Chapter 6.

Projections of recycling and secondary materials

This chapter presents the projections of recycling and secondary materials use in the central baseline scenario. The first section presents an overview of the current situation on the use of secondary materials resulting from recycling. The second section presents projections of the recycling sector and the third section illustrates the impacts for secondary materials use to 2060, focusing on the competition between processing of primary and secondary materials.

KEY MESSAGES

Recycling rates vary widely for different materials. Biomass and fossil fuels generally don't lend themselves to recycling, as they are expended or degraded when used. Many non-metallic minerals are too cheap or difficult to recycle. Some may however be downcycled, for building waste can be used for lower-value purposes such as road filler. For metals, recycling rates can be as high as 70%, such as for iron and steel. For several metals, competitive markets for recycled scrap exist. The recycled metal content in the economy is generally lower than the recycling rates, which is expected in growing economies: recycled content does not currently rise above 50%. As a result, the share of secondary materials in total materials use is limited, and is only significant for some metals.

Projections and trends

- Secondary materials (the result of processing recyclable waste into raw materials that can be used again) currently make up a modest part of total materials use. Many metals have substantial recycling rates, and scrap metals are used as secondary material. The share of secondary lead has surged in recent years to above 50%, while secondary steel has gradually declined to below 30%. Secondary shares for aluminium, zinc and copper are even lower. Recycling – and hence secondary materials use – is rare for non-metallic minerals; concrete is for example often used as low-value road filler.

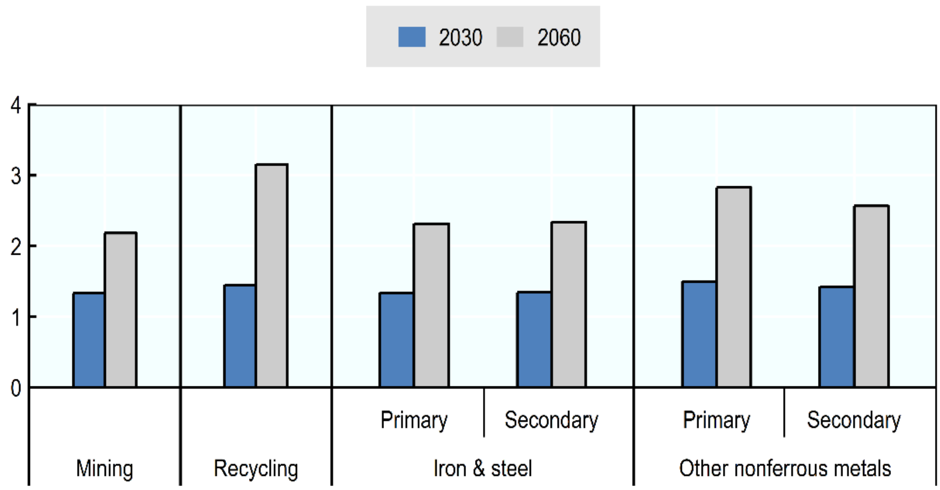
- The recycling sector is projected to more than triple in size between 2017 and 2060 (see Figure 6.1). While both recycling and mining are projected to increase until 2030 at about the same pace, recycling is projected to grow more substantially from 2030 on. This is driven by the growth dynamics of developing countries: the high-growth phase triggers a boom in infrastructure, drawing largely on primary materials. As economies mature, however, and the increase of waste materials increases the availability of recyclable materials, the recycling sector begins to rise in importance.

- Recycling of materials is, however, projected to remain a small percentage of the total economy: the use of both primary and secondary materials is projected to rise in the central baseline scenario. Given the projected technology trends and unchanged policies, the supply of secondary materials is insufficient (or too expensive) to meet the demands of a growing economy.

- While the costs of recycling are projected to decline in comparison to mining new materials, the expansion of secondary materials is hampered by relatively high labour costs. As wages are projected to grow more rapidly than other production inputs, this implies a gradual decrease in the share of secondary materials in overall materials use, at least for non-ferrous metals.

Figure 6.1. The recycling sector is projected to outpace the mining sector

Growth of output between 2017 and 2060, index 1 in 2017



Source: OECD ENV-Linkages model.

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Areas of uncertainty

There are many uncertainties surrounding these projections. One modelling challenge is to develop consistent, comparable measures of raw primary materials (ores), raw secondary materials (scrap), and refined materials (from primary and secondary sources). The research quantified the likely impact of alternative assumptions about population growth and income convergence on the evolution of the output of the mining and recycling sectors, and on the share of secondary metals in total metals production. In both cases, this showed only a very minor impact as these are more driven by specific assumptions on structural change and technology developments than by macroeconomic conditions.

Policy implications

Further policy efforts are needed to broaden the scope of recycling to more materials, to increase the recycling rates of those materials where they are currently well below their potential, and to further increase the share of secondary materials use in total materials use. Chapter 5 has already highlighted that materials use needs to be further decoupled from economic activity, at both the sectoral and macroeconomic level. The technical and economic potential for increased recycling, together with the need to further reduce reliance on primary materials, implies that a policy mix is needed that can boost resource efficiency and stimulate the transition towards a more circular economy.

6.1. Secondary materials are only a modest part of total materials use

Secondary materials are the result of processing recyclable waste (scrap materials) into raw materials that can be used again. Secondary materials may be complete substitutes for primary materials, or may only be used in lower-value applications ("downcycling"): for instance when using recovered concrete as road filler. The processing and use of secondary materials are driven by the availability of scrap materials, and the cost-effectiveness of processing technologies using secondary materials input compared to primary materials.

In this report, secondary materials use projections are restricted to those that can substitute for the raw primary materials that are covered in the model. De facto, this implies only secondary metal projections are included in the analysis, as fossil fuels are expended through combustion, biomass is degraded after being used and non-metallic minerals are often recovered only in degraded form, e.g. usable only for downcycling.

Projections of recycling are for a much wider set of resources, and also includes recycling of processed materials. These processed materials are not explicitly covered in the current report, which focuses on primary versus secondary raw materials. While processed materials such as plastic and textiles can be recycled, unlike metals the raw material part can in general not be fully recovered without loss of value (crude oil cannot be recovered from plastic in an economically viable fashion, nor cotton from textile). They are captured in the model solely through the use of recycled products by the various processing sectors (for instance chemistry, furniture making and textiles).

One challenge in this modelling exercise resides in reconciling the physical measures of raw primary materials (ores), raw secondary materials (scrap), and refined materials (from primary and secondary sources). In some cases, the original mineral is recovered in the recycling process. In others, a processed form of the mineral is recycled. For example, the primary material iron ore is used to make steel, and steel scraps can be used as substitutes for iron ore in steel production. Sections 7.2 and 7.3 in Chapter 7 provide more detailed case studies for copper and iron and steel, respectively, and can provide further insights into recycling prospects for these specific metals.

While primary materials are usually measured in their raw form (as in Chapter 5: the weight of metal ores and non-metallic minerals, or the weight of biomass and fossil fuels), secondary materials are usually measured in their refined state. An alternative approach would be to present the volumes of scrap available and processed, but this would require a full stock accounting across the whole economy for all materials and all regions, which is not yet available. When comparing primary and secondary materials (for instance when assessing their environmental impacts in Chapter 8), the refined material measure is used.

Table 6.1 shows the recycling rates for a range of metals as detailed in UNEP (2011[1]). Recycling rates are presented for two metrics: *end-of-life (EoL) recycling rates*, i.e. the degree to which commodities are recycled at the end of life, and *recycled content*, i.e. the degree to which materials currently used in production consist of secondary materials. Recycling is at present mainly limited to materials that produce sufficient returns from recycling, which in many cases means that they must be present both in sufficient quantities and in sufficiently high concentrations in the supplied waste.

For many of the metal groups, recycling rates are substantial. The highest recycling rates are observed for chromium, followed by tin, iron and steel and platinum. Recycling rates for the other metals are generally much lower. High recycling rates do not necessarily translate into high shares of recycled content in existing commodities, not least due to long lifetimes of the products that contain metal. As production volumes keep increasing, inputs of both primary and secondary materials grow, and the recycled content remains substantially smaller than the EoL recycling rate.[1] A large potential for increasing recycling rates implies that the availability of recycled materials for secondary production could significantly increase without running into supply problems of secondary material.

Table 6.1. Estimates of current recycling rates and recycled content of metals

	End-of-life Recycling Rate (%)	Recycled Content (%)
Ferrous metals	70	40
Aluminium	55	35
Chromium	90	19
Copper	50	30
Gold	50	30
Manganese	53	37
Nickel	60	35
Silver	65	30
Tin	75	22
Zinc	40	23
Platinum group metal		
Iridium	25	17
Palladium	65	21
Platinum	70	20
Rhodium	55	40
Ruthenium	10	55
Other metals		
Antimony	20	5
Cobalt	32	68
Indium	0	38
Magnesium	39	33
Molybdenum	30	33
Niobium	53	22
Rhenium	17	60
Tantalum	5	20
Tungsten	46	40

Note: Recycled content refers to the secondary content of the refined metal production.
Source: Own calculations based on UNEP (2011[1]).

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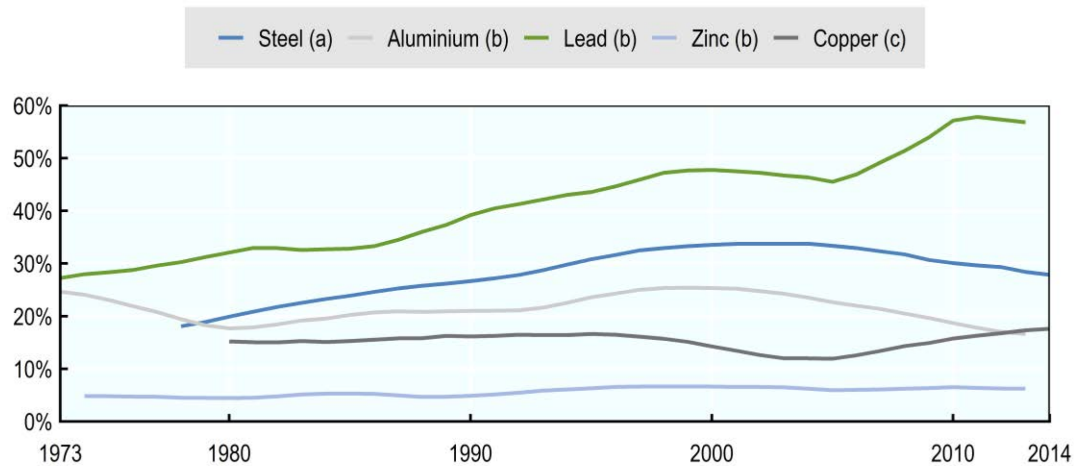
Recycling is much rarer for non-metallic minerals. Concrete, which constitutes the bulk of non-metallic minerals in terms of weight, is often downcycled, e.g. concrete waste is used as road filler; while cement cannot be recycled. Some processed materials can also be recycled (glass is a good example) or downcycled (glass into glass wool as insulation materials).

Nonetheless, secondary materials make up a modest part of total materials use. Figure 6.2 presents the recent trends for selected metals. Significant increases have only been achieved for lead. For steel, the increases of the previous century were partially undone in the last decade; Section 7.3 in Chapter 7 delves into possible reasons for this. Shares of secondary processing have remained rather low for aluminium, copper, and especially zinc.

Figure 6.2. The share of secondary metals is very heterogeneous across selected metals

Shares of secondary metals in total global production (5-year moving averages)



Note: The share of secondary metals is computed as the total production of refined metal from secondary sources in total refined material production.
Source: Own calculations based on (a) Worldsteel Association (2018[2]), (b) ABREE (2016[3]), and (c) USGS (2016[4]).

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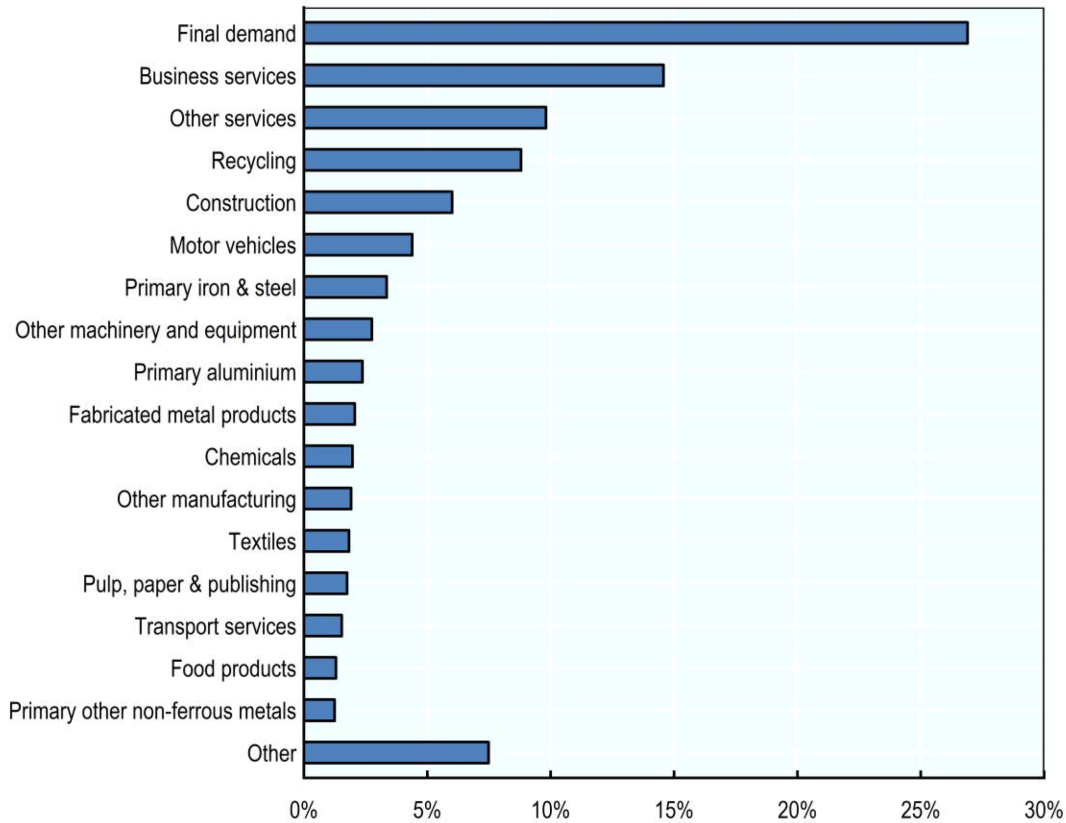
Many different sectors use recycling as an input in their production (Figure 6.3). The recycling sector as modelled in this report corresponds to the recycling activity of all materials (not only metals, but also plastics, textiles, construction materials, glass, wood etc.). For instance, 10% of the output of the recycling sector goes to iron and steel primary production, 8% to the reprocessing of secondary steel. Also important are recycling activities for fruits and vegetables production (5%)[2], rubber and plastic (5%), and paper (5%). As a consequence, the recycling sector is a very wide activity which deals with varied streams of materials.

One challenge in correctly incorporating the recycling sector in the modelling framework is that currently a substantial share of recycling activities is provided by the informal sector, in particular in non-OECD countries. Box 6.1 explain the main issues and their consequences for the projections. This poses only limited drawbacks for the calculations, as the modelling framework directly projects secondary materials provision, without an explicit link to the source of the materials in the recycling process (as explained in Section 2.2 in Chapter 2).

Figure 6.3. Many sectors use recycling as input

Percentage of total demand for output of the recycling sector in 2017



Source: OECD ENV-Linkages model.

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Box 6.1. Representing informal sectors is challenging

Informal recycling activities are significant, as discussed in a recent UNEP report: "In many cities around the world there is a considerable presence of the informal sector in waste management, particularly in cities where there is no formal separate collection system for recyclable materials… The informal sector recovers, reuses or recycles valuable materials from waste and thereby contributes to sustainable resource management." (UNEP, 2016[5]).

The economic system of the OECD ENV-Linkages model used in this report is calibrated on the basis of countries' national account information at the base year. By definition, national accounts do not include informal economic activities (although they sometimes report an approximation of these). The modelling framework is thus unable to feature the activities of waste collection, material recycling and reprocessing that occur in the informal sector.

While this has little consequence for the main results presented in the report, this absence means that the production costs of the recycling sector are underestimated as some of the waste input expenses have been omitted. This will probably have little impact on the projection of the real costs of recycling in the long run.

The absence of the informal recycling activity also implies an underestimation of the recycling rates in the base year of the model. This could affect the prospects for increasing recycling rates in the future.

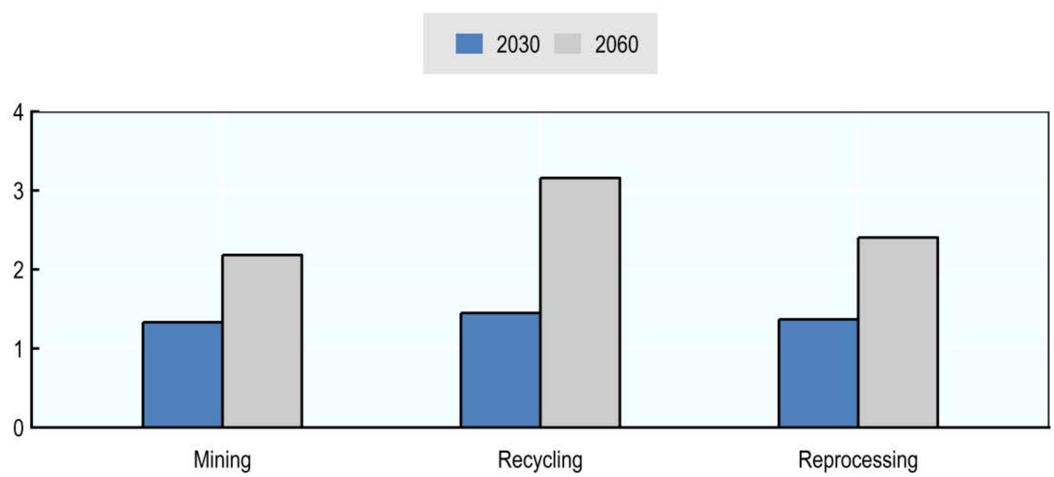
Nevertheless, as countries develop, the informal sector share can be expected to decline progressively, causing these underestimations to vanish.

6.2. Recycling is projected to triple

The recycling sector is projected to more than triple in size between 2017 and 2060 (Figure 6.4). In contrast, mining activities approximately double during that period, growing more slowly than GDP. This indicates a projected increase in the weight of the recycling sector in the economy. However, both sectors remain small compared to the size of the global economy: mining decreases from 0.7% to 0.6% of total output while the share of recycling maintains more or less constant share just below 0.04%.[3]

Figure 6.4. The recycling sector is projected to outpace the mining sector

Growth of global sectoral output between 2017 and 2060, index 1 in 2017



Source: OECD ENV-Linkages model.

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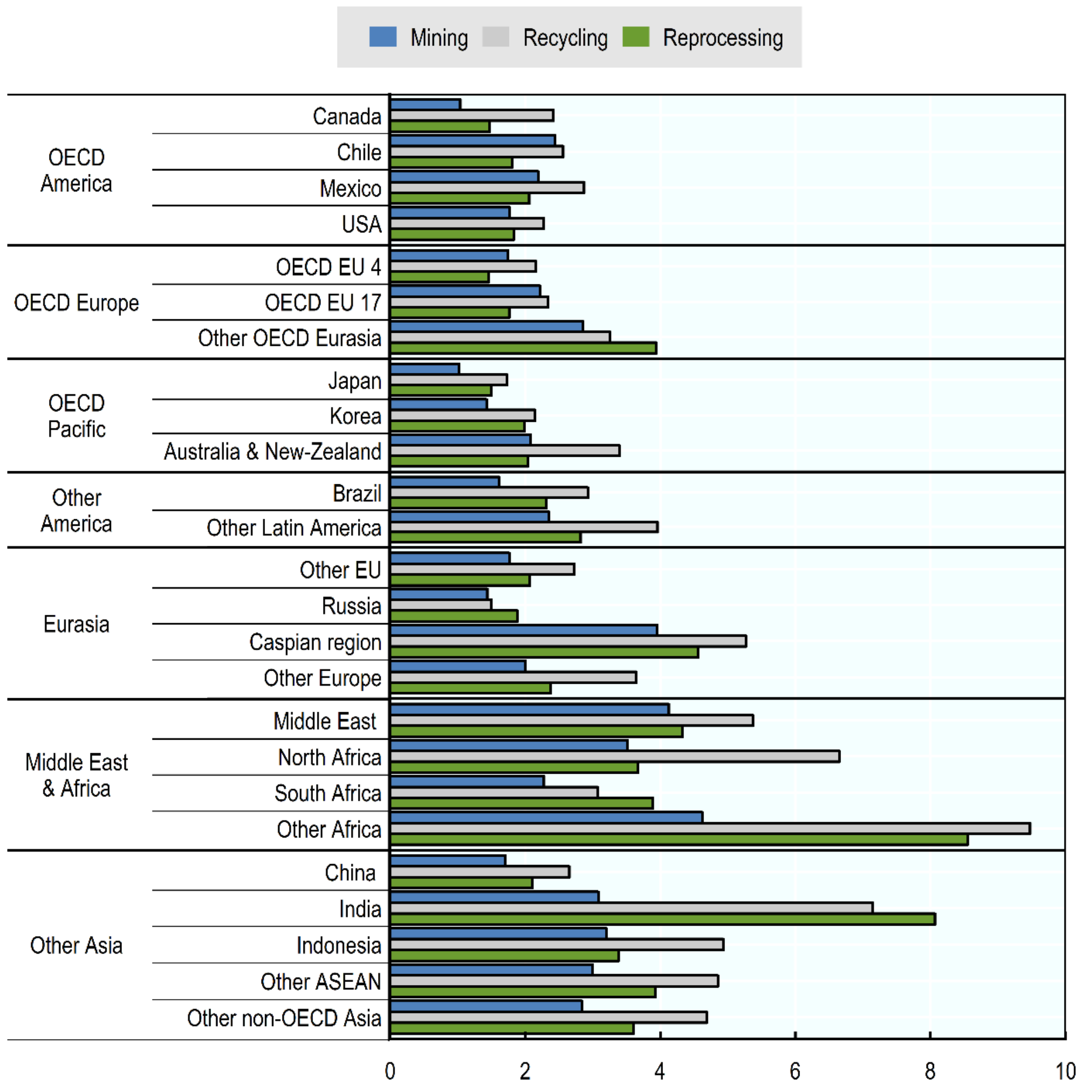
The regional dynamics largely follow the global evolution. Figure 6.5 illustrates that the recycling sector is projected to grow faster than the mining sector in all represented regions. Furthermore, in most regions the projected growth of the reprocessing sectors is faster than the growth of mining as well; regions with strong projected growth in recycling are also projected to have rapidly growing reprocessing sectors.

Figure 6.5. In almost all regions, recycling is projected to grow more rapidly than mining

Growth of output between 2017 and 2060, index 1 in 2017



Note: See Box 2.1 in Chapter 2 for definitions of recycling and reprocessing and Table 2.1 in Chapter 2 for regional definitions. In particular, OECD EU 4 includes France, Germany, Italy and the United Kingdom. OECD EU 17 includes the other 17 OECD EU member states. Other OECD Eurasia includes the EFTA countries as well as Israel and Turkey. Other EU includes EU member states that are not OECD members. Other Europe includes non-OECD, non-EU European countries excluding Russia. Other Africa includes all of Sub-Saharan Africa excluding South Africa. Other non-OECD Asia includes non-OECD Asian countries excluding China, India, ASEAN and Caspian countries.

Source: OECD ENV-Linkages model.

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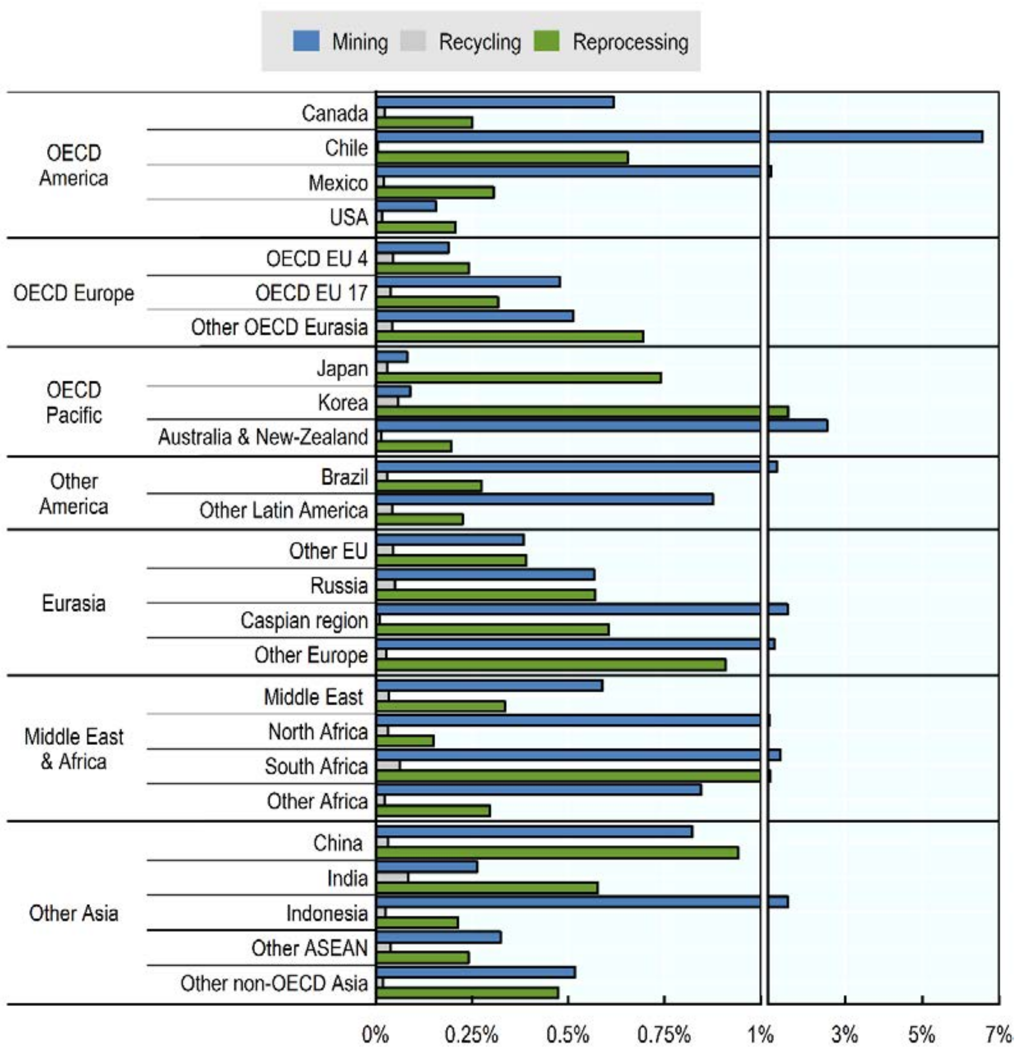
However, the speed of growth of mining, recycling and reprocessing is variable across countries. While OECD countries are projected to roughly double the size of the recycling sector, the mining sector more than doubles in specific resource-exporting countries (Chile, Mexico, Other OECD Eurasia, Australia) and grows more modestly in other OECD countries. In most OECD countries, but not Other OECD Eurasia (which includes the EFTA countries, plus Israel and Turkey), the reprocessing sector growth roughly follows that of mining.

Similarly, the recycling sector in non-OECD countries is projected to increase faster than the mining sector (Figure 6.5). However, the much higher growth rates of economic activity and materials demand imply a rapid increase in all three sectors. The recycling sector is projected to grow fastest in the emerging and developing economies (not least India and the African regions except South Africa). The metal reprocessing sectors are also projected to grow faster than mining in most non-OECD countries, and in India are projected to outpace even the rapidly increasing recycling sector. At the global level, the mining, recycling and reprocessing sectors are projected to multiply their output levels between 2017 and 2060 by 2.2, 3.2 and 2.4, respectively.

Figure 6.6. The recycling sector is projected to remain small in all regions

Share of the sectors in the economy in 2060, sorted by the highest share of the recycling sector



Source: OECD ENV-Linkages model.

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Nonetheless, the projected share of the recycling sector in 2060 still remains very small in comparison to the overall size of the economy (Figure 6.6). The share of the recycling sector in the total value of the economy is projected to remain below 0.1% in all countries, with India coming closest to that level.

The share of the metal reprocessing sector is, however, projected to be similar to the share of the mining industry globally (0.5%). However, this share varies widely by country (Figure 6.6). Resource-rich economies rely on mining exports and their mining sector thus represents a higher share of value added (see for instance Chile or Australia). These geographical differences entail opportunities for resource importing countries to use reprocessing as a source of growth and employment.

Box 6.2 discusses the plausibility of increased recycling in a baseline scenario from a technical perspective. For most materials, current end-of-life recycling rates are below their technical and economic potential, and there is thus room to increase recycling rates, even in absence of policies to stimulate recycling.

Box 6.2. The potential for increasing recycling rates

In the industrially developed world the metallurgical step of recycling for the most important metals can be considered optimized given current production costs, market incentives and policies. As reported in UNEP (2013[6]): "*Ingenuity in metallurgy has helped the industry to drive the efficiency of recycling of ferrous and base metals (e.g. steel, stainless steel, aluminium, copper, zinc, lead, nickel, tin) ever closer to the limits that are permitted by physics and thermodynamics*".

More non-ferrous metals (i.e. aluminium and copper) could be extracted from bottom ash. UNEP (2011[11]) estimates that the current extraction from waste streams of 130 kt (of which 65% aluminium) could be tripled in 2020 as a result of better process technology and an increase in waste-to-energy plants.

The extent of the collection is far from optimal in most industrialized countries : "*In many cases (sometimes despite legislation) small articles or Waste Electrical and Electronic Equipment are not collected separately for recycling but disposed of with Municipal Solid Waste*" (UNEP, 2013[6]). For smaller electronic equipment, a doubling of the collection rate could be achieved. Larger equipment (e.g. cars or industrial production equipment) already has a considerably higher collection rate, so there is no such potential for improvement. Given the different shares of metal use in smaller or larger electronic equipment, the potential for increased recycling from electronics is particularly high for cobalt, gallium and indium; average for gold, silver, palladium and platinum; and moderate to poor for rare earth elements.

In view of these arguments, the recycling percentages for aluminium, cobalt, indium and gallium can be assumed to be below their technical potential. This also applies to more commonly used metals like zinc, tin and lead.

Secondary materials provided by the recycling sector depend on the availability of waste. Waste streams are not modelling in this report, so the link between waste generation and recycling cannot be made (see Section 2.2 in Chapter 2). The World Bank has, however, used the central baseline scenario presented in Chapter 3 to project future municipal waste. These waste projections are briefly presented in Box 6.3.

Box 6.3. Municipal solid waste is a growing issue

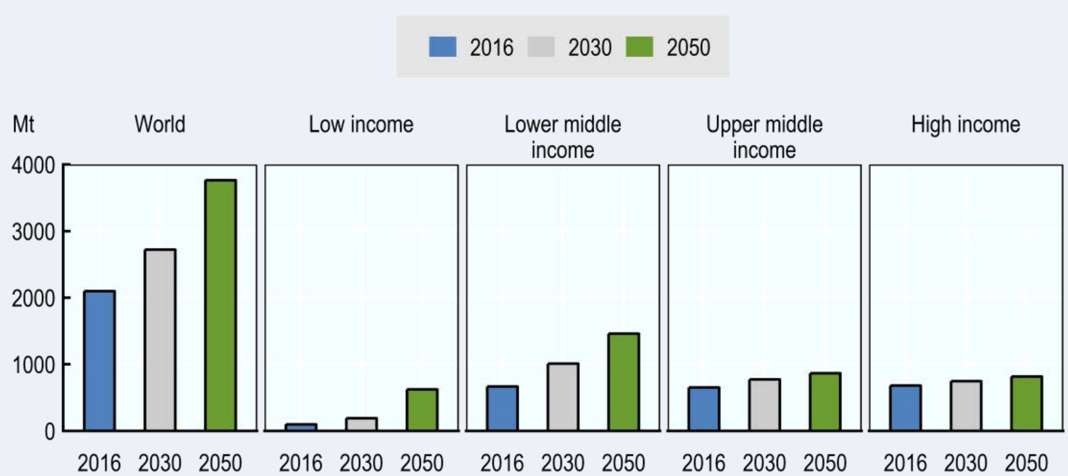
Waste is a growing global issue with serious consequences for the environment and public health, when not managed properly. Waste management is of particular concern in urban areas, where the high population density leads to both high level of waste generation and strong potential impacts on health due to the proximity of inhabitants. The modelling framework used in this report does not allow quantification of future waste generation. However, the World Bank (2018[7]) makes projections of future Municipal Solid Waste (MSW) – defined as residential, commercial and institutional waste – that are based on the central baseline scenario presented in Chapter 3.

According to the World Bank projections (2018[7]), 2.1 Gt of MSW is currently generated worldwide; this averages 0.77 kg per person per day at the global level, but has a wide range in different countries – from 0.12 kg to 4.39 kg. Although high-income countries only account for 16% of the world population, they generate approximately 32% of the world MSW (680 Mt). A conservative estimation suggests that at least 25% of MSW is not managed in an environmentally safe manner.

Global MSW is projected to grow to 3.8 Gt by 2050 (see figure below). MSW generation per capita in high-income countries is projected to increase only slightly (by 11%) by 2050, while in low-income countries, it is expected to nearly triple. MSW is shown to increase at a faster rate for low income countries but to slow down as their income increases. The total MSW generation quantity in low-income countries is expected to increase by more than a multiple of six by 2050.

Figure 6.7. Projected municipal waste generation increases in all regions to 2050

Municipal waste generation in Mt

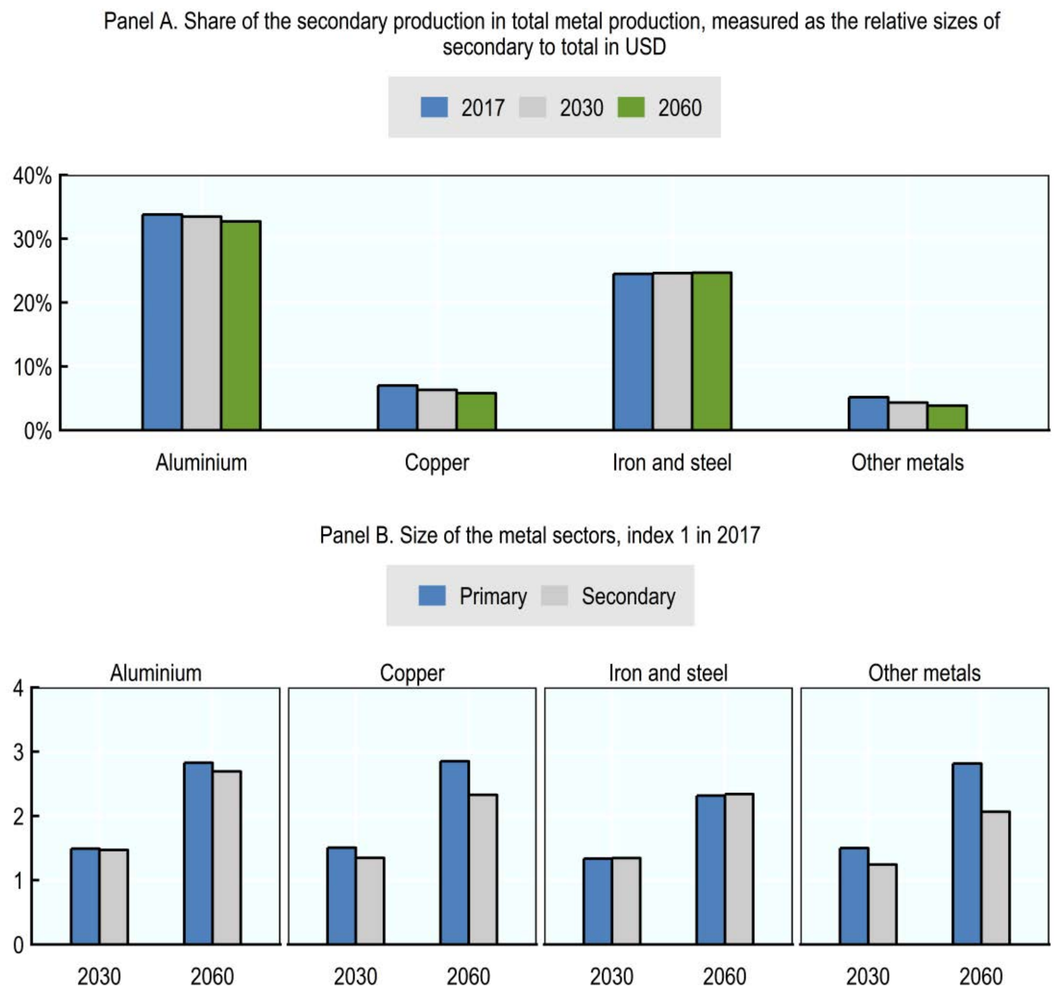


Source: World Bank (2018[7]).

6.3. Secondary metal production is projected to grow as fast as primary metal production

In this report, the projections of secondary metals use are driven by demand. The different metals processing sectors depicted in the model can produce the same good using two types of material inputs: (i) primary materials, from the processing of mined, extracted metals, and (ii) secondary metals, from the recycling of waste scrap. The process that uses primary metals is usually more energy and capital intensive and less labour intensive than the process using secondary metals (cf. Figure 4.11 in Chapter 4). The secondary metal production is projected to increase at roughly the same pace to 2060 than primary, as seen in Figure 6.8.

Figure 6.8. The share of secondary metal production is projected to remain roughly unchanged until 2060



Source: OECD ENV-Linkages model.

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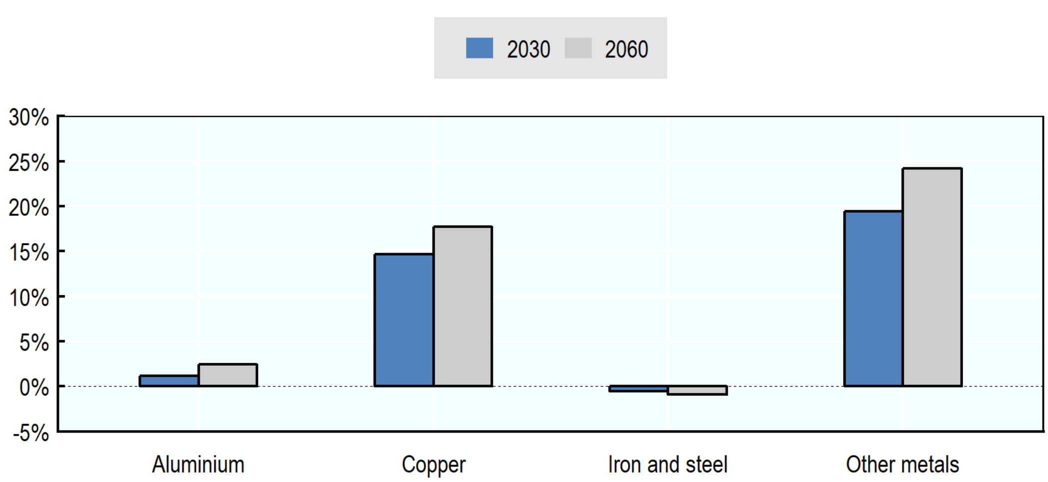
For copper and other non-ferrous metals the share secondary is projected to slightly decline. For iron and steel, where the secondary production is relatively more mature, and cost differentials between primary and secondary are smaller, the projections show no significant difference between both.

As discussed above, the needs of emerging and developing economies for materials is so large that they need the primary materials to build stocks. That will in turn increase the availability of scrap stocks for later recycling (see Chapter 7 for more insights on the future availability of scrap metals for copper and iron and steel), thus opening up the possibility to shift towards more production based on secondary materials in response to policies.

As described in Chapter 2, relative price differentials drive the dynamics of competition between primary and secondary materials. Figure 6.9 shows how these price changes affect the relative production costs of secondary metals versus primary metals production. On the one hand the prices of metal ores and scraps change over time in favour of secondary metal production (cf. Figure 4.10 in Chapter 4). But this effect is dominated by the relative increase in wages compared to capital costs. As primary production of non-ferrous metals is more capital intensive and secondary production more labour intensive (Figure 4.11 in Chapter 4), this wage increase reduces the growth potential of secondary metals production in the central baseline scenario. Thus, the evolution of the cost competitiveness of secondary metal production compared to primary metal production favours primary sources for non-ferrous metals throughout the whole projection horizon. However, the projected medium run dynamics of copper and other non-ferrous metals imply growth in primary production, as emerging and developing economies are projected to grow strongly and build their material stocks. The increased maturation of these economies then relies on primary materials, while at the same time paves the way for scrap availability for recycling in the long run.

Figure 6.9. The relative price of secondary non-ferrous metals is projected to increase

Evolution of the ratio of secondary metal price to primary metal price compared to 2017



Source: OECD ENV-Linkages model.

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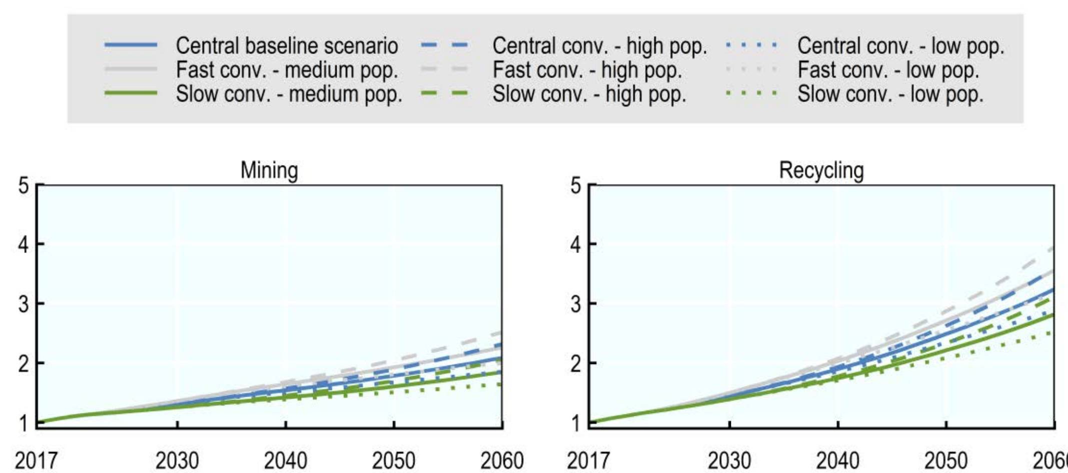
6.4. Uncertainty surrounds the recycling and secondary materials projections

There are many uncertainties surrounding these projections. For example, the assumed substitutability between primary and secondary materials is based on relatively weak empirical evidence. Similarly, the evolution of the costs of recycling vis-à-vis mining hinges on assumptions regarding technological change and price developments. A full analysis of these uncertainties is beyond reach for this report. But the impact of the alternative assumptions about population growth and income convergence as described in Section 3.4 in Chapter 3 can be quantified. These quantitative results should not be seen as indicative of the full uncertainty range surrounding the central baseline projections of recycling and secondary materials use, but only serve to highlight the role of these socioeconomic drivers.

Figure 6.10 highlights how the socioeconomic uncertainties could affect the evolution of the output of the mining and recycling sectors. The graph shows that the output of these sectors is about as sensitive as GDP. This implies that the effect of these uncertainties on structure of the economy is very limited.

Figure 6.10. Mining and recycling output vary with population and income convergence assumptions in proportion to GDP

Sectoral output growth; index 1 in 2017



Source: OECD ENV-Linkages model.

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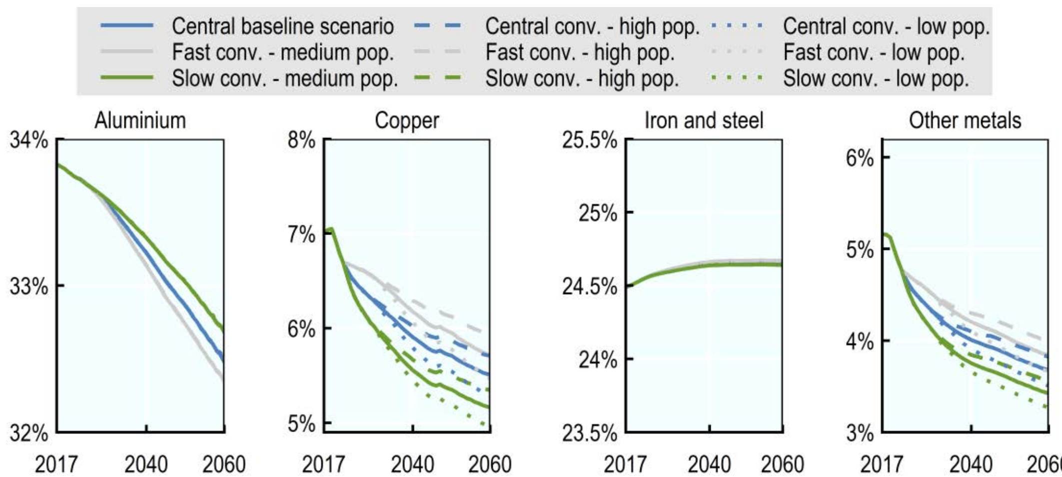
The alternative assumptions on population and income convergence also have only a very minor impact on the projected evolution of the share of secondary metals in total metals production, as shown in Figure 6.11. These socioeconomic assumptions are not strong enough to change the overarching trend that the share of secondary gradually declines for aluminium, copper and other metals, while it stays more or less stable for iron and steel.

Of course, changes in modelling assumptions that directly affect the trade-off between primary and secondary materials, or the evolution of recycling and mining sectors, are likely to have a much larger impact. These include the elasticity of substitution between primary and secondary production processes and assumptions that affect relative price changes, i.e. those on structural change and technology development in the mining, recycling and reprocessing sectors. Changes in policies will also have a significant impact on these trends.

Figure 6.11. The share of secondary metals is projected to change little under alternative population and income convergence assumptions.

Evolution of the share of secondary metal in percentage of total production



Source: OECD ENV-Linkages model.

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Notes

[1] In some cases, recycled content is higher. This can be the case when a lot of material is recovered at the production stage: these materials will then not be counted towards end-of-life recycling as they do not go through the waste handling process.

[2] This includes e.g. recycling boxes for transporting the produce.

[3] These figures only include extraction of primary materials and provision of secondary materials, not their (re-)processing which carried out by the corresponding industrial sectors.

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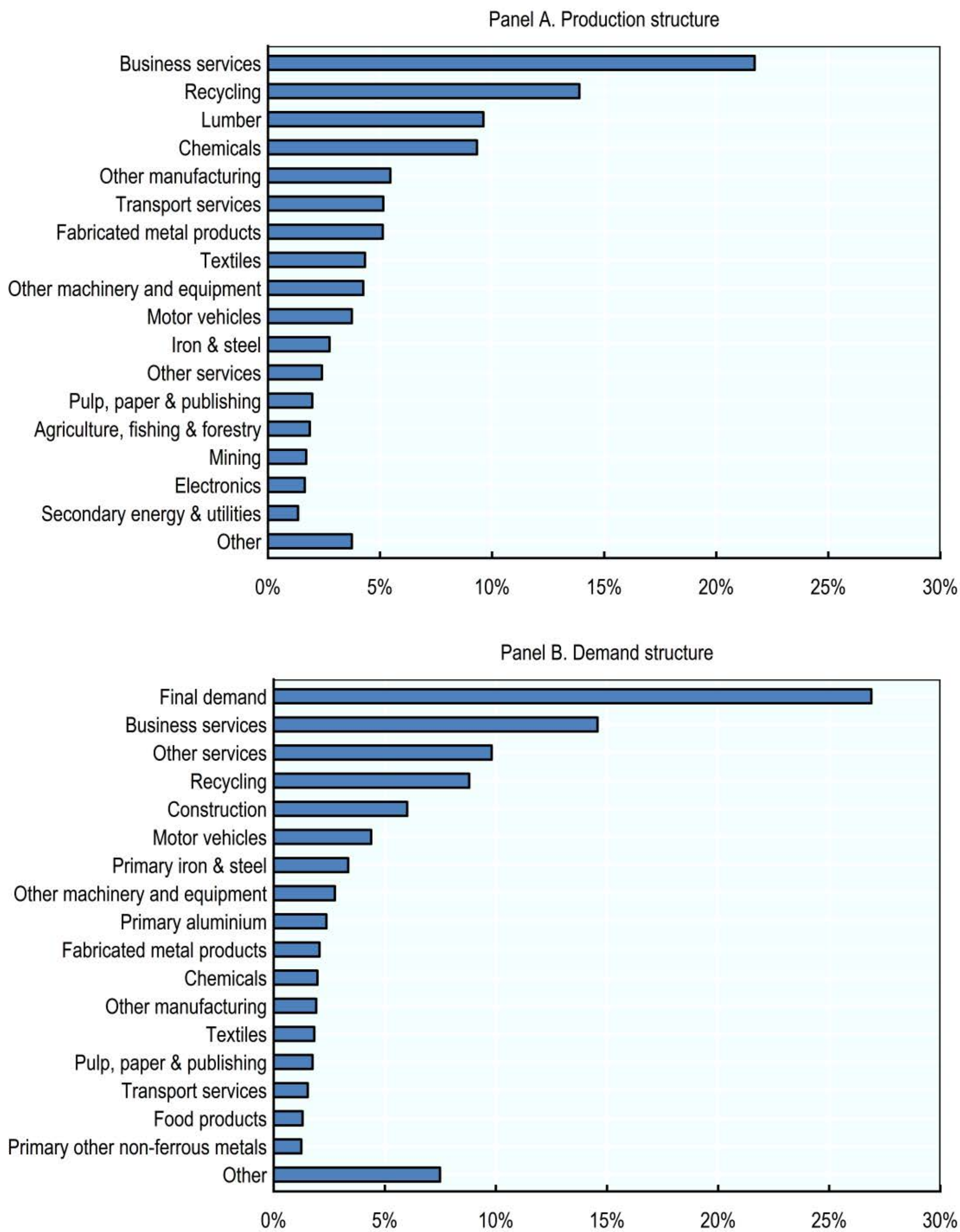
Annex 6.A. Detailed results and supplementary materials

The recycling sector was split from the manufacturing sector in the GTAP database using the structure from the Exiobase database (see Figure 6.A.1). Panel A shows the production structure of the recycling service: most of the cost structure of the sector consists of labour costs (27 %), and capital costs (21 %). Furthermore, this sector overall benefits from no taxes applied to it. Furthermore, 18 % of production costs are dedicated to Services while 8 % are dedicated to self-consumption in the recycling sector itself. Finally, land transport is a key input as goods need to be collected.

Interestingly, the tax rates are very heterogeneous across countries for the recycling sector (see Figure 2.A.1). While input tax rates are positive for all countries – ranging from -0.1 % to 10.2 % – other production tax rates are very small. A remarkable figure is China with a very high subsidy, leading to a -13.6 % tax rate. Other countries range from -0.9 % to 1.5 %. The high subsidy in China explains the global tax rate close to zero (in Figure 6.A.1).

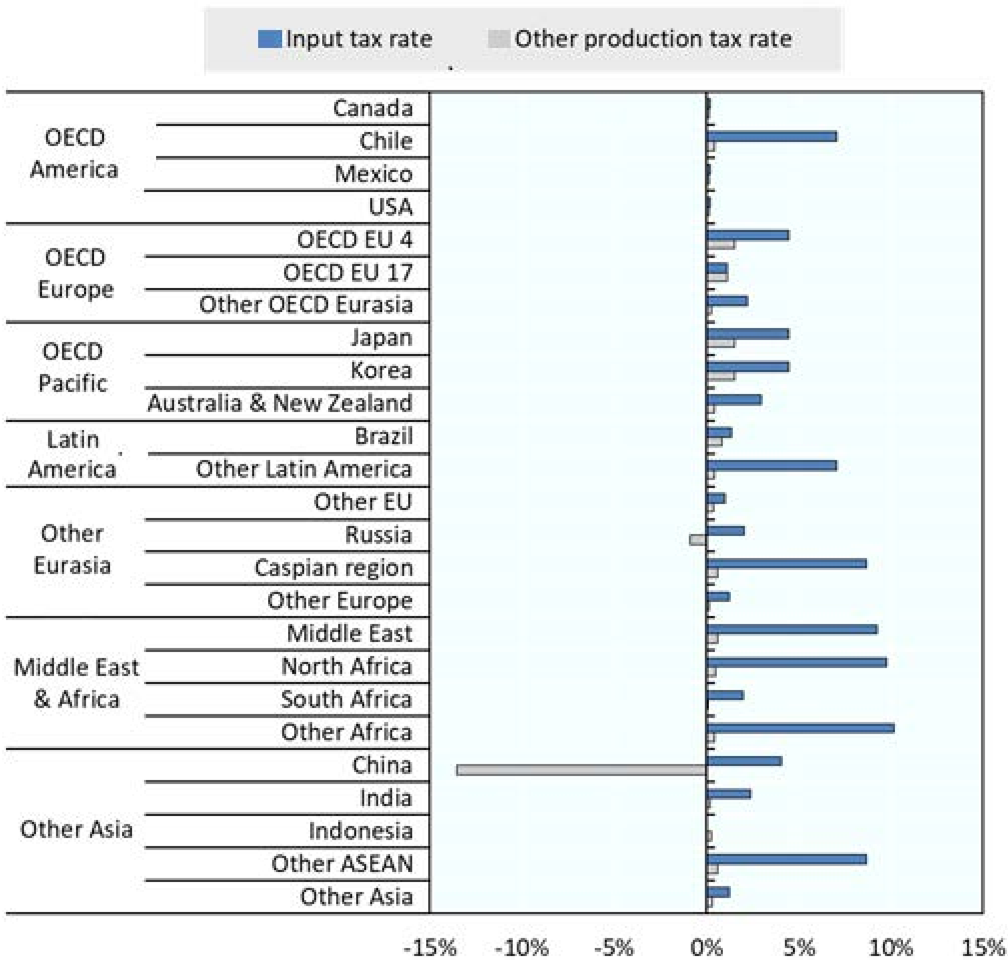
Figure 6.A.1, Panel B depicts the demand structure. While 10 % goes to Investment, and 4 % to households, the largest consumer is the Iron and steel processing (primary for 10 % as well as secondary for 8 %). Self-consumption also constitutes the end point of 8 % of the sector production. Aside from steel, the ‘Vegetable and fruits’ sector is one of the big consumer of this service with 5 % (for the pallet boxes?). The governmental services uses about 4 %, while plastics, paper and textiles appear next (respectively 4 %, 4 %, and 3 %). Construction only uses about 2 %, while at the same levels as ‘Fabricated metal products’, ‘Aluminium Primary’ and ‘Aluminium Secondary’.

Figure 6.A.1. Global production and demand structure of the recycling sector

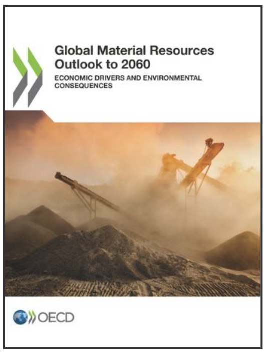


Source: Own compilation from Exiobase 3 database (Stadler et al., 2018[8]).

Figure 6.A.2. Production tax rates for recycling



Source: Own compilation from Exiobase 3 database (Stadler et al., 2018[8]).



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