot be replicated in all countries. Although metal sorting can take place on a smaller scale and thereby at a more local level, large scale and volume are needed to justify investments in re-melting or smelting, a process where metals are recovered from waste and refined into usable grades. Smelting requires significant investments in large scale integrated metallurgical plants and sufficient metallic waste and scrap to operate, especially for the recovery of precious and special metals that are often present in low concentrations.[35] Sufficient scale and reliability of supply are important prerequisites for competitiveness. These aspects will become even more important as technologies advance and smaller-volume minor metals and specialty metals will be recycled. Economies of scale will dictate that few recycling facilities exist worldwide in small-volume scrap metals which will necessitate trade in these materials.[36]

Trade in used, refurbished and remanufactured goods

Promoting the reuse of products through exports of second-hand goods such as used cars and second-hand textiles increases their circularity. In practice, however, the diversity in export shipments of end-of-life goods pose problems as it is often difficult to distinguish trade in second-hand products from products that are exported for recycling and recovery. Moreover, the reuse industry participants are very heterogeneous, ranging from small traders to charity organisations to large specialised refurbishers.

The circularity of used goods may cause concerns from a domestic policy perspective of an exporting country since they could be considered as "leakage" from official programmes such as EPRs. Conversely, second-hand goods imported into some countries may hinder the transition towards an energy efficient

[33] http://www.nortonrosefulbright.com/knowledge/publications/143940/nsw-proximity-principle-repeal-environment-protection-authority-set-to-repeal-the-proximity-principle-as-part.

[34] United Kingdom Management Plans for Exports and Imports of Waste, https://www.planningni.gov.uk/index/policy/planning_statements_and_supplementary_planning_guidance/pps11/pps11_introduction/pps11_waste_management_strategy/pps11_regional_self_sufficiency.htm.

[35] Economies of scale are crucial to ensure that the costs associated with recycling of consumer waste electronics are competitive, as only a limited number of such plants can treat materials sourced internationally (Hagelüken et al., 2016).

[36] Furthermore, demand for some of these minor and specialty metals that are used in smaller quantities comes from the electronics and the environmental goods sectors. Demand in these sectors for raw materials is high and many are available in few countries. Wind and photovoltaic energy sectors for example use neodymium, praseodymium, dysprosium, indium, gallium and silicon metal; electric vehicles and other sustainable mobility solutions need cobalt, lithium, natural graphite, antimony and other materials. In some cases, these primary materials are found in only a few countries.

and low carbon economy due to slower market transformation and may place added pressure on the management of end-of-life products (Yamaguchi, 2018). Some new appliances sold today, for example, are 50-70% more energy efficient than those produced 10 years ago.[37] In addition, trade in second-hand goods can displace industries in importing countries that produce new products. Some countries have placed import restrictions on second-hand goods to increase control over these flows, and to support local industries that produce new products.

The global trade in remanufactured products is growing, with the United States and the European Union currently responsible for most of it. Exports of remanufactured goods by the United States totalled USD 12 billion in 2011, when the value of its remanufactured production was USD 43 billion (US International Trade Commission 2012). In both the United States and the European Union, remanufacturing accounts for just under 2% of production (IRP, 2018). There are however substantial obstacles to trade in refurbished and remanufactured products. They include regulatory protection, import bans, unfavourable consumer perception, and the lack of a common definition of remanufactured goods. In addition, existing trade classifications contain no specific codes related to reuse, repair, refurbishment or recovery, i.e. trade classifications make no distinction between new and used products. Therefore, little trade data are available for re-used and re-manufactured products.

The imprecision of classifications has led to trade barriers meant for used products or waste being applied to re-manufactured goods. Firms have been facing difficulties to recover their end-of-life products or product components across borders for refurbishment and remanufacturing since these products are often classified as waste. The problem lies in distinguishing trade in second-hand products from products that are exported for remanufacturing or for recycling. For instance, EMAF (2016) notes that Brazil, China and the Russian Federation do not have standards that distinguish remanufactured products from used products, and therefore they do not permit imports.

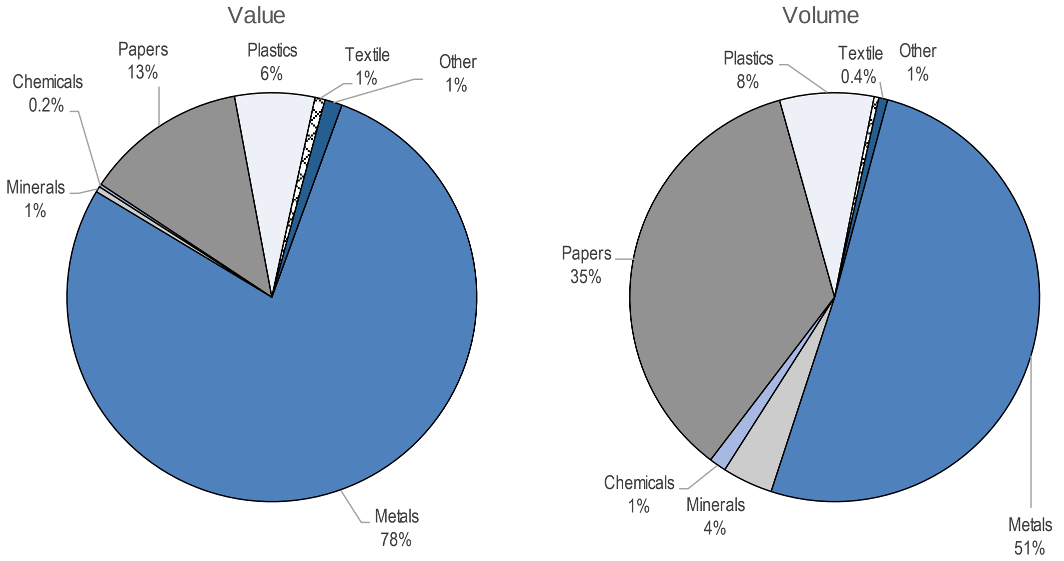
Current trends in the trade of metallic waste and scrap

Metallic waste and scrap is the most traded of all categories of waste and scrap (plastics, waste paper, biomass, etc.) in both value and volume terms, accounting for about 80% of the value of trade and over half of the volume of trade in waste and scrap (Figure 1). Not only is metallic waste and scrap the most traded, but recycling these materials has the greatest potential to be economically viable given their high unit values. Metallic waste and scrap is generated either as a by-product of the production process of mining, refining and producing industrial products or from recycled goods that provide recovered metals and non-metallic materials that re-enter the production cycle as inputs (see Section 3).

Trade in waste and scrap is, however, a relatively new phenomenon as it was almost non-existent 30 years ago. Since the early 2000s, trade in metallic waste and scrap has grown considerably (Figure 2), although at a relatively slower rate than the trade flows of primary minerals. Exports of metallic waste and scrap amounted to USD 82 billion in 2017 up from USD 22 billion in 2002 which represented 27% of the value of trade in primary minerals and metals. In volume terms, trade increased less, from 85 Mt to 119 Mt between 2002 and 2017, pointing to sharp increases in the price of metallic waste and scrap. Trade in metallic waste and scrap is dominated by iron and steel, copper, aluminium and gold, with all other scrap metal accounting for only 19% of the value of exports.

[37] Intervention by a representative of Whirlpool, World Circular Economy Forum (WCEF), Yokohama, Japan, October 2018.

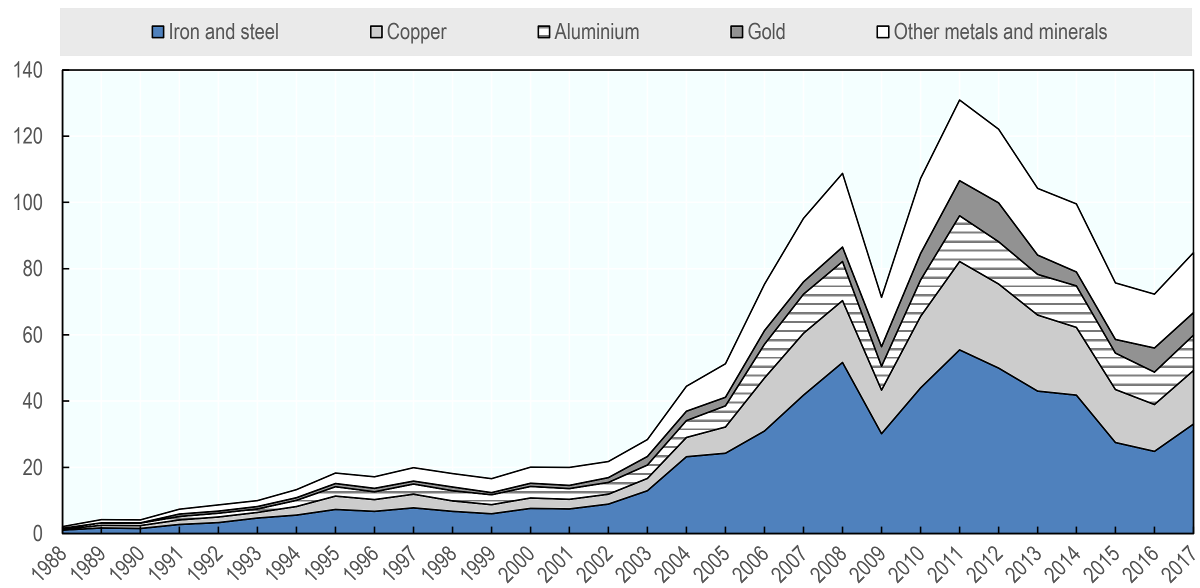
Figure 1. Trade in waste and scrap products, 2016



Note: Non-metallic waste and scrap definitions taken from Kellenberg (2012). See COM/TAD/ENV/JWPTE(2018)2 for details.
Source: BACI International Trade Database based on Comtrade data.

Figure 2. Exports of metallic waste and scrap products

USD billion



Source: UN Comtrade.

Recycling is a mature industry for metals that are used in large volumes (base metals) or in materials with intrinsically high value, such as gold and platinum.[38] Recycling rates depend fundamentally on the ease of collecting waste, the complexity of pre-processing prior to actual recycling, the costs of the technology, labour costs in the recycling industry and the selling price of the material once it has been recovered and recycled. The price of metallic waste and scrap is strongly impacted by prices of corresponding primary materials as they are substitutes in some production processes, depending on the technologies used. Recycling of bulk metals has significant energy benefits compared with production from primary sources. Steel, copper, and aluminium recycling can reduce the energy used to produce primary metal by 60-75%, 84-88%, and 90-97%, respectively (UN Environment, 2013). Since energy costs are one of the highest inputs into metals processing industries, demand for metallic waste and scrap for use as a raw material is high. Since metals production using secondary waste and scrap rather than primary mined minerals as its raw material uses substantially less energy, maximizing recycling of metallic waste and scrap not only diminishes the consumption of non-renewable primary resources but also represents a substantial savings on energy used in the production of metals.

The economies with the greatest stocks of scrap metal – countries of the European Union, United States and Japan – are also the largest exporters, representing about 70% of metal waste and scrap exports (Figure 3). Problems of unsuitability of certain types of scrap to serve as inputs for high quality products caused by contamination, as described in Section 3 above, generate surpluses in certain market segments that are exported to countries whose stocks of scrap are insufficient to meet demand. This is the case, for example, of steel scrap for construction materials and casting aluminium alloys for the automobile industry. China, Turkey, Korea and India are all large importers of metallic waste and scrap in addition to the European Union member states and the United States. China has by far the largest trade deficit in metallic waste and scrap (Figure 3).

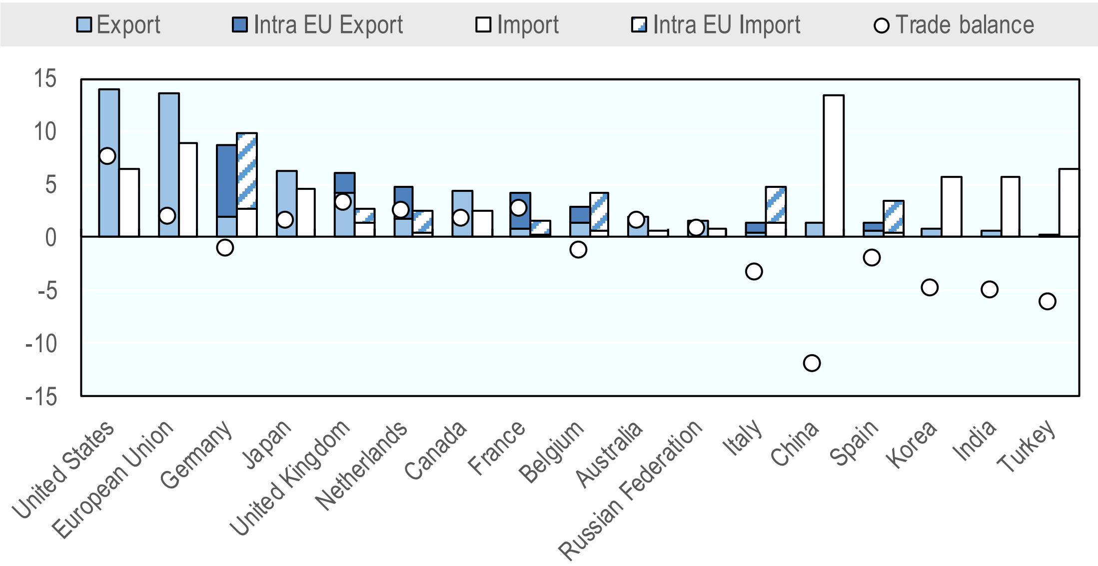
Export restrictions – export prohibitions, quotas, taxes, non-automatic export licensing requirements, and any other export restriction – are frequently applied to metallic waste and scrap. In fact, there are more export restrictions applied to waste and scrap than to any other type of primary raw material (Annex Figure A B.1), and this is consistently the case over time (Figure 4). Even on the main traded waste and scrap products, export restriction levels are high: 40% of traded copper waste and scrap is subjected to at least one type of export restriction; 30% of aluminium and 20% of iron and steel are subjected to export restrictions (Figure 5). Moreover, once export restrictions are in place, they are rarely removed.[39]

[38] Although recycling is generally concentrated on high-volume base metals, recycling of some materials such as lithium have started to increase recently owing to the growth in consumption of lithium batteries. For example, lithium and cobalt are two main components of electric vehicle, solar panel and wind turbine batteries. An electric vehicle battery can contain as much lithium as 1 000 smartphones (WEF, 2019). The European Union and China have introduced laws making carmakers responsible for recycling batteries. However, global recycling rates for lithium and cobalt are very low, mostly due to raw material price fluctuations, product design without consideration of second-life uses, inefficient collection infrastructure, technological and safety concerns, transparency issues regarding secondary processes and the hibernation of electronics (Church et al., 2019).

[39] https://resourcetrade.earth/stories/trade-restrictions-on-metals-and-minerals#section-218.

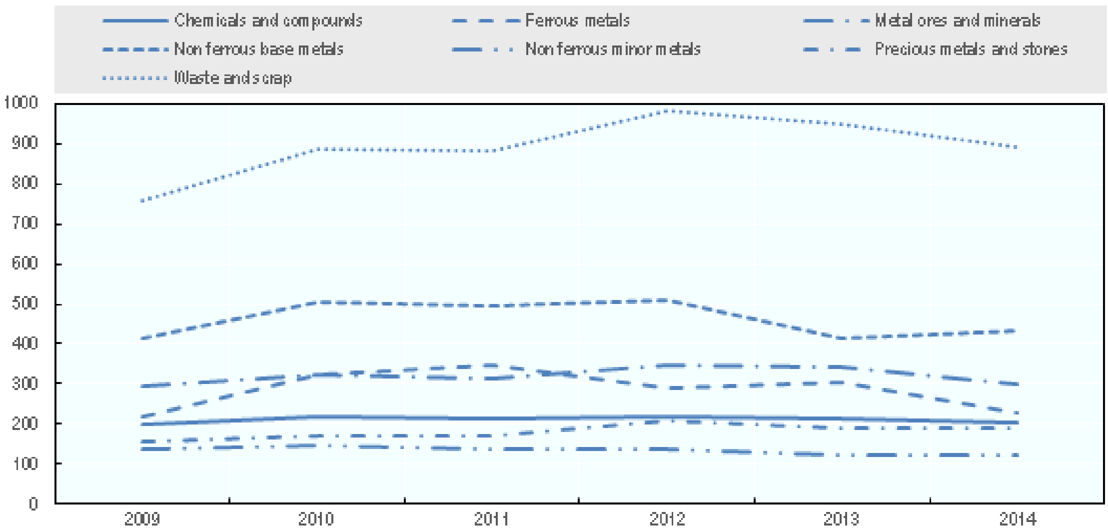
Figure 3. Main importers and exporters of metallic waste and scrap

USD billion



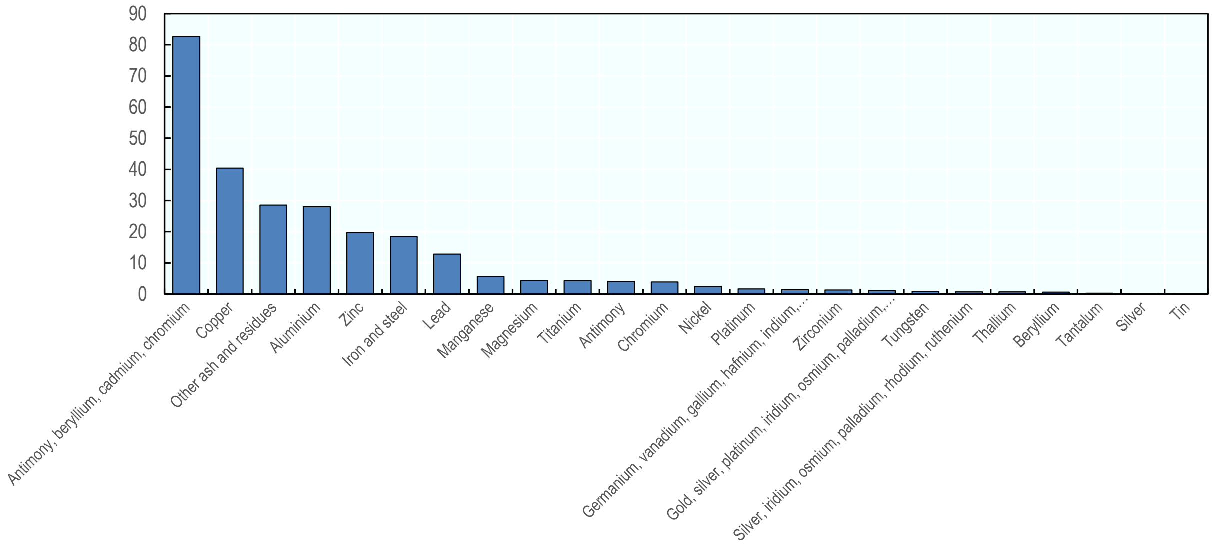
Note: Countries shown are among the top 10 exporters or importers of waste and scrap products in 2017. The European Union as a whole does not include trade between countries of the European Union. For individual countries of the European Union, however, trade both within and outside the customs union is included.
Source: UN Comtrade.

Figure 4. Number of restrictions by type of products, 2009-14



Source: OECD Inventory of Export restrictions on Industrial Raw Materials, https://qdd.oecd.org/subject.aspx?Subject=ExportRestrictions_IndustrialRawMaterials.

Figure 5. Share of world imports of waste and scrap products subject to export restrictions in the partner country, 2014



Note: Individual products may appear several types on the x-axis due to the HS product definition of waste and scrap products.
Source: OECD Inventory of Export restrictions on Industrial Raw Materials and UN Comtrade.

The main types of export restrictions applied to waste and scrap are export taxes and non-automatic export licenses, although 12% of export restrictions applied are prohibitions (Annex Figure A B.2). Export taxes are highest in China, where a rate of 40% is applied to various types of steel scrap, and the Russian Federation, where a rate of 30-50% is applied to copper scrap and 50% on aluminium scrap. In countries with insufficient or non-existent recycling capacity, such export taxes suggest that recovery of metallic and non-metallic materials may not take place. High export taxes provide a disincentive for exporters of waste and scrap to trade, increasing the supply of such materials in the country imposing the tax. Increased supply of waste and scrap will lower its price thereby creating a disincentive to recycle such material. Less recycling in turn serves to increase extraction of non-renewable primary natural resources to respond to continued global demand for steel, copper, aluminium and other metals. Export restrictions can also hinder economies of scale in metal recovery that can be achieved in large, sophisticated facilities.

The prevalence of export restrictions negatively impacts trade in waste and scrap. Restrictions on the export of metallic waste and scrap will negatively impact collection rates in countries that impose them. Lower trade flows due to these trade barriers in turn puts upward pressure on international prices, making scrap metal less competitive vis-à-vis primary mined material which are substitutes in some production processes. These impacts are even more pronounced in the case of export prohibitions.

The main stated purpose of using export restrictions is to safeguard domestic supply thereby lowering prices for domestic downstream users (Annex Figure A B.3). However, in the case of scrap metals, this may be counterproductive as lower domestic prices in countries that impose export restrictions provides a disincentive for further collection and will therefore not lead to increases in availability. Some countries using export restrictions on waste and scrap state that they do so in order to monitor or control export activity.

Export restrictions are higher and more prevalent on metallic waste and scrap than import restrictions. Import tariffs on secondary products tend to be low. The simple average of import tariffs applied on metallic waste and scrap products is 1% (Annex Figure A B.4); the figure for trade-weighted import tariffs is 4%. Seventy percent of waste and scrap products are imported with a zero import tariff.

Trade barriers on scrap metal serve to decrease availability of these materials on global markets and provide dis-incentives to their collection in countries that impose restrictions. Increasing trade and availability of metallic waste and scrap would contribute to closing material loops and serve to decrease energy consumption in production of metals due to greater energy efficiency in production processes using recycled material. Trade in recovered minor metal material will be particularly important, as new technologies emerge to separate and recycle them, to ensure economies of scale for recycling operations as these materials are available in small quantities.

Some trade agreements include provisions to limit the use of export restrictions between signatory parties. Since export restrictions are usually implemented on an MFN basis (i.e. they apply to all countries to which goods are exported), this means that signatory parties will probably reduce their use of export restrictions also to countries outside the agreement. Some countries have agreed to give up the right to impose quantitative export restrictions except on metal waste and scrap, which is the case in Israel in their regional trade agreement with Canada, or reserve the right to prohibit or control exports of second-hand goods as in Southern African Development Community (SADC) countries (Korinek and Bartos, 2012).

Trade agreements are a powerful instrument through which to regulate trade policies and could be used more extensively to respond to some of the challenges posed by circular economy objectives. Ideally, they can facilitate trade in waste and scrap so that material that is potentially recyclable flows from countries where recycling is low to those where it is higher. Unintended consequences such as the diversion to landfill of materials that cannot be processed, can be tackled when economic partnership and preferential trade agreements include ongoing processes to monitor their implementation.

The European Union has undertaken to engage with trading partners in promoting circular economy outcomes, including in the context of trade agreements such as that under discussion with Indonesia.[40] Trade agreements could include tariff free and duty free access for environmental goods and services and promote the free flow of technologies that allow closing and narrowing circular loops. Technology is continually developing to allow for the use of lower-grade wastes, for example, and greater propagation of such technologies could positively impact circular economy outcomes. Trade agreements could also monitor trade in waste and second-hand goods in order to ensure that freely flowing goods are not creating new types of waste that countries are ill equipped to handle.

Some trade agreements include specific provisions regarding rules of origin for used products and secondary materials. In the United States-Mexico-Canada agreement (USMCA), for example, as was the case in NAFTA, secondary materials are assumed to have originated in North America if they are processed in one of the three countries, as well as derived from used goods collected in one of the three countries.[41]

[40] https://ec.europa.eu/info/news/european-commission-promotes-circular-economy-and-green-partnerships-japan-and-indonesia-2018-oct-24_en.

[41] https://www.recyclingtoday.com/article/nafta-usmca-deal-impact-on-recycling-industry/.

6. The specific case of e-waste

E-waste, or waste electrical and electronic equipment (WEEE), is a term used to cover all electrical and electronic equipment (EEE) and its parts that have been discarded by its owner without the intent of reuse (UNU/StEP Initiative, 2013). Rapid product innovation and replacement, and shorter product lifespans – especially for information and communication technology products and consumer equipment – are increasing the amount of e-waste and posing a significant challenge to waste management around the world. The number of electronic devices is growing exponentially, with connected devices expected to attain 25-50 billion globally by 2020, from around 10 billion in in 2015 (WEF, 2015). The exponential growth of EEE and ever shorter lifespans of EEE products implies that a large volume of many different metals and minerals is increasingly available for recovery. E-waste may contain precious metals such as gold, base metals like copper and nickel as well as rare materials of strategic value such as indium and palladium (WEF, 2019). A lot of these metals could be recovered, recycled and used as secondary raw materials for new goods but the challenge is the incredible complexity of these products that can be made up of more than 1 000 different substances (WEF, 2019).

E-waste flows, while not the largest waste streams, are the fastest growing globally. The global e-waste generation has been estimated to be 42 million metric tonnes (Mt) in 2014 and forecasted to increase to 50 Mt by 2018 (Baldé et al., 2015). Yet, only 6.5 Mt of the 42 Mt of e-waste were documented and recycled by national take-back systems with the highest standards. The UN estimates that each year, USD 52 billion worth of electronic waste is thrown away, dominated by gold, copper and plastics, with only 13% recycled (Tsinghua University School of Environment, 2018).

Although the European Union and the United States were once responsible for most of this waste, China, India, countries of Latin America, and other growing economies now generate more e-waste in aggregate. China alone generated an estimated 6 Mt of E-waste in 2014.

The composition of waste streams varies significantly by item. Complex products like electronic devices are designed to integrate the functions of different products in a single article. This has led to the production of smaller items containing an increasing number of different materials – including copper, tin, precious metals (gold, silver, and palladium), and hazardous substances – with additives and components often glued together or integrated into the main product structure. Even unsophisticated mobile phones can contain more than 40 elements, and these are often alloyed to form an array of individual components. This makes materials separation extremely difficult and reduces the potential for repair and recycling. In order to increase the potential for re-use, re-manufacturing of these goods and recycling of their materials at end of life, product design enabling separation of individual components and elements is essential.

Separate collection streams is the first challenge faced by some countries. Small appliances are sometimes disposed of with household waste while consumer durables with high steel content may be collected and treated under non-compliant and sub-standard conditions with other metals scrap. While collection is generally conducted on a local or regional scale, pre-processing often makes use of interregional operations. At the country level, there are a variety of approaches to facilitate the collection and management of e-waste, such as landfill bans, extended producer responsibility (EPR) and stewardship programmes, and advanced recovery fee (ARF) systems. However, minimum purity requirements to ensure an economically viable materials yield are difficult to obtain when products made from very different materials are collected and processed as one stream.[42] The collection and state-of-the-art treatment of e-waste is still limited, with most nations still lacking proper management systems. While progress is visible, current processes still depend on pre-sorting of incoming feedstock, often done manually.

State of the art recovery and recycling are more difficult to achieve in open cycles taking place in a business to consumer (B2C) environment, where product ownership changes each time a transaction occurs, and transparency is low. Flows under business-to-business (B2B) closed loop systems with a limited number of players are easier to monitor, control and improve. For example, over the past two decades, partnerships involving policymakers, producers and recyclers in various countries have created specialized “take-back and treatment systems” to collect e-waste from final owners and process it in professional treatment facilities. As a result, material losses are significantly lower.

In the European Union, roughly 40% of the annually generated e-waste is officially reported to be treated with state-of-the-art recycling; in the United States and Canada, the level is around 12%; for China and Japan, it is around 24-30% (Baldé et al., 2015).[43] The European Union has introduced with the EU WEEE Directive obligations as regards the separate collection of e-waste and has set specific targets for the separate collection of e-waste, which are increasing over time. Regulations like the 2012 EU WEEE Directive outline minimum selective depollution treatment and mandate the development of minimum standards for the treatment, including recovery, recycling and preparing for reuse, of e-waste. Following a mandate by the European Commission, CENELEC, the European Committee for electrotechnical standardization, has developed a series of European standards and technical specifications for the treatment and preparation for reuse of e-waste. The EU WEEE Directive also allows processing to take place outside the region, provided that the shipment of e-waste complies with existing rules, notably the EU Waste Shipments Regulation. The EU WEEE Directive provides that e-waste exported out of the European Union only counts towards fulfilling obligations and targets related to recycling and recover if the exporter can prove that the treatment takes place in conditions that are equivalent to EU requirements.

However, the extent to which raw materials are recycled, and the level of safety, health and environmental measures and control procedures differ considerably not only on a global scale but even within the European Union. High quality recycling is costly and the difference between the value of the recovered materials and the costs of the entire recycling treatment chain are impacted by technology, regulations and enforcement. Hence, the costs for environmental health and safety compliant recycling can be higher than transport costs incurred in the export of complex products, especially at times of depressed raw material prices. This often tilts the playing field in favour of the informal recycling sector that avoids registration, regulations and taxes. Despite agreements that ban or restrict cross border shipments of hazardous and other wastes, illegal trade bypasses regulations that impose obligations to manage waste in an environmentally sound manner. There is some evidence that bilateral trade in waste increases if there is divergence in environmental policy enforcement between trading partners (Kellenberg, 2012). This suggests that in some cases waste may be exported to countries with more lax environmental standards and without adequate capabilities for managing this type of waste, which leads to sub-optimal use of resources throughout the lifecycle of products.

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[42] Shredding, for example, is a common pre-processing technique for the recycling of electronic goods, but it causes a loss of much of the embodied value within the products. See European Environmental Agency (2017).

[43] State of the art recycling involves the following steps: (i) Removal of toxic components and materials; (ii) Pre-processing; (iii) Manual dismantling; (iv) Mechanical separation (shredding, breaking, sequential sorting); (v) End-processing; (vi) Base metal refinery; (vii) Precious metal refinery; (viii) Plastics recycling; (ix) Batteries recycling; (x) Other component treatment; and (xi) Disposal of non-recyclable residues (Baldé et al., 2015).

Many nations seek to control or prevent the inflow of e-waste, but such flows are difficult to track due to classification challenges and are also subject to some undocumented, often illegal trade. For example, some shipments of e-waste may have been disguised as shipments of used equipment to avoid control procedures that manage the shipment of waste. Although exporters may be required to notify of pending e-waste shipments, some have reported exports of hazardous waste as second-hand goods, waste for recovery, or waste for disposal. Detecting fraud is difficult.[44] Moreover, the participation in e-waste illegal activities often does not appear risky to offenders due to the low probability of being prosecuted and sentenced. Even if cases are successfully prosecuted, the penalties foreseen in legislation and applied in court decisions are typically low. In many cases, the fines imposed are less than the profits gained from one illegal shipment.[45]

Huisman et al. (2015) find that in Europe (the EU-28 plus Norway and Switzerland) only 35% (3.3 million tonnes – Mt) of all the e-waste discarded in 2012 ended up in the officially reported collection and recycling systems. The other 65% (6.15 Mt) was either exported (1.5 Mt), recycled under non-compliant conditions in Europe (3.15 Mt), scavenged for valuable parts (750 000 tonnes) or simply thrown away (750 000 tonnes), meaning that there is a substantial loss of materials directed to compliant e-waste processors. Undocumented exports of e-waste from the European Union to third countries were estimated by the report at about 0.4 Mt. Curiously, ten times that amount (4.65 Mt) was wrongfully mismanaged or illegally traded within Europe itself. Huisman et al. (2015) estimate the total value of materials diverted from compliant processing in Europe at between EUR 800-1 700 million. Another study by Geeraerts et al. (2015) estimates that 2.98 Mt of e-waste was illegally exported from the European Union in 2012 (and 1.16 Mt to China alone) which corresponded to a EUR 31-38 million loss for the EU e-waste recycling industry, assuming that the average intrinsic value of e-waste is about EUR 300 per tonne.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal and the 2001 OECD Decision of the Council on the Control of Transboundary Movements of Wastes Destined for Recovery Operations are two international regulatory frameworks that combat the flow of hazardous waste (Box 2). Despite the Basel Convention's positive impact on regulating e-waste flows, it is unclear whether it accurately addresses the bulk of flows amidst changing trade patterns (Lepawsky, 2015).

The Basel Convention allows transboundary movements of hazardous and other wastes if the waste in question was to be traded subject to the prior consent procedure whereby a movement can take place only upon consent of countries of import and transit. Beginning in 1994, an effort known as the "Ban Amendment" was designed to prohibit any transboundary shipments of hazardous waste intended for disposal, recovery or recycling from Annex VII countries (European Union, OECD and Liechtenstein) to any non-Annex VII country that is part of the convention, while allowing trade of hazardous waste between non-Annex VII countries. The Ban Amendment entered into force on 6 December 2019 for 98 Parties that ratified the amendment.

One of the issues is caused by Annexes VIII and IX which respectively characterise what will and will not count as hazardous waste. A large number of components and materials that comprise e-waste – such as plastics, metals and glass – appear in both Annexes and, depending on a variety of factors, may or may not be considered waste in general or hazardous waste specifically. Since 2010, the Basel Secretariat has been drafting technical guidelines on e-waste intended to distinguish between 'waste and non-waste'. They

44 Electronic tracking is the preferred method for characterizing transboundary e-waste flows, with the two technologies most frequently used being radio frequency identification (RFID) and global positioning systems (GPS) (Lee et al., 2017).

45 Huisman et al. (2015) suggest several actions to harmonise and enhance the penalty systems.

were adopted on an interim basis in 2015, on the understanding that they are of a non-legally binding nature and that the national legislation of a party prevails over the guidance provided within the technical guidelines. At its 13th meeting in 2017, the COP established an Expert Working Group to undertake further work on these technical guidelines. Following this work, revised guidelines were adopted on an interim basis at the fourteenth meeting of the Conference of the Parties in 2019.

The illegal trade in e-waste suggests a regulatory gap that some countries are filling. The EU WEEE Directive provides tools to EU Member States to fight the illegal export of e-waste more effectively, especially when they are disguised as legal shipments of used equipment to circumvent EU waste shipments rules. The Directive obliges exporters to test whether equipment works or not, and provide documents on the nature of shipments that could be thought illegal. The European Union is also considering adopting criteria for the assessment of equivalent conditions for the treatment of e-waste when this takes place outside the European Union.

Increasingly, e-waste imports are also working or repairable equipment. Limiting the trade in e-waste to recycling for material recovery and disposal leaves aside the intrinsic value that can be obtained from the repair and reuse of electronic parts and equipment that often outpaces the value of the material content of these products. Therefore, current policies that promote export prohibitions focusing on shredding for material recovery preclude the environmental benefits to be gained from repairing, reusing and refurbishing equipment and components (Yamaguchi, 2018).

Although at the national and regional level, a proximity principle is commonly applied to ensure that waste is treated as close as possible to the point of generation, there is growing awareness that trade can provide opportunities to help boost global recycling rates. It will nevertheless be necessary to ensure that this increase in global recycling does not lead to low value-added recycling (downcycling). There is increasing recognition that non-hazardous waste could be traded for further processing and recovery under proper controls. Tools like electronic tracking, blockchain techniques, materials stewardship and custody over parts and equipment along the global value chain can be used as methods for establishing international networks for better data exchange, global monitoring of exported e-waste, and detecting potential cases of non-compliant disposal or recycling operations.

Box 2. The Basel Convention and the 2001 OECD Decision of the Council on the Control of Transboundary Movements of Wastes Destined for Recovery Operations

International trade in waste is regulated by multilateral environmental agreements, such as the Basel Convention and the 2001 OECD Council Decision. Their aim is to control hazardous and other waste being shipped to countries with weak capacities to manage it in an environmentally sound manner, creating negative impacts on human health and the environment.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (the Basel Convention) was adopted in 1989 in response to the tightening of waste legislation in industrialized countries that significantly increased the costs of domestic disposal and created a financial incentive to export waste for processing and disposal. It entered into force on 5 May 1992 seeking to control the transboundary movements of hazardous waste, including e-waste, which was generally exported from high- to low-income countries. As of February 2020, there are 187 signatory countries.[1]

The Basel Convention works through a combination of a listing of defined hazardous wastes and a principle of prior notification of intent to export and consent to import. The Convention allows Parties to restrict or prohibit the import or export of hazardous or other wastes for disposal. In addition to hazardous and other wastes which are listed in the Convention, Parties can define additional wastes as hazardous under their national legislation, in which case control procedures apply for transboundary movements involving such Parties. All transboundary movements must be properly documented to be considered legal, to both ensure that importing countries wilfully accept the wastes, and that environmentally sound management has been agreed upon. Trade with non-Parties is prohibited unless non-Parties are bound by national, multilateral or regional agreements providing a similar level of protection.

Basel Parties are required to report on their transboundary movements of hazardous and other wastes and their disposal however reporting has been patchy. Only about 50% of countries submit an annual report.

The OECD Decision concerning the Control of Transboundary Movements of Wastes Destined for Recovery Operations was adopted on 14 June 2001 and amended in 2008 in order to harmonise its provisions with the Basel Convention, in particular with regard to the classification of wastes subject to control. It proposes a simplified waste management procedure as well as a risk-based approach to assess the necessary level of control for materials. The OECD System is based on two types of control procedures: the Green Control Procedure for wastes presenting low risk for human health and the environment and, therefore, not subject to any controls other than those normally applied in commercial transactions; and the Amber Control Procedure for wastes presenting sufficient risk to justify their control. Wastes exported outside the OECD area, whether for recovery or final disposal, do not benefit from this simplified control procedure.

Member countries have the possibility to designate “pre-consented recovery facilities” for which they do not raise objections concerning regular transboundary movements of certain waste types. Transboundary shipments to pre-consented facilities benefit from an accelerated procedure.

Member Countries have the obligation to inform the OECD of any pre-consent they grant to their recovery facility. The database of OECD Trans-boundary Movements of Waste inventories pre-consented waste facilities including the types of waste treated, technologies used, and the quantity of waste accepted.

1. http://www.basel.int/Countries/StatusofRatifications/PartiesSignatories/tabid/4499/Default.aspx#enote1.

Source: Basel Convention, http://www.basel.int/Countries/StatusofRatifications/PartiesSignatories/tabid/4499/Default.aspx and OECD Control System for Waste Recovery, http://www.oecd.org/env/waste/theoecdcontrolsystemforwasterecovery.htm.

7. Final considerations and implications for trade policy

This paper aims to contribute to reflections on how select aspects of trade policies can support transition to a more resource efficient and circular economy. Circular business models can promote responsible stewardship throughout the lifespan of products, support the introduction of new technologies that prolong the useful life of products and parts and facilitate their repair or remanufacture, support the wider diffusion of products that are produced using resources more efficiently, and promote re-use, re-manufacture and recycling of waste and end-of-life final goods. Trade policies can contribute to the use of products where resources are used more efficiently and that are more easily repaired or refurbished. They can support greater resource efficiency and circularity by contributing to increased coherence in waste and scrap standards, lowering trade barriers on recyclable materials, and tackling problems of trade in waste, in particular e-waste, that is exported to countries with inadequate recycling facilities.

Trade flows in used, remanufactured and refurbished goods, secondary materials and waste and scrap are not always well accounted for due to the lack of precision in the current trade classification systems. This imprecision implies that trade policies cannot differentiate between these very different types of goods. In particular, the trade classification, the Harmonized System (HS), does not differentiate between used, re-manufactured and new products, nor does it differentiate between levels of contamination of waste and scrap. For example, there is no HS code for e-waste.[46]

Clear and globally accepted definitions of what constitutes waste, scrap and secondary materials, including e-waste, are lacking. Various definitions and guidelines exist at national, regional and international level including those developed by the Basel Convention, the EU WEEE Directive, IMPEL, WCO, UNU, INTERPOL, ISRI (Institute of Scrap Recycling Industries, Inc.) and StEP Initiative, and could be drawn on in consideration of international definitions. Defining and setting consistent guidelines is a complex but necessary task requiring collaboration and agreement between stakeholders as goods, secondary materials and waste and scrap are reported at various stages of the recycling value chain and in different classifications. There may be a role for one or multiple conveners to facilitate international agreement of terms, definitions and classifications of waste, scrap and secondary materials.

Increased trade in re-used and remanufactured goods will impact domestic schemes such as Extended Producer Responsibility (EPR) or stewardship programmes. EPRs, stewardship programs, and other producer and consumer arrangements that promote recycling will increasingly need to be internationalised. Engagement with industry organizations on ways in which to globalize stewardship will be desirable. As trade in goods is shifting toward trade in goods bundled with services, it may imply changes in stewardship from producers of goods to include providers of services. These changes suggest that consumers may have longer-term relationships with services providers, and are known to them, compared with traditional models of purchase of goods where producer and consumer do not maintain contact post-purchase. Leveraging the information and relationships of service providers could be explored in order to strengthen mandatory or voluntary EPRs as a tool to capture a greater share of goods that reach obsolescence for reuse, remanufacture or recycling.

Lowering tariff and non-tariff barriers to trade on secondary raw materials will help to close material loops. Export restrictions on metallic waste and scrap are more prevalent than on primary raw materials. Since the two materials are substitutes in some production processes, taxing secondary materials more provides implicit support for mined primary raw materials. Moreover, using waste and scrap as raw material input into the production of metals not only conserves non-renewable resources used to produce them, but also uses 60-97% less energy for the most commonly used materials thereby contributing to decarbonisation of the global economy. Allowing more secondary metallic materials to enter global markets by reducing trade barriers should incentivize higher collection levels, which in turn would make more secondary metallic material available for the metal production process.

The importance of enabling trade in waste, scrap and secondary raw materials will increase as technologies evolve to enable recycling of metallic material that are used in small quantities. Many of these materials are used in electronic products and goods that enable the transition to a less resource-intensive economy such as renewable energy and sustainable mobility solutions. Economies of scale will dictate that few recycling facilities exist worldwide in small-volume metals, and trade in these materials will be

[46] The Harmonized System (HS) classification is updated every five years under the responsibility of the United Nations Statistics Division (UNSTAT). The latest version of the HS was released in 2017.

particularly important to ensure that waste, scrap and secondary materials reach those facilities. Achieving economies of scale is already highly relevant in some developing countries and the situation is particularly acute in small, island economies.

Trade in e-waste, the fastest growing waste stream, to countries that have inadequate processing and recycling facilities will need to continue to be addressed. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal and the 2001 OECD Decision of the Council on the Control of Transboundary Movements of Wastes Destined for Recovery Operations are two regulatory frameworks regulating waste flows and clarifying the rules that apply to different waste and secondary materials, which currently vary between countries. However, there is an increase in the illegal or undocumented trade in waste, especially e-waste, to countries with inadequate recycling capabilities. More information is needed on recycling capabilities in countries importing e-waste and their suitability to handle such imports. One model for gathering such information is the OECD Database of Transboundary Movements of Wastes, which collects information regarding recycling facilities and the types of waste they accept, and institutes a procedure for exporting waste to pre-consent recovery facilities. Such procedures could be extended to countries outside the OECD area and could include more detailed information regarding the level of contamination of different materials. Internationally recognized certification of recycling facilities would help to ensure environmentally sound management of traded waste and scrap.[47] The Basel Convention is a powerful instrument for containing negative spillovers from trade in waste, but compliance could be enhanced. Although reporting is in principle obligatory, it is only done by about 50% of signatory nations in any given year.

Policies that move from national or regional approaches – where some countries or regions accumulate materials that can be costly to reprocess in their territories – and facilitate the development of international models in which resources flow to areas with comparative advantages for their recycling and remanufacture, can aid in closing material loops. It will be necessary to ensure that increasingly global recycling maintains a high level of value-added of the recycled material and avoids downcycling. Technological improvements can aid in internationalizing closure of material loops, such as sensors that establish material composition of waste and scrap in order to better sort waste types and blockchain technologies that track products through their lifecycle. In order to diffuse these technologies widely, they should not be subjected to unnecessary barriers to their trade. An enabling trade and investment environment regarding services will be necessary to support the increased services that result from a transition to a more circular economy.

This is a new area of analysis. Trade in waste and scrap, for example, has existed in substantial quantity only for about 15 years. The interface between trade and the circular economy is broad and touches on many aspects of trade and domestic policy frameworks, including services and investment. The complex issues it brings can best be discussed in international fora. Global partnerships will need to be forged, to agree and enforce trade rules, to combat illicit exports and ensure waste is not exported to countries without adequate treatment capabilities, and to contribute to closing global material loops by ensuring secondary materials are available for reuse, remanufacture and recycling in the most efficient and sustainable way possible. Preferential trade agreements can also be leveraged to enhance circularity through sustainable trade in used and remanufactured goods, secondary materials and waste and scrap.

[47] See the 2004 OECD Council Recommendation on the Environmentally Sound Management of Waste, https://www.oecd.org/env/waste/environmentallysoundmanagementofwaste.htm.

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Annex A. Circular economy policies in China

In 2002, China adopted a new model aspiring to build a closed loop of material flows within the national economy, later branded “circular economy”. The model aimed at overcoming the country’s environmental and resource management problems, while achieving improvements in resource productivity and environmental efficiency (Geng and Doberstein, 2008). China’s move towards circularity began as a policy objective implemented through different policies (World Bank Technical Assistance Program China, 2009). A chapter in the country’s 11th Five-Year Plan (for 2006–10) was devoted to it, and the Circular Economy Promotion Law approved by China’s State Council in 2009 required local and provincial governments to consider such issues in their investments and development strategies. Targets were initially enacted for five industries: coal, steel, electronics, chemicals and petrochemicals. The circular economy was upgraded to a national development strategy in the 12th Five-Year Plan (2011–15).

Since 2006, the Chinese government has approved a series of measures to develop e-waste recycling at the national level, including providing subsidies, investing in infrastructure and developing regulations for recovery and recycling of high priority electronic goods.

Extended producer responsibility (EPR) started in 2011 with the establishment of a pilot subsidy system under the “Old for New” policy for the collection and treatment of e-waste. The initiative originally resulted in the partial formalization of these activities but once the subsidies were scaled back in 2012, the recycling rate dropped, highlighting the program’s lack of long-term financial sustainability. That year, the central government released a series of policies to regulate and support formal dismantling and recycling firms, issuing additional permits and providing subsidies to those working legally. It also began collecting taxes from producers to subsidize downstream waste collection and treatment activities, under an e-waste treatment fund. This system, with minimal changes, still exists today.

At the end of 2016, China’s State Council passed the “Extended Producer Responsibility System Implementation Plan” laying out a roadmap to 2020 to connect the value chain from production to waste treatment and disposal. The goal is to reach 40% recycling for four product categories: electronics, automobiles, lead-acid batteries and packaging products. By 2025, the plan aims to reach a recycling rate of 50% and achieve a rate of 20% of recycled materials used in the production of electronics. However, as of 2017, recycling of aluminium, tin, cobalt and rare earth elements (REE) were behind target, and 38% of e-waste was processed via formal recycling (Tsinghua University School of Environment, 2018).

Released in July 2017 under the 13th Five-Year Plan, the “Circular Economy Leading Action Plan” supports the integrated development of the recycling industry through implementation of EPRs, development of reverse logistics systems, support for large-scale development of remanufacturing, development of regional recycling systems and promotion of the use of recycled materials.

These policies are starting to produce results. According to China’s National Bureau of Statistics, from 2005 to 2013 resource intensity and waste intensity had improved by 35% and 47%, respectively, although the recycling and reuse of waste improved more slowly, by 8%. China’s resource intensity fell from

4.3 kilograms of materials per unit GDP in 1990 to 2.5 kilograms in 2011.[48] Yet, China's overall resource consumption rose fivefold during these two decades, from 5 billion tonnes to 25 billion tonnes.[49]

The Chinese government has adopted policies to restrict imports and improper treatment of e-waste and establish domestic collection and recycling systems to promote environmentally-sound treatment. Imports of e-waste were formally banned in 2000, followed by domestic regulations that prohibit imports of most waste into China.[50] The legislation separates wastes into three categories – strictly prohibited from importation, restricted imports and exempt from regulation. Waste electronics and machinery are generally strictly prohibited from being imported. Waste having undergone considerable processing can be reclassified as raw material, and thus imported. Second-hand electronic products are not covered by the waste legislation, rather they are regulated by the Ministry of Commerce, primarily under the Electronic Import Measures policy of 2008.

Nevertheless, imports of illegal flows of e-waste are estimated to be as high as 462 000 tonnes per year, mixed with other scrap material and shipped directly to Chinese ports, or transiting through Free Trade Zones or third countries (United Nations University/StEP Initiative, 2013).[51] However, since the import of mixed-metal scrap for recycling is legal in China, it is often quite difficult to determine the point at which a shipment of metal scrap with e-waste shredded into fine particles and blended into the mix is regarded as an illegal import.

[48] The level of resource intensity of OECD countries is currently around 0.5 kilograms per dollar of GDP (Mathews and Ta, 2016).

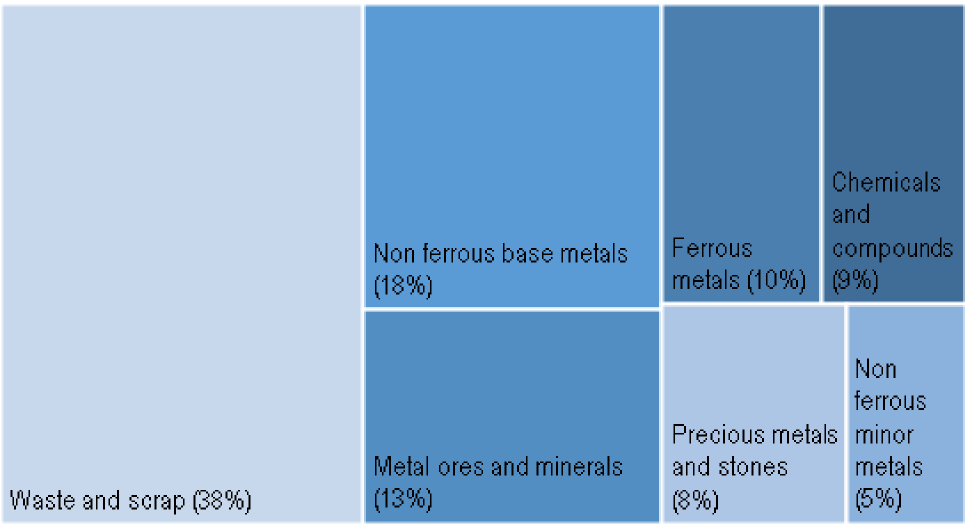
[49] The Ellen MacArthur Foundation takes stock of the advances that have taken place in China in increasing circularity and suggests policy areas where China could strengthen its transition to a more circular economy (Ellen MacArthur Foundation, 2018).

[50] Such as the Solid Waste Import Management Measures passed in 2011, and the Imported Solid Wastes Catalogue, adopted in 2015. See United Nations University/StEP Initiative (2013).

[51] Hong Kong, China and Viet Nam are known for redirecting electronic waste to China. Imports of second-hand EEE and e-waste into or through Hong Kong, China is legal if an import license is obtained in Hong Kong, China. The Vietnamese government has banned the import of e-waste but allows the import of second-hand EEE for re-export.

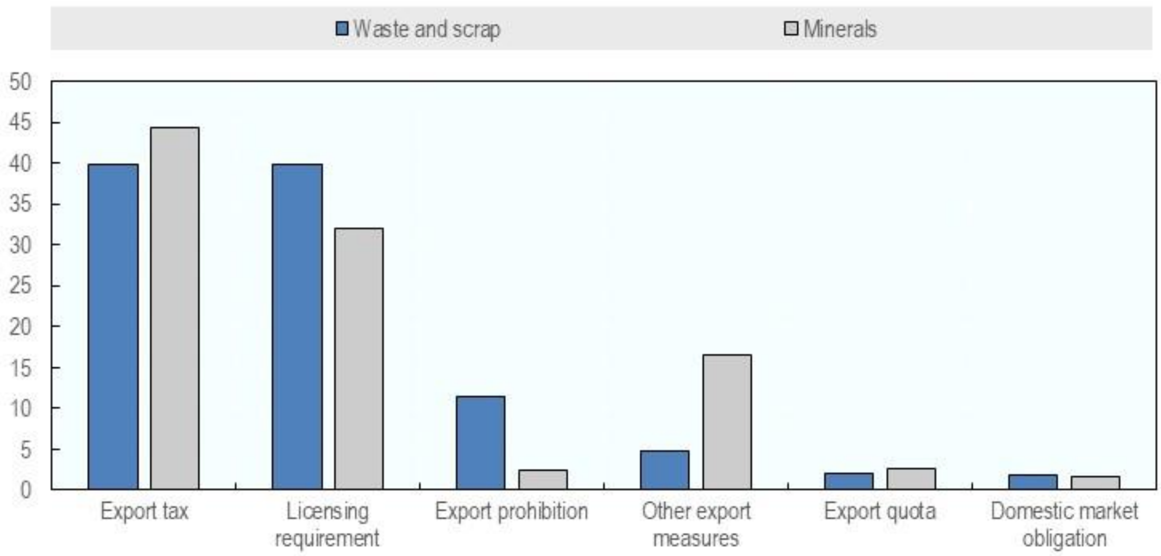
Annex B. Trade restrictions on metallic waste and scrap

Figure A B.1. Number of export restrictions, 2014



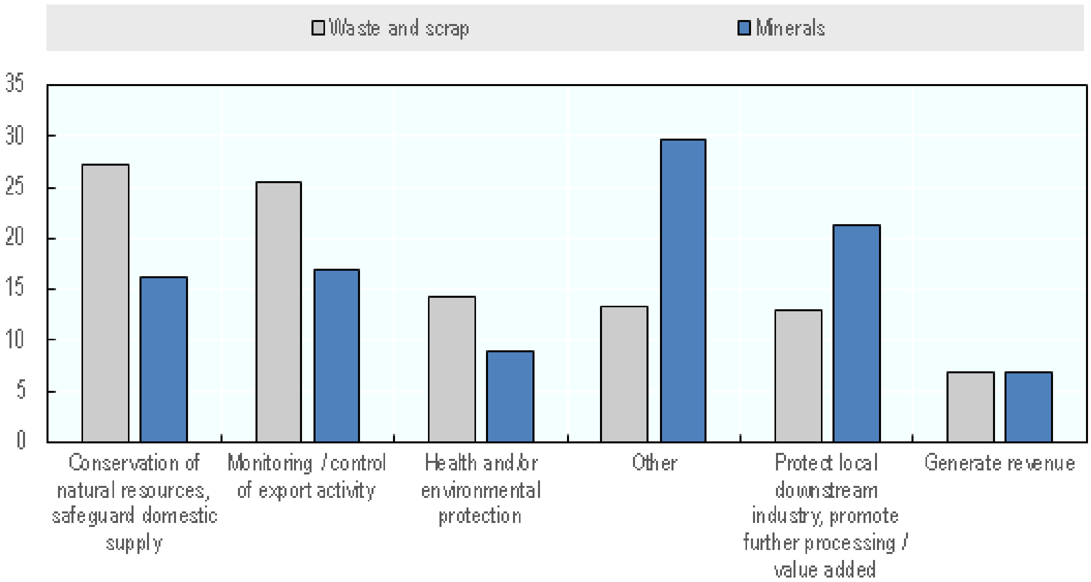
Source: OECD Inventory of Export Restrictions on Industrial Raw Materials.

Figure A B.2. Type of export restrictions, percentage, 2014



Source: OECD Inventory of Export Restrictions on Industrial Raw Materials.

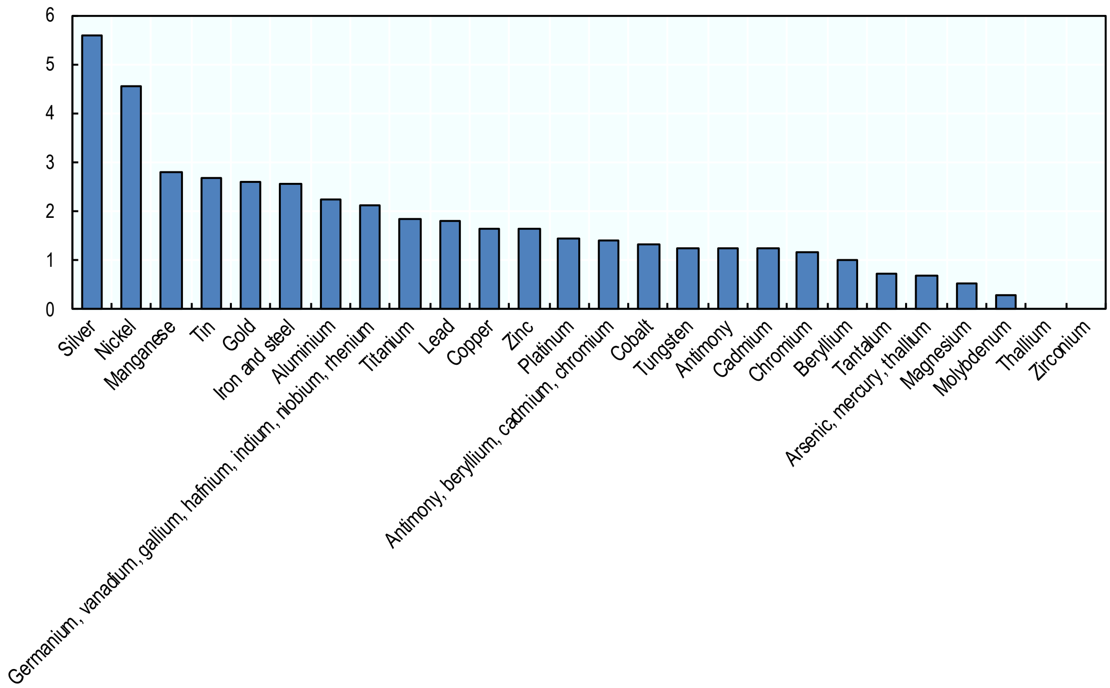
Figure A B.3. Share of export restriction by policy purpose regrouped in six categories after removing the "No purpose reported" category, 2014



Source: OECD Inventory of Export Restrictions on Industrial Raw Materials.

Figure A B.4. Average import tariff on waste and scrap products

MFN, trade-weighted, percentages, 2014



Note: Individual products can appear in several categories due to the HS product definition of waste and scrap products.
Source: UN Trains.