European Commission

European Innovation Partnership on Raw Materials

Raw Materials Scoreboard

RAW MATERIALS 2020/21

The Raw Materials Scoreboard is part of the monitoring and evaluation strategy for the European Innovation Partnership (EIP) on Raw Materials.

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More information on the European Innovation Partnership (EIP) on Raw Materials is available at https://ec.europa.eu/growth/tools-databases/eip-raw-materials/en.

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European
Innovation
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Materials

3rd Raw Materials Scoreboard

Marble is a metamorphic rock formed from limestone under extreme heat and extreme pressure. It is widely used as building material.

Foreword

When the European Commission published its European Green Deal at the end of 2019, it made very clear that raw materials are key enablers of the EU's twin green and digital transition. They are at the heart of our industrial ecosystems. Wood, stone, clay make up our houses, we are transported around the world in steel and aluminium, and half the periodic system goes into a smart phone. The supply chain disruptions caused by the COVID-19 pandemic, as well as increasing trade and geopolitical tensions, have called our renewed attention to the vulnerabilities that exist in value chains relevant to the EU's security, sustainability, and strategic interests.

The European Innovation Partnership on Raw Materials conceived the Raw Materials Scoreboard as a tool to monitor the field and the competitiveness of the specific EU industry. In creating it, we have widened the knowledge on raw materials. It enables the European Commission to increase the EU economy's resilience and ability to withstand shocks by basing its policies on solid evidence. It helps us to address the need to decouple economic growth from resource use and to identify opportunities to boost the circular economy.

This knowledge also provides the foundation of the increasingly important work on foresight, which helps to identify trends and generate likely scenarios and models. With these, we can chart our path for the transition to a digital, carbon-neutral economy, and anticipate and mitigate future risks. As Member States of the European Union are designing their recovery plans from the Covid-19 crisis, they could also benefit from the knowledge presented here.

The Raw Materials Scoreboard looks at the wide range of raw materials we use and provides insights into this complex topic. It discusses issues relating to our supply of raw materials, from domestic, global, and secondary sources. Raw materials can also play a decisive role in achieving the sustainable development goals, and this publication therefore takes a closer look at their economic, environmental and social dimension. All throughout, it becomes clear that these issues are deeply interconnected.

The Directorate-General Internal Market, Industry, Entrepreneurship and SMEs and the Joint Research Centre have a long history of close collaboration in the field of raw materials. From research to foresight, from the assessment of critical raw materials to circular economy, and on the now three editions of the Raw Materials Scoreboard, our services have fruitfully and successfully worked together to increase intelligence and make the knowledge on raw materials accessible to the public.

We are pleased to present to you the third edition of the Raw Materials Scoreboard. It is the last update in this mandate of the European Innovation Partnership on Raw Materials. Priorities and perspectives change over time in its parent organisation, and so they will inevitably for the Raw Materials Scoreboard. Together with you, we look forward to its future.

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Executive summary

Introduction

Raw materials have moved into the political spotlight because of their importance for the twin green and digital transition and geopolitical developments.

This section provides an overview of the raw materials supply chain. It takes a closer look at markets and trade, and presents the flow of materials through the EU economy.

The last section of the Introduction clarifies the scope of materials, the changes to this edition and criteria for data used.

Raw materials supply in the EU

Appropriate mineral policies and public acceptance of mining projects are essential for successful mining development

Extraction of raw material resources depends on significant mid- to long-term investments, which are enabled by appropriate mineral policies that inform coordinated frameworks (Indicator 1). The perception of company managers on national mineral policy frameworks improved for EU countries with significant extractive activities during the last decade, while investment attractiveness fell slightly in the last two years.

The success of raw material extraction projects depends inter alia on acceptance by the local and regional communities (Indicator 2).

The EU's mineral potential remains underexplored, despite a few new mining developments

Exploration to discover new deposits in the EU (Indicator 3) is key for domestic supply. Limited exploration activities took place across the EU. Some mineral exploration projects identified in the 2018 Scoreboard progressed towards more advanced stages and some started production. The budget for exploration activities remains low compared to other regions in the world.

Once the mineral reserves are defined and their feasibility is demonstrated, mining activities in the EU can develop (Indicator 4). Mining activities in the EU remained stable compared with the 2018 Scoreboard. A few new mining activities have started, e.g. four lithium mines which follow the increasing demand for battery materials. Other existing mines have plans to expand.

Domestic raw materials production can improve the secure and sustainable supply to the manufacturing industries

Growing demand on wood resources marks the strategic shift towards increasing use of renewable resources (Indicator 5). Wood harvest in Europe's forests remains within the limits of what it is considered to be sustainable. However, growing stock accumulation is slowing down.

Providing input to the EU's industrial ecosystems, domestic extraction remains largely stable for the broad categories (Indicator 6). Extraction of wood has been steadily increasing at a higher rate than extraction of other materials (Indicator 6). Additional imports and secondary supply of base metals feed the EU processing and refining industry.

Raw materials in the global context

Raw materials production continues growing in other regions

The EU share of global production is key to understanding the challenge of guaranteeing a sustainable supply of raw materials

Figure i: The Raw Materials Scoreboard at a glance.

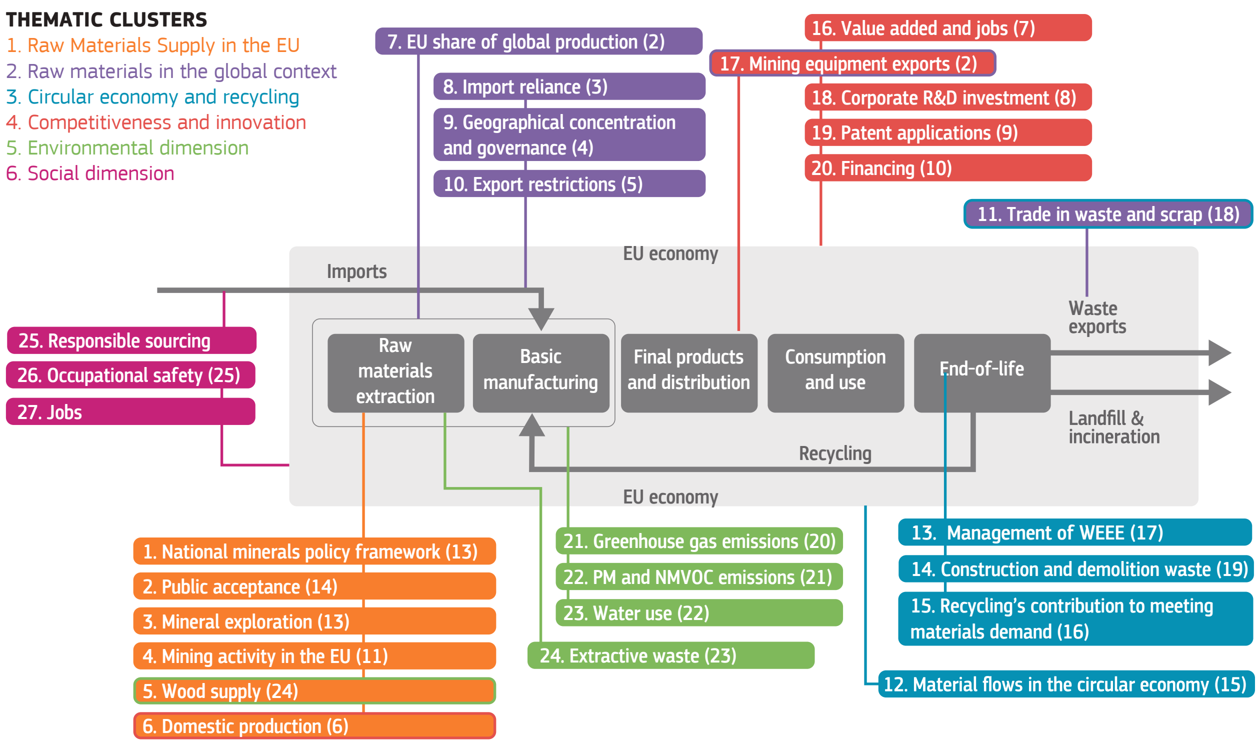


Table i: Scope of the Scoreboard

Classification		Materials
Metallic minerals and metals	Iron & steel	Iron & steel
	Ferro-alloy metals	Chromium, manganese, molybdenum, tungsten and vanadium
	Non-ferrous base metals	Aluminium, copper, lead, nickel, tin and zinc
	Precious metals	Gold, silver and platinum group metals (platinum, palladium, rhodium, ruthenium and iridium)
	High-tech and other non-ferrous metals and metalloids	Antimony, arsenic, beryllium, bismuth, cadmium, cobalt, gallium, germanium, hafnium, indium, lithium, magnesium, niobium, rhenium, strontium, titanium, tantalum, tellurium and zirconium
	Rare earths	LREE, HREE and Scandium LREE (light rare earth elements): cerium, lanthanum, neodymium, praseodymium, samarium HREE (heavy rare earth elements): dysprosium, erbium, europium, gadolinium, holmium, lutetium, terbium, thulium, ytterbium, yttrium
Non-metallic minerals	Construction materials	Aggregates (sand, gravel, and crushed natural stone), various brick clays, gypsum, ornamental and building stone
	Industrial minerals	Baryte, bentonite, borates, diatomite, feldspar, fluorspar, kaolin, limestone, magnesite, natural graphite, perlite, phosphate rock, potash, salt, silica sand, sulfur, (elemental) talc, zircon
Biotic materials		Natural cork, natural rubber and industrial roundwood (timber)
Other		Coking coal, selenium

to EU manufacturing industries (Indicator 7). The EU is the third largest producer of industrial minerals and industrial roundwood, while its share is low for iron and ferro-alloys, non-ferrous metals and precious metals. The EU's share of global mining dropped, mainly due to growing production elsewhere.

Import reliance varies greatly for different materials and stages in the value chain, and remains high for several materials

EU import reliance for raw materials (Indicator 8) gives relevant insights about the security of raw materials supply. The EU is almost self-sufficient for non-metallic minerals, while it remains dependent on imports of metal ores. Import reliance is varies greatly for different materials and stages in the value chain.

The global production of many raw materials continues to be highly concentrated in a few non-EU countries (Indicator 9). This increases the risk of supply disruptions.

The total number of raw materials affected by export restrictions remained quite stable (Indicator 10), though in recent years different types of export-restricting measures are used. The share of global production affected by export restrictions remains high for some commodities.

The trade in waste and scraps, a potential source of secondary materials, can affect raw materials supply to the EU

Waste and scraps, including those traded within and from/to the EU (Indicator 11), can potentially be recycled into secondary materials. The EU is currently a net exporter of waste from iron and steel, paper and cardboard, copper, aluminium and nickel and a net importer of precious metals waste. From 2017, non-EU countries have been imposing import restrictions on paper and cardboard waste affecting trade.

Circular economy and recycling

The economy's circularity remains low and it would benefit from improved resource-efficiency and increased re-use, remanufacturing and recycling

Increasing circularity is part of achieving the EU's Green Deal objectives and strengthening the security of supply for raw materials. Data show, however, that the circular use of materials in the EU remains low (Indicator 12). Construction materials make up a large part of the EU's use of raw materials (on a mass basis). These accumulate long-living in-use stocks. The level of circularity varies from material to material and is the highest for metals.

Recycling of waste of electrical and electronic equipment is efficient for secondary bulk metals, but not for critical raw materials.

Waste of electrical and electronic equipment (WEEE) (Indicator 13) contains a wide range of materials and is a potential source of secondary critical raw materials. Data on WEEE management shows an increase in collection, but with significant differences between EU Member States. Recycling of WEEE mainly addresses bulk metals, while critical raw materials are recycled to a much lower extent. Preparation for re-use is still limited.

Construction and demolition waste (Indicator 14) is the largest waste flow (in mass) in the EU. Though the revised Waste Framework Directive requires EU Member States to take measures to achieve the re-use, recycling and other material recovery, EU Member States' data are not sufficiently comparable regarding backfilling to allow conclusions.

Overall, recycling's contribution to meeting demand is currently low, with several factors limiting the availability of secondary materials

When collection and treatment is well managed, recycling can make a relevant contribution to meeting materials demand (Indicator 15). Overall, recycling's contribution to meeting demand stands low. Only in a few cases, secondary materials approach or surpass one third of current materials demand or more. Several factors limit the share of recycled materials to overall demand, including growing demand, limited economic or technical feasibility of recycling, low collection rates, product lifespan and losses in manufacturing or use.

Competitiveness and innovation

A positive trend started for the added value of the raw material sectors in 2014, with materials recovery as the most dynamic in relative terms

Raw materials extraction and intermediate manufacturing industries create added value in the economy (Indicator 16). Overall, a positive trend restarted in 2014 for the raw material sectors, with a 13% increase by 2017. The most dynamic sector was materials recovery (up 34%).

Added value impacts the whole raw materials value chains. For example, the increase of added value from extraction activities to the manufacturing sectors (including also the construction sector) was close to 35-fold. Repair and materials recovery contributed more than double the added value of extractive activities.

EU manufacturers of mining equipment were the world's leading exporter of mining equipment over the reporting period (Indicator 17). Between 2011 and 2017, Japan and China were also net exporters of mining equipment, while the United States became a net importer in 2016.

Innovation was observed in the EU's raw materials sector, but at a slower pace than the leading global players

Corporate R&D investment (Indicator 18) in the EU's raw material sectors continued growing between 2016 and 2018. However, the growth of corporate R&D intensity (i.e. R&D investment compared to sales) slowed down.

The number of patent applications (Indicator 19) in the raw material sectors filed by EU applicants increased by 16% between 2012 and 2016. During this period, China filed the most patent applications, with the number of applications rising at a higher rate in almost all sectors. Japan ranked second, although the total number of patent applications steadily dropped. The sector with the highest number of applications was the production and manufacturing of metals, while the highest relative increase was for patents in the production and manufacturing of biotic products.

In 2016 the global metals and mining sector started to become more attractive to investors again.

After a downward trend in global financial indicators (Indicator 20) in 2011-2015 for the metals and mining sector, in 2016 the sector started becoming more attractive to investors. For the EU-based companies this rebound occurred already in 2015.

Environmental dimension

The decarbonisation potential in each industry will be greatly determined by the availability of cleaner energy options, and the potential emission savings associated to different industrial processes

Greenhouse gas (GHG) emissions from the EU raw material sectors (Indicator 21) continued to decline in 2012-2015, except for mining and non-ferrous metals industries. Over the same period, global GHG emissions from raw materials production rose. However, industries did not always cut their emissions per unit of material produced (emissions intensity).

Emissions of particulate matter (PM) and non-methane volatile organic compounds (NMVOCs) (Indicator 22) increased for several raw material industries in 2012-2015 in the EU, while they decreased globally. This emissions increase originated mostly from the paper and wood industries. Some sectors also increased their emission of pollutants per unit of material produced.

Water use is essential to raw materials production, which could become increasingly relevant under climate change scenarios

Water use by the raw materials industry (Indicator 23) could become increasingly relevant under climate change scenarios, with depleting water resources and increasing risks of flooding in certain regions of Europe. For the time being, and based on limited available data, water used for basic metals manufacturing rose in some EU Member States. It decreased for the paper industry and mining and quarrying sectors. Increases in water use generally took place in locations where water stress is not currently an issue.

The generation and management of extractive waste (Indicator 24) is also a key consideration for the sustainability of the sector. Limited available data show that the generation of extractive waste in the EU was relatively stable with minor changes between 2004 and 2016, and on a downward trend since 2012. In addition, the limited data available on the recovery of raw materials from extractive waste suggest that the recovery rate is low, for reasons of economic and technological feasibility.

Social dimension

The Commission increasingly promotes responsible sourcing and decent working conditions

Responsible sourcing (Indicator 25) provides insights into efforts to ensure a transparent and sustainable supply of raw materials, covering environmental and social considerations. Due diligence is becoming an increasingly common practice in companies.

Ensuring employment and decent working conditions are longstanding policy targets for the EU, complemented more recently by the European Pillar on Social Rights. Occupational health and safety (Indicator 26) is vital since the raw material sectors are more exposed than others to occupational risk. Incidence rates of non-fatal accidents in the forestry and paper manufacturing sectors have been declining in 2015-2017, while slightly increasing or remaining stable in other raw material sectors.

The number of jobs in different raw material sectors is growing

The EU Industrial strategy recognises the role of raw materials in job creation (Indicator 27), particularly in manufacturing industries. Ongoing changes, such as the move to a more circular and low-carbon economy, are reflected in the types of sectors in which jobs are being created. In 2017, the contribution of the raw material sectors to employment varied across EU Member States, ranging from 3 to 17% of the total number of employees in the industrial sector. The number of jobs has been growing in almost all raw material sectors in 2014-2017, mining and quarrying being the sectors with the highest growth rates.

Apatite is a phosphate mineral, primarily used in the manufacture of fertilizer. It can also contain significant amounts of rare earth elements.

Introduction

Raw Materials in the political spotlight

The evolution of society and raw materials have always been intricately connected – the prehistoric periods are, after all, named after the raw materials that enabled progress: stone, bronze and iron ages. And throughout history, advances in materials and technologies have aided development and increases in welfare. However, unfettered consumption has brought our planet to its limits[1] and imperils its future. Access to and overexploitation of resources remains a driver for conflicts, geopolitical tensions and environmental damage[2]. Once again, we are looking for technological solutions, among others, to make our way of life more sustainable and in order to decouple economic growth from resource use.

In 2019 the Commission published the European Green Deal[3] , setting a sustainable EU economy as a goal. This is the core of the EU's environmental, climate and industrial policy, setting the target of a carbon-neutral economy by 2050, zero pollution, and increasing the CO_2 reduction targets to 55% by 2030. These ambitions are based on the 2018 Communication 'A clean planet for all[4]', which looked at different scenarios on how to reach the Paris Agreement goals. The EU's objectives will drive a strong transformation of the EU economy. In response, the High Level Group on Energy-intensive Industries drew up a masterplan for a competitive transformation of the energy-intensive industries[5], which analyses possible transformation pathways and how to achieve them. The Commission is committed to making this transition smoother and fair across regions and economic sectors.

A new circular economy action plan[6] aims at increasing the circularity and retention of raw materials in the EU economy. Following from this, the Commission proposed a regulation on batteries and waste batteries[7] to ensure a competitive, sustainable and circular batteries value chain in Europe. The proposal includes provisions for increased collection, for mandatory supply chain due diligence and for transparent information to consumers and to recyclers on content of the batteries, among others.

In the beginning of 2020, the Commission also adopted a 'New Industrial Policy for the EU'[8], a strategy to help Europe's industry lead the twin transitions towards climate neutrality and digital leadership. It also emphasises the need to increase resilience and strategic autonomy at a time of increasing global competition, including to diversify networks for raw materials. At the time of publication, the update of the industrial strategy[9] will have been adopted, drawing lessons from the COVID-19 crisis and presenting a deeper analysis of ecosystems. Its accompanying staff working document on strategic dependencies[10] will take a look also at raw materials.

The COVID-19 crisis has exposed global dependencies of the EU economy, not just when it came to medical supplies, but also for the import of raw materials and technologies (e.g. semiconductor chips). It has exacerbated supply vulnerabilities, as many mines around the world closed[11], and logistics and production ground to a halt[12]. Its effects, however, reach beyond the supply chain. World Bank forecasts from summer 2020 state that the world economy could shrink by 5.2% that year, with a possible drop of per capita incomes by 3.6%[13]. With Next Generation EU, the Commission has proposed a recovery plan that '*turns the immense challenge we face into an opportunity, not only by supporting the recovery but also by investing in our future: the European Green Deal and digitalisation will boost jobs and growth, the resilience of our societies and the health of our environment.*'[14]

A recovery that moves the EU towards these objectives needs large amounts of raw materials for climate-neutral energy generation and storage, e-mobility and digital infrastructure[15]. To address the issues of resilience and sustainability, the Commission adopted an action plan on critical raw materials in September 2020[16], and launched the European Raw Materials Alliance[17] shortly thereafter. The OECD[18] and the International Resource Panel of the UN environmental programme (UNEP-IRP) project that global consumption of resources will grow tremendously in the coming decades. According to the OECD (Figure 1) material extraction is projected to grow by 40% up to 2040 and close to 90% by 2060 (both values as compared to 2017). The UNEP-IRP report states that '*over these last 50 years we have not once experienced a prolonged period of stabilization or a decline in global material demand.' The biggest growth in demand for material has occurred in upper-middle income countries; countries that are newly industrialising, with the infrastructure demands and quality of life gains that come with it* [19].

By resource type, non-metallic minerals, which include construction materials, will see the highest growth both total and per capita (Figures 1 and 2). This is in line with the expected expansion of infrastructure and housing needed for a growing world population and life standards. The only resource type that sees slowing growth is fossil fuels, reflecting the global push to move towards a low-carbon society.

Figure 1: Global material use by resource type: a) historical data (world, 1990 - 2017) and b) projection (world, 2018 - 2060)[20]

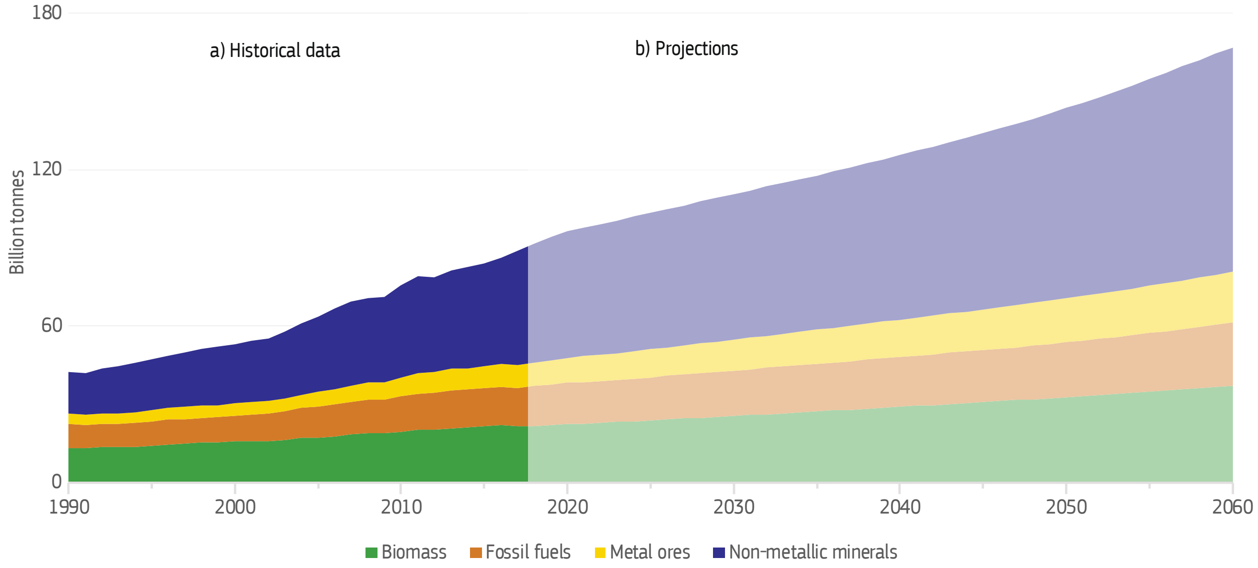
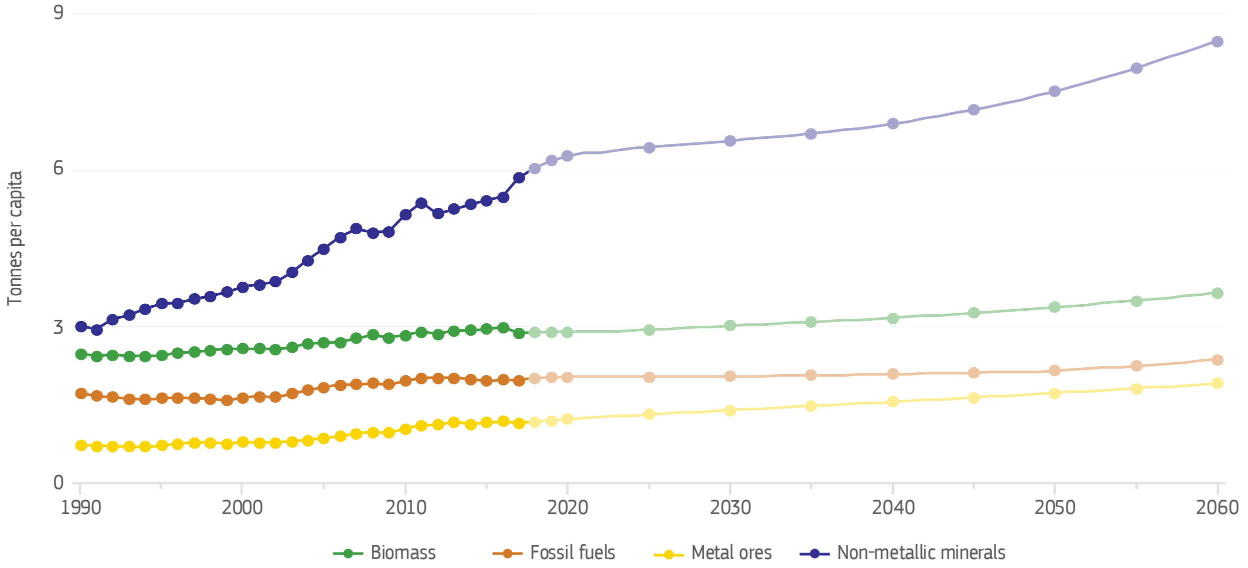


Figure 2: Global material use per capita by resource type: a) historical data (world, 1990-2017) and b) projection (world, 2018-2060)[21]



Part of the increased demand in non-metallic minerals and metals may be attributed to manufacturing and connecting the renewable energy and e-mobility technologies that will deliver on the European Green Deal[22]. It will be essential to balance the trade-off between the climate benefits of the deployment of low-carbon technologies and the increase in greenhouse gas emissions, which the necessary raw materials extraction may entail.

Boosting the circular economy provides opportunity here. According to the analysis in Cluster 3, the full potential of the circular economy has not been met yet, and further efforts are needed. Its advantages however are clear: secondary raw materials have a large potential for GHGs emissions savings and can reduce the need to extract primary resources. Retaining the value of materials would cut waste to a minimum. Manufacturing industries could increase their profitability while having a reliable source of raw materials[23]. Closing the loop on raw materials from product design to materials recovery is a no-regrets action for the EU and globally.

Major socioeconomic and environmental impacts of this increased demand are likely, and mitigation is necessary. Some regions of the world notably combine mineral endowment with cheap labour and little control of environmental and social impacts. Human rights abuse and severe pollution are often in the news[24], highlighting the imperative to fulfil raw materials demand sustainably, especially as it increases in the future. As a recent UNEP-IRP report[25] outlines, the role of minerals governance is crucial in translating minerals wealth into lasting social and economic gains. Mining can positively contribute to e.g. Sustainable Development Goal 1 on poverty reduction, if payments of royalties and taxes by industries are invested in socioeconomic development. This potential impact should not be underestimated: Artisanal mining alone provides a source of livelihood for more than 42 million people worldwide[26].

Responsible sourcing, which in practice means assessing, preventing and mitigating major risks along the supply chain, is becoming a reality in both business[27] and policy. In 2021, the Conflict Minerals Regulation[28] came into force: it requires EU companies to import tin, tungsten, tantalum, their ores and gold (3TG) from responsible and conflict-free sources only[29]. To aid EU SMEs, the Commission has created the 'Due Diligence Ready![30]' tool. It has also launched the Horizon 2020 'RE-SOURCING' project, which explores the main approaches to conduct responsible sourcing focusing on three key sectors: (i) mobility, (ii) renewables and (iii) electronics[31].

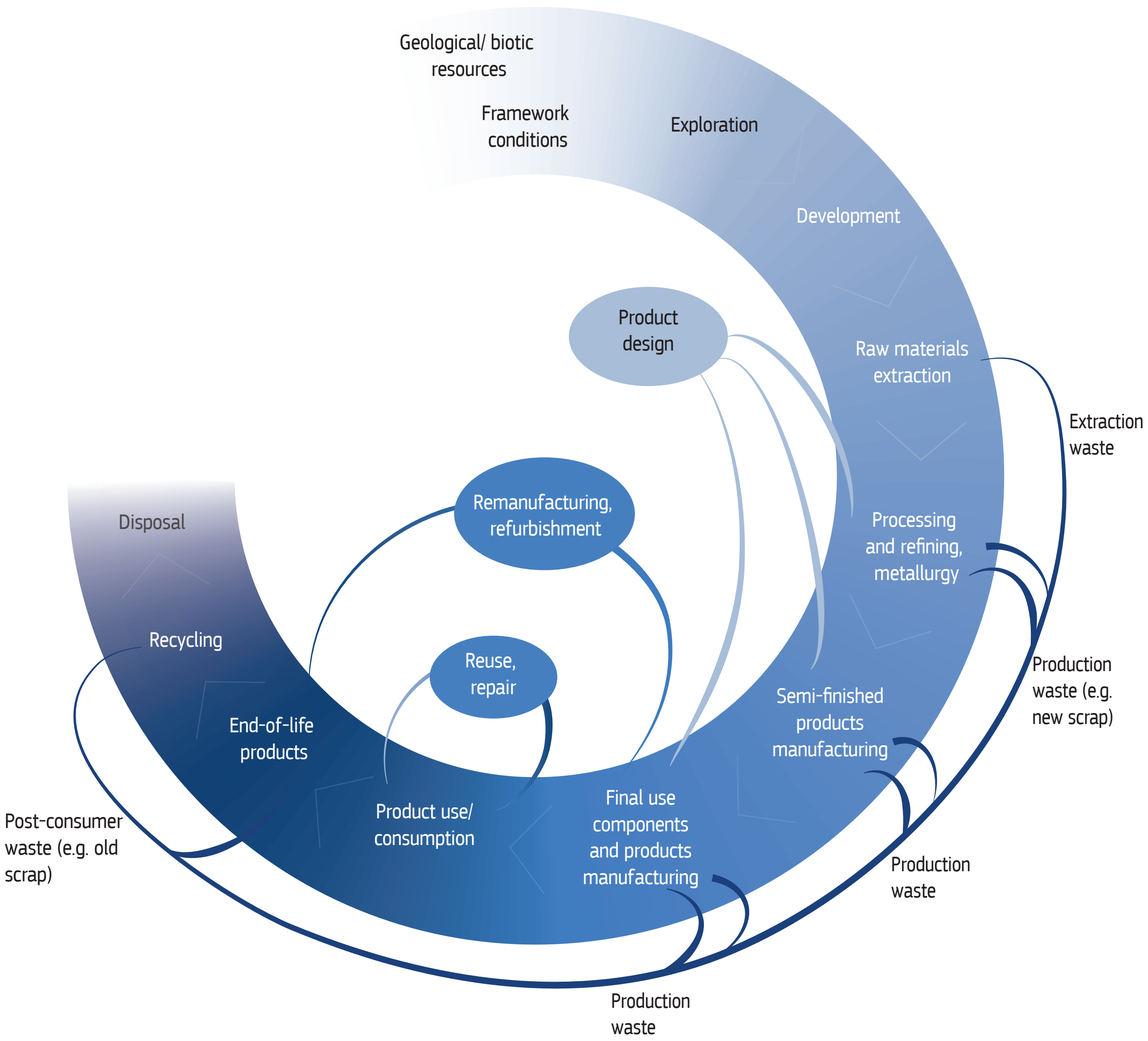
While consumer awareness about the sourcing of the raw materials contained in their goods is still low, news stories can alert them to the issues at stake. As in e.g. the textile and food retail markets, this may lead to a higher demand for responsibly and sustainably sourced raw materials.

With this framing in mind, it is necessary to go into a little more detail on the supply chain of raw materials.

The raw materials supply chain

Production

Figure 3: Raw materials supply chain[32]



Raw materials are, depending on their nature, mined, quarried (construction materials) or harvested (biotic materials).

Exploration for raw materials can be greenfield, i.e. in an area with no mining activities, or brownfield, i.e. in areas with existing (sometimes closed) mines, indicating the availability of certain raw materials. This endeavour requires geological knowledge, as well as financial investments (Indicator 3). Exploration efforts for construction and biotic materials are smaller, though of course proper identification of the resources (i.e. composition, species) still has to take place.

A sound legal and a societal framework is a prerequisite for all operations along the value chain (figure 3) The legal framework sets out the conditions under which and where these activities are permitted, such as environmental protection and land-use planning. A strong rule of law protects the often substantial investment and ownership of the resources and good governance creates socially sound conditions[33]. Next to the legal framework, the societal framework determines how permissive or adverse the society is to exploration and extractive activities. This is influenced by traditions and experiences, by knowledge and crucially, by trust and transparency. Initiatives and legislation such as the OECD's due diligence guidance for responsible supply chains, the EU Forest Law Enforcement, Governance and Trade (FLEGT)[34] and the Timber Regulation[35] and the UN's Aarhus Convention[36], are helpful in this respect to address issues and increase responsibility. The legal and social frameworks are discussed in more depth in Indicators 1 and 2.

The development of a mine or quarry entails assessing the economic viability – in three, increasingly detailed stages: 1) order of magnitude, 2) preliminary feasibility or prefeasibility and 3) detailed feasibility – and the environmental impacts. The time interval between the initial discovery and commissioning a commercial mine ranges greatly from a few years to decades. While globally the historic[37] average time between discovery and mining was about 12.5 years across all commodities, in the last decade it appears to average to 15-20 years[38], varying by commodity[39], influenced by the business cycle and commodity prices[40] as well as other factors[41].

The mined material is typically first prepared through mechanical methods, such as cutting, crushing or milling. It is then further concentrated or refined through chemical and physical processes like magnetic separation, flotation, chemical leaching or smelting, among many others. These processes are referred to as 'beneficiation'. Considerable amounts of crude metal ores must be extracted to produce a small quantity of pure minerals. Some raw materials, especially those that are more exotic, are usually produced as by-product of another ore, making the economic viability and quantity dependent on the main ore (e.g. most cobalt is a by-product of copper or nickel mining). Waste from the extraction and refining process is commonly referred to as tailings. It can be rich with other materials and serve as a source of secondary raw materials.

Semi-finished products are produced from the concentrated and refined ores, and these are then used for the final end product. The iPhone 6, for example, contained 30 raw materials[42], with many higher estimates for current smart phones to be found.

The supply chains of construction materials and biotic materials may be shorter: slabs of stone are cut from quarries and need little further refinement, or timber for construction may be only cut into the right proportions and dried. Further processing might be needed depending on the end product.

Trade and markets

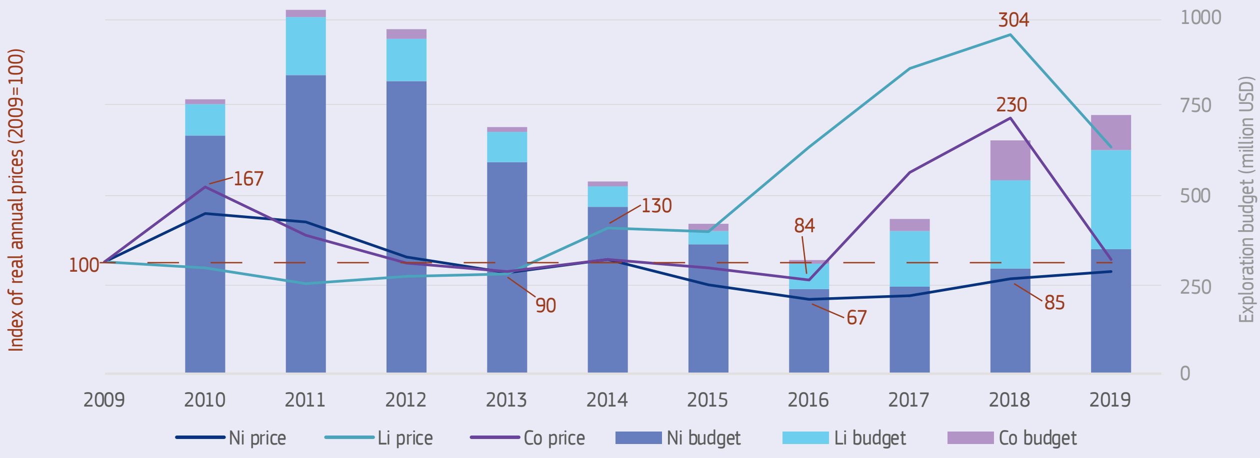
Raw materials are goods, and many, especially base and precious metals are traded on global commodity markets. For those not traded on open markets, contracts or off-take agreements between raw materials producers and manufacturers are common. Supply and demand on the markets influence the price of raw materials, which has direct and indirect implications for the whole value chain, from the exploration and extraction stage, the number of smelters or processing facilities, to the manufacturing and ultimately on recycling. Box 1 explores this relationship with examples on battery raw materials. In the production stages, research into alternatives for materials too expensive or hard to procure is common, in an effort to keep production stable and costs low.

Price and exploration budget for Nickel, Cobalt and Lithium

The international metal and mineral markets follow a cyclical pattern based on supply and demand dynamics that is described by economists as a 'super cycle.' A growth in demand results in supply lagging behind demand and makes commodity prices surge. This triggers the supply-side response through the rise in prospecting and building of new mines. The subsequent increase of supply will outstrip demand leading to production overcapacity and large stocks that flood the market and, consequently, lower commodity prices. Reduced exploration and mine closures will be the result of the price drop leading to less material availability.

Trends in prices and exploration spending for battery raw materials in the last years are an example of the above cyclical pattern (Figure 4). Exploration expenditure followed closely the changes in nickel price at a higher pace and with a small time lag. For lithium and cobalt the price boom since 2015 and 2016, respectively, drove their exploration budget to a record high in 2018. The jump in cobalt price was a driver for adding (almost) EUR 100 million to global exploration budget. Despite a significant price drop for both commodities in 2019, the impact in exploration spending for cobalt was negligible, while for lithium exploration spending increased even further in 2019. The resilience in exploration budgets for cobalt and lithium can be attributed to the expectation for exponential demand growth in the next years for both metals due to rising market penetration of electric vehicles. Therefore, policy actions and business developments, such as the push for electric vehicles, can potentially also motivate investments, as investors expect demand and subsequently prices to increase or the market to stabilise.

Figure 4: Prices and global exploration budget for Ni, Co and Li 2009/2010-2019[43]



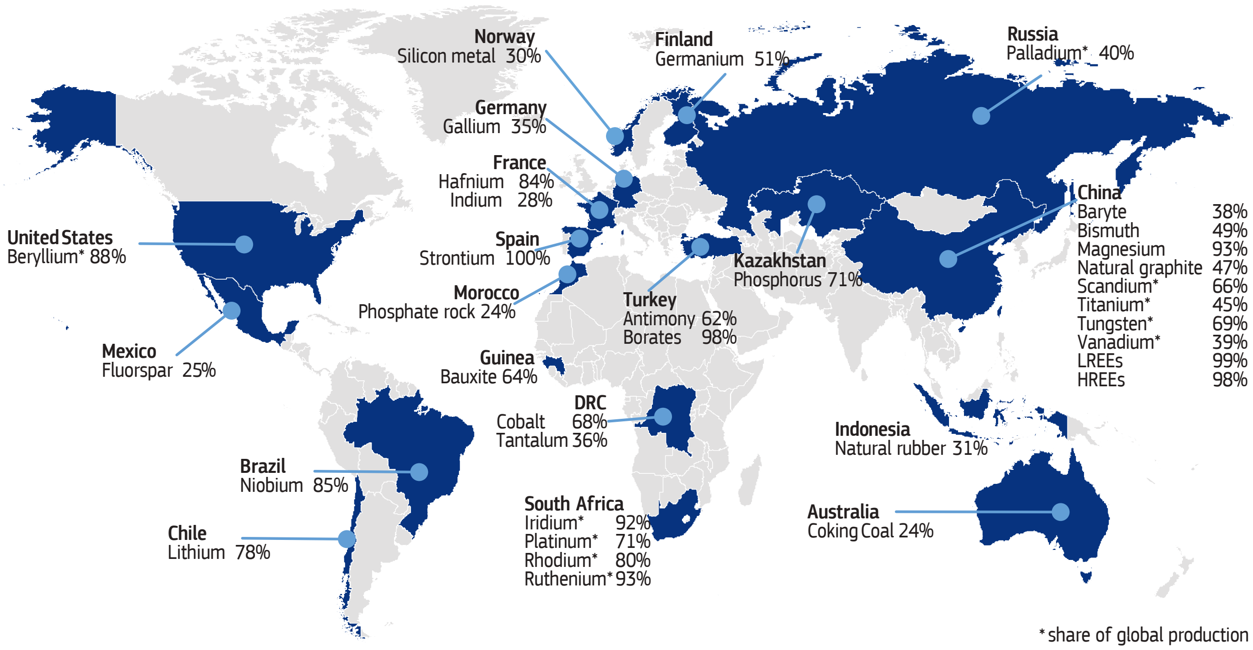
While short-term price fluctuations are perfectly normal for raw materials, long periods of much lower/higher price could have a major impact. For instance, in buyer countries higher prices might raise concerns about the security of supply, especially for raw materials with high supply concentration and poor governance, while in supplier countries much lower prices might lead to closures that put the economy at risk, especially when the country's economy relies on mining sector[44].

Due to the previously discussed lead times for new extractive operations, these tend to lag behind price peaks. Price drops during the start-up time can therefore reduce economic viability and result in freezing the activity. The early phase from inception to permitting constitutes a high-risk phase of project development and is particularly vulnerable.

For materials that are only produced in a small number of countries and/or by a few companies, the market can easily become captive and trade distorted. Market concentration can occur due to geology, e.g. large and/or high-grade deposits occur only in certain regions, or due to climate conditions, e.g. rubber production is concentrated in tropical climates where rubber trees grow. (Geo-)politics and economics can also lead to concentrated markets.

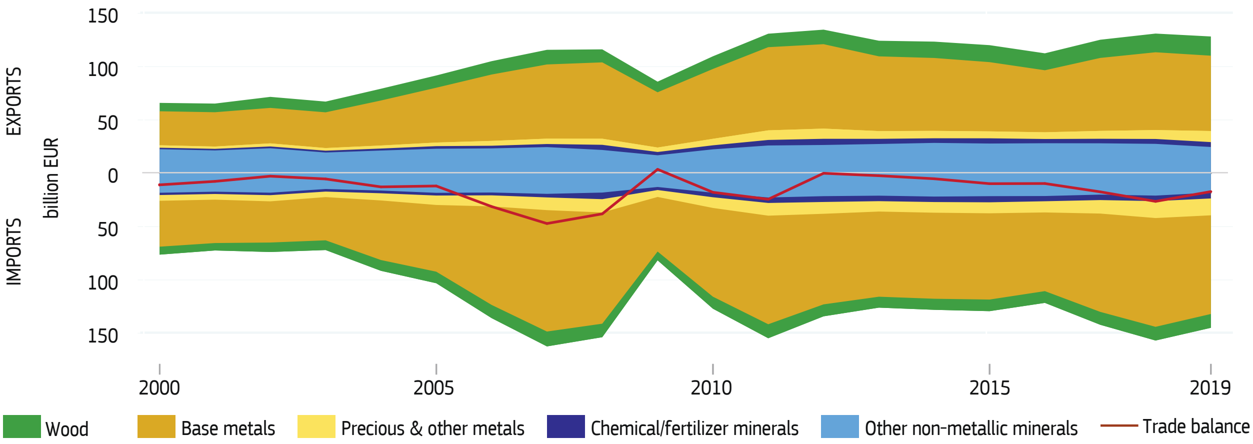
The Commission looks at the concentration of raw materials supply during its assessment for the list of critical raw materials[45]. They are identified by high economic importance and a high supply risk. Figure 5 shows the main global suppliers for critical raw materials and the percentage they deliver to the global market. More on supply concentration and EU vs global sourcing can be found in Indicator 9.

Figure 5: Global suppliers of EU critical raw materials[46]



The trade balance of raw materials gives insights for the EU reliance on their imports. Figure 6 shows that the EU is a net importer of metals. Most trade is for base metals, exceeding the other groups by far in terms of both value and volume. It is a net exporter of non-metallic minerals. This tends to concern rather specific products such as precious stones, clay and kaolin, marble, granite or salt. The trade balance for non-metallic minerals is positive in value terms, but negative when calculated in quantities[47]. The price of high volume construction materials is often too low to warrant transport over large distances, and their market is therefore often localised. It is also a net exporter of wood, for which exports increasingly exceeded imports over the years.

Figure 6: Trade balance for the main raw materials categories[48]



Trade networks for most raw materials are global and complex. Materials are also traded at every step in their value chain, branching off into diverse semi-finished products for numerous end products. The box below shows an example of the trade in copper ores and concentrates and in refined copper.

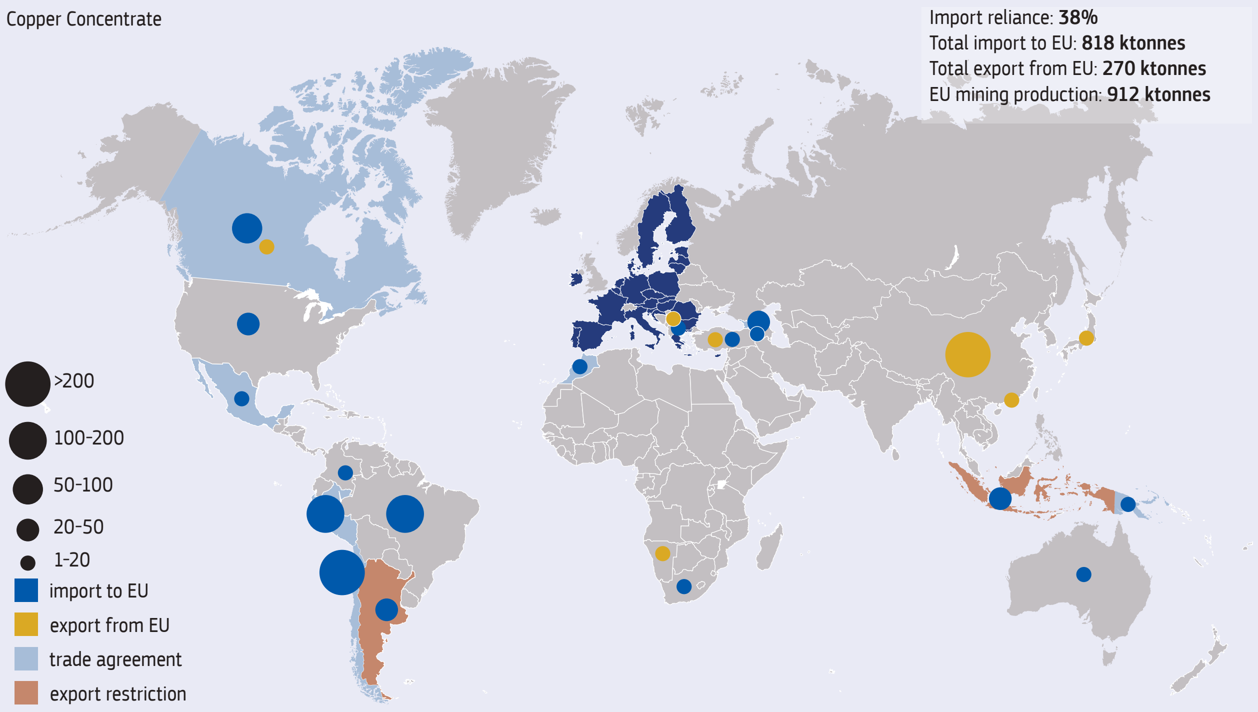
Trade in copper

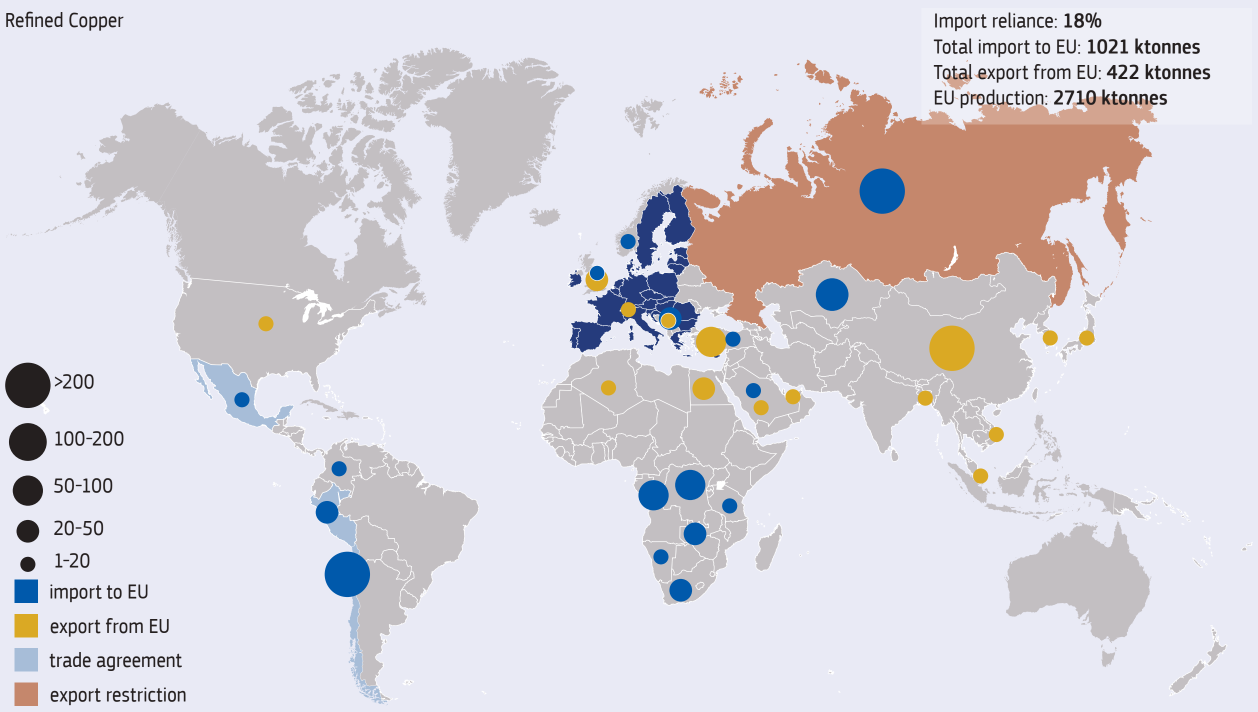
Globally, more than 10 000 kt of copper concentrates were traded in 2018[49] and 2019[50]. The top three global exporters of copper ores and concentrates in both years were (i) Chile, (ii) Peru and (iii) Australia, while the top three importers were (i) China, (ii) Japan and (iii) Spain in 2018[51] , with the Korean Republic taking third place, instead of Spain, in 2019[52].

The largest share of EU exports goes to China, which is the biggest producer of smelted and refined copper worldwide. However, the volume of EU exports is about 1/5th of EU imports. Stepping up the value chain to refined copper (lower figure), the worldwide production of refined copper was around 24 000 kt in both 2018 and 2019, including 4 000 kt secondary copper. China is the largest producer of refined copper, providing more than 1/3rd of global supply. Most is however used domestically, as China is also the largest importer of refined copper. The US and Italy ranked second and third in 2019[53] .

The EU trades copper (in all stages of processing) with a range of nations across all continents, and sourcing is therefore well diversified. South American countries are the main sources of copper ores and concentrates imported into the EU, and Chile is the biggest exporter of refined copper worldwide. Trade agreements ensure undistorted trade between countries. Other countries impose export taxes, potentially leading to less trade. In addition, several EU countries produce copper ores and concentrates: Bulgaria, Finland, Poland, Portugal, Romania, Slovakia, Spain and Sweden[54]. Germany is among the top 20 producers of refined copper, and in 2019, Poland and Belgium were among the top exporters[55].

Figure 7: EU trade network of copper[56] (2018)





Feeding the economy

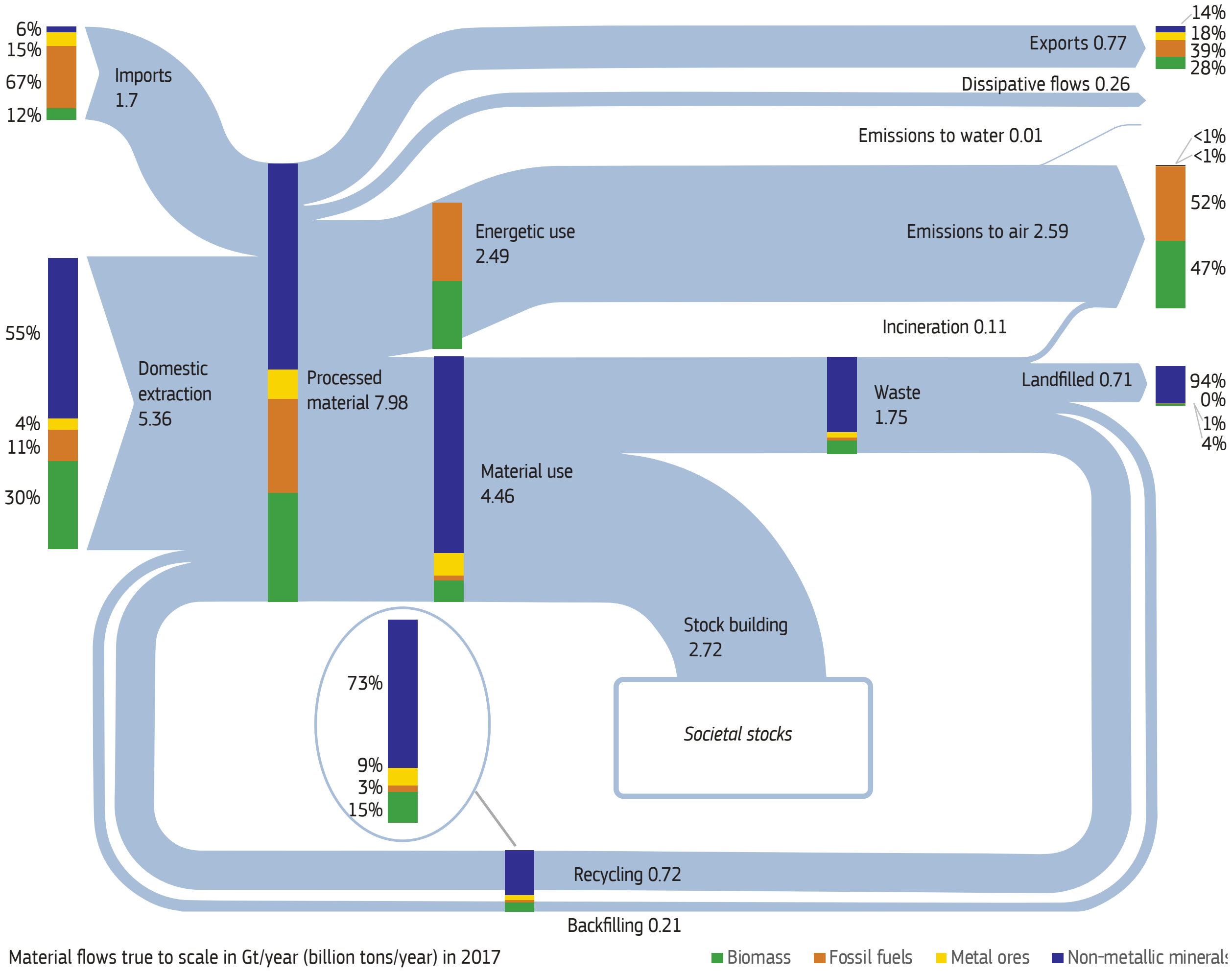
It is not an easy task to track raw materials that enter the EU economy either through extraction or trade to their destination. The Commission adopts two complementary approaches: firstly, it studies individual raw materials in material system analyses (MSA), which gives a detailed overview of imports and exports at different stages, uses and accumulation in societal stocks (Indicator 12). Secondly, it investigates the flow of all non-agricultural raw materials in the monitoring of the circular economy[57].

Figure 8 shows the flow and accumulation of four material categories: (i) metals, (ii) non-metallic minerals, (iii) biomass and (iv) fossil energy materials in 2017. Biomass includes biotic raw materials both for material and energetic use (e.g. paper and pellets). Figure 5 shows that domestic extraction of non-metallic minerals, which contain construction materials and industrial minerals, is much larger than imports of these materials. While they are the biggest contributor by mass to societal stocks and recycling, they are also the largest part of landfilled waste, highlighting that opportunities for increasing circularity of these materials exist. However, fossil energy materials, while being a large part of EU imports, contribute little to stock-building (these would be plastic and chemicals), and most of them result in emissions to air, where usable gases (e.g. carbon-containing) are not typically recovered. A comprehensive look at all of the EU materials flows highlights bottlenecks. Over time, this analysis allows us to monitor whether opportunities have been realised or not. More on this in Indicator 12.

The Commission, as part of its monitoring of the circular economy, produces Sankey diagrams of the material flows since 2010[58]. The (now interactive) year-on-year comparison shows stable flows for the EU as a whole up to 2017.

While this is not a very long timeframe, it is still remarkable considering the previous discussion on the increase in resource demand (figure 1). Looking at per capita consumption, high-income countries have the highest material demand[59], indicating that they outsource the material- and energy-intensive production, which keeps their material demand stable.

Figure 5: Material flows in the economy (EU, 2017)[60]



The Raw Materials Scoreboard

Scope

The Scoreboard looks at raw materials that are not used for fuel nor food. For instance, when indicators contain wood, it is always as raw material input for e.g. construction, pulp- and papermaking or chemicals, not as (bio-)fuel; similarly, where coking coal is included, it is for its use in e.g. making steel and carbon fibres.

The indicators within the Scoreboard look at a range of raw materials – often grouped into metals, minerals and biomass, but also sometimes individually. While most indicators provide data at EU level, in certain fields they look through the lens of Member State performance.

Table 1 shows how the Scoreboard addresses raw materials categories. However, it is important to note that the classification may vary significantly among indicators, since the different data sources aggregate materials in different ways. Raw materials may equally be covered at different stages of their supply chain for different indicators. The methodological notes at the end of the Scoreboard provide information on the range of materials under analysis in the indicators.

Table 1: Materials covered by the Scoreboard

Classification		Uses[61]	Materials
Metallic minerals and metals	Iron & steel	Steel is closely linked to numerous industrial ecosystems, such as automotive, construction, electronics and renewable energy production.	Iron & steel
	Ferro-alloy metals	Ferro-alloy metals are mainly used in steelmaking as alloying elements. They improve the properties of steel, for instance increasing strength or resistance to corrosion, rendering steel the most widely used metal.	Chromium, manganese, molybdenum, tungsten and vanadium
	Non-ferrous base metals	Non-ferrous base metals are irreplaceable for many products in the automotive, aerospace, mechanical engineering and construction sectors. Their unique thermal, electrical, and isolating characteristics coupled with high recyclability and low weight make them indispensable to achieving the EU's energy and resource-efficiency goals.	Aluminium, copper, lead, nickel, tin and zinc
	Precious metals	Precious metals include rare metals of high economic value. They are not only used as investment products but also in a variety of industrial applications such as electronics and auto catalysts.	Gold, silver and platinum group metals (platinum, palladium, rhodium, ruthenium and iridium)
	High-tech and other non-ferrous metals and metalloids	Beyond base and precious metals, many non-ferrous metals and metalloids are key for high-tech products, low-carbon technologies and industrial applications such as Li-ion batteries and glass production.	Antimony, arsenic, beryllium, bismuth, cadmium, cobalt, gallium, germanium, hafnium, indium, lithium, magnesium, niobium, rhenium, strontium, titanium, tantalum, tellurium and zirconium
	Rare earths	For physicochemical and commercial reasons, rare earths can be divided into light (LREE) and heavy (HREE) rare earth elements. Their use for low-carbon technologies makes them critical for the strategies to meet the EU climate-neutrality targets. They are also essential for high-tech applications and the defence sector.	LREE, HREE and Scandium LREE (light rare earth elements): cerium, lanthanum, neodymium, praseodymium, samarium HREE (heavy rare earth elements): dysprosium, erbium, europium, gadolinium, holmium, lutetium, terbium, thulium, ytterbium, yttrium
Non-metallic minerals	Construction materials	Among the non-energy extractive industries, the construction minerals sector is the largest one. It has the highest tonnage of extracted minerals, the greatest number of companies and employees, and the largest turnover.	Aggregates (sand, gravel, and crushed natural stone), various brick clays, gypsum, ornamental and building stone
	Industrial minerals	Industrial minerals such as baryte, kaolin or salt are extracted within the EU to supply a wide range of industries. For some minerals, such as magnesite, fluorspar, kaolin and potash, Europe is a major global producer.	Baryte, bentonite, borates, diatomite, feldspar, fluorspar, kaolin, limestone, magnesite, natural graphite, perlite, phosphate rock, potash, salt, silica sand, sulfur, (elemental) talc, zircon
Biotic materials		Forestry activities feed the EU forest-based industries: woodworking, furniture, pulp and paper manufacturing and converting, and printing. These activities can be carried out in natural or planted forests.	Natural cork, natural rubber and industrial roundwood (timber)
Other			Coking coal, selenium

Faithful readers will notice that the indicators import reliance and trade restrictions now look at five materials, instead of a wide range. The five materials represent certain uses and sectors:

1. Copper – digital and electrical infrastructure. As a base (or bulk) metal, copper is produced and used in large quantities. It has this in common with metals such as iron/steel, aluminium and zinc. It was chosen for detailed analyses for its importance for the digital and electrical infrastructure, which is expanding due to efforts in electrification and digitalisation.

2. Cobalt – e-mobility. Cobalt is today one of the most important materials in the manufacturing of batteries, together with lithium, nickel, manganese and graphite. Every rechargeable battery contains cobalt, making it ever-present in our everyday lives. It is also an important alloying element, lending the resulting metal high strength, corrosion- and wear resistance and high temperature stability.

3. Platinum – electronics. Platinum is a precious metal, like gold or silver. It is part of the platinum group metals together with palladium, rhodium, iridium, osmium and ruthenium. Its high ductility and stability make it useful for electronics, and it is contained today in almost every electronic device. Platinum group metals are also excellent catalysts, and used in conventional cars to reduce emissions, in fuel cells to convert hydrogen to electricity and in chemical manufacturing.

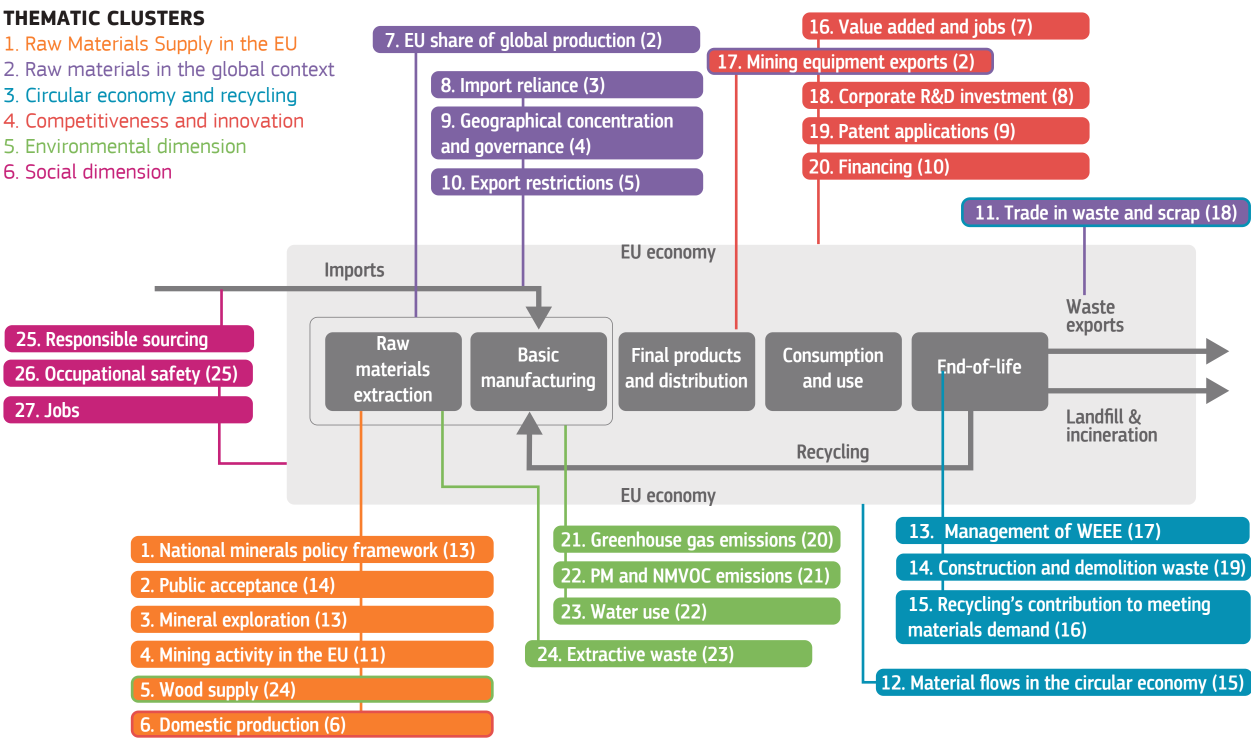
4. Tungsten – defence and aerospace. Tungsten is one of the hardest and heaviest elements, and commonly used for the manufacture of hard materials used in heavy-duty tools. As an alloy, its hardness and high melting point makes it useful for rocket parts, missiles or ammunition. It's also used for the vibration motor in smartphones[62].

5. Rare earth elements (REEs) – renewable electricity generation. The rare earth elements neodymium, dysprosium, samarium and praseodymium are used for their strong magnetic properties. Magnets turn kinetic energy into electricity (in e.g. wind generators) and vice versa (in e.g. electric cars). While the large group of REEs has many diverse applications, these are especially relevant for the transition to a climate-neutral economy powered by renewable electricity generation. They are equally relevant in the digital realm as hard disk drives use them as magnets to write and store data.

Structure and changes

In its third edition, the Scoreboard has a new structure, following more closely the value chain of raw materials. It now looks at how much the EU can supply for itself and under which conditions (Cluster 1), where the remainder comes from and the geopolitical implications thereof (Cluster 2), and how we are doing on keeping materials in our system (Cluster 3). It also places more emphasis on sustainability, from economic (Cluster 4) to environmental (Cluster 5) and societal considerations (Cluster 6).

Figure 8: The Scoreboard – structure of clusters and indicators along the supply chain



Note: the number of clusters reflects their position in the document. Cases in which an indicator was located in a different cluster in the 2018 edition are indicated by a square with the related cluster colour. Numbering of indicators in the 2018, whenever different to this edition is mentioned in brackets at the end of indicators' name.

While the indicators have been reordered, their analysis is as far as possible based on the same methodology and data sources as in the 2018 edition to ensure comparability. To emphasise the monitoring aspect of the Scoreboard, new data points compared to the 2018 edition, are indicated in the figures, where possible. The analysis now refers to the EU as the EU-27, where possible. This affects not only the last data points but also the whole data series for indicators providing historic data. In some cases, updating the EU geographic scope compared to the previous editions of the Scoreboard can have a significant impact on the results. These cases are further explained in the specific indicators.

There are also two new indicators: (i) Indicator 25 on Responsible sourcing and (ii) Indicator 27 on Jobs. The former replaces the 2018 indicator on Sustainability reporting, for which no data were available to continue the analysis. Jobs presents the data on employment previously contained in the Indicator Value added and jobs, allowing for more considerations of this aspect of the raw materials area.

In an attempt to better link the content of the Scoreboard to other monitoring schemes that follow-up on aspects linked to raw materials, symbols have been added to indicators that closely link to:

- Indicators used to monitor the Sustainable Development Goals (SDGs) e.g.

- Indicators from the Monitoring Framework of the Circular Economy

The search for RACER data…

An ad hoc working group was set up for the first Scoreboard of 2016 to help select the indicators to be included in the Scoreboard. Almost 30 experts representing a balanced range of interests considered close to 70 different indicators. Indicators were evaluated against the 'RACER' criteria[63] , which set out that every indicator needs to be:

- **R**elevant
- **A**ccepted (by all stakeholders)
- **C**redible (i.e. from interest groups)
- **E**asy (to compute and to understand)
- **R**obust.

During the selection process, it became clear that the data and indicators available are subject to certain limitations, and all indicators are imperfect proxies of complex phenomena. Also, especially in the raw materials area, very few data sets can be perfectly disaggregated, and most data sets suffer from a certain degree of imperfection and incompleteness, e.g. gaps for certain countries, lack of harmonisation, significant time lag.

During the discussions with the ad hoc working group, it was agreed that these limitations are unavoidable, but there are ways to partly overcome them:

- By compiling a set of complementary indicators, each with their pros and cons. For example, the issue of 'framework conditions' is covered by a set of complementary indicators on public acceptance, mining and metals production in the EU, and exploration activities, which together provide a more complete picture.
- By clearly explaining the data limitations in both the text and the methodological notes of indicators.

For some important issues, there are no data available that meet the RACER criteria. This is addressed by providing a qualitative description of the issue, which may include data not compliant with the RACER criteria. These qualitative indicators are clearly marked in the Scoreboard.

The EIP on raw materials

The launch of the European Innovation Partnership on Raw Materials (EIP-RM) in 2012 has been one of the main milestones of the EU's raw materials initiative.

This partnership marked a new approach for streamlining efforts and accelerating the market take-up of innovations that address the EU's main challenges. The EIP-RM addresses the entire raw materials value chain, from the extraction (exploration, mining, quarrying and wood harvesting) to the processing of raw materials to make intermediate materials as well as recycling. It covers all non-energy, non-agricultural raw materials, i.e. metals, minerals and biotic materials.

The EIP's objectives

[From the EIP's Strategic Implementation Plan Part I, Section 2.1 p. 13]

'The overall objective of the EIP on Raw Materials is to contribute to the 2020 objectives of the EU's Industrial Policy — increasing the share of industry to 20 % of GDP — and the objectives of the flagship initiatives 'Innovation Union' and 'Resource Efficient Europe', by ensuring the sustainable supply of raw materials to the European economy while increasing benefits for society as a whole.

This will be achieved by:

- Reducing import dependency and promoting production and exports by improving supply conditions from EU, diversifying raw materials sourcing and improving resource efficiency (including recycling) and finding alternative raw materials.
- Putting Europe at the forefront in raw materials sectors and mitigating the related negative environmental, social and health impacts.''

The Scoreboard is an initiative launched by the European Innovation Partnership (EIP) on raw materials. It is part of the EIP's monitoring and evaluation scheme. The Scoreboard's purpose is to provide quantitative data on the issues referred to in the EIP's objectives. The Scoreboard covers the EIP's general objective to ensure the sustainable supply of raw materials to the European economy while increasing benefits for society as a whole. It also provides the raw materials policy context, and other criteria related to the competitiveness of the EU raw materials sector.

Overview

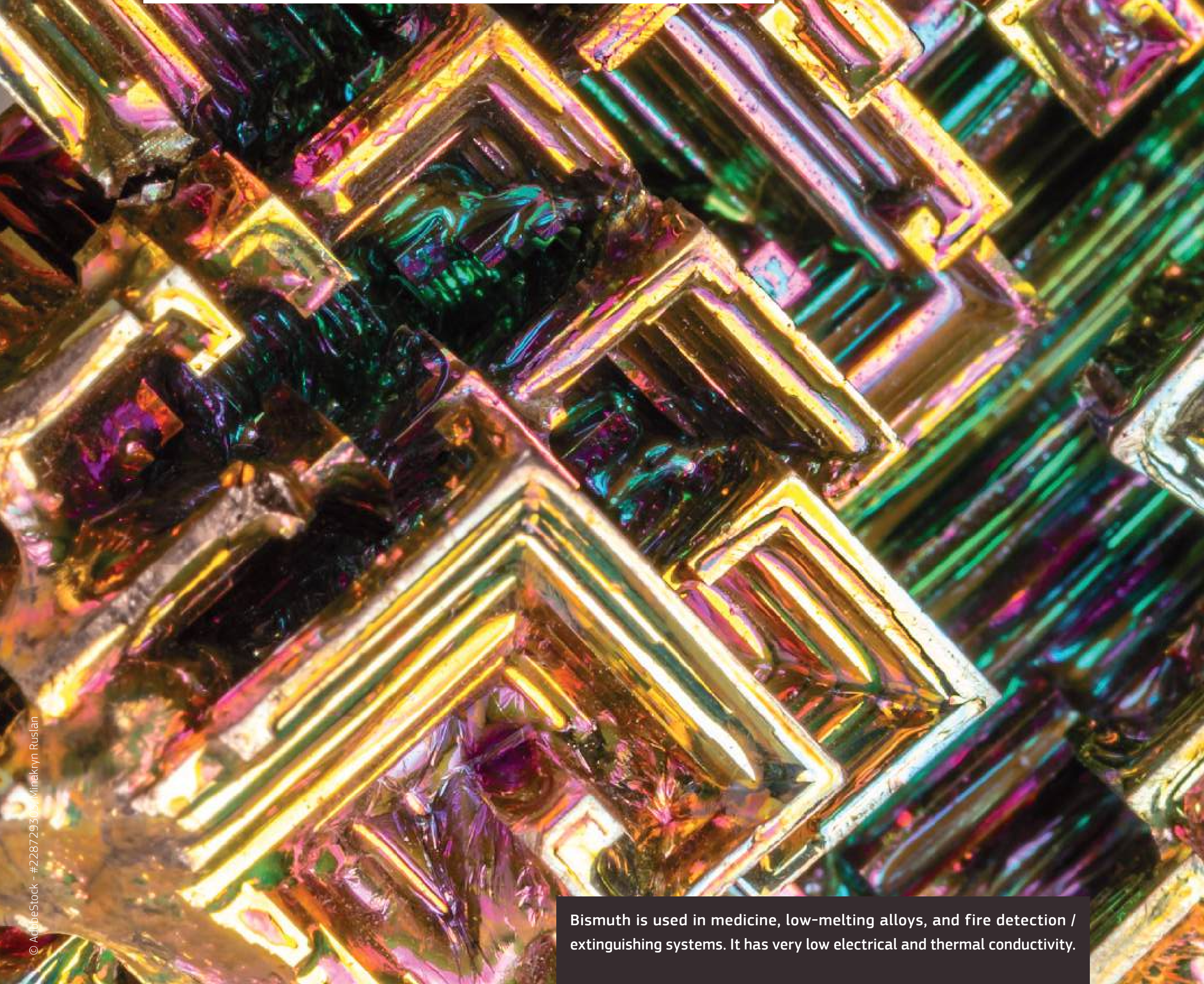
Access to domestic and overseas raw materials is essential for European industry sectors such as clean technologies, digital, space, mobility, and defence applications.

Indicators

Extracting raw materials often depends on significant mid- to long-term investments, which are facilitated by appropriate mineral policies embedded in coordinated frameworks (indicator 1). In practice, raw material extraction projects and the related downstream industries also rely on being accepted by the local and regional public (indicator 2).

Extracting minerals requires both the discovery of mineral deposits and access to resources. Therefore, minerals exploration in the EU is indispensable to discover new deposits (indicator 3). Once the mineral reserves have been defined and their feasibility shown, mining production in the EU (indicator 4) ensures that the downstream industries can draw on a domestic mineral supply.

The strategic shift towards increasing use of renewable resources has also put pressure on European forests, requiring a balance between felling rates and the regional wood growth rates (indicator 5). To check whether the EU has an adequate level of self-sufficiency, extraction and production in the EU is compared with the EU consumption for various material categories (indicator 6).



Bismuth is used in medicine, low-melting alloys, and fire detection / extinguishing systems. It has very low electrical and thermal conductivity.

Raw materials supply in the EU

Indicators

1. National minerals policy framework
2. Public Acceptance
3. Minerals exploration
4. Mining activity in the EU
5. Wood Supply
6. Domestic production

SCOREBOARD

Raw materials in the global context:
7. EU share of global production, 8. Import reliance, 9. Geographic concentration and governance, 10. Export restrictions

Competitiveness and innovation:
18. Corporate R&D investment, 20. Financing

Circular economy and recycling:
12. Material flows in the EU, 13. WEEE management

EU self-sufficiency for raw materials;
Recycling rate of wooden packaging

1. National minerals policy framework

Key points:

- According to the policy perception index and the investment attractiveness index, national mineral policy frameworks have improved in some EU countries during the last decade. In the last year, investment attractiveness increased considerably in Finland, Ireland, Sweden, and Portugal.
- Since minerals are managed at national, and often regional, level, policy frameworks differ significantly across the EU.

Overview and context

National minerals policies and stringent implementing regulatory frameworks can promote the development of mining projects and improve the security of raw materials supply.

Key elements that determine the adequacy of mineral policies include streamlined permitting, the stability of the framework conditions, transparent decision-making, stakeholder involvement, and ensuring access to mineral deposits[64]. National minerals policy frameworks have a direct effect on minerals exploration activities (indicator 3), mining activities (indicator 4), and have an indirect impact on the EU share of global production (indicator 7), the circular economy and recycling (indicator 12), and corporate R&D investment (indicator 18).

Many aspects of non-energy raw materials extraction are Member State competences and are out of the scope of the Treaty on the Functioning of the European Union. The distribution of competences at national level results in countries taking different approaches[65], as presented in the MINLEX study[66] for the extractive industry sector for 2015-2017. In 2019, this study was integrated and updated in European Commission's Raw Materials Information System (RMIS)[67].

Going beyond the inventory of information on national frameworks, this analysis makes use of two index datasets published by the Fraser Institute Annual Survey of Mining Companies[68]. These report on managers' perceptions of various aspects related to framework conditions. First, the policy perception index (PPI) is used as a proxy for the perceived adequacy of the policy framework. However, the policy framework is not the only determinant of the performance of the sector and decisions on further investment: other factors, such as mineral potential and market conditions, may be even more important. Therefore, information on the investment attractiveness index (IAI), which combines perception of the policy framework with perception of geological attractiveness, is also considered here.

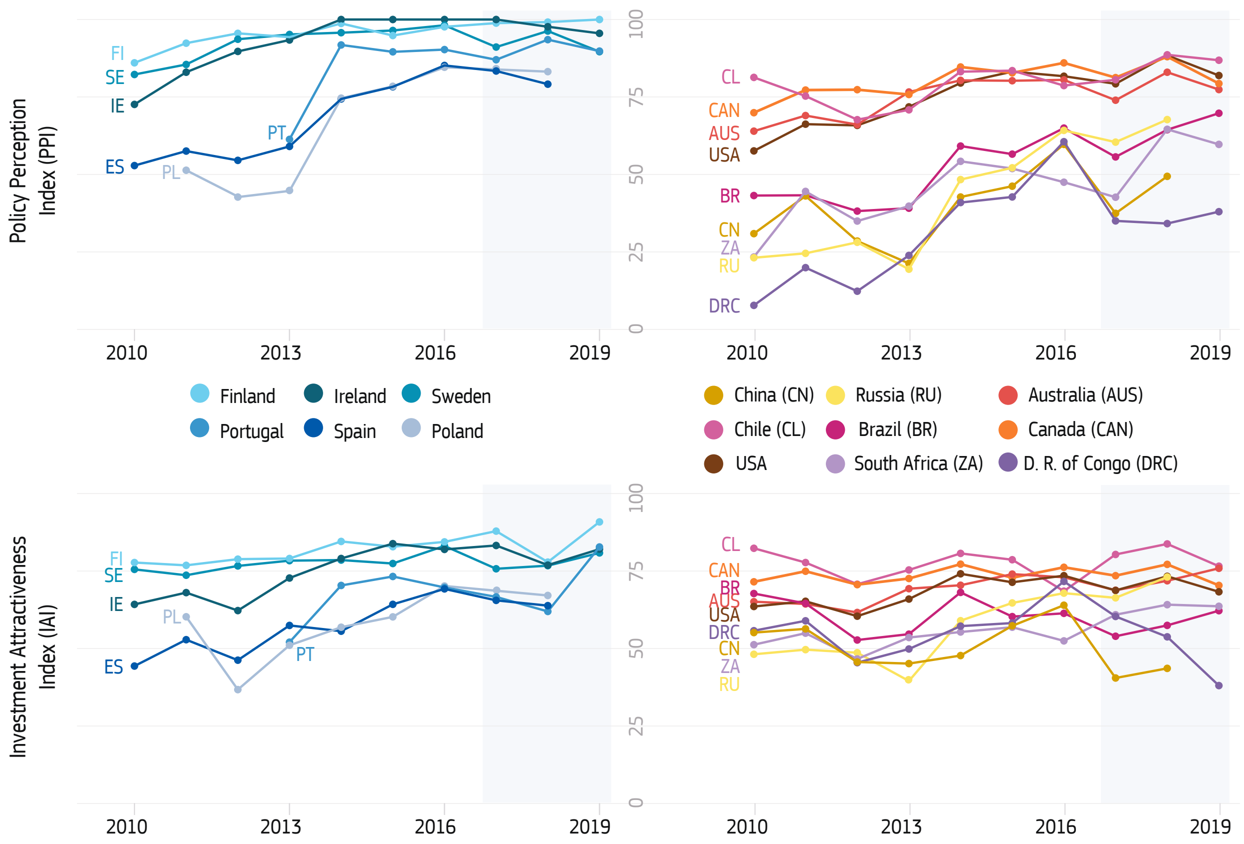
Facts and figures

Figure 1.1 presents the PPI and IAI for selected major mining EU and non-EU countries in 2010-2019. The PPI takes into account policy-relevant factors such as burdensome regulations, regulatory duplication, uncertainty concerning the administration of current regulations, the legal system, disputed land claims and socioeconomic agreements, environmental regulation, taxation levels, and infrastructure. The IAI complements the PPI, combining the perception of the policy with geological attractiveness[69]. The PPI and IAI annual surveys have a global coverage of around 100 jurisdictions, covering also some EU countries. The country selection, both for EU and non-EU countries, differs from the previous edition of the Scoreboard to allow for a comparison over time[70]. The countries selected represent all continents evenly, and are long-term producing countries with a significant extraction output, meaning they are permanent targets of the surveys.

As a general trend, policy perception improved over the last 9 years for most countries presented. For Ireland, Spain, Poland and Sweden the surveys showed a slightly negative trend in the last 3 years. It is, however, too early to draw conclusions. The investment perception of Sweden and Ireland has, on the other hand, improved in the same timeframe.

Scores for investment attractiveness were more balanced between the EU and non-EU countries, as non-EU countries were geologically more attractive. The IAI decreased slightly in the EU between 2016 and 2018 but improved in 2019. Among the EU countries, Ireland, Portugal, Sweden and Finland were the front-runners of the sector.

Figure 1.1: Policy perception index and investment attractiveness index between 2010 and 2019 (selection of EU and non-EU countries, 2010-2019)[71].



National minerals policies – insights from Horizon 2020 projects

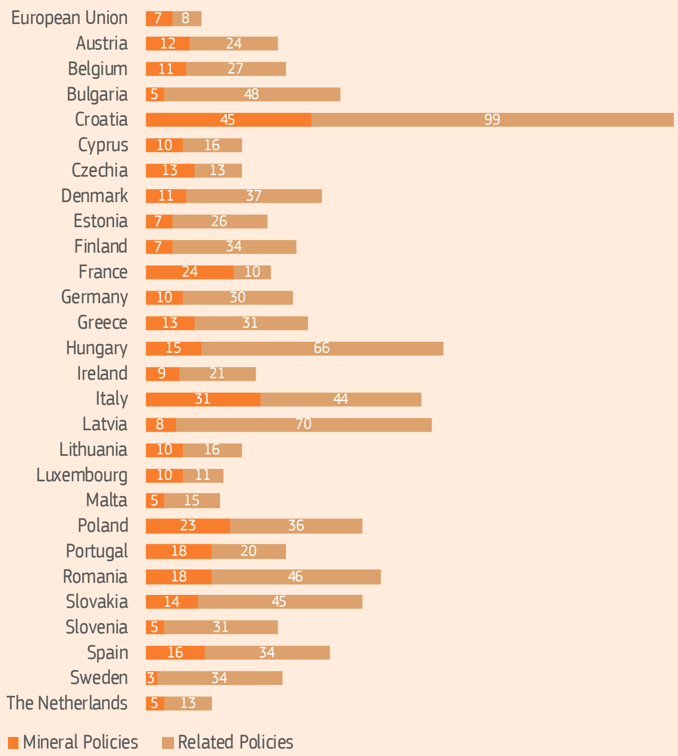
It is difficult to compare the EU countries' framework conditions for mining, in spite of the inventory in the Raw Materials Information System and publications on global[72] and EU[73] scale. A number of recent EU Horizon 2020 projects covered this topic at global[74], EU[75] and regional[76] level.

The Horizon 2020-funded MIN-GUIDE project's key objectives were:

- to provide guidance for EU and Member State minerals policy,
- to facilitate minerals policy decision-making through knowledge co-production for transferability of best practice minerals policy, and
- to foster community and network building for the co-management of an innovation-catalysing minerals policy framework.

The MIN-GUIDE inventory covers around 1300 relevant policy and legislative documents. The distribution and overall number of both policies and regulations in EU countries indicate indirectly that the minerals framework conditions are rather diverse across Europe (Figure 1.2).

Figure 1.2: Number of mineral policy documents and other related policy documents in EU countries in 2018[77].



The recently finished MINLAND project studied national minerals policies in the context of spatial development and land use planning. The sterilisation, i.e. becoming inaccessible, of minerals deposits through other competing land uses such as urbanisation and nature conservation is a major factor influencing the supply of raw materials from domestic European sources. The project calls for an integrated and optimised process in land use planning and minerals policies, and for networking and sharing sustainable land use practices.

Conclusion

A stable and efficient minerals policy framework remains crucial to create the proper conditions to foster the domestic supply of raw materials in the EU. Policy frameworks vary among EU countries. The related performance indicators considered here show that several EU countries have leading policy perception index positions on a global scale over the last 9 years. The IAI trends of EU countries are also favourable. Ireland, Portugal, Sweden and Finland also rank well in the absolute sense in the IAI.

2. Public acceptance

Key points:

- According to the INFACT project survey, there is a positive attitude towards mining in terms of the importance of the sector for the whole economy, the chances for employment and having independent own mineral resources.
- Coupling primary and secondary raw materials and consumer goods in the public perception may improve the current image of the raw materials sector. It seems that the public currently views the secondary raw materials sector more favourably. However, it remains to map, characterise and technologically test the feasibility of secondary resources replacing primary materials, including the life-cycle analysis of the secondary downstream value chain.

Overview and context

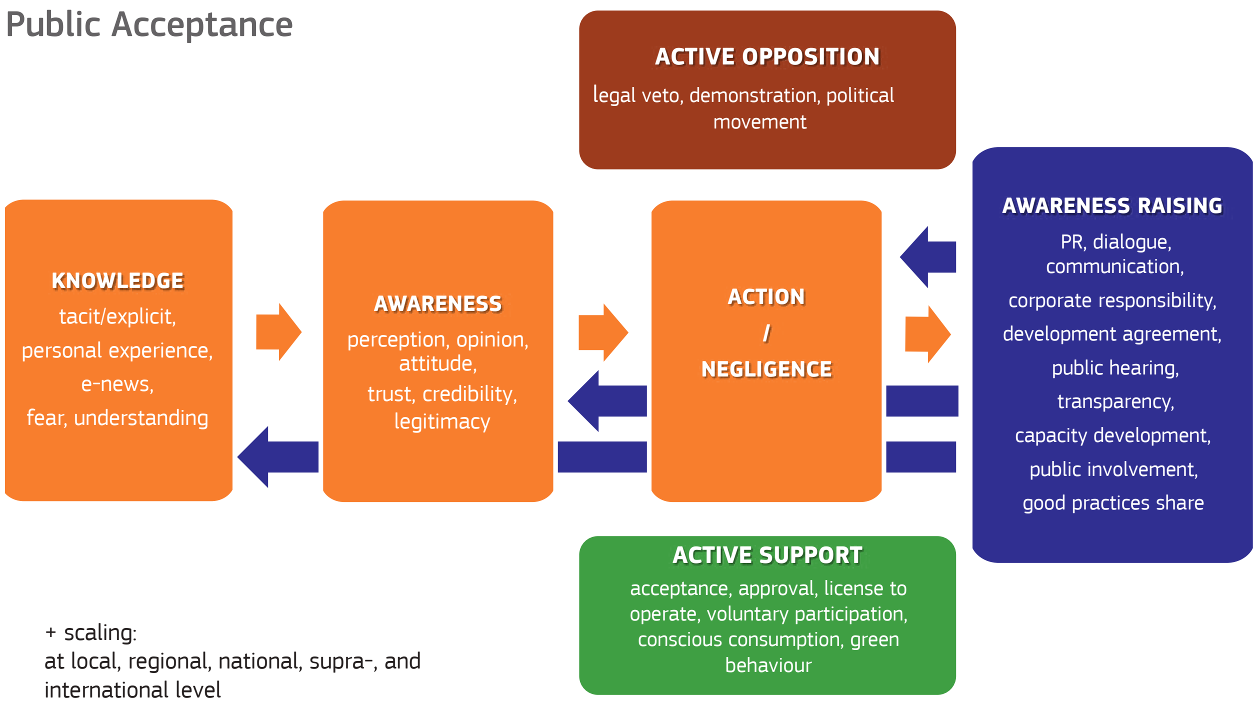
Public acceptance is the No. 1 business risk for the second consecutive year on Ernst and Young's Risk radar for mining and metals[78], but it is also relevant all along the value chain. In fact, public acceptance is an overarching indicator for upstream and downstream activities, as well as for primary and secondary raw materials, especially in a broader context when awareness and sustainable consumption are taken into account. It therefore also impacts on the success of the circular economy, e.g. through influencing collection rates or recycling activities (indicator 15).

Tacit knowledge and personal experiences provide the basis for perceptions on a given topic. The resulting sum of individual perceptions, that is public awareness, can change in a short time, especially from positive to negative. Tailings dam failures, chronic pollution, and fatal accidents are abrupt drivers of opinion. Changing public opposition to passive tolerance or active support requires a lot of persistent effort. Public relation campaigns, transparent stakeholder dialogues, cultural heritage (mining museums, local heritage ceremonies) may help develop positive public opinion. Figure 2.1 presents most of these considerations in a broad context.

Other emerging concepts include the 'sustainable development licence to operate' promoted by the United Nations International Resource Panel[79]. This addresses a broader subject matter covering all environmental, social and economic concerns that fall within the remit of the Sustainable Development Goals and related targets.

Public acceptance can be interpreted at international[80], national[81], and local[82] levels. The regional scale is particularly relevant in federal states and in countries with regional subsidiarity such as Germany, Italy or Canada, where the extractive industry is a key contributor to the regional economy[83]. Public surveys also address specific commodities[84], certain stages of the raw material value chains[85], or monitor NGOs' activity on certain sectors, companies and topics[86].

Figure 2.1: Relationships between terminologies and concepts related to public acceptance[87].



The biotic raw materials extractive sectors, such as the logging and rubber industries, also face challenges in relation to public opinion[88]. The public considers and combines issues such as climate change, loss of biodiversity, and workers' safety when thinking about logging. Stakeholder involvement and engagement is a core element of sustainable forest management[89] – see indicator 5 – which resulted in good practice cases. The pulp and rubber industries are similarly regarded as potential polluters by the broader public[90]. Increased use of earth observation monitoring tools, such as the Copernicus services[91], ESA[92], CORINE[93], and EIONET[94] could increase the transparency of biotic materials and minerals extraction operations, and so build public trust.

The promotion of combining and coupling public perceptions along all the different stages of the value chain could be a long-term objective to pursue. A person who opposes the development of extractive and manufacturing activities can simultaneously be a consumer of the goods produced by these sectors. However, research suggests that consumers still have only limited awareness of the origin of the materials in the products they use (see section on the search for RACER data).

Public awareness appears to be more favourable on secondary raw materials interpreted in the context of the circular economy, e.g. selective collection and recycling of household and electronic waste[95]. The public has green behaviour in household waste collection but there are differences in motives[96]. Consumer behaviour is an important factor in product design and choice (e.g. product ecodesign and ecolabel)[97], during use, and for waste collection, as a significant portion of valuable materials is lost or temporarily locked up[98].

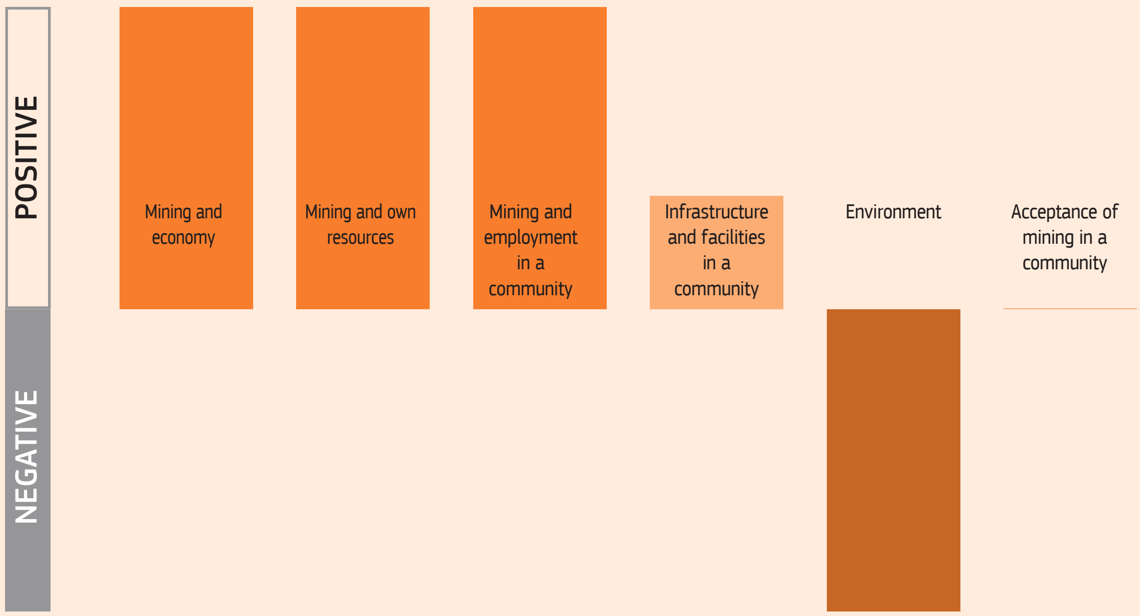
The interlinkages among policy objectives (e.g. reducing landfilling and incineration, promoting ecodesign) that are in turn connected to raw materials (e.g. recovering critical raw materials) are less known, and the public may not be aware of them at all. It is vital to raise consumers' awareness of the minerals they use, and to promote a shared vision on a sustainable global system of mineral production and consumption. The Green Deal and the circular economy policy can help raise public awareness and further develop consciously environmentally friendly consumer behaviour.

Country surveys on public acceptance

Recent Horizon 2020 projects performed multi-country surveys which gathered thousands of responses. The most representative of these projects is INFACT[99], comprising three EU countries and 3 000 respondents (Figure 2.2). The project found a positive attitude towards mining as regards the importance of the sector for the whole economy, the chances for employment and having independent own mineral resources. The people surveyed saw the benefits of mining for the local infrastructure and facilities. They also did not negatively value mineral exploration in general, with the exception of drilling. Still, the environmental impact of mining was seen as a huge issue.

As a recommendation, the project found that as 'today it is increasingly easier for affected members of the public to access information online, it also becomes increasingly important to actively engage the affected groups' right from the beginning of planning an agenda. It may be important for a mining company to arrange a meeting with local people to inform them about activities and impacts. Also giving a possibility to ask questions face to face may be important to local people and other stakeholders, and may help to avoid misunderstandings when they occur.'

Figure 2.2: Public attitude in Germany, Spain and Finland towards different topics of mining and mineral exploration[100].



The search for RACER data …

In the 2016 edition of the Scoreboard, this indicator was based on a Eurobarometer survey about the public perception of companies' behaviour[101]. In comparison with other sectors, mining companies (including oil and gas extraction) were perceived as making relatively less effort to operate responsibly. Based on the monitoring of NGOs' activity, SIGWATCH[102] found similar results to the 2015 Eurobarometer. In EU countries less than half of people responded 'yes' to the question on whether they consider that companies in the mining industry are making efforts to behave responsibly.

The Environmental Justice Atlas[103] shows social conflicts on environmental issues with information on countries, companies, conflicts and commodity types. When selecting the category 'Mineral ores and building materials extraction', 597[104] cases are filtered out from the 2 960 total (20%)[105]. 7% of cases are in the 'Waste management' category[106].

In recent years, many EU Horizon 2020 projects have also dealt with the social dimension and public acceptance of extractive activities. Their list is published by EASME[107]. Most of them worked on methodological developments (e.g. MIN-GUIDE, ORAMA, MINLAND, SLIM) or carried out surveys limited to 100-200 responses mainly by insider professionals (e.g. MINLAND), and/or focusing on certain materials (e.g. SECREETS, SLIM), value chain stages (INFACT), or different public acceptance scales (STRADE, INTRAW, REMIX, MIREU).

In addition, a recent international survey by the Swedish government[108] studied the sustainability preferences and choices of consumers in six countries (the United States, the United Kingdom, Sweden, Germany, India and Japan) based on 6 000 responses. The survey mapped consumers' attitudes on a number of environmental and social concerns, their knowledge of the material-product linkages, and their choices. It found that the least influential attribute in their decision-making is the source of the constituent raw materials.

The Commission's Joint Research Centre also searched for potential quantitative data from online news services, e.g. using http://emm.newsbrief.eu, but the results were not considered suitable for the Scoreboard as they did not meet the RACER criteria.

3. Minerals exploration

Key points:

- Although mineral exploration is key to expanding or even maintaining current production levels, only limited exploration activities took place across the EU, with considerable differences among Member States.
- Compared to the situation depicted in the 2018 Scoreboard, some mineral exploration projects have progressed towards more advanced stages and some have started production.
- The EU's mineral potential remains under-explored, and the budget for exploring for metallic minerals in the EU remains low compared to other regions in the world.

Overview and context

The future availability of raw materials from domestic sources is determined by the success of mineral exploration projects. Mineral exploration involves a series of activities intended to find a viable quantity of mineral ores that are economically beneficial and technically feasible for extraction. It requires geological knowledge and technological feasibility as well as social, environmental, political, and legal acceptability.

Mineral exploration is considered a high-risk business, with one successful mine in 1 000 geological projects[109]. Mineral prices and future metal demand are the main drivers of exploration activities. As an example, the expectations for higher future demand[110] for electric vehicle batteries led to a rise in lithium prices of over 250% from 2015 to mid-2018. Following this increase, the budget and new exploration activities for lithium increased around the world[111],[112].

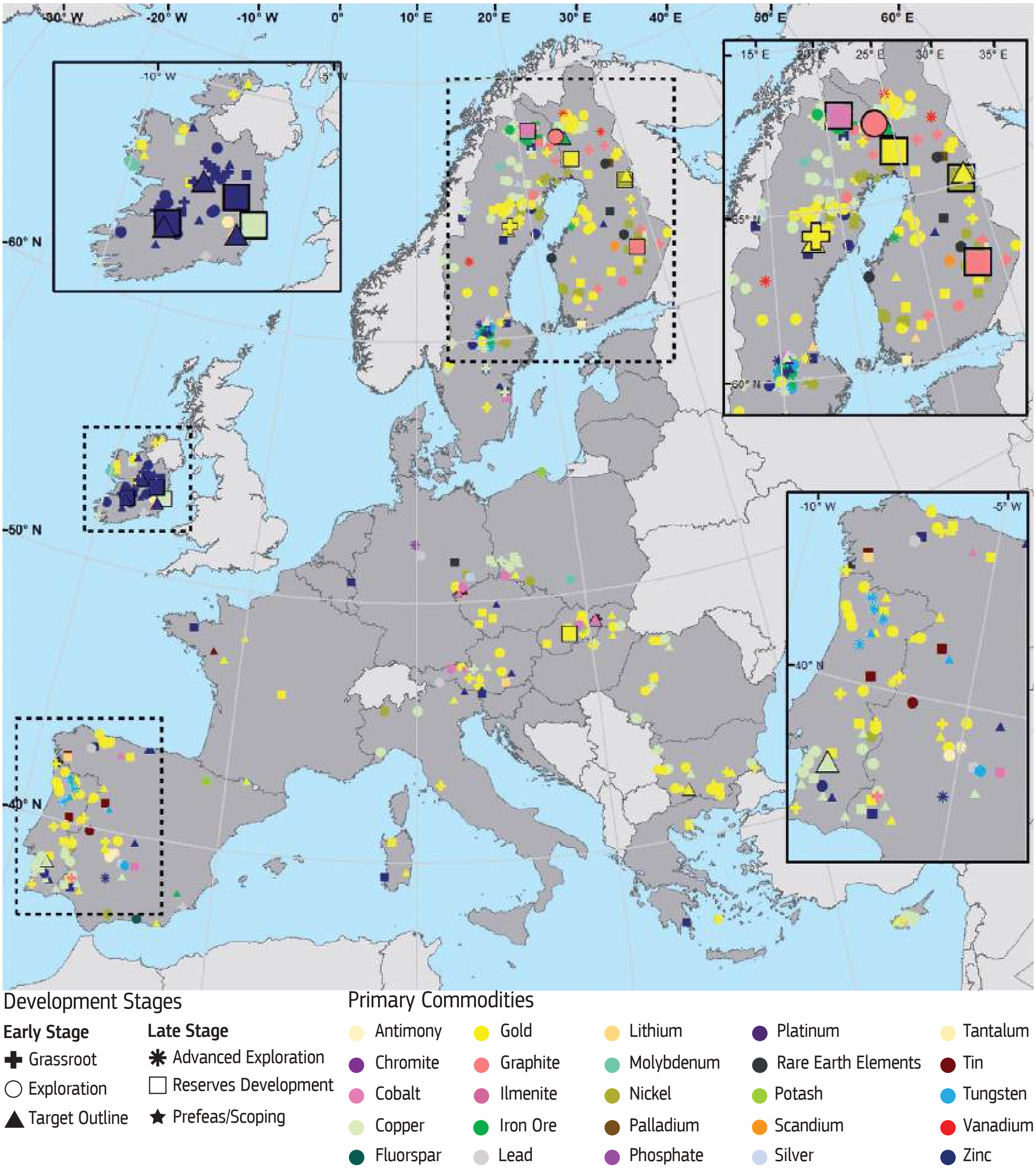
The investment in a mining project is long-term by nature and requires a large amount of capital. The decision to invest in exploration activity in the EU is also challenged by other important issues such as permit and licences; public acceptance (see indicator 2); exploration technologies; mine design; environmental, health and safety issues; and the access to relevant knowledge and information on minerals, to name but a few[113]. The EU accounted only for 3% of global exploration expenditure in 2017, yet it consumes 25-30% of the metals produced globally[114].

Facts and figures

Figure 3.1 shows that mineral exploration activities in the EU in 2019 remained concentrated in Ireland, Spain, Portugal, Sweden and Finland, countries regarded as attractive for investment in exploration (see indicator 1). Gold, copper and zinc are still the main target commodities. It shows significant differences among Member States in terms of mineral exploration activities, similarly to the 2018 Scoreboard.

More than 25 exploration projects mapped in the 2018 edition of the Scoreboard (2017 data), have progressed towards a more advanced exploration stage. In addition, about 6 exploration projects from 2017 proceeded to the feasibility stage and 3 projects advanced to the production stage in 2019. Compared to the exploration activities of selected commodities in the 2018 Scoreboard, approximately 54 new exploration projects have been listed. More than half of these projects are at an early stage, targeting gold and copper. The remaining projects aim for metals such as nickel, platinum, vanadium and zinc. As the global demand for batteries for electric vehicles has grown, new exploration projects for lithium and cobalt have been launched in the EU, for example in Austria and in Spain.

Figure 3.1: Mineral exploration activities in the EU-27 (2019)[115]. The advancing projects are indicated by larger points.



In its action plan on critical raw materials the Commission puts forth identifying potentially viable projects for CRMs in the EU to increase domestic production. It is working with Member States to validate and verify the available data. Figure 3.2 shows the progress of this action. The comparison with figure 3.1 shows that not all exploration activities become commercially viable and in comparison with figure 4.1, the number of validated activities is still above the current number of productive mine sites (see indicator 4).

Figure 3.2: EU database of CRMs potentially viable projects (19.03.2021)[116].

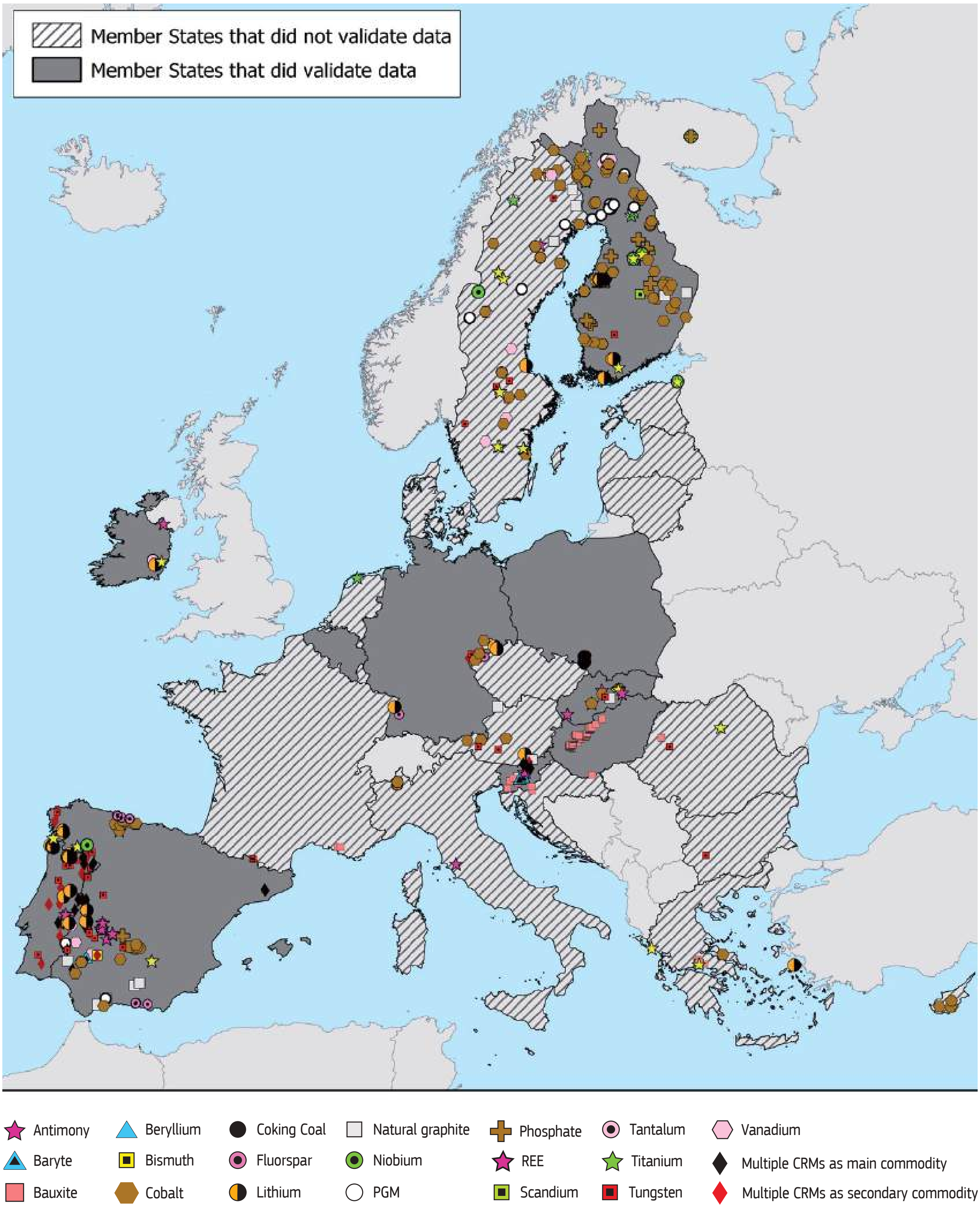
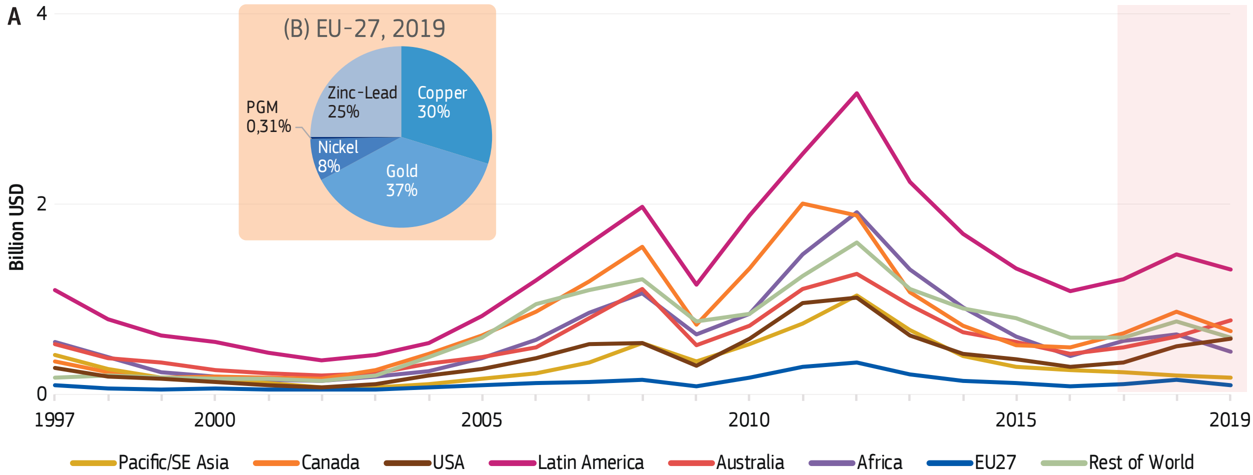


Figure 3.3 presents the total budget allocated to exploration activities by world region over time. The coverage of the data source means that the exploration budget in the Figure is limited to copper, gold, nickel, platinum group metals (PGM), and zinc-lead. The highest investment amounts allocated to exploration were still seen in Latin America, Canada and Australia. The Figure shows how since 2012, declining market prices for metals have led to a drop in exploration budgets[117]. As metal prices became stronger from 2016, the exploration budget increased worldwide until 2018. It then fell from 2018 to 2019, except in the United States and Australia, where the budget continued to grow.

The EU's exploration budget in 2019 remained low compared to other world regions. Similar to the 2017 exploration budget (see 2018 Scoreboard), the 2019 exploration budget was mostly allocated to gold (37%), followed by copper (30%), zinc (25%), nickel (8%), and a very small percentage (<1%) to PGM. The lack of junior companies[118] that would be most likely to invest in new explorations is one of the factors behind the low exploration budget in the EU[119].

The EU also actively invests in knowledge on mineral exploration. There are ongoing projects in the EU that address exploration technologies, for example NEXT[120], and Smart Exploration[121].

Figure 3.3: Exploration budget by world mining region (1997-2019) (A) and distribution of exploration budget among various metals in the EU (2019) (B)[122].



Conclusion

Mineral exploration is a key component of the EU's strategy for increasing the domestic supply of primary raw materials. The prices of materials and future demand are among the main factors that drive mineral exploration activities.

In the past 2 years, mineral exploration activities continued in the EU, with differences across Member States. Investment in metalliferous ore exploration in the EU remains low compared to other regions in the world. Gold and copper are still the main target materials for exploration investments, but interest in battery raw materials (cobalt, nickel and lithium) is increasing considerably.

4. Mining activity in the EU

Key points:

- The mining activity pattern in the EU remains similar to that shown in the 2018 Scoreboard with moderate changes; a few new mining activities started and some mines have been closed. A limited number of existing mines are planning expansion.
- Following the increasing global demand for lithium for batteries, four EU lithium projects that were in the exploration stage in 2017 have now become active mines.

Overview and context

Mining and quarrying activities in the EU produce basic metals, specialty metals, precious metals, industrial minerals and construction materials, but coverage does not always reflect domestic demand. The EU is nearly self-sufficient in construction minerals and several industrial minerals (see indicator 6) but remains highly dependent on imports of other raw materials (see indicator 8). Domestic production of raw materials may also reduce the sourcing of materials from low governance regions (see indicator 9), thus mitigating the indirect environmental burdens outside the EU.

Starting new mines to increase the current production requires a series of exploration activities and underlying investments (indicator 3). A profitable mine project must have demonstrated technical and economic feasibility, taking into account socioeconomic, environmental and legal constraints.

Facts and figures

Figure 4.1 shows the location of mines of metal and selected industrial minerals and the estimated production/production capacity in the EU based on 2019 data. The Figure refers to the main commodity targeted by each activity, which implies that all other co- or by-products are not shown on the map (i.e. a copper mine may also produce zinc, silver, lead and gold). Mine projects indicated as 'Producing' include those that are fully operational or in the expansion stage. 'Non-producing' mine projects are those in the construction phase, undergoing a feasibility study, in the pre-production phase, in limited production, or in the satellite phase.

While most of the mining projects reported in the 2018 Scoreboard (data for 2017) remained the same, there have been several changes in the status of some mining projects over the last 2 years. As many as 13 new mining activities (highlighted with a black border line) have been identified since 2017. The new projects are either under feasibility study or actively producing, targeting precious metals, graphite, zinc, copper, tungsten and manganese. Following the increasing global demand for lithium for batteries, four lithium mining projects (two in Portugal, one in Spain, and one in Austria) that were in the exploration stage in 2017 have become active mines. Two potash mines have been closed and some mines continue exploration activities.

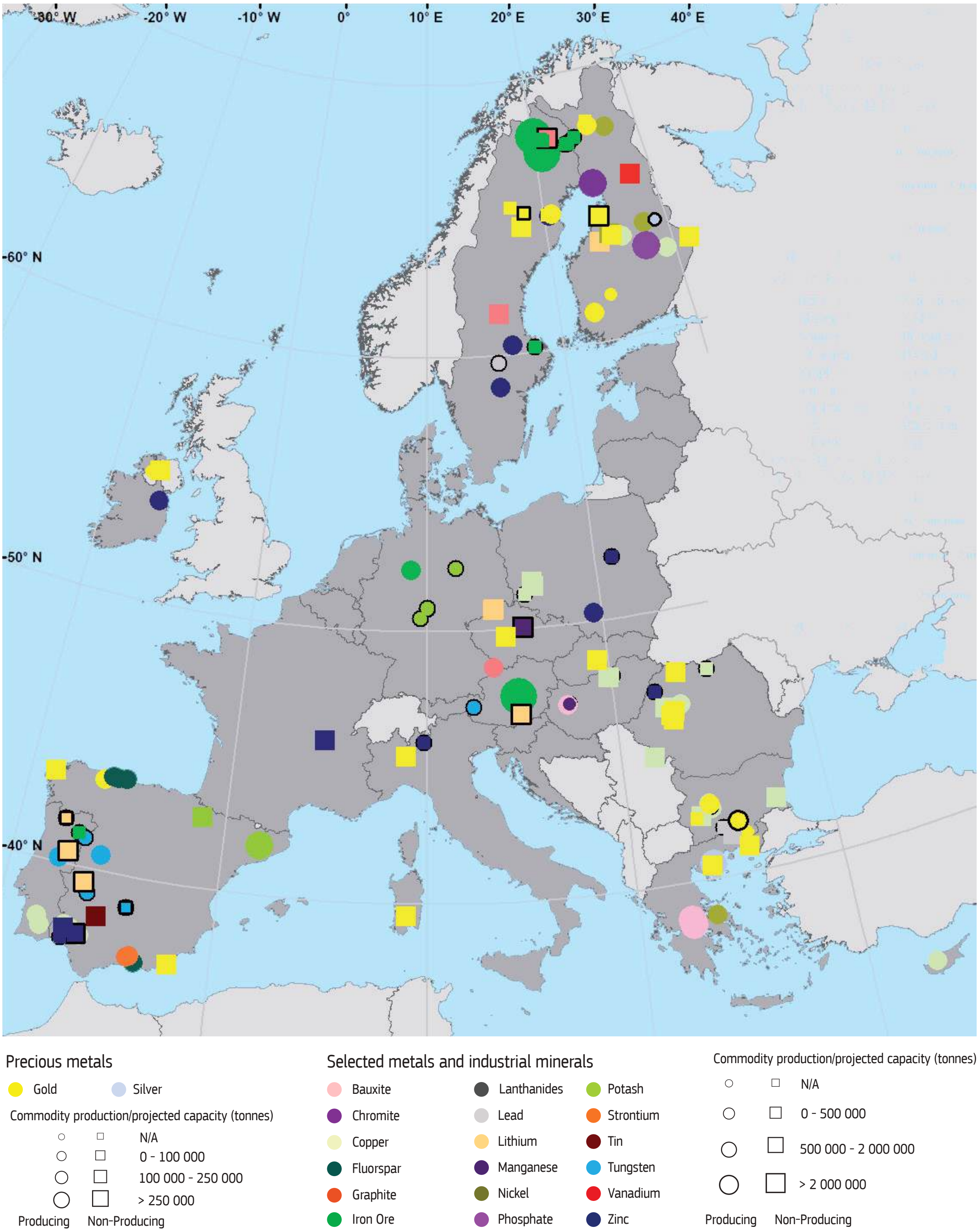
As well as the raw materials presented in Figure 4.1, the EU also produces construction materials[123]. Where they are produced is significant in supplying local and regional markets. Indicator 6 (domestic production) provides information on the share of the EU's demand for raw materials met by mines and quarrying production within the EU.

Conclusion

The increasing global and domestic demand for raw materials drives the development of mining activities in the EU, as shown in the case of lithium. Nevertheless, new projects for strategic metals such as copper did not enjoy a similar demand pull. Similar to the situation depicted in the 2018 Scoreboard, the expansion of mining activity and the related domestic production are currently not sufficient to satisfy demand for raw materials, and the EU remains highly reliant on imports, in particular for metallic minerals.

The Commission has launched initiatives to address the challenge of ensuring a sustainable supply of raw materials from EU sources· It initiated the European Battery Alliance, which brings together industrial and innovation actors, Member States, and the European Investment Bank to create a competitive and sustainable battery cell manufacturing value chain in Europe. The European Investment Bank, as the financial actor for the Alliance, has recently confirmed its support to the European battery industry by financing battery-related projects in 2020, including raw materials extraction projects[124]. Most recently, the Commission has published a communication on critical raw materials, which sets out an action plan to secure the sustainable supply of raw materials for the EU's industrial ecosystems[125]. The Commission also launched the European Raw Materials Alliance[126] to strengthen industrial value chains.

Figure 4.1: Mine production of metal and selected industrial minerals in the EU-27 (2019)[127]. New projects are indicated by circle points (active, producing) and squares (active, non-producing) with a black border line.



5. Wood supply

Key points:

- In 2015, felling rates in EU countries were below 100% of annual growth, and most were below 85%.
- The EU's forest growing stock has been increasing since 1990 and seems to have continued growing in the last 5 years. Yet the rate of growing stock accumulation is slowing down.
- Increasing demand for woody biomass could put pressure on forests. Sustainable forest management is essential to preserve the whole set of forest functions and products.

Overview and context

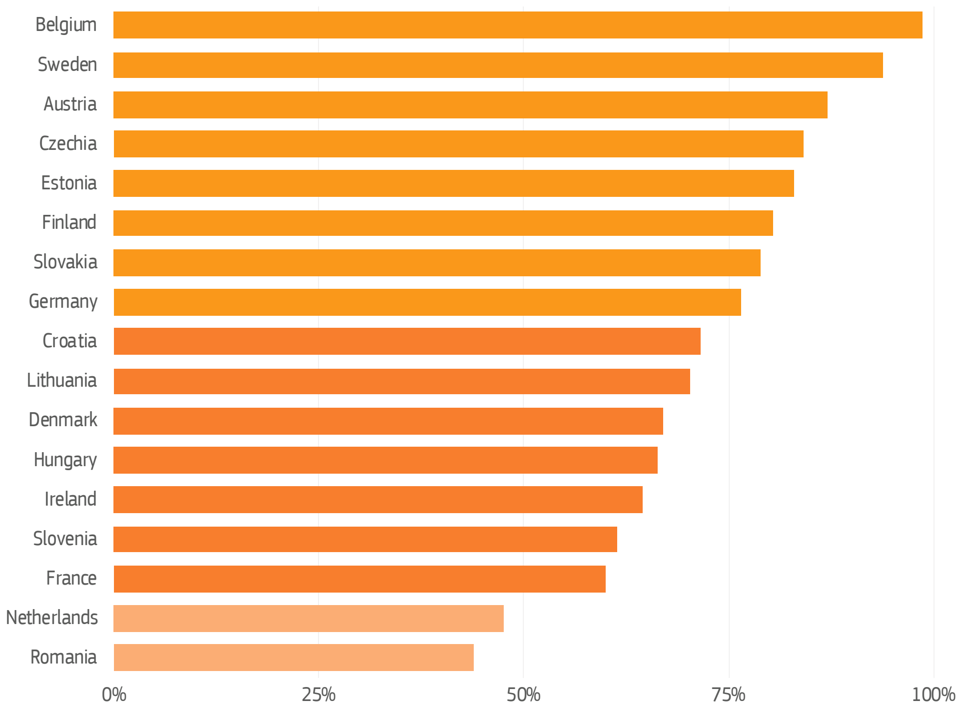
Forests carry out essential functions and provide multiple products to our society. Wood is one of their main products. Its versatile properties allow its use in a wide range of applications such as infrastructure, construction, furniture, utensils, pulp and paper. Some parts of the tree are considered high value and have a more straightforward purpose, such as sawn wood or veneers, while the value and use of by-products and residues is more varied[128]. Wood is also used for energy generation (biomass and biofuels)[129].

EU forests produce close to 20% of the industrial roundwood in the world (see indicator 7), with some EU countries among the world's top-10 producers[130]. The EU's wood-based upstream sectors generated EUR 98 billion of valued added in 2017[131]. Over 56% of wood supply to the EU comes from domestic removals, around 19% from wood by-products of the wood industries, and 4% from post-consumer wood[132]. While the net trade balance, imports minus exports, of wood with non-EU countries was less than 2%, volumes of intra-EU trade are high since the northern EU region produces more that it uses[133]. Half of the wood is used to create materials in the sawmill, wood pulp and panel industries; the other half is used for energy[134].

The use and production of wood has increased in the EU between 2009 to 2015[135], with a slight increase in the share of wood used to generate energy[136]. The sector has also experienced significant changes in how wood is obtained from forests and how it is used for multiple purposes, for example changes in wood harvesting, woodworking and in the pulp and paper industries. These changes are expected to continue[137].

Meeting demand for wood while preserving forest functions requires sustainable forest management (SFM)[138]. SFM is explicitly recognised under SDG 15[139], and monitoring it requires gauging multiple aspects, such as forests' productive and regenerative capacity, as well as social and environmental factors. The Commission has developed the Bioeconomy Strategy[140], which sketches the transition towards a sustainable and circular, bio-based, low-carbon economy based on the sustainable use of biomass, while retaining the services that forests provide. However, there remain

Figure 5.1: Felling rates as a percentage of net annual wood net increment (EU countries, 2015)[146].

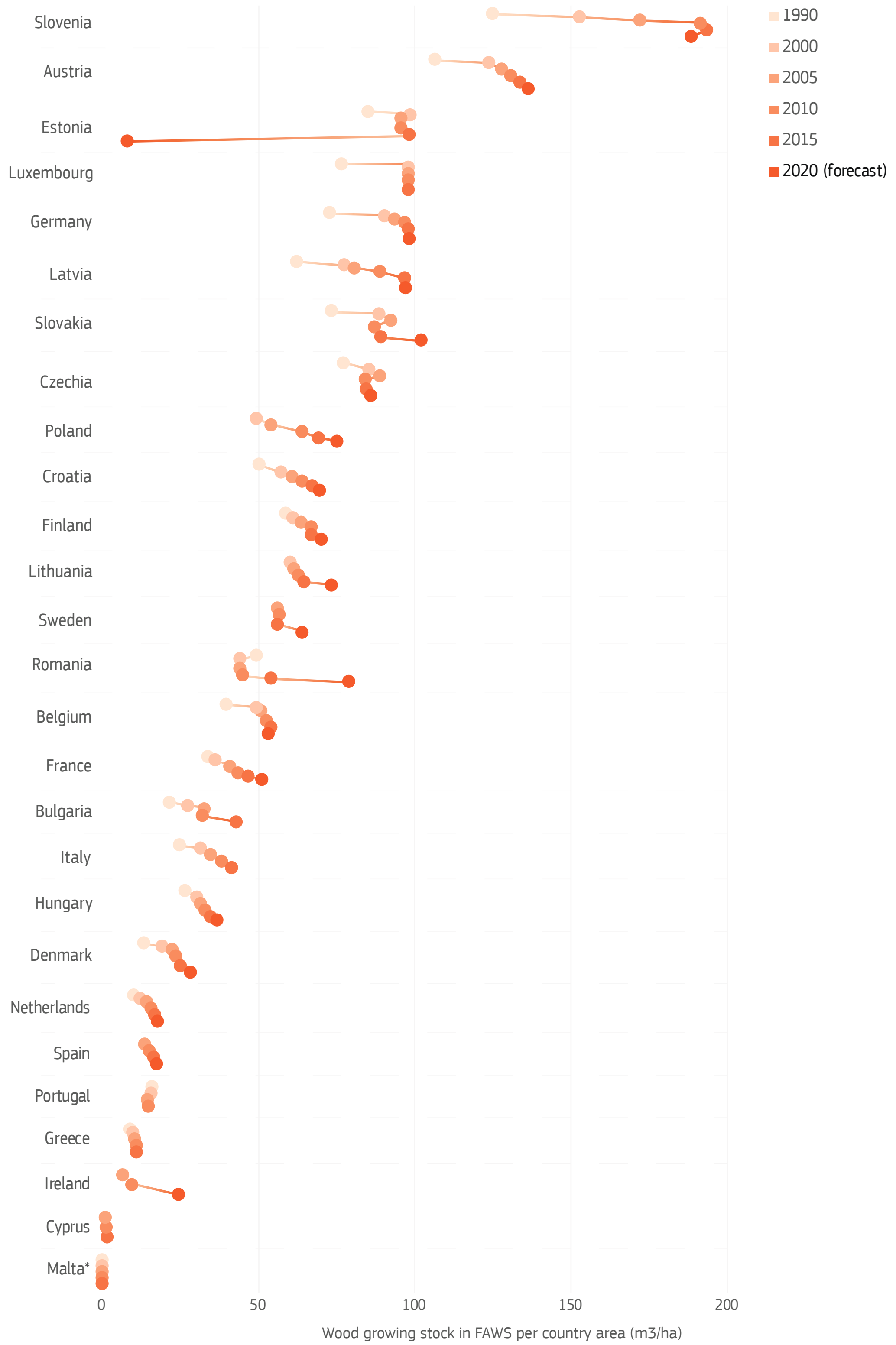


several challenges, for example increasing the value of wood as a secondary raw material, e.g. through standards to better recover post-consumer wood, which will help improve its quality as secondary raw material, or the increasing demand for biomass as a decarbonisation strategy[141].

Facts and figures

Figure 5.1 gives an overview of felling (utilisation) rates – i.e. the proportion of wood cut down in EU forests – as a percentage of the net annual increment – i.e. net yearly wood growth of the forests. This indicator belongs to the updated set of pan-European

Figure 5.2: Wood growing stock in forest available for wood supply per country area (m^3/ha) (EU-27, 1990-2020)[147]. Data for 2020 are forecasts. Countries are ordered according to 2015 values.



* Data for Malta is for total forest area (forest available for wood supply plus other forest area). Forecasts (2020 data) for some countries have not been provided.

indicators for SFM criteria under the Forest Europe[142] process, developed by EU Member States and other European countries.

The Figure shows that in 2015 (the last year for which data are available) felling rates in all EU countries were below 100%, which is considered within the limits of SFM. This shows that forest wood stocks were allowed to increase (see Figure 5.2 below), and ensures that the forest remains a carbon sink[143].

Values for most countries were also below 85%, meaning there should be no undue negative environmental impacts. Many countries' felling rates were even lower than 60%, e.g. Romania, the Netherlands, or France. Some countries, e.g. Sweden and Austria, had relatively high felling rates, yet below 100%, due to their high total standing wood volumes and intensive planned wood use.

Figure 5.2 presents the EU's forest growing stock in forest available for wood supply from 1990 to 2020. The growing stock represents the volume of living trees[144], and is a combined effect of the increase of forest area and of growing stock per area unit. Growing stock shows whether forest stocks are expanding or shrinking, their potential wood supply and helps to estimate carbon stocks. To help compare countries, growing stock values are presented relative to country areas. Data for 2020 are forecasts, since the Forest Europe report was released in 2020.

The Figure demonstrates that the EU growing stock (in forest available for wood supply), which increased from 1990 to 2015, is expected to continue increasing until 2020 in about half of EU countries. Indeed, wood growing stock is among the few indicators for which the EU is likely to meet 2020 objectives, as highlighted by the European Environment Agency EU's natural environment scoreboard[145]. However, the accumulation rate of growing stock is slowing down.

Figure 5.2 also shows the large differences in potential wood supply across EU countries, which point to the need for different strategies for sustainable wood use.

Conclusion

In the last three decades, felling rates have been kept under sustainable limits overall, and EU growing stocks have been on an upward trend. This also applies to the more recent years, although the rate of growing stock accumulation is slowing down.

Competition for wood for energy use and for manufacturing innovative products is expected to increase. Greater use of wood is also seen as part of the EU's efforts towards decarbonising the economy. This may require greater mobilisation of wood and possibly increasing wood imports. Forests are also directly threatened by climate change, which is expected to increase the frequency of droughts, diseases, fires, pests and other disruptions in many forest ecosystems.

Considerable efforts will be needed to balance domestic wood supply while preserving forest functions, including biodiversity conservation, through SFM to maintain and even increase the availability of wood biomass. The Commission has recently published a (non-binding) guidance document on the cascading use of wood[148]. It includes illustrative examples of good practices for the circular use of wood by the wood, paper and chemical industries[149]. The Commission has also adopted a new Forest Strategy, a new Biodiversity Strategy for 2030 and an associated action plan as part of the European Green Deal.

6. Domestic production

Key points:

- Domestic extraction of materials used in construction significantly decreased after the economic crisis in 2008, but has shown some recovery since 2014.
- The production of industrial minerals has been relatively stable in the last 10 years, while in the same period metal and wood extraction grew.
- The EU's processing and refining capacity for some metals needs to be sustained by import and secondary sources.

Overview and context

Domestic production is the backbone of a stable and secure supply of raw materials to the economy. Domestic production helps reduce raw material supply risk associated with low governance (see indicator 9) or export restrictions (see indicator 10), and may lessen reliance on imports (see indicator 8). Domestic production is also closely linked to the EU's self-sufficiency for raw materials, which is an indicator within the circular economy monitoring framework[150].

While its availability is determined by mineral/natural endowment, price and demand are the major driver of materials production[151]. The social, environmental and political situation are also important factors in raw material production activity. Furthermore, having an adequate processing capacity is indispensable for the production of some raw materials.

Generally, materials are classified into different categories. Construction minerals are non-metallic minerals primarily used for construction, such as limestone. Industrial minerals are the products of other mining and quarrying activities, and include for instance chemical and fertiliser minerals. Metals derive from mineral ores and have very specific physical-chemical features. Wood comprises timber used for purposes such as construction or furniture and, as in this analysis, also often includes wood for energy purposes.

Facts and figures

Figure 6.1 presents EU trends in domestic extraction (solid lines) by category of raw materials, and as compared to domestic material consumption[152] (dashed lines) from 1970 to 2017. The figure on extraction cannot be directly compared with results in the 2018 Scoreboard, due to changes in materials grouping[153]. For instance, 'wood' refers not only to 'industrial roundwood' as reported in the previous editions of the Scoreboard but also includes wood fuel[154].

Figure 6.1 shows that extraction of construction materials was the highest in terms of volume throughout the period. It grew significantly from the mid-1990s to 2008, prior to the global financial crisis. There was then a dramatic drop in construction material extraction until 2012. Since then and until 2017, extraction of materials for the construction sector has remained relatively stable.

Domestic extraction of metals showed a decreasing trend, though this reversed in the last 10 years. Being based on volumes and not on monetary values, the category 'metals' mostly reflects trends in commodities extracted in large volumes, such as iron ore and copper. Although they have a high unitary value, minor and trace metals are less visible in this bulk figure. Indicator 8 (import reliance) provides a detailed overview of how well EU production can meet domestic demand for several metals.

Similarly to construction minerals, the 2008 financial crisis resulted in declining extraction of industrial minerals until 2015, after which extraction stabilised.

Wood extraction increased considerably in 1996 and has since shown slow but stable growth, temporarily interrupted by the 2008 crisis.

Figure 6.1 shows that the EU domestic production of wood and construction materials has managed to meet consumption since 1970. Despite being the third largest producer of industrial minerals, the EU consumed more than its production between the mid-1990s and 2017. Between 1970 and 2017, EU domestic production of metals has been low compared to EU demand.

Figure 6.1: Domestic extraction (solid lines) and domestic consumption (dashed lines) by raw material category (EU-27, 1970-2017)[155].

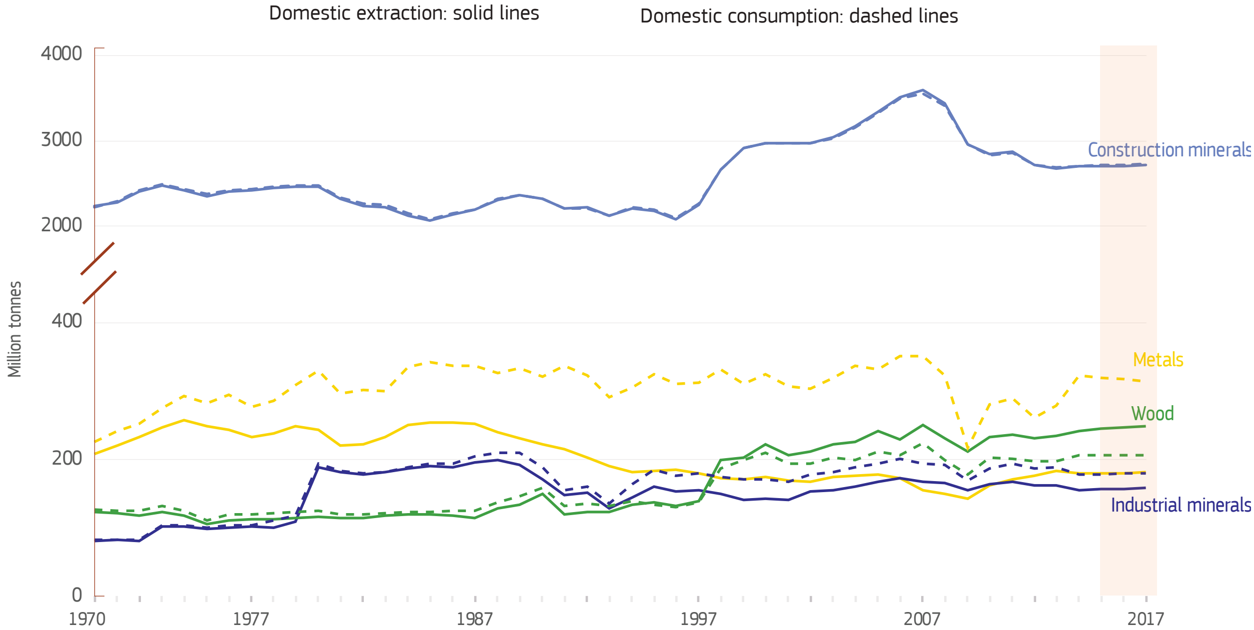
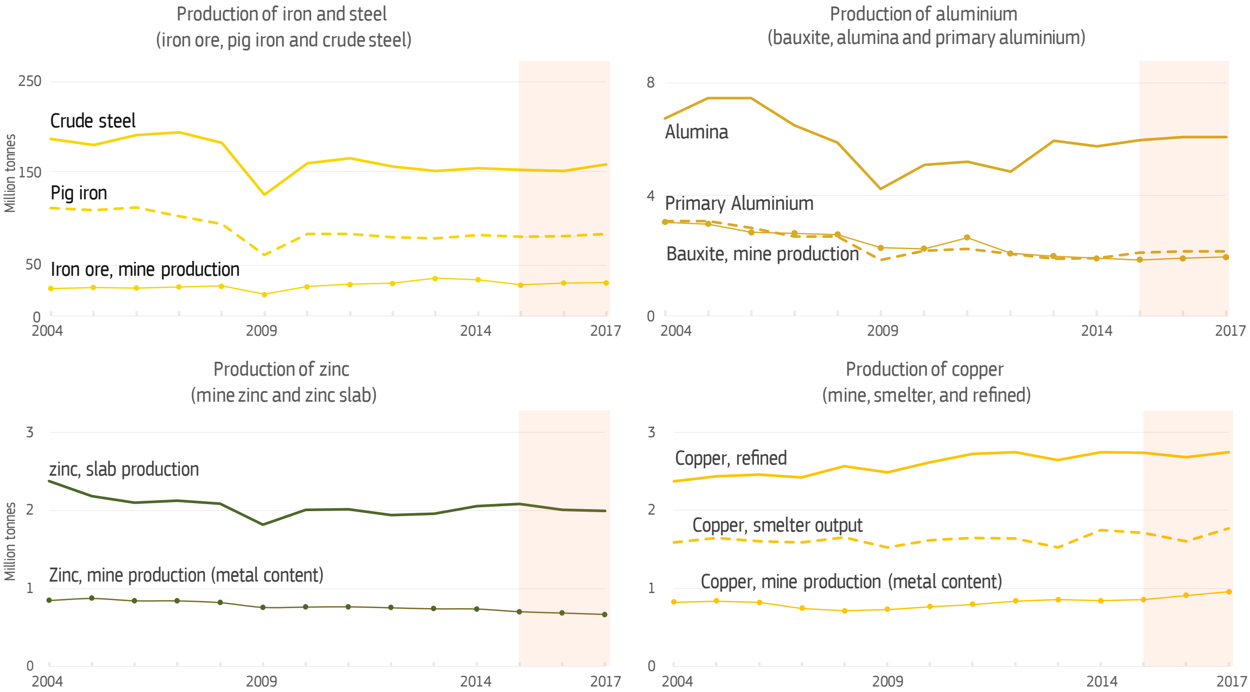


Figure 6.2 presents the production trend of a selection of metals (aluminium, zinc, iron and copper) at the mining and processing stages[156] from 2004 to 2017 in the EU. Data shown at the processing stage include inputs not only from domestic extraction but also from imports and secondary (recycled) materials.

The Figure shows that mining production for the selected metals was relatively stable over the whole period. The impact of the financial crisis is shown by the general jump in the production of metals at the processing and refining stages from 2008 to the level in 2009, except for copper which continued to rise due to increasing demand. The negative impact of the crisis has now partially lifted, and is reflected in the relatively stable production from the processing and refining stages of these metals. Nevertheless, the quantity of output at these stages was less than before the financial crisis. Since the last reported year in the 2018 Scoreboard (2015), domestic production of these metals at different stages has remained relatively stable.

The EU's production of the processed and refined forms of aluminium, zinc, iron and copper remained higher than its mines produced them. The Figure suggests the importance of other sources of raw materials such as imports and secondary materials to sustain the production of this sector. See indicator 15 about the contribution of recycling to the EU supply of raw materials.

Figure 6.2: Domestic production of a selection of metals (EU-27, 2004-2017)[157]. A slight difference may exist between Figure 6.2 and Table 7.1 due to the use of different data sources.



Conclusion

Domestic extraction of construction materials, metals and industrial minerals has shown signs of recovery following the 2008 financial crisis and remained relatively stable in 2015-2017, while the production of wood has increased. The trend in domestic extraction and consumption of raw materials in the EU shows the EU is self-sufficient in construction materials and wood.

Through the Raw Materials Initiative, the Commission has promoted various activities that address the challenges to securing the sustainable supply of raw materials within the EU. Examples of these activities include research and innovation projects on the extraction and processing of raw materials through the Horizon 2020 programme and the EIT Raw Materials. The EU action plan for the circular economy highlights the need to use resources more efficiently and how secondary raw materials can be used to secure materials supply.

Overview

The deposits and resources of raw materials are not evenly distributed across countries, with high concentration of a material in single countries or a climatic region. Being commodities, raw materials are traded on the global market and their supply is determined by a number of factors besides cost.

Indicators

The EU share of global production (indicator 7) is key to understanding the challenge of guaranteeing a sustainable supply of raw materials to EU manufacturing industries. One indicator that gives relevant insight on that aspect is EU import reliance for raw materials (indicator 8). Concentration of supply, and governance in the countries the EU sources from, both have implications not only for sustainability of the materials but also for supply risks (indicator 9). Related to the latter, the imposition of export restrictions also affects supply risks (indicator 10). Trade in waste (indicator 11), a potential source of (secondary) materials, can also determine the supply to the EU, especially for specific materials.

Fluorite (or Fluorspar) is an important industrial mineral, used in a wide variety of chemical, metallurgical, and ceramic processes.

Raw materials in the global context

Indicators

7. EU share of global production
8. Import reliance
9. Geographical concentration and governance
10. Export restrictions
11. Trade in waste and scrap

SCOREBOARD

Raw materials supply in the EU:
1. National minerals policy; 4. Mining activity; 6. Domestic production.

Circular economy and recycling:
all indicators

SUSTAINABLE DEVELOPMENT GOALS

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

EU self-sufficiency for raw materials; Trade in recyclable raw materials

7. EU share of global production

Key points:

- The EU is the third largest producer of industrial minerals and industrial roundwood. Its share in global production is low for iron and ferro-alloys, non-ferrous metals and precious metals.
- Mining production in the EU was stable during the last 20 years but metal ore extraction has slightly increased since 2008. However, the EU's global share of mining decreased, mainly due to growing production elsewhere.

Overview and context

Material supply chains are generally interlinked and global. While the primary material input to the economy is composed of two flows, i.e. domestic extraction and import, the downstream material flows usually form a wide network.

Global demand for raw materials is increasing rapidly. This is mainly driven by extensive consumption arising from global population growth, and consequently, by the manufacturing and construction industries in emerging economies, giving rise to keen international competition for secure and sustainable access to supply. It is therefore important to understand the EU's market position in terms of its share of global production. This indicator, in combination with indicator 6, with data on domestic production and consumption, and with indicator 9 on geographical concentration of production, can help to understand the picture.

The level of globalisation in materials production (and the related trade flows) differs across raw materials, due to factors such as unit price and transport costs. Therefore, some materials are more suited to domestic sourcing. This is the case, for example, for aggregates and industrial minerals, while other materials are stock exchange commodities with global trade, such as metals.

Facts and figures

Figure 7.1 presents the share of global production by world region from 1984 to 2017. It shows data for iron and ferro-alloy metals, non-ferrous metals (excluding bauxite), precious metals, industrial minerals and industrial roundwood. The figure shows that the EU was the world's third biggest producer of industrial minerals and industrial roundwood. The EU share of global production is lower for iron and ferro-alloys, non-ferrous metals and precious metals.

The figure also shows that, although the production of raw materials generally increased globally in 2016-2017, EU and North American production has been quite stable for all raw materials categories[158]. Precious metals are an exception to this, with the EU slightly increasing and North America decreasing its share. On the other hand, mining production in Asia decreased from 2015. This was partially counterbalanced by the rapidly increasing output in Latin America and Oceania of iron and ferro-alloy metals, non-ferrous metals and precious metals.

The slowdown in production growth rates for industrial minerals and iron and ferro-alloys may indicate an economic slump, especially in emerging economies. In particular, Asia saw a fall in production of non-ferrous metals between 2015 and 2016.

Figure 7.1: Share in global production for different material categories by world region (1984-2017)[159]. For data on mining production, the UK is excluded (EU-27) only since 2015. For industrial roundwood, data refers to EU-27.

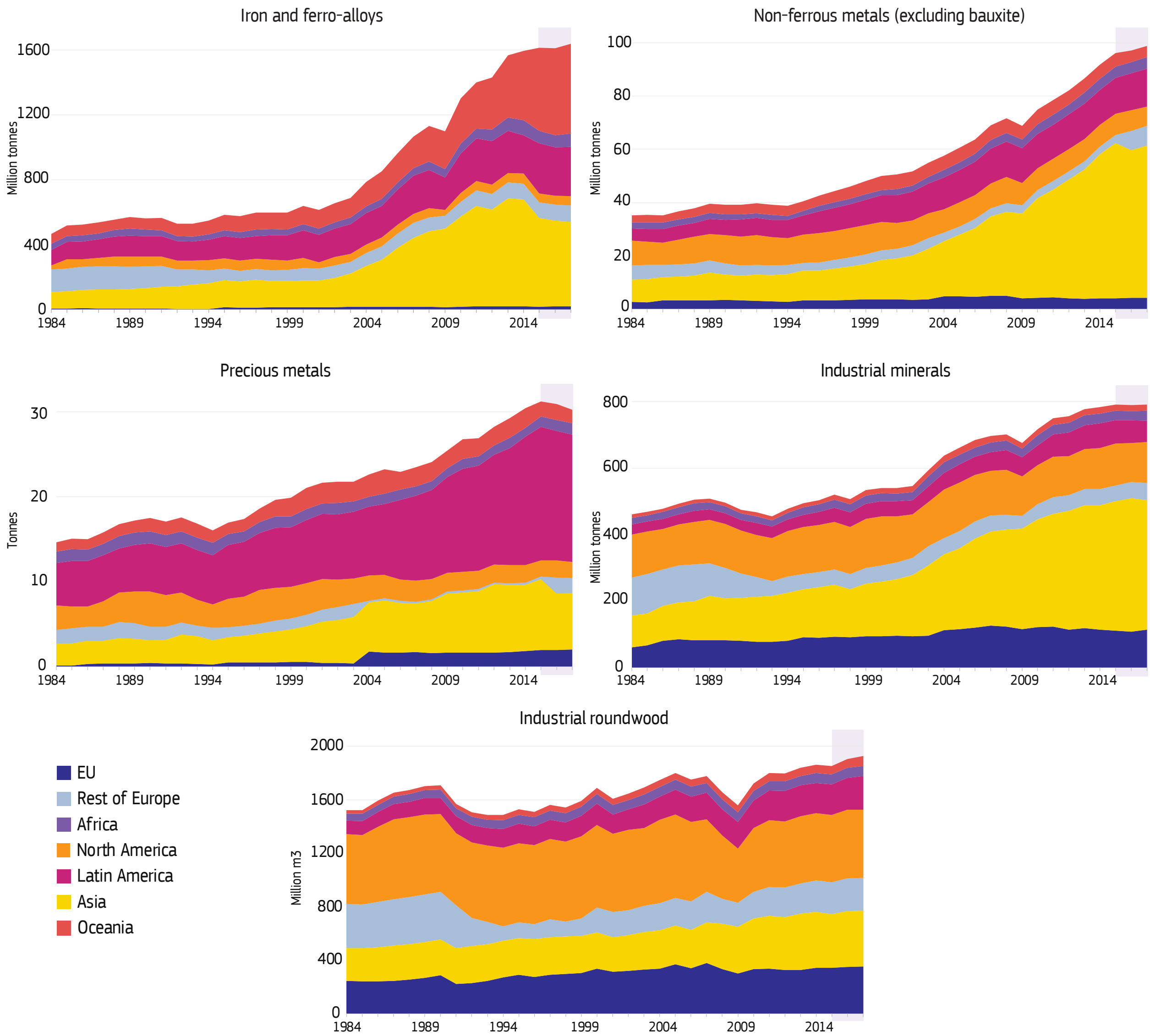


Table 7.1 presents the volumes of production in world regions for representative groups of commodities, most of which belong to the non-ferrous metals group covered by Figure 1.1. Data corresponds to the stage with higher supply risk, in line with the *Study on the EU's list of Critical Raw Materials (2020)160.*

The table shows that the EU's share of global production is rather small for the individual abiotic materials presented. This is also reflected in a high import reliance, as highlighted in indicator 8, where – for most selected abiotic materials – import dependency is higher than 60%.

The table shows that the production of bauxite, zinc, chromium and lead is highly concentrated in China, which has a global share of more than 35%. China's leading role in iron production, however, has changed dramatically, dropping from 44% to 10% since 2014. As a consequence, Australia is now the world's major producer of iron.

Copper is mainly extracted in Latin America, where the main producer is Chile. Production of chromium is mainly distributed between China and South Africa.

The situation is different for industrial roundwood, for which the EU is one of the main producers, accounting for almost 20% of world production.

Table 7.1: Five-year average (2012-2016) global production of selected raw materials for selected countries and world regions[161].

Material	Stage	Production	**World**	*EU27*	*Australia*	*Africa*	*Canada*	*China*	*Latin America*	*United States*	*Top 3 producing countries****
Bauxite	Extraction	% (kilotonnes)	**100% (281 124)**	1% (2 009)	**28% (80 092)**	9% (24 449)	-	**20% (56 110)**	**18% (51 938)**	0% (228)	Australia (28%) China (20%) Brazil (13%)
*Chromium***	Processing	% (kilotonnes*)	**100% (6 158)**	4% (273)	-	**30% (1 817)**	-	**37% (2 300)**	2% (108)	-	China (37%) South Africa (28%) Kazakhstan (14%)
Copper	Extraction	% (kilotonnes*)	**100% (18 700)**	4% (792)	5% (969)	**9% (1 672)**	4% (666)	**9% (1 726)**	**44% (8 248)**	7% (1 328)	Chile (30%) China (9%) Peru (9%)
Iron ore	Extraction	% (kilotonnes)	**100% (2 038 750)**	2% (36 368)	**35% (707 335)**	5% (101 102)	2% (44 413)	**10% (197 100)**	**21% (435 702)**	2% (49 960)	Australia (35%) Brazil (18%) China (10%)
Lead	Extraction	% (kilotonnes*)	**100% (5 100)**	4% (223)	**12% (631)**	2% (91)	-	**49% (2 518)**	**12% (615)**	7% (353)	China (49%) Australia (12%) United States (7%)
Nickel	Extraction	% (kilotonnes*)	**100% (2 271)**	2% (47)	11% (258)	5% (116)	10% (228)	4% (96)	**18% (403)**	1% (19)	Indonesia (18%) Philippines (17%) Australia (11%)
Zinc	Extraction	% (kilotonnes*)	**100% (13 330)**	5% (726)	**11% (1 409)**	1% (161)	3% (402)	**37% (4 925)**	**20% (2 624)**	6% (797)	China (37%) Australia (11%) Peru (10%)
Industrial roundwood		% (thousand m^3)	**100% (1 851 139)**	**18% (336 937)**	1% (25 743)	4% (73 502)	8% (149 874)	9% (160 777)	**12% (230 313)**	**19% (354 018)**	United States (19%) Russia (10%) China (9%)

* Metal content. ** The metal considered is ferro-chromium with a content of 56% chromium. *** The last column reports the three countries with highest production volumes, whereas the three regions with highest production outputs are highlighted in bold.

Conclusion

The global production of most primary raw materials has increased rapidly since the turn of the century. Since 2015, the growth rate in production of iron and its alloys, and industrial minerals, has slowed and precious metals output has diminished, albeit modestly. These developments may signal a decelerating global and/or regional economy, e.g. in Asia. In this period, the supply concentration pattern changed for some materials, with an increasing role for Australia and Latin America, and a lower share for China. In the EU, primary raw materials production has remained quite stable in absolute amounts. However, in terms of global production, the EU's contribution is relatively small for most raw materials, except for industrial roundwood and industrial minerals.

8. Import reliance

Key points:

- The EU is almost self-sufficient in non-metallic minerals, while for metal ores it remains dependent on imports. Nevertheless, import reliance is very mixed for different materials and stages in the value chain.
- This can be illustrated by cobalt, for which import reliance is 86% at the mining stage but only 27% at the processing stage; or copper, for which the EU's import reliance is 42% at the mining stage but only 16% for refined copper.

Overview and context

Import reliance illustrates the extent to which a country uses imports to meet its demand for materials for its domestic production.

The EU relies on imports for several raw materials due to various factors, the most important being the occurrence of natural resource endowments and their exploration. Many of the raw materials for which the EU faces supply challenges are those employed in the technologies that enable green growth, such as solar photovoltaics, batteries, electric vehicle motors, wind turbines and fuel cells. The COVID-19 pandemic has led to supply chain disruptions that might further increase the risk to supply.

High levels of import reliance can specifically threaten the security of supply when major global producers apply restrictions to trade, e.g. export restrictions (indicator 10), and when production is highly concentrated in countries with low levels of governance (indicator 9). In the latter cases, responsible sourcing of materials (indicator 25) becomes essential, since importing materials often implies shifting social and environmental burdens to non-EU countries.

Import reliance does not necessarily constitute a risk to security of supply, as long as there is significant diversification in trade partners. Import reliance can be reduced by following different strategies, for instance boosting domestic minerals exploration (indicator 3) and domestic production (indicator 6) or increasing the supply of materials from recycling (indicator 15).

Import reliance is directly connected to self-sufficiency[162], an indicator included in the European Commission's 2018 monitoring framework for the circular economy[163].

Facts and figures

Figure 8.1 shows import reliance over time for three raw material categories (timber (industrial roundwood), metal ores, and non-metallic minerals). It highlights that the EU is import-reliant on metal ores, although to a smaller extent than during the period before the 2008 financial crisis. This is explained by the increase in domestic production over the last decade, to a greater extent than the increase in net imports (imports minus exports). From 2008-2018, the most recent year for which statistics are available, import reliance for metal ores ranged between 30% and 40% and stabilised over the last three of these years. Figure 8.1 also highlights that the EU is self-sufficient for non-metallic minerals, and becoming almost completely self-sufficient for timber (industrial roundwood).

Figure 8.1: Import reliance by material category (EU-27, 2000-2018)[164].

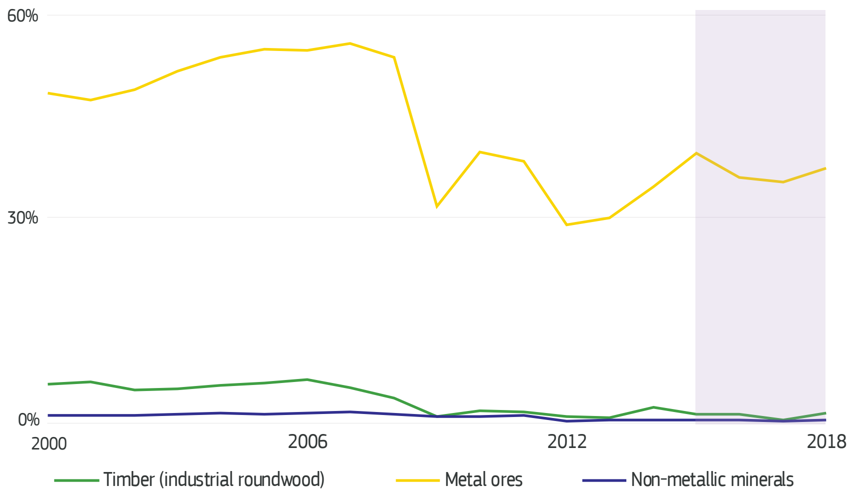
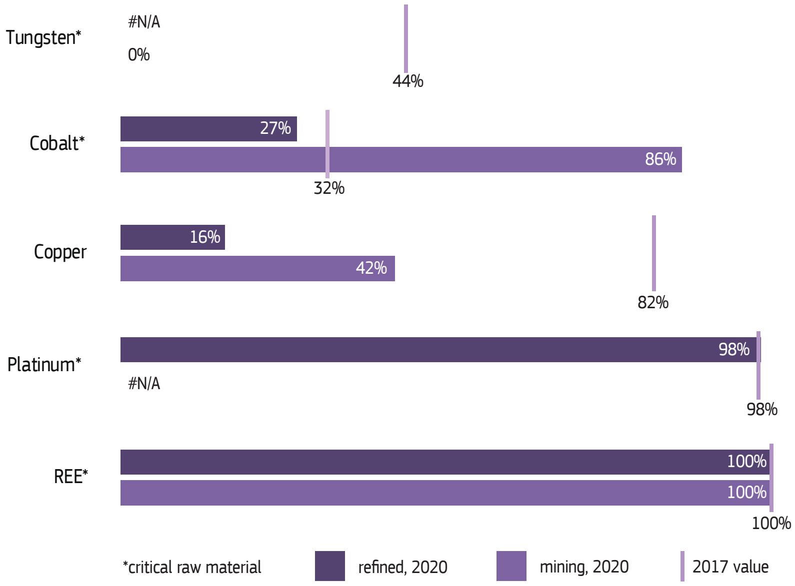


Figure 8.2 presents the EU import reliance for five raw materials: tungsten, cobalt, copper, platinum and the rare earth elements (REE) group[165]. These were selected, as explained in the introduction, for their particular relevance to specific industrial ecosystems: defence, space, emobility, construction, digital and renewables. Data shown are from the 2017 and 2020 criticality studies. For the 2020 study, import reliance at both mining and refining stage is displayed whenever available[166].

Figure 8.2 shows that import reliance can be very mixed for different materials and stages in the value chain. For tungsten, import reliance is zero at mining stage. The EU is a net exporter of tungsten ores and concentrates, thereby completely self-sufficient, and therefore import reliance can be considered to be zero. This represents an improvement on the situation in 2017 (highlighted in the 2018 Scoreboard), when import reliance was 44%. At the processing stage, import reliance of tungsten could not be assessed properly mainly due to data incompleteness and confidentiality. Despite the current self-sufficiency for tungsten ores, some factors can put tungsten supply at risk. One example is the high concentration of smelters globally, for which China is the most important. Another stems from various export restrictions covering 93.8% of the global production of tungsten concentrates[167] (see indicator 10). The EU is a large consumer of tungsten, the second largest globally after China. Tungsten is used for a wide range of applications, mainly in the production of hard materials based on tungsten/cemented carbides.

Import reliance for cobalt varies across the value chain. For cobalt ores and concentrates, EU import reliance is estimated at 86%. This is considerably higher than the estimations contained in the previous edition of the Scoreboard[168], but results are not comparable due to methodological adjustments[169]. Supply of cobalt at the mining stage is likely to remain challenging in the future, especially due to the significant concentration of supply in the Democratic Republic of the Congo (DRC), a country with unethical practices in artisanal mining. In fact, cobalt ores, concentrates and intermediates are sourced mainly from the DRC (68% of EU sourcing) and only in part from domestic production in Finland (14% of EU sourcing).

Figure 8.2: Import reliance for selected raw materials[170].



By contrast, EU import reliance for refined cobalt is 27%. This relatively low value is explained by the fact that refined cobalt mainly originates from domestic production in Finland (54% of EU sourcing) and Belgium (7% of EU sourcing). Despite the rising trend in global production of cobalt at both mining and refining stages, keeping pace with the strong demand for cobalt in rechargeable batteries remains challenging[171].

Import reliance for copper also varies across the value chain. For copper ores, EU import reliance is 42%. This is considerably lower than in the 2018 Scoreboard, again, as for cobalt, due to improvements in the methodology[172]. For refined copper, import reliance is 16%. Copper is the most used heavy non-ferrous metal and it has a wide range of applications, for example in the production of energy-efficient power circuits and infrastructure construction.

The EU is heavily reliant on platinum imports. Import reliance for platinum in unwrought or in powder form is 98%, excluding consumption of refined platinum metal originating from secondary materials (which is produced domestically). Import reliance has been assessed only at processing (metallurgical) stage and the value remained unchanged as compared with the 2018 Scoreboard. Platinum in unwrought or powder form is sourced mainly from South Africa (42% of total imports) and the United Kingdom (25% of total imports). Platinum is critical for its use in autocatalysts, which accounts for 75% of EU platinum demand. It is also used in computer chips and motherboards, as well as in hydrogen fuel cells.

Since there is no European extraction of rare earth elements[173] (REE) at all, the EU is 100% reliant on REE imports. These are also the materials with the highest supply risk[174], which arises from several factors. These include a very high concentration of global production in China (around 70% of the global market of REE ores[175]), a lack of diversification in EU sourcing[176], and trade barriers to exports applied by China[177] (see indicator 10). Rare earth elements are used in many applications, such as high performance magnets, and in general they lack substitutes with comparable cost and technical performance.

Conclusion

EU reliance on imports varies greatly, not only by raw material, but also by its stage of processing. As in the case of cobalt and copper, the EU might have low import reliance in terms of refined material but it has considerably higher import reliance at the mining stage.

A high level of import reliance does not automatically imply low security of supply – a well-diversified supply and trade network significantly lowers supply risk.

With the Raw Materials Initiative of 2008 and the 2020 Communication *Critical Raw Materials Resilience: charting a path towards greater security and sustainability178,* the European Commission proposed a strategy to increase EU security of supply by diversifying international and domestic sourcing and by promoting supply of secondary raw materials from European sources. Innovation, both from the public and private sector, plays a key role in reaching this goal and is especially fragile due to the supplementary challenges induced by the current pandemic. Thus, as part of the European Union's response to the COVID-19 pandemic, in May 2020, EIT RawMaterials launched a booster call to support start-ups, scale-ups and SMEs[179].

9. Geographical concentration and governance

Key points:

- The global production of raw materials continues to be highly concentrated in a few nonEU countries.
- Many raw materials supplied to the EU come from countries with low standards of governance.
- The high supply concentration of raw materials may take place at different stages in the production chain.

Overview and context

Governance can be monitored by reviewing changes in a country's political and economic stability. In particular, as is the case for the information used in the present analysis, it can measure the process by which governments are selected, monitored and replaced, the capacity of the government to effectively formulate and implement sound policies, and the respect of citizens and the state for the institutions that govern their economic and social interactions[180].

The EU's critical raw materials methodology uses information on the governance level of countries producing raw materials to assess the supply risk of materials. This methodology views the supply risk in terms of both global supply (see also indicator 7) and of materials supplied to the EU[181]. While the global supply profile of a material reflects the share of the major countries producing raw materials, its EU sourcing profile points to the countries from which the EU obtains raw materials.

For a proper assessment of supply risk, it is important to consider that the risk may occur at different stages in the supply chain of raw materials (extraction, processing, etc.) Indeed, supply risk values may vary strongly for the different supply chain stages of a specific material. In this context, the EU critical raw materials assessment[182] identifies 'supply bottlenecks', i.e. where the material supply risk is estimated to be higher.

In addition, the EU may also face a higher risk to fulfil its demand for raw materials as it is highly dependent on imports from other countries (indicator 8).

Facts and figures

Figure 9.1 shows the supply concentration for a broad selection of raw materials[183] and the governance level of their producing countries. Specifically, the figure displays the share of global supply (upper bars) and the share of supply to the EU (lower bars). The colour assigned to each country reflects its governance level, based on the Worldwide Governance Indicators[184] (WGI). Raw materials for which supply risk occurs at processing stage are highlighted in blue; for the remaining materials, the extraction stage is considered. In line with the 2020 criticality assessment, the supply stage presented and the critical materials list have changed in comparison with the 2018 Scoreboard[185]. Also, some data limitations apply[186].

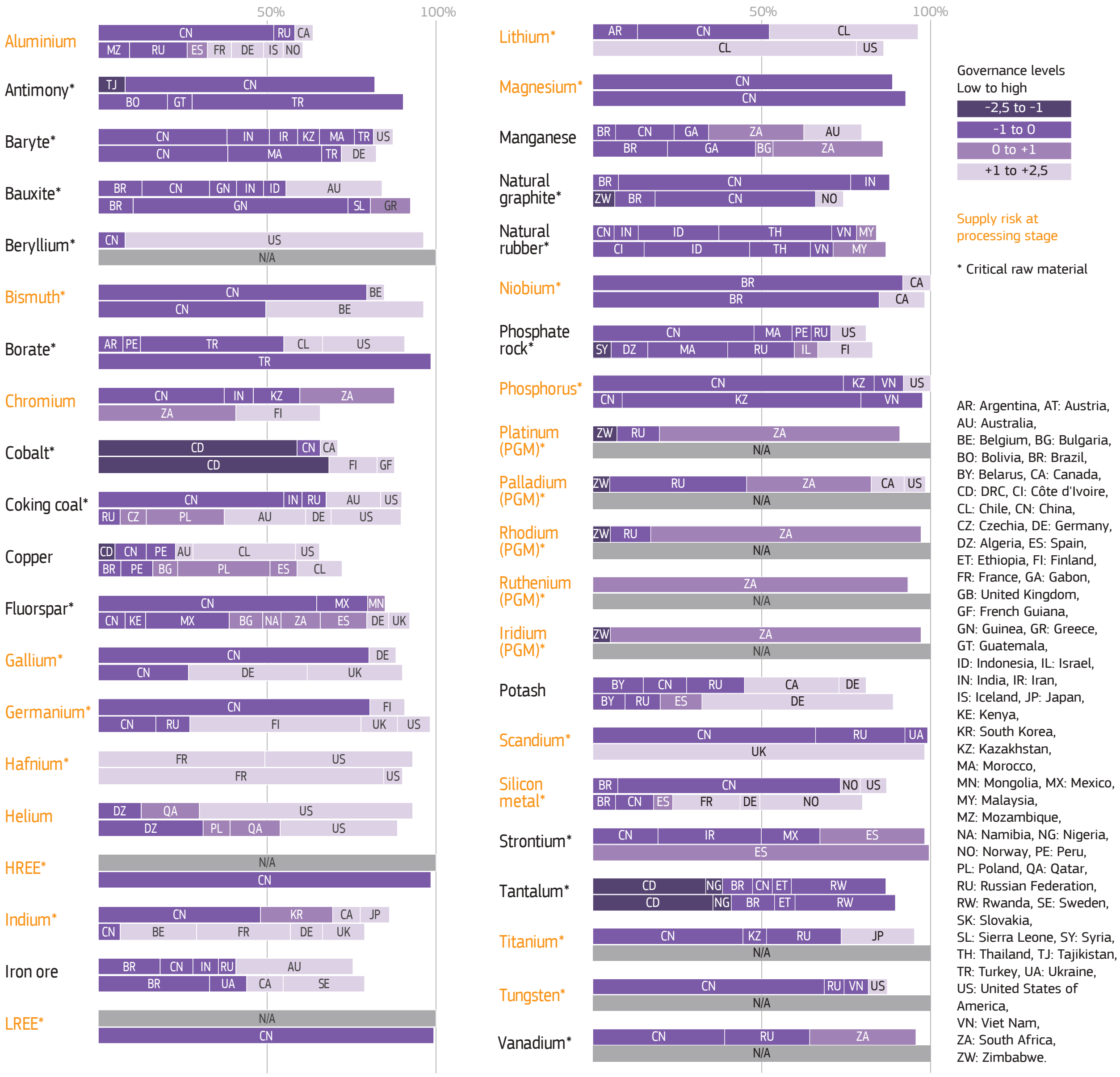
The figure shows the same picture as in the 2018 Scoreboard for most of the major producing countries globally, for suppliers to the EU and for governance levels. This means that the global supply and EU sourcing of most of the materials in Figure 9.1 are still mostly associated with countries with relatively low governance levels.

At extraction stage, cobalt and tantalum are examples of materials where the global supply and EU sourcing are concentrated in nations with low to the lowest levels of governance, according to the WGI classification. At processing stage, a very high concentration of supply is observed for heavy and light rare earth elements, in terms of EU sourcing. The processing capacity of these raw materials is thought to be exclusively owned by China, making it the major player in the global market.

The figure also reflects that the supply to the EU may come from nations other than the major global suppliers, for example in the case of silicon metal and scandium at processing stage. While silicon metal and scandium production are highly concentrated in China, the EU sources most of its silicon metal from Norway and scandium from the United Kingdom, countries with higher governance levels.

Figure 9.1 also shows that the EU only supplies a limited number of raw materials domestically, for example hafnium and potash.

Figure 9.1: Geographical concentration of global production (upper bar for each material) and supply to the EU-27 (lower bars) (average 2012-2016) and the corresponding governance level in producing countries (2016)[187].



Conclusion

The global production of raw materials remains concentrated in countries with low governance levels. The EU sources many of its raw materials from countries with low governance levels, posing a higher risk of possible supply disruptions, either at extraction or processing stage.

The EU Raw Materials Initiative, and more recently the Action Plan on Critical Raw Materials, sets out a strategy to secure access to raw materials supply from global markets, within the EU and from secondary sources. The strategy includes raw materials diplomacy to ensure sustainable access to raw materials from global markets, complemented by, for example, a responsible sourcing policy such as the Conflict Minerals Regulation[188] and sustainable and responsible mining practices and transparency[189]. Within the EU, securing the right legal and regulatory conditions[190] may improve domestic sourcing. Improving the availability of secondary raw materials is the third pillar of the strategy. The EU circular economy action plans[191] aim to contribute to greater recycling and re-use, leading to the increase of secondary raw materials supply.

10. Export restrictions

Key points:

- Several changes in the use of export-restricting measures, such as prohibitions, quotas, and taxes, took place worldwide over the period 2009-2017.
- Nevertheless, the total number of industrial commodities affected by all 13 types of export restrictions remained quite constant.
- Of the five strategic materials analysed, three of them (cobalt, rare earths and tungsten) saw their share of global production affected by export restrictions reaching more than 70%.

Overview and context

Supplier countries of raw materials can impose restrictions on exports of minerals and metals[192] to meet various political objectives: promoting their domestic processing industries; generating tax revenues; reducing depletion of natural resources, etc. The continuing growth in global demand for metals and non-metallic minerals[193] could further push raw materials exporters to increasingly make use of export restrictions to secure local supply.

On the other hand, export-restricting measures might distort competition on global markets by boosting the price of commodities. Such distortions may be brought about by export taxes and charges, or by reducing the overall quantity supplied on global markets through the imposition of export quotas or bans. This is often done for the benefit of domestic industries and has serious consequences for countries with high import dependencies, such as the EU. Export restrictions might also cause global shortages of raw materials.

The case of China and rare earths provides a clear illustration of the impact of supply disruptions for economies relying massively on imports. Since the world production of rare earths is almost entirely concentrated in China, several countries depend on China for its supply. China maintained severe export restrictions on rare earths in 2006-2015, peaking in 2010. These export restrictions resulted in global concerns about security of supply and very significant price hikes of rare earths. They were only removed in 2015 after a ruling by the WTO Appellate Body in a case brought by the United States in 2012, subsequently joined by the EU, Japan and other countries. More recently, there were leaks in the media suggesting that China could again use its policy intervention to control the supply of rare earths, as a response to the escalating trade conflict with the United States[194], which is heavily reliant on China's exports of rare earths. The subsequent supply shortages can severely affect downstream industries, such as the automotive and high-technology sectors[195]. That is why importing countries often seek to expand their domestic production capacity and diversify their raw materials provision.

The EU does not impose restrictions on its exports of industrial raw materials. The EU also requests that its trade partners remove any such restrictions via trade negotiations (including by tabling a dedicated chapter on energy and raw materials in free trade agreements) and through its market access strategy, in order to ensure undistorted and rules-based international trade in raw materials.

Facts and figures

Figure 10.1 presents the number of industrial commodities affected by worldwide export restrictions by type of restriction over the period 2009-2017. The annual figures are calculated by counting the commodities (identified by HS 6-digit[196]) affected by each of the 13 types of measure that were imposed in a certain year by the 73 countries covered in the OECD's Inventory of Export Restrictions on Industrial Raw Materials. Except for some limited product or country exemptions, most export restrictions have a global reach.

Despite some fluctuations, the total annual number of HS 6-digit commodities concerned by all 13 types of restriction stayed more or less the same over the period analysed: from 1 310 commodities in 2009 to 1 350 in 2017.

While the annual number of industrial commodities affected by export taxes and export quotas decreased over the period 2009-2017, more commodities were restricted by export prohibitions, customs restrictions, qualified exporter lists and fiscal taxes.

Figure 10.1: Total number of (HS 6-digit) industrial commodities affected by export restrictions worldwide, by year and type of measure (2009-2017)[197].

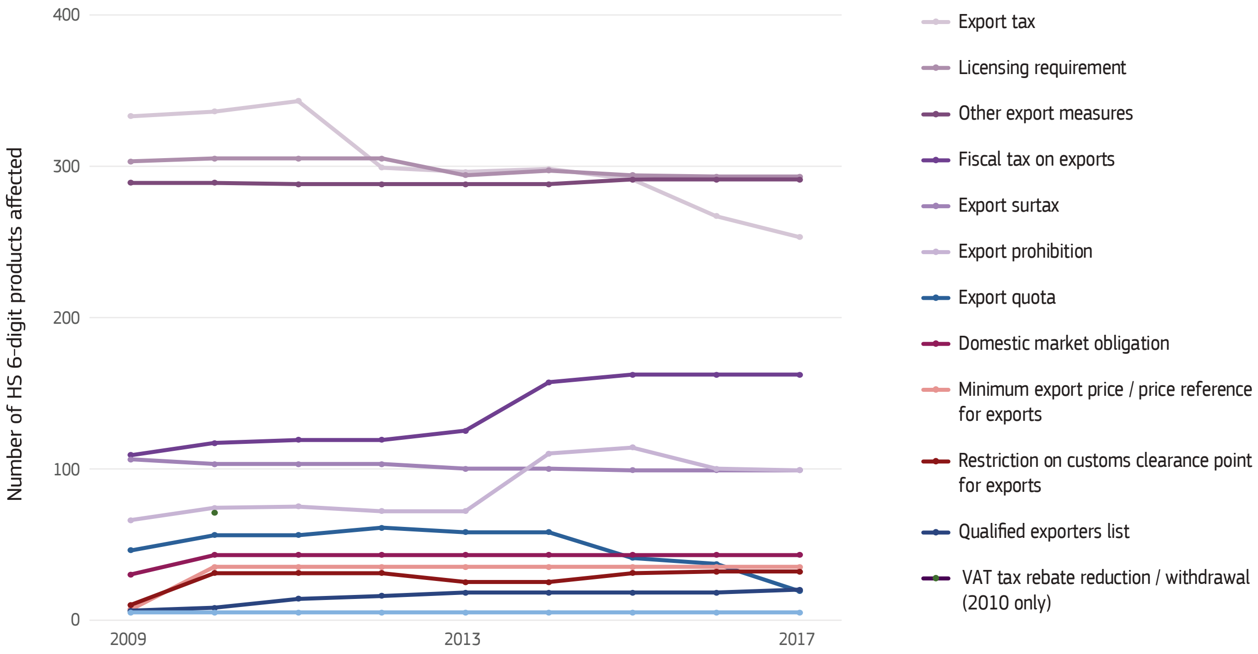


Figure 10.2 presents the proportion of global production subject to export restrictions in 2017 and also in 2014 (i.e. the reference year in the 2018 Scoreboard), 2017 and 2018 for a selection of primary raw materials. A raw material is considered subject to export restrictions if at least one of the 13 export-restricting measures taken into account was in place in the producing countries. The selected materials are identified as strategic to the EU, and include cobalt, copper, platinum, rare earths and tungsten. For each of these materials, only the commodities corresponding to the first processing stage – i.e. metal ores and minerals – were taken into account.

As shown in Figure 10.2, the share of global production affected by export restrictions was higher than 70% for cobalt, rare earth elements and tungsten. In 2018, China applied export restrictions on three out of five of the selected materials: platinum, rare earth minerals and tungsten ores and concentrates. As far as tungsten is concerned, four of the largest producing countries – China (with a global production share of more than 80%), Vietnam, Russia and Bolivia – imposed restrictions on tungsten exports.

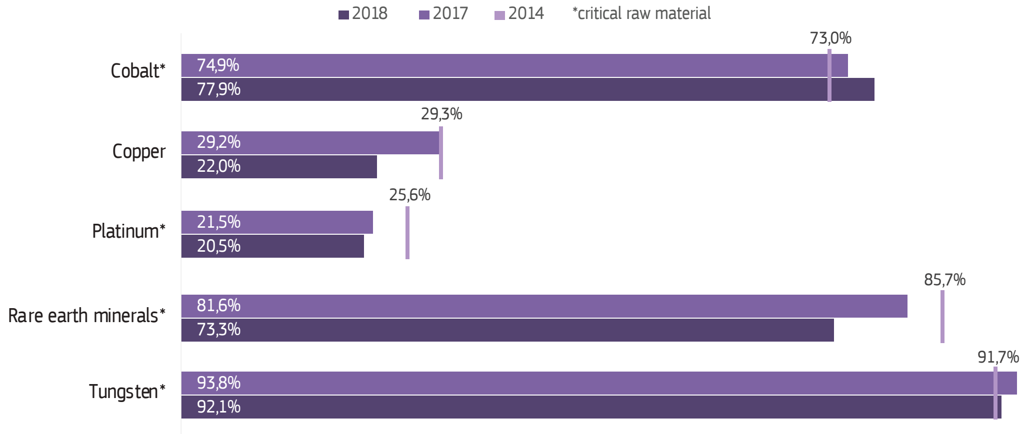
Conclusion

Despite a change in the use of measures (such as export prohibitions, quotas, taxes, etc.) used around the world to restrict exports of raw materials over the period 2009-2017, the total number of industrial commodities affected by all 13 types of measure remained quite constant.

For three of the five strategic raw materials analysed, the share of global production affected by export restrictions remains substantial (i.e. higher than 70%).

Through its trade agreements and market access strategy, the EU continues to insist on removal or reduction of export duties, taxes, or other charges imposed on some industrial raw materials, and of any market distortions.

Figure 10.2: Share of global primary production of five selected raw materials subject to export restrictions (world, 2014, 2017, and 2018)[198].



11. Trade in waste and scrap

Key points:

- The EU is currently a net exporter of waste 'iron and steel', 'copper, aluminium and nickel' and 'paper and cardboard', whereas it is a net importer of 'precious metals' waste.
- Iron and steel was the most traded waste by mass in 2019 (almost 16 million tonnes exported to non-EU countries), followed by paper and cardboard (6 million tonnes exported).
- Exports of paper and cardboard waste in the last 2 years have been largely affected by import restrictions by non-EU countries.

Overview and context

Waste and scrap are a production source of secondary raw materials, which can be used to meet countries' demand for materials (see indicator 15). Secondary materials are generally characterised by lower environmental impacts compared with primary ones, for example concerning carbon footprint[199]. An amount of waste does not necessarily correspond to an equivalent amount of secondary raw materials, since the quality and quantity of the secondary raw materials produced depend on the efficiency of the recycling processes. Since detailed statistics for secondary raw materials are not available, 'waste stream' flows can be used as a proxy. With the same approach, the 'trade in recyclable raw materials' indicator is one of those included in the circular economy monitoring framework[200].

The treatment of waste in a country depends on various factors, such as the availability and capacity of recycling infrastructures and the cost of recycling versus the price of secondary raw materials. High local recycling costs and/or low price of secondary raw materials can incentivise waste trade. Exporting waste to non-EU countries means that resources leave the EU, representing a potential loss of valuable materials and affecting the circularity of the European economy (see indicators 12 and 15). At the same time, if applicable rules for waste shipment and waste management (see indicator 13) are respected, international waste trade driven by supply and demand is a natural and legitimate phenomenon.

Imports and exports of waste and scrap are also affected by EU policies[201] and by trade restrictions introduced in foreign countries. For example, China introduced a ban on the import of plastic and paper scrap in 2017, which required the EU recycling sector to adapt[202].

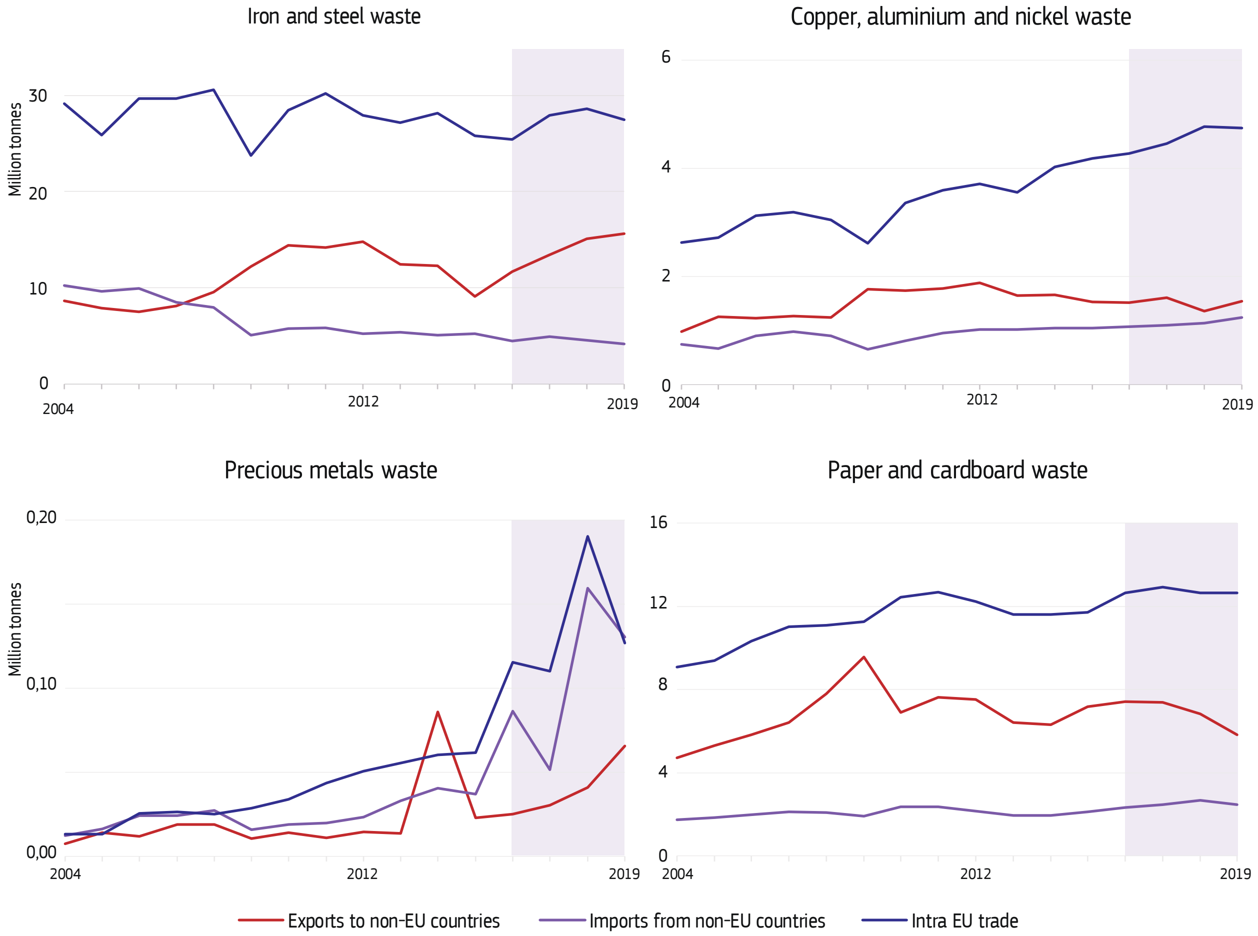
Since China introduced the ban, neighbouring Asian countries and some African countries have become increasingly targeted by shippers of illegal waste. Due to its intrinsic illegal nature, this is a little-known phenomenon, which is assumed to have potential negative consequences for human health and the environment, beyond financing criminal organisations[203]. There is still not enough available data to get a clear picture of illicit international waste flows. Developing dedicated international databases (e.g. on seizures) and enhancing border control can, in the future, make it possible to identify and fight waste trafficking[204]. Having dedicated data on secondary raw materials, not only on import and export of waste and scrap, could also contribute to improving the monitoring.

Facts and figures

Figure 11.1 shows EU trade (EU imports, EU exports and intra-EU trade) of some relevant waste and scrap flows, such as 'iron and steel', 'paper and cardboard', 'copper, aluminium and nickel' and 'precious metals', during the 2004-2019 period. This waste originates from a wide range of sectors (e.g. transport, construction and building, packaging, batteries, consumable and household appliances). These waste streams also include some critical raw materials for the EU (e.g. platinum group metals in e-waste and rare earth elements in electric motors), and metals that are crucial for strategic sectors (e.g. nickel, which is expected to become more and more relevant for the battery sector[205]).

Total net exports (i.e. total exports minus total imports) to non-EU countries of these four types of waste (as in Figure 11.1) grew significantly compared with two decades ago: in 2019, net exports were 15 million tonnes, around nine times higher than in 2004. Compared with 2016, overall net exports grew by 18%. The increase in waste trade over that period was driven by a number of potential factors, including: (i) high prices for scrap in combination with low transportation costs; (ii) increasing external demand for materials; and (iii) uneven distribution of recycling capacity among EU and non-EU countries[206]. On the other hand, collection and recycling policies and targets set in EU waste directives were discouraging waste movement for disposal (although their effects are difficult to assess).

Figure 11.1: Trade of selected waste and scraps — 'iron and steel', 'paper and cardboard', 'copper, aluminium and nickel' and 'precious metals' (EU-27, 2004-2019)[207].



Among recyclable waste types, 'iron and steel' was the most traded in terms of mass. The EU exported about 16 million tonnes to the rest of the world in 2019, while about 4 million tonnes were imported, and about 27 million tonnes were traded within the EU. Between 2016 and 2019, EU exports to non-EU countries of 'iron and steel' waste increased by 34%, while imports remained almost stable.

Between 2004 and 2019, net exports of 'paper and cardboard' waste grew by 13%. Due to the introduction of Chinese bans on waste imports, exports of 'paper and cardboard' waste from the EU to China suddenly halved after 2017. At the same time, EU exports of such waste towards other non-EU countries increased. The absence of end markets for waste paper in 2018 and 2019 has resulted in a sharp decline in recovered paper prices (i.e. the price in 2019 was a quarter of the 2017 price).

As for 'copper, aluminium and nickel' waste, net exports to non-EU countries steadily decreased from 2012, halving between 2016 and 2019. Over the same period, intra-EU trade increased instead. Such trends might be related to an increase in the price of these metals and to the increased attention given to scrap recycling in the EU.

Since 2004, the EU has mainly been a net importer of 'precious metals' waste (i.e. we import more than we export). This waste stream is particularly dependent on the flows of silver scrap, which represent the highest fraction of mass. Trade in this type of waste also fluctuates greatly over time, probably arising from price changes in commodities.

Similar to China, other countries (such as Malaysia, Thailand and Vietnam) have already introduced, or are planning, restrictions to imports of some types of waste (e.g. plastic waste). In the short term, this could represent a challenge for the EU, since not all Member States currently have the capacity to properly manage these waste streams. Moreover, while trade restrictions could encourage the development of EU recycling capacity, they could also act as an incentive for illegal waste trafficking.

Figure 11.2: Trade of selected waste and scrap (in volume and value) – exports to non-EU countries and imports from non-EU countries (EU-27, 2019)[208].

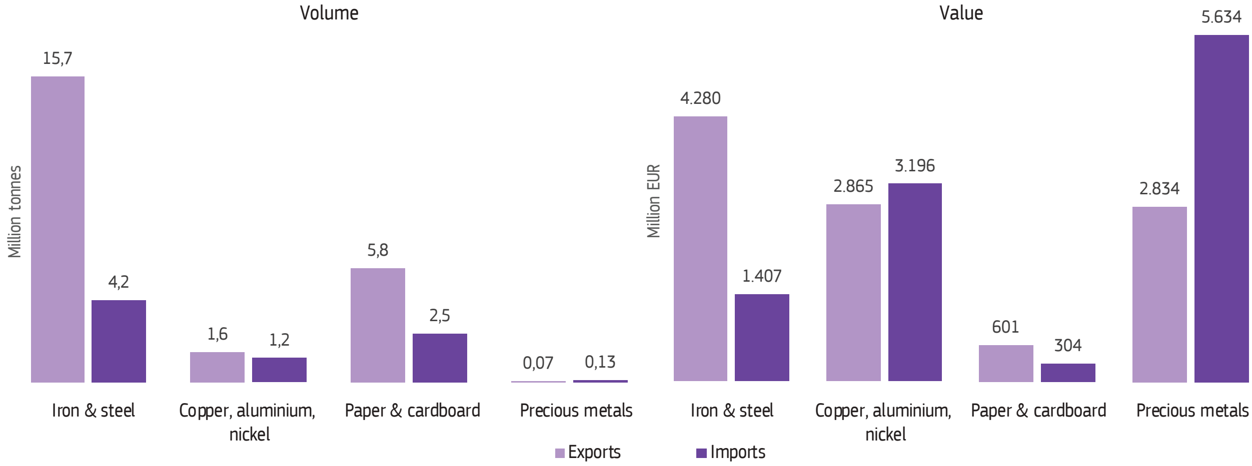


Figure 11.2 presents trade in selected types of waste and scraps in 2019, measured by trade volume and value. 'Iron and steel' waste was the most traded material, by both volume and value of exports. However, while 'precious metals' were negligible in terms of mass flows, they were the most important flow in terms of import value, and very relevant even in terms of exports. Compared with 2016, the import value of 'precious metal' scrap rose by almost 90%, while that of 'copper, aluminium and nickel' rose by 30%. On the other hand, 'paper and cardboard' waste was traded significantly more than 'copper, aluminium and nickel' and 'precious metals' waste in terms of mass, but had a lower trade value as a consequence of recent trade bans. Trade flows of waste were also influenced by changes in the prices of both scrap and primary materials. This implies that coupling mass-based indicators for waste with economic values can help to better capture the complexity of waste management (see also indicator 13).

Conclusion

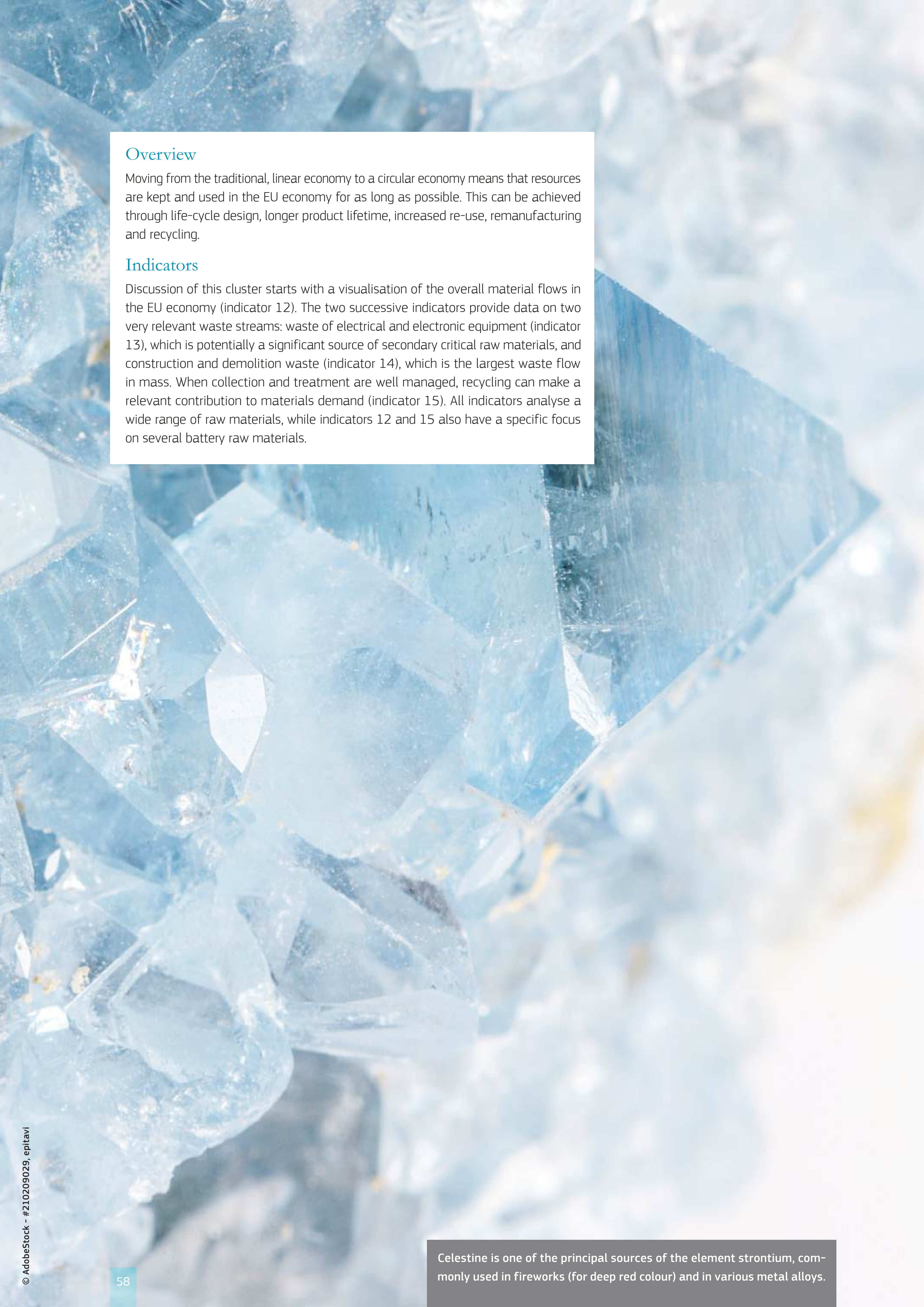
The EU exports a significant amount of waste that is potentially recyclable into secondary raw materials. If applicable rules for waste shipment and waste management are respected, such exports, driven by supply and demand, are a natural and legitimate phenomenon. At the same time, they represent a loss of raw materials for the EU. Compared with 2016, net exports of 'iron and steel' waste increased by almost 60%, whereas for 'copper, aluminium and nickel' and 'paper and cardboard' net exports decreased by almost 30%. For 'precious metals', they remained almost constant. Relying too heavily on exports and treatment of waste outside the EU has proved risky. In particular, the introduction by non-EU countries of restrictions on waste trade (especially on waste 'plastic' and 'paper and cardboard') poses certain challenges to waste management in the EU itself. These effects, for example, include flooding the EU with large amounts of paper scraps that Member States are currently not able to cope with, either because handling them exceeds the capacity of the recycling facilities or because it is not economically viable.

Overview

Moving from the traditional, linear economy to a circular economy means that resources are kept and used in the EU economy for as long as possible. This can be achieved through life-cycle design, longer product lifetime, increased re-use, remanufacturing and recycling.

Indicators

Discussion of this cluster starts with a visualisation of the overall material flows in the EU economy (indicator 12). The two successive indicators provide data on two very relevant waste streams: waste of electrical and electronic equipment (indicator 13), which is potentially a significant source of secondary critical raw materials, and construction and demolition waste (indicator 14), which is the largest waste flow in mass. When collection and treatment are well managed, recycling can make a relevant contribution to materials demand (indicator 15). All indicators analyse a wide range of raw materials, while indicators 12 and 15 also have a specific focus on several battery raw materials.



Celestine is one of the principal sources of the element strontium, commonly used in fireworks (for deep red colour) and in various metal alloys.

Circular economy and recycling

Indicators

12. Material flows in the circular economy

13. Management of waste of electrical and electronic equipment (WEEE)

14. Construction and demolition waste

15. Recycling's contribution to meeting materials demand

SCOREBOARD

Raw materials supply in the EU:
6. Domestic production

Raw materials in the global context:
8. Import reliance, 11. Trade in waste and scraps

Competitiveness and innovation:
16. Value added, 19. Patent applications

Environmental dimension:
21. Greenhouse gas emissions, 22. Particulate matter and NMVOC emissions

Social dimension: 27. Jobs

EU self-sufficiency for raw materials;
end-of-life recycling input rates (EOL-RIR);
recycling rate of e-waste;
recovery rate of construction and demolition waste;
contribution of recycled materials to raw materials demand

12. Material flows in the circular economy

Key points:

- Non-metallic minerals (in particular construction materials) take up the highest share of the EU's domestic production and material use. The main final applications of fossil energy materials/carriers and biomass are in energy production.
- In 2017, recycling and backfilling of non-metallic minerals provided more than 8% of the total input of raw materials to the economy.
- 34% of the EU's raw materials inputs enter long-living in-use stocks each year. These stocks become available for recycling only after several years and even decades.

Overview and context

Circular economy is defined as a state in which 'the value of products, materials, and resources is maintained in the economy for as long as possible, and the generation of waste is minimised'[209]. The European Commission first adopted an action plan to support its circular economy ambition in 2015. To further boost the EU transition towards circular economy, a second circular economy action plan[210] followed in 2020 and aimed to ensure that the resources used are kept in the EU economy for as long as possible.

A material flow analysis (MFA) provides a comprehensive dataset used to quantify the amount of materials flowing in and out of the economy and to monitor material use in society including recycling loops and quantities that are accumulated in stocks, which together can be used to determine their level of circularity. In the context of circular economic policies, MFA can be a crucial tool in providing the necessary information for decisions related to the development of circular economy in the EU. The Commission's 2018 circular economy package includes a monitoring framework to measure progress towards a circular economy at both EU and national level. This monitoring framework consists of material flow visualisations and a set of 10 key indicators that cover each phase of a raw material's life cycle and the related economic aspects.

The Commission also started to develop material system analysis (MSA) studies focusing on individual (critical) raw materials. An MSA is a particular type of MFA, using specific boundary conditions within the geographical scope of the European Union. MSA studies can also be used to infer conclusions related to the circularity of specific materials used in the EU. This indicator presents an MFA of the EU economy and an example of an MSA (cobalt).

One effective illustration of the circular economy at macro level is a Sankey diagram of material flows[211], which provides, for a given year, a representation of how materials flow in the economy from import and extraction over to production, use and then waste and re-use (recycling and backfilling). The Sankey visualisations here present material flows in the EU economy in different levels of aggregation: the overall material flows, material flows for specific material categories, and material flows for single materials. The three types of Sankey visualisations make it possible to infer the circularity of the EU economy and to calculate several indicators of the circular economy monitoring framework. Examples of such indicators include: (i) end-of-life recycling input rates (see also indicator 15); (ii) import reliance (see indicator 8); (iii) trade of secondary raw materials (see indicator 11); and (iv) recovery of construction and demolition waste (see indicator 14). Additionally, these visualisations also show what happens to resources extracted domestically (see indicators 3, 4 and 6) and how the EU is disposing of them or keeping them in the economy.

Facts and figures

Figure 12.1 shows the overall material flows through the EU economy in 2017. In line with the Commission's circular economy monitoring framework[212], the methodology differs slightly from that followed in the previous edition of the Scoreboard. The figure shows Eurostat data on material flows (inputs and outputs), including food and feed in the energetic use of biomass.

Figure 12.1 shows that in 2017 more than 67% (5.36 billion tonnes - Gt) of the mass of raw materials processed in the EU originated from domestic extraction, 21% (1.7 Gt) was imported and 12% arose from recycling and backfilling (0.72 Gt and 0.21 Gt, respectively). This level of circularity has remained constant since 2010[213]. At the same time, the EU increased its dependency on imports: in 2014, 20% of processed raw materials in the EU was imported, in comparison with 21% in 2017. However, such conclusions need to be handled with extreme care since the methodology and data sources were slightly adjusted compared to those used in the previous edition of the Scoreboard.

Of the 7.98 Gt of materials that were processed in the EU economy, 31% (2.49 Gt) were used for energy purposes, which implies a transformation into emissions to the atmosphere. 10% (0.77 Gt) were exported and 3% dissipated (0.26 Gt). Most important for the circular economy are the 56% (4.46 Gt) that were used as materials.

Short-lived products with a lifespan of less than one year were included in the 1.75 Gt that entered waste treatment flows in 2017, as were manufacturing losses. The remaining 61% (2.72 Gt), which mostly consist of construction minerals, were used to build up and maintain societal in-use stocks[214] (e.g. buildings, infrastructure and other goods with long lifespans). These stocks only become available for recycling once the long-life goods reach their end-of-life.

From the total end-of-life waste generated (1.75 Gt), 41% remained in the EU economy through recycling and 12% through backfilling (approximately 0.92 Gt in total). On the other hand, 3.31 Gt of materials left the economy e.g. as emissions to air and to water and waste disposal.

Figure 12.1: Material flows in the economy (EU-27, 2017)[216]

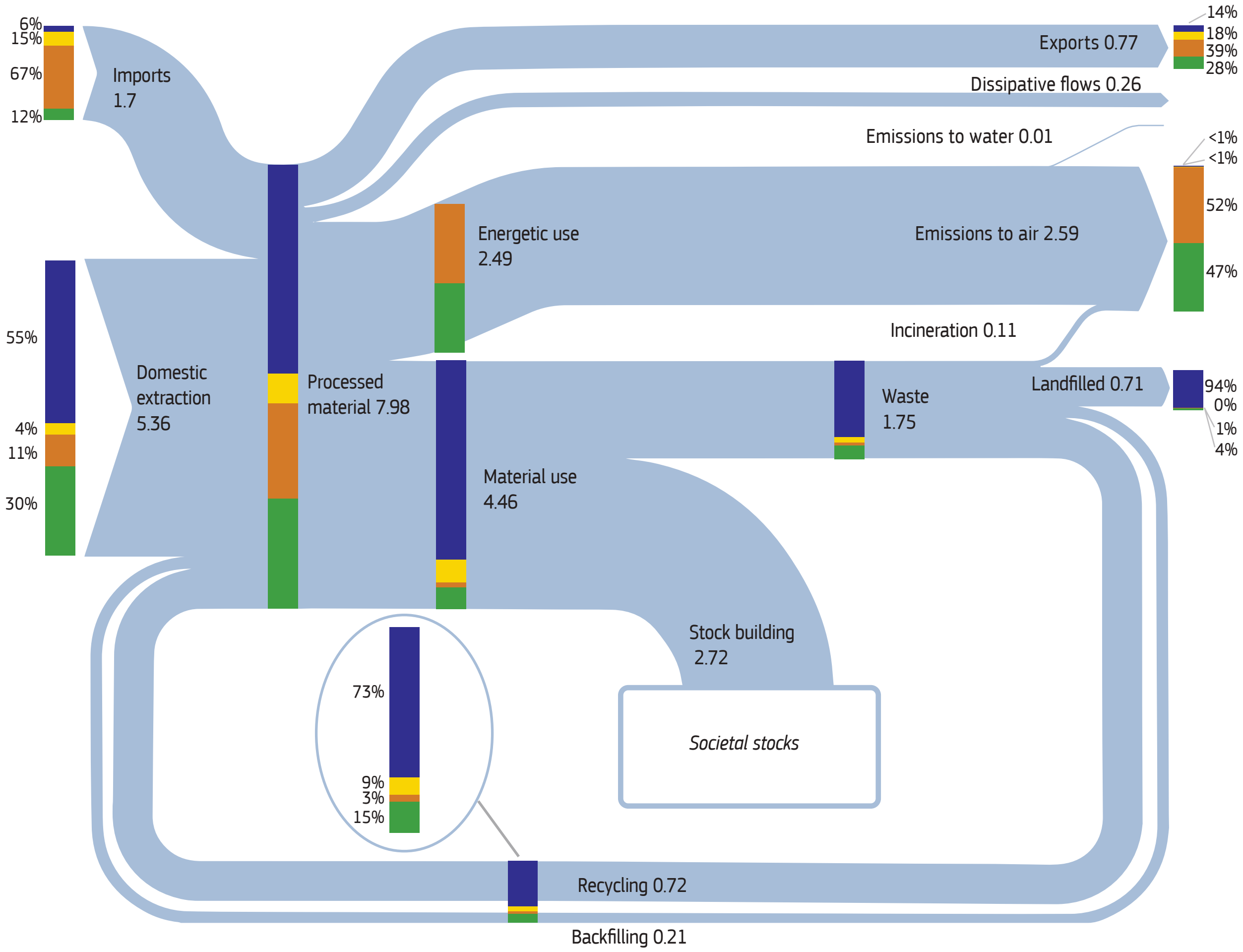
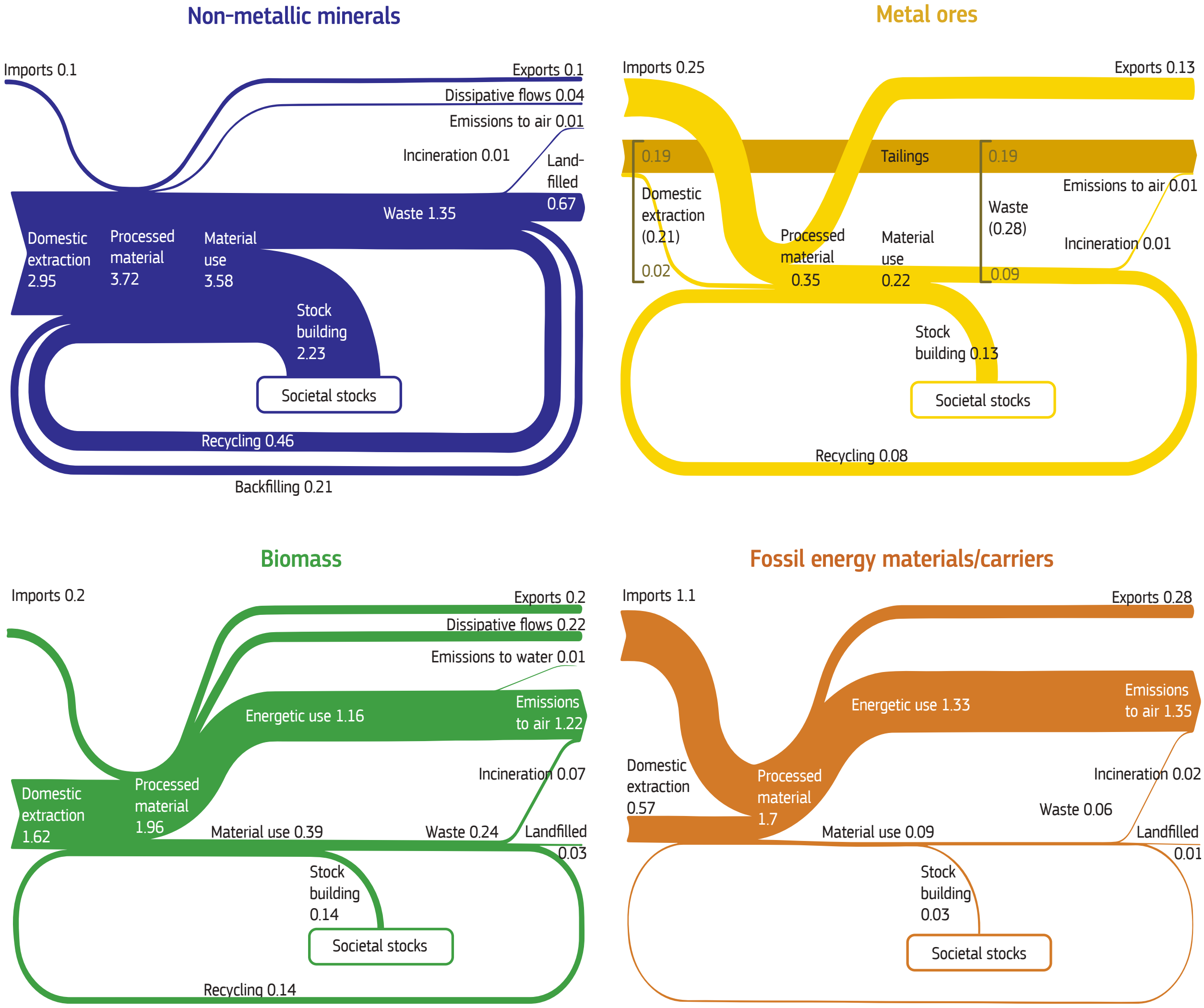


Figure 12.2: Material flows for single material categories in the EU economy (in billion tonnes/year) (EU-27, 2017)[217]



Based on the overall material flows described in Figure 12.1, Figure 12.2 provides disaggregated information on the flows of individual material categories in the EU.

Non-metallic minerals (top left) include construction minerals and industrial minerals. They represented the highest share of material processed in the EU (3.72 Gt), in terms of mass. After use, around 2.23 Gt were added to societal in-use stocks and around 1.35 Gt were collected for treatment. About 0.67 Gt of all non-metallic minerals were recovered (0.46 Gt through recycling and 0.21 Gt through backfilling), equivalent to 18% of all inputs. In 2017, the recycling and backfilling of non-metallic minerals alone provided more than 8% of the total input of raw materials to the EU economy.

Despite their high economic and strategic importance, metal ores (top right) only represented a minor proportion of the EU's material consumption in terms of mass. 46% of metals (0.25 Gt) came from imports. Domestic extraction was divided into pure metal (0.02 Gt) and extractive waste (0.19 Gt), which become end-of-life waste (typically accumulated in tailings). Domestic recycling accounted for 23% of metals processed in 2017 (0.08 Gt out of 0.35 Gt, excluding extractive waste). In 2017, 24% of processed metals were integrated into societal in-use stocks, and the same percentage was exported (0.13 Gt).

Similarly to 2014, in 2017 nearly one fourth of processed material in the EU was biomass (bottom left), most of which was wood from domestic extraction. About 7% (0.14 Gt) of processed biomass was secondary biomass from recycling (e.g. from paper recycling). Approximately 20% (0.39 Gt) of processed biomass was consumed for material uses such as pulp and paper production, construction, or manufacturing of other wood products (e.g. furniture). About 7% (0.14 Gt) of processed biomass was added to societal in-use stocks[215].

The majority of fossil energy materials/carriers (bottom right) were used for their energetic value. Less than 5% of processed fossil energy carriers were used as plastic, oils, tyres, or for chemical purposes — where carbon could be recovered at end-of-life. In fact, only 2% of the processed material was fed back into the economy as recycled materials.

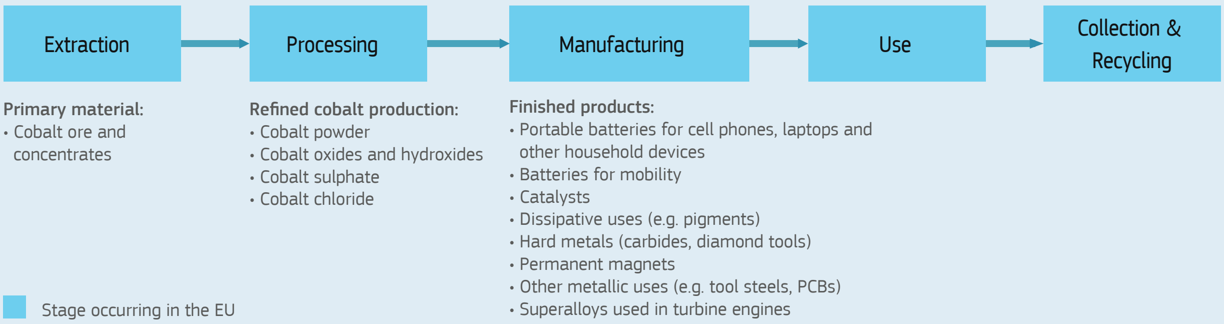
Material system analysis of a relevant critical raw material – cobalt

This box summarises the material flows of cobalt for the EU in 2016, calculated following the Commission's material system analysis (MSA) methodology[218]. This MSA study investigates the stocks and flows of cobalt through the EU economy along the overall supply chain, from extraction until end-of-life management.

Cobalt (Co) is a transition metal not abundant in the Earth's crust, and is part of the flows for metal ores described above in Figure 12.2. It is considered a critical raw material for the EU economy[219] and is a fundamental material for Li-ion battery technology, which is considered a strategic value chain for the EU. Moreover, cobalt is one of the four raw materials explicitly mentioned in the strategic action plan on batteries[220] as a priority raw material under the 'secure access raw materials' pillar.

Cobalt is mainly obtained as a by-product of nickel and copper, and it is usually concentrated at the extraction site before being traded. Figure 12.3 shows the value chain of cobalt, showing that there is capacity in the EU for processing cobalt in all its life-cycle stages.

Figure 12.3: Value chain of cobalt[221]



Cobalt flows and stocks

As shown in Figure 12.4, in 2016 3 kt Co in cobalt concentrates were extracted from domestic mines in Finland. At the same time, mining activities disposed of 0.7 kt Co in tailings. A total of 14 kt Co of refined cobalt were produced in Finland, Belgium and France in 2016. The rest of the input to the refining process was provided by: imports of primary, secondary, and semi-processed cobalt (Co intermediates) mainly from the Democratic Republic of Congo; and secondary cobalt from manufacturing and post-consumer scrap produced inside the EU (domestic scrap). Most of the domestic scrap corresponds to material recovered from post-consumer functional recycling; in the manufacturing phase most of the generated scrap was recycled in the manufacturing stage.

With the refined cobalt produced in the EU and imported cobalt, the EU industry manufactured various finished products containing around 24 kt of cobalt (see Figure 12.5).

Figure 12.4: Simplified Sankey diagram of the flows of cobalt in the EU (without the UK); imports of processed material include 10.3 kt of semi-processed material and 8.5 kt of processed material[222]

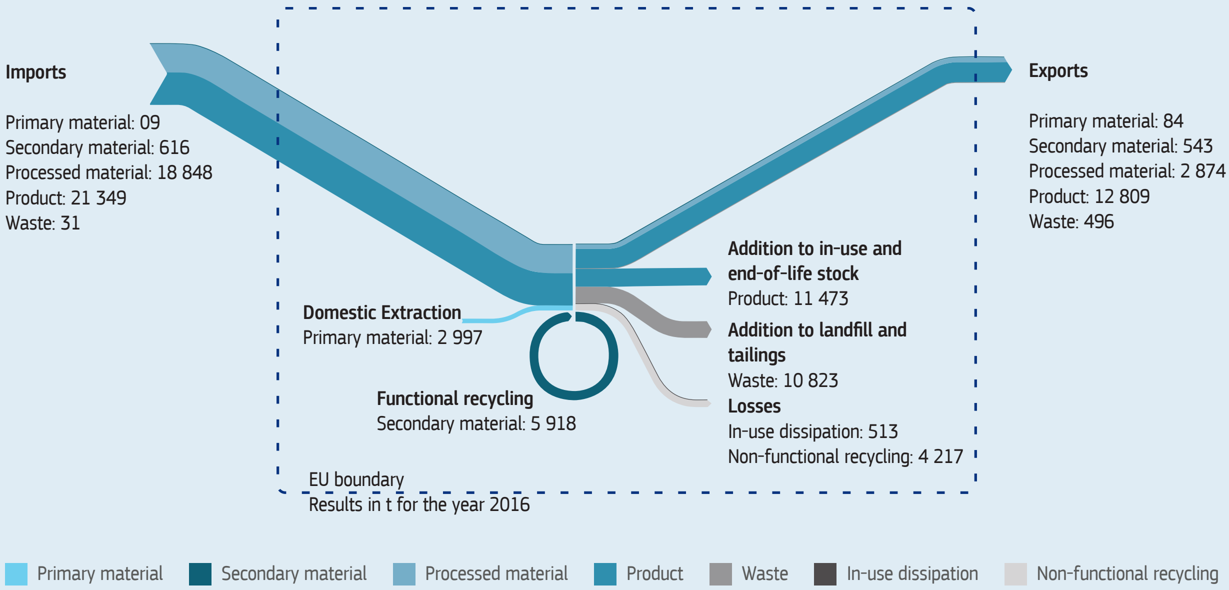


Figure 12.5: Shares of finished products containing cobalt manufactured in the EU (24 kt of Co) and other uses of cobalt in the EU manufacturing industry (left), and used in the EU (33 kt of Co) (right)[223]

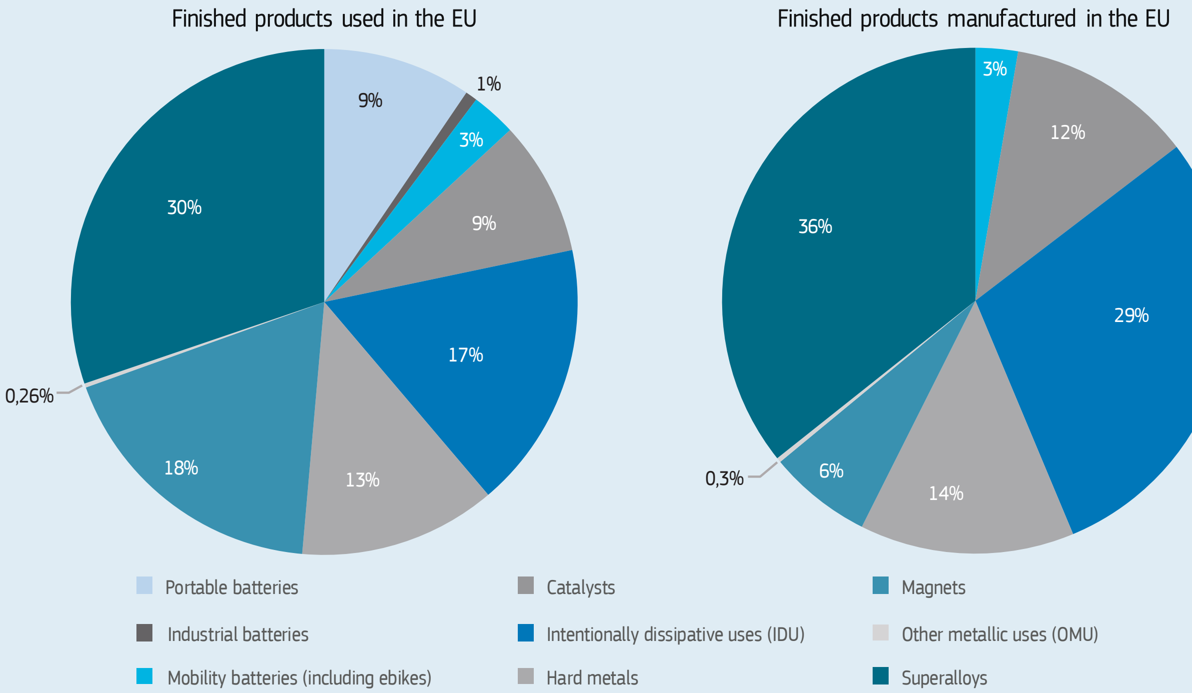


Figure 12.5 also shows that batteries account for 3% of EU manufacturing demand, mainly for the production of e-mobility batteries. In the use phase, 9% of cobalt consumed was embedded in portable batteries and smaller shares were used in mobility and industrial batteries (3% and 1%, respectively).

In 2016, the quantity entering the use stock each year was around 11.5 kt of cobalt (see Figure 12.4). This accounts for the annual addition to the in-use stock and the hibernating stock[224]. At the same time, in 2016, about 0.7 kt of cobalt left the stock as exports of products for re-use, 0.5 kt were dissipated in use (presented in Figure 12.4 as losses), and around 20 kt Co went to waste management.

Cobalt circular economy

Of the total amount of cobalt scrap collected (i.e. more than 20 kt Co), only 6.4 kt Co (considering also the secondary material exported) was functionally recycled in 2016. This results in a collection rate near 60% and in an end-of-life recycling rate (EOL-RR) of 32%. The resulting ratio of recycling from old scrap to European demand for cobalt in the manufacturing stage (end-of-life recycling input rate (EOL-RIR)) stands at 22% (see indicator 15). Note that Figure 12.4 shows that about 11 kt of cobalt-bearing scrap was wasted and considered as addition to landfill.

In order for the EU to increase the circularity of cobalt, it has to decrease: (i) cobalt losses in waste; (ii) downcycling, and; (iii) exports of recycled cobalt. Despite respectable end-of-life recycling rates in some applications (e.g. superalloys), other applications such as magnets and other alloys containing cobalt are predominantly recycled into stainless steel and the cobalt content is not recovered. Furthermore, there are applications from which cobalt cannot be recovered, for example pigments, glass, and paints.

Conclusion

Like in the analysis presented in the 2018 Scoreboard (2014 data), in 2017 the Sankey diagrams show that a large part of the EU's mass material use consists of construction materials, many of which are accumulated in long-living in-use stocks. The level of circularity varies by material and is the highest for metals.

The ratio between volumes of recycled material and the total material input to the EU economy has been stable for the last 7 years at 12%.

The EU economy's circularity could be improved further by: (i) decreasing dissipative uses; (ii) decreasing waste in the manufacturing and processing stages; (iii) increasing the re-use and recycling rates of materials (in production processes and products) whenever technically and economically feasible, and (iv) increasing the durability, reparability and upgradability of products that remain in in-use stocks.

Primary resource extraction would still be needed, even more when considering the huge quantities of speciality materials that are required for the low-carbon transition. This reinforces the necessity of improving both domestic materials extraction and the efficient use of resources in all stages of a material value chain.

13. Management of waste of electrical and electronic equipment (WEEE)

Key points:

- Around 3.7 million tonnes of waste electrical and electronic equipment (WEEE) were collected in 2017 in the EU, compared to 8.9 million tonnes of electrical and electronic equipment (EEE) put into the market in the same year.
- WEEE officially reported as collected is usually efficiently recycled and recovered, although preparation for re-use is still limited.
- Recycling of WEEE mainly addresses bulk metals, and to a lower extent critical raw materials.

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Overview and context

In the EU, around 8.9 million tonnes of electrical and electronic equipment (EEE) such as washing machines, computers, TV sets, fridges and cell phones are put on the market every year (around 20 kg per capita)[225], leading to a massive generation of waste.

WEEE statistics include waste flows that are officially reported as collected (in accordance with the WEEE Directive[226]). Large amounts of WEEE are still improperly or illegally collected and treated[227]. Starting from 2016, collection targets for WEEE have been set as percentage (45%) of EEE put on the market in the three previous years[228]. Even considering the time gap between the EEE put on the market and those reaching their end-of-life, the amount of WEEE collected is well below estimations on the amount of WEEE that is generated (around 10 million tonnes)[229].

While WEEE may appear to be a small waste stream in terms of mass compared to other waste streams (e.g. construction and demolition waste, as reported in indicator 14), the treatment of this kind of waste is a potential source of several valuable and critical secondary raw materials (see box below). Indeed, WEEE is a complex waste stream that contains up to 60 different elements of the periodic table, including several critical raw materials (CRMs). For example, about 95% of gallium, 87% of germanium, 81% of indium, and around 50-80% of rare earth elements are contained in EEE (e.g. in semiconductors, integrated circuits, optical fibres, lightings, displays, LED, magnets, etc.)[230].

Many of these valuable materials are recovered with high efficiency (e.g. ferrous metal, copper, aluminium and various precious metals)[231,232]. Several materials in WEEE are however lost in shredding residues or diluted into other recycled fractions, including several CRMs (e.g. silicon, indium, tantalum and rare earth elements)[233]. Recycling of these materials is currently either technologically not feasible or economically not viable[234] and this is reflected by low values of their end-of-life recycling input rates (see indicator 15). The recycling efficiency of special materials (such as some CRMs) can also be influenced by the availability of recycling technologies (including metallurgical separation and refining processes), by the product's design and by the care taken in dismantling at the WEEE treatment facilities[235,236].

Data on WEEE used here are based on official European statistics. A number of European research projects have also contributed to improving the quality of information about WEEE in the EU (such as the ProSUM Horizon 2020 project[237]).

Facts and figures

Figure 13.1 gives an overview of the amounts (per capita) of WEEE that were officially reported as collected by Member States, and the amounts that were prepared for re-use and recycled in 2017[238], along with the collection target[239] as set by the WEEE Directive (2012/19/EU).

The figure shows that there are significant differences across EU Member States as regards the amounts of WEEE collected, prepared for re-use and recycled. It also shows that 17 EU Member States met their collection target for 2017.

In 2017, the overall WEEE collected in the EU reached about 3.7 million tonnes[240]. As shown in Figure 13.1, an average of about 8.3 kg of WEEE per capita were collected in the EU in 2017[241]. This is much lower than the estimated amount of WEEE generated (19 kg per capita)[242]. However, the collection rate increased compared to the 2015 values presented in the 2018 edition of the Scoreboard (it was then 7.3 kg/inhabitant)[243].

The percentage of WEEE collected per capita was about 40% of the EEE put on the market, and this value remained almost constant between 2015 and 2017. Even considering the average lifetime of the EEE, the large discrepancy between WEEE collected and estimations of the WEEE actually generated can be explained by a series of reasons such as: (i) improper disposal of WEEE by consumers (e.g. in waste bins); (ii) waste flows that are not properly reported as collected; (iii) waste flows that are illegally recycled; or (iv) waste flows that are illegally exported[244].

Figure 13.1 also shows the quantity of WEEE per capita that was recycled and prepared for re-use by EU Member States. 'Preparing for re-use and recycled' refers to the ratio between WEEE prepared for re-use and recycled and WEEE collected. Preparing for re-use keeps raw materials in the societal stocks (see indicator 12). In 2017, about 6.8 kg per capita of WEEE were recycled while only 0.1 kg per capita was prepared for re-use[245]. This represents a slight increase compared to 2015 data (they were then 5.8 kg of WEEE recycled and less than 0.1 kg re-used per capita, respectively)[246]. Within the data reported on recycling and preparation for re-use, so far, only 9 EU Member States reported some preparation for re-use of WEEE in 2017[247]. It should be noted that the recast WEEE Directive 2012/19/EU added ´preparation for re-use´ to a joint ´preparation for re-use and recycling´ target for each category of WEEE for the first time, to be applicable from 15 August 2015. Therefore, it is expected that, year by year, there should be an increase in the amount of WEEE prepared for re-use and progress in reaching these targets.

Figure 13.1: WEEE officially reported as collected and WEEE prepared for re-use and recycled (amounts per capita) and collection targets of WEEE for EU countries (EU-27, 2017)[248]. Average WEEE collected in the EU (in 2015 and 2017) are displayed as horizontal lines.

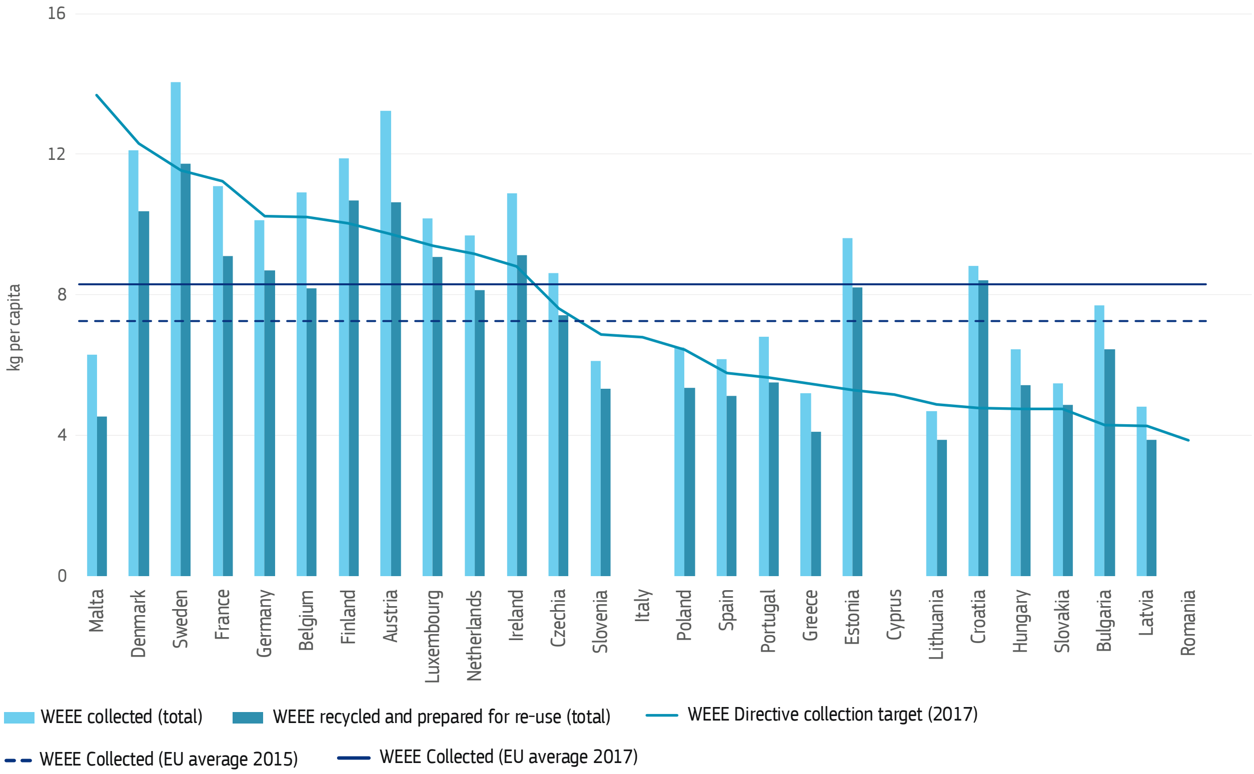


Figure 13.2 shows the total amount of WEEE 'prepared for re-use and recycled' and the share by WEEE category (type and numbering as set by the WEEE Directive). In 2017, the total mass of WEEE prepared for re-use and recycled in the EU was 3.1 million tonnes, hence increasing compared to the 2.6 million tonnes reported in 2015[249]. Similarly to the data for 2015 (as presented in the 2018 edition of the Scoreboard), 'large household appliances' (such as washing machines, dishwashers and fridges) was by far the most relevant category, contributing to more than 50% of the amount (in mass) of WEEE recycled and prepared for re-use. The second most relevant category of WEEE prepared for re-use and recycled in 2017 was 'consumer equipment and PV' (14.2%) (it was 'IT and telecommunication' (16.6%) in 2015).

Figure 13.2: Total amount of WEEE 'prepared for re-use and recycled', and shares per WEEE category (EU-27, 2017)[252]

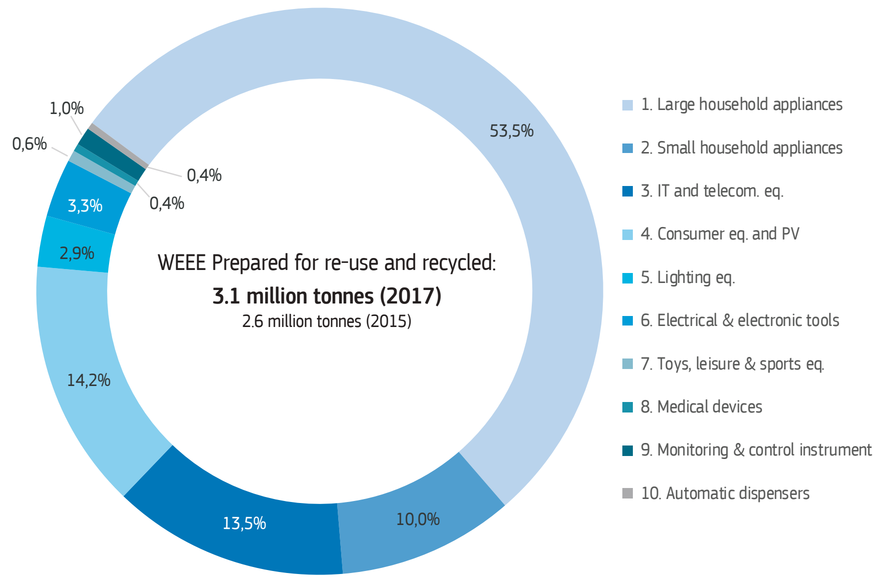
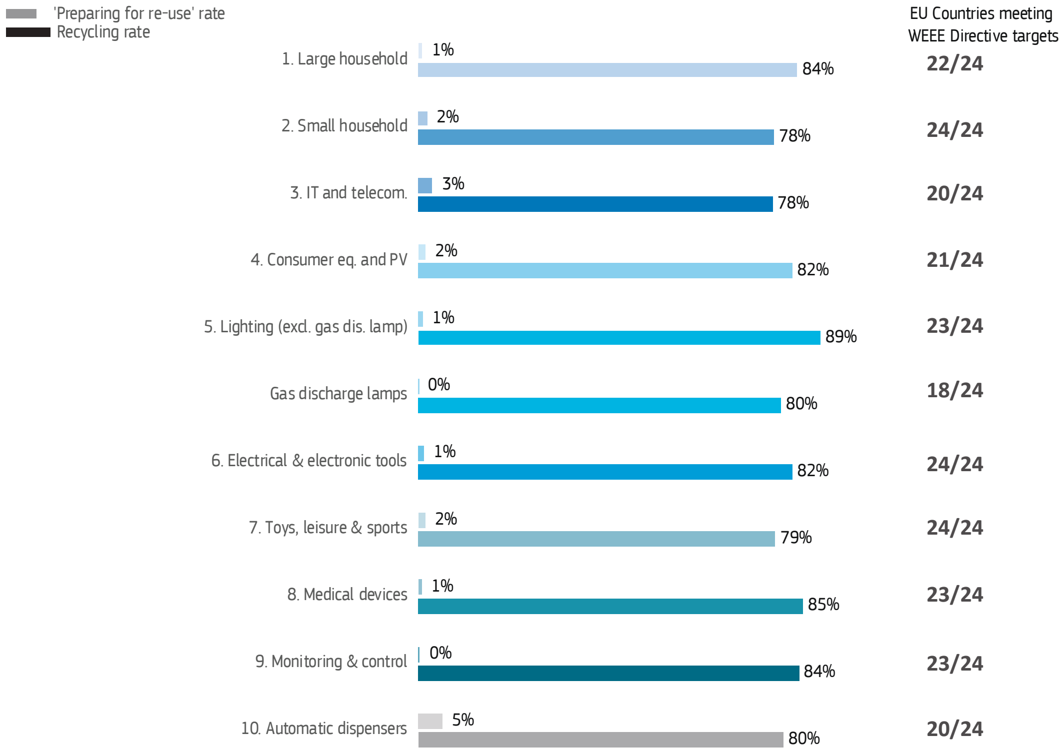


Figure 13.3: 'Preparation for re-use' rate and 'recycling' rate per WEEE category, and the number of EU member countries that achieved the targets of the WEEE Directive on WEEE 'prepared for re-use and recycled' (EU-27, 2017)[253]



Apart from the collection targets depicted in Figure 13.1, the WEEE Directive also sets targets for the EU Member States on the rates of WEEE that should be 'prepared for re-use and recycled' and 'recovered', also differentiated per WEEE category[250]. Figure 13.3 shows the disaggregated rates of WEEE 'prepared for re-use' and 'recycled', per WEEE category (average percentages for the EU in 2017). Although the WEEE Directive refers to an aggregated target for both WEEE prepared for re-use and WEEE recycled, Figure 13.3 presents the re-use and recycling rates separately to better illustrate the contribution of both activities. Overall, although the dataset is not complete, and as the figure illustrates, the large majority of EU countries achieved the 'preparation for re-use and recycling' targets set by the WEEE Directive, similarly to the situation in the 2018 Scoreboard. However, for some categories the number of compliant countries has increased (e.g. for 'large household appliances' and 'automatic dispensers') and has slightly declined for other categories (e.g. for 'IT and telecommunication', 'consumer equipment and PV' and 'gas discharge lamps').

The figure shows that the recycling rates were generally high, ranging from 78% (for 'IT and telecommunications' and 'small appliances') to 89% for ('lighting equipment'). On the other hand, 'preparing for re-use' rates were generally very low (usually below 3%), with values slightly higher for 'automatic dispensers' (5%). In general, values of the 'preparation for re-use' and of the recycling rates did not sensibly change compared to the 2018 edition of the Scoreboard.

It is important to notice that the re-use and recycling rates are mainly dependent on the mass of materials recycled. High recycling rates are generally due to the recycling of base metals (e.g. ferrous metals, aluminium, copper), which form most of the mass of many WEEE. Plastics and other materials (including several CRMs) are instead characterised by low or null recycling rates. Research and industry are currently engaged in many efforts to increase the recycling rate of these valuable materials[251].

Conclusion

Several million tonnes of EEE— which contains large amounts of valuable raw materials, including several CRMs — are put on the EU market each year. In the last 10 years, WEEE collected per capita has been continuously increasing, although the collection rates are not uniform across EU Member States. Similar trends have been observed for WEEE prepared for re-use and recycled.

However, the amount of WEEE collected is much lower than the estimations based on the amount of WEEE actually generated. This could be explained by large amounts of EEE being stored in stocks (hence not available for recycling) or by WEEE being improperly collected, illegally treated or illegally exported. WEEE that is officially reported as collected generally has a high recycling rate, especially for bulk metals and precious metals (such as gold, silver and platinum group metals). In contrast, losses of several materials as CRMs (such as rare earth elements, indium, gallium, magnesium and silicon) are very high even in proper WEEE recycling channels.

Recycling rates of raw materials contained in end-of-life screens: a spotlight on data from one EU country

WEEE are rich in precious metals and CRMs[254] and therefore they represent a valuable potential source of secondary raw materials. Data on raw materials contained in EEE placed on the market, stocked and WEEE generated[255] in recent years in the EU are available in the EU Urban Mine Knowledge Data Platform (EU-UMKDP) produced by the ProSUM project[256,257]. However, data on collection and recovery performance as required by the WEEE Directive (2012/19/EU) are currently only monitored based on the overall weight per WEEE category (see also Figure 13.2). Therefore, data fall short as regards capturing how well WEEE management contributes to producing secondary raw materials for trace elements, both in volume and quality.

There have been several attempts in academia to go beyond weight-based indicators. For example, Nelen et al. (2014)[258] and later Van Eygen et al. (2016)[259] proposed innovative indicators combining recycling efficiency and the Commission's criticality assessment. Nevertheless, the results are significantly influenced by elements that are highly present in terms of weight though are not critical (e.g. iron and copper) but have high economic importance due to their use by different sectors. In addition, the scope of these indicators is limited to recycling processes, and it is known that several CRMs are lost before recycling, e.g. due to limited collection.

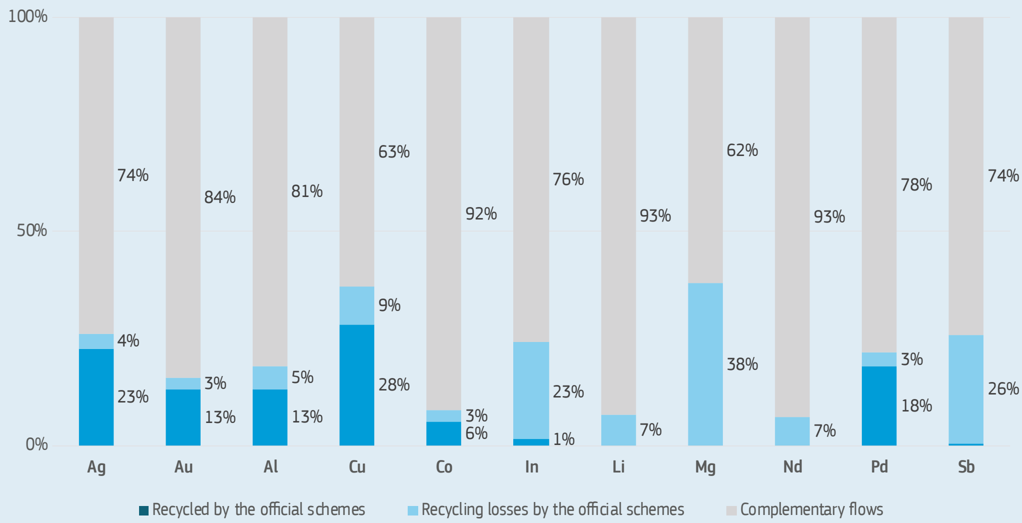
More recently, Horta Arduin et al. (2020)[260] went further and provided some novel indicators that address collection and recycling rates for specific raw materials contained in WEEE. These indicators were tested on the ´screens´ WEEE category, focusing on 11 critical, non-critical and precious raw materials[261] and using 2017 data on collection and treatment performance of the official schemes in one EU country (France). The 'screens' category (which includes televisions and computer monitors, laptops and tablets) is particularly interesting because the technology switched from cathode-ray tube (CRT) to flat panel display (FPD) in the early 2000s and this had a strong influence on the volumes and types of material available for collection and recycling[262].

In France, the overall weight-based recycling rate of screens was 78% in 2017[263]. Note that this rate only considers the flows collected by official schemes, and is highly influenced by the recycling of base metals (e.g. ferrous metals, aluminium and copper).

Through the novel indicators developed in the study mentioned above, it was possible to quantify the share of selected raw materials effectively recycled in official WEEE channels in 2017 (see Figure 13.4, where recycling rates are indicated in blue). Considering the total WEEE generated, it was possible to show that most of the potential secondary raw materials were actually diverted into ´complementary flows´[264] (grey series in Figure 13.4), and a smaller part was lost during processing (red series in Figure 13.4). The recycling rates ranged from 28% for copper to 0% for neodymium and magnesium (Figure 13.4). For example, although magnesium was rather well collected in screens (up to 38% in weight), it was mostly sorted together with aluminium scrap and was recycled as Al-Mg alloys. Because the study only considered elements recycled into secondary raw materials with same or similar properties, the recycling rate of magnesium was noted as 0%.

These modest results found for the recycling of the targeted raw materials highlight four main challenges: 1) low collection rate of screens by official schemes, especially of FPD screens; 2) losses in manual or mechanical pre-processing (e.g. for magnesium); 3) absence of recycling processes at industrial scale for some raw materials (e.g. neodymium); 4) low economic incentives compared to recycling costs (e.g. lithium).

Figure 13.4: Recycling rate, losses during recycling and in complementary flows, for targeted element in screens in France (2017)[265]



This novel indicator is neither fully validated, nor available in all the EU countries. Besides providing interesting results, it is rather data intensive. While specific monitoring indicators are being validated, recovery of valuable and critical raw materials arising from WEEE can be improved by putting in place treatment standards, taking inspiration for example from the voluntary certification scheme developed by the Horizon 2020 project CEWASTE[266].

14. Construction and demolition waste

Key points:

- Construction and demolition is the biggest source of waste, contributing to around a third of all waste in the EU (in mass).
- Reported recovery rates in the EU are already very high (close to 90%), although a large share seems to be related to backfilling operations.
- Data on construction and demolition waste are currently not sufficiently robust, mainly due to differences in data reporting across EU countries.

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Overview and context

Construction and demolition is the single biggest source of waste (in mass) in EU: it accounted for 35% of all waste[267] in the EU in 2016 (787 million tonnes[268]). Construction and demolition waste (CDW) arises from activities such as building construction, total or partial demolition of buildings and civil infrastructure, and road construction and maintenance. It accounts for a large share of the non-metallic minerals waste flows produced in Europe (see indicator 12).

The revised Waste Framework Directive (WFD)[269] required the EU Member States to take the necessary measures to achieve the re-use, recycling and other material recovery, including backfilling, of a minimum of 70% by weight of non-hazardous CDW by 2020[270]. The rules for calculating the recovery rate have been precisely set by Annex III of Decision 2011/753/EU. However, according to a recent study by the European Environmental Agency[271], these rules do not include all categories of produced waste (e.g. soil waste), which could lead to an overestimation of the recovery rate.

In addition, the composition of CDW changes depending on the geographical context, reflecting the different construction techniques used in different countries[272]. Based on studies from the scientific literature, bricks, ceramic and tiles generally account for most of CDW[273]. The second most present material in CDW is wood (around 10%) in Nordic European countries, and concrete in Southern European countries (also around 10%)[274,275]. Other main constituting materials are: stone and asphalt (between 0 and 5% each); metals (between 1 and 3%); paper and plastics (between 1 and 2% overall); gypsum (between 0.5 and 3%); and glass (below 0.5%).

The most (economically and environmentally) valuable fractions (e.g. metals, plastics, glass) represent only a small percentage of all CDW[276]. Important factors determining whether materials can be fed back into the economy include: the design of buildings and choice of materials; whether selective demolition takes place; and the existence of quality assurance schemes to build up trust in recycled materials[277].

CDW is subject to a mandatory recovery target (70% from 2020) under the WFD 2008/98/EC. EU Member States generally reached very high recovery rates in 2016 (86.5% of all construction and demolition). 7.7% of this recovery is related to backfilling operations[278], which – in terms of its environmental performance – ranks lower than recycling according to the WFD (Article 4, Waste hierarchy). Commission Decision 2011/753/EU defines backfilling as a "recovery operation in which suitable waste is used for reclamation purposes in excavated areas or for engineering purposes in landscaping, and the waste is a substitute for non-waste materials". In the revised WFD, the definition of backfilling has been tightened as "waste used for backfilling must substitute non-waste materials, be suitable for the aforementioned purposes, and be limited to the amount strictly necessary to achieve those purposes". Backfilling can be considered as low-quality recovery, although it still grants some benefits since it obviates the need for additional natural resources[279]. According to WFD Article 37(2), EU Member States should report the amount of waste used for backfilling and other material recovery operations separately from the amount of waste prepared for re-use or recycled.

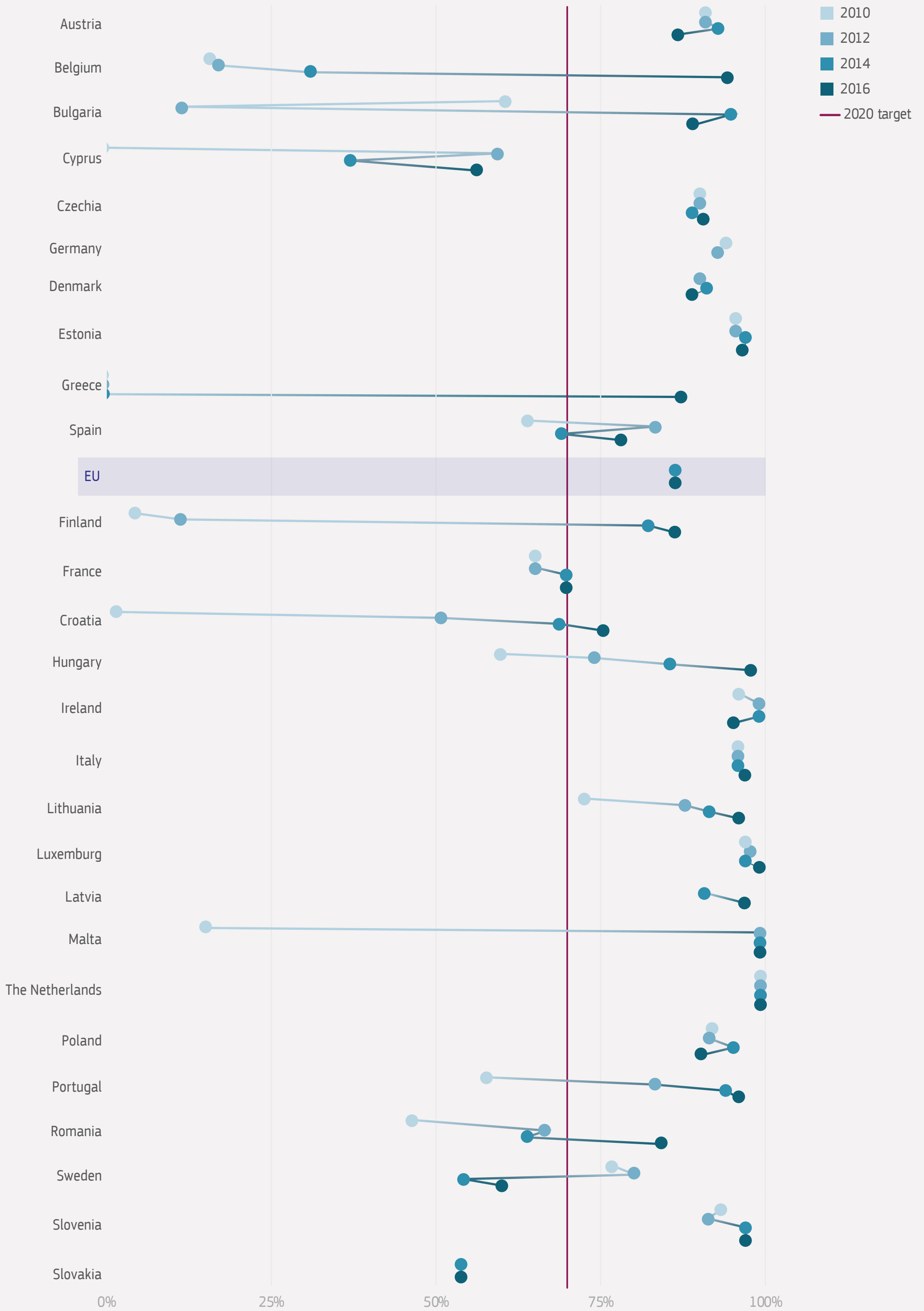
Selective demolition, advanced sorting and re-use of materials are still rarely deployed in the EU. For example, special types of feldspar and kaolin are essential for the manufacturing of ceramic and tiles; however, current practices and technologies are unable to separate and recycle such materials, and substituting them with other materials is difficult or even infeasible. During the demolition of buildings, ceramics are collected unsorted, together with other materials from CDW, and then crushed and used as filler for new construction works (e.g. as substratum for new roads). This practice does not retain the value of the materials and is not conducive to a circular economy[280].

Some initiatives aim to improve recycling of CDW. These include the EU construction & demolition waste management protocol, which was published with the overall aim of increasing confidence in the CDW management process and trust in the quality of CDW recycled materials[281]. This goal can be achieved with different strategies, such as: (i) improved waste identification, source separation and collection; (ii) improved waste logistics; (iii) improved waste processing; (iv) quality management; and (v) appropriate policy and framework conditions.

Guidelines for carrying out waste audits before building demolition and renovation work were also developed in 2018 to provide guidance to operators on how to facilitate and maximise the recovery of materials and components[282]. These guidelines recommend in particular to compile a detailed inventory of constructive elements (e.g. pillars, beams, walls, slabs) and the type, amount and quality of materials used. Based on this information, operators should define the waste streams that are technically and economically separable and recyclable.

The search for RACER data…

Figure 14.1: Recovery rate of construction and demolition waste in the EU (2010-2016)[283]



Data on 'mineral waste from construction and demolition' are currently available in Eurostat[284] and collected every two years in accordance with Regulation (EC) No 2150/2002 on waste statistics. Based on this dataset, the CDW 'recovery rate' can be calculated for each EU country and monitored over time (see Figure 14.1).

This indicator, which covers only the non-hazardous fraction of waste, is included within the set of indicators of the circular economy monitoring framework[285]. The CDW recovery rate can be expressed as the ratio between the mass recovered (including recycling and backfilling operations) divided by all CDW collected and treated. As shown in Figure 14.1, several EU Member States reached very high CDW recovery rates in 2016, with the average EU rate of about 87%. Noticeably, some EU countries had a sudden rise in recovery rates within a few years, which might be due to e.g. changes in the reporting system (see more details below).

Although backfilling has been defined by the legislation, the dividing line between recycling and backfilling differs among EU countries, and this is reflected by inconsistencies in reporting and statistics[286]. There are also diverging views on whether all backfilling operations constitute 'genuine' recovery[287].

In 2017, the Commission commissioned a study on the ´Resource-efficient use of mixed waste´[288]. The study aimed in particular to assess the plausibility of official CDW statistics, to identify sources of inaccuracy and best practices regarding statistics in EU Member States, and to formulate recommendations. It identified that monitoring and data collection for CDW were often not accurate (due e.g. to problems in the data collection methodology, inconsistencies with detailed national and international data, unexplained outliers, and abnormal temporal evolution)[289]. For example, the study observed that, in 2012, among the 15 countries that reported zero amounts of CDW backfilled, 13 actually had backfilling operations. For these countries, it was unclear whether the respective amounts had been included in the reported recycled amounts (since e.g. they could not be reported separately) or whether the amounts had not been reported at all. The study also concluded that most EU Member States would benefit from more guidance on how to report their hazardous CDW data correctly (allocation to the right waste code, sharing practices regarding surveys and systems for reporting, etc.). Moreover, the study analysed potential alternative policy targets, for example setting a 70% recycling target for CDW by 2030 without including material backfilling. The authors of the study concluded that this new target could encourage EU Member States to boost recycling, for example by directing inert CDW currently backfilled towards production of aggregates, in order to raise their recycling rate. A subsequent Commission study in 2018[290] also estimated that the investment costs needed in the EU to reach this more ambitious 70% recycling target for CDW (excluding backfilling) would range between EUR 839 million and EUR 1.2 million[291].

For the monitoring of the recovery of CDW, it is essential to keep backfilling separate from other material flows recycled. To make statistics fully useful and comparable, the EU should work towards aligning the reporting of CDW statistics in all Member States.

15. Recycling's contribution to meeting materials demand

Key points:

- Recycling's contribution to meeting demand is generally low.
- Only in a few cases does the availability of secondary materials approach or surpass one third of current demand (e.g. rhenium, tungsten, iron, tin and zinc), and only in one case does it reach above 50% (lead).
- While the contribution of secondary raw materials to meeting manufacturing needs heavily depends on the evolution of demand, other factors currently limit their availability as well, including: economic or technical feasibility, collection rates, lifetime of products or losses in manufacturing or use.

Overview and context

Boosting the supply of secondary materials through recycling is an important part of the EU raw materials initiative[292] and the circular economy action plan[293],[294.] In addition, as highlighted in the Ecodesign Directive[295], better product design can facilitate high quality recycling.

As the backbone of resource efficiency, recycling is therefore key to a more circular economy in the EU (indicator 12), which in turn translates into a lower import dependency (indicator 8) and a more secure (indicator 9) and sustainable supply of raw materials. The contribution of recycling as an input to manufacturing is seen as a risk-reducing factor in the EU's criticality assessment[296] and criticality frameworks used elsewhere[297]. Recycling is also a key element for improving sustainability, as secondary materials have potentially lower environmental impacts when compared with primary raw materials (indicator 21). Recycling is also expected to boost EU competitiveness, as set out in the Commission's circular economy action plan.

There are multiple barriers to a further uptake of recycling, which can help understand the currently low end-of-life recycling input rates and circularity (indicator 12), as well as the future potential of recycling in the EU[298] : (i) recycling of many materials from end-of-life products and waste streams is not economically feasible; (ii) there is a lack of suitable technologies or infrastructure available for collection and recycling; (iii) some materials are contained in long-life products (e.g. buildings or other infrastructure); (iv) there are losses due to manufacturing or in-use dissipation[299] ; and (v) demand for several materials is growing.

Recycling routes and the way they fit into a more comprehensive supply chain need adequate understanding and indicators. Recycling rates at different points in the recycling chain have different, but complementary meanings. Thus, while the end-of-life recycling rate (EOL-RR) is the percentage of a material in post-consumer waste flows that is actually recycled, the end-of-life recycling input rate is the material input to the production system that comes from recycling of post-consumer scrap[300]. The end-of-life recycling input rate is included within the circular economy monitoring framework[301].

Facts and figures

Figure 15.1 shows end-of-life recycling input rates (EOL-RIR) for the 83[302] candidate raw materials assessed in the EU 2020 criticality assessment[303]. The figure updates the values presented in the 2018 edition of the Scoreboard in line with the latest available data from the EU material system analyses[304] (see the methodological notes). The figure (the periodic table) shows that, with few exceptions, secondary raw materials generally represent a small share of manufacturing inputs.

The figure can be analysed based on manufacturing groups:

The highest EOL-RIR is for lead (75%), the only value above 50%. Fifteen raw materials fall in the 25-50% range, which certainly represents a significant contribution to meeting EU demand, among which: rhenium (50%), tungsten (42%), iron ore (31%), tin (31%) and zinc (31%). Many of these belong to mature supply chains, where well-established collection and recycling routes have been operating for a long time.

Among the raw materials critical for the EU, high EOL-RIRs are found for tungsten (42%), europium (38%), yttrium (31%), palladium (28%), rhodium (28%) and platinum (25%).

The 10-25% range of EOL-RIRs is relatively well represented, with 16 materials that include major metals (e.g. aluminium, chromium, copper, magnesium and nickel) and some specialty or precious metals (e.g. iridium, ruthenium and silver).

For most specialty metals and rare earth elements, secondary materials contribute only marginally to materials´ demand, often only around 1% or less. Primary extraction is often cheaper than recycling for these materials, as they are integrated into today's products in small quantities, making their collection and recycling costly both in terms of money and environmental impact. Their availability at end-of-life is also limited as their use has only recently increased and many products are still in use. Demand for these materials in modern technologies such as low-carbon energy and transportation systems, modern communication, and defence systems is currently increasing.

Battery raw materials have quite variable recycling contributions to demand, ranging from a relatively well-established and efficient recycling chain for cobalt (22%) to nearly non-existing for lithium (0%). Lithium is sometimes collected (because it is associated with other metals, e.g. cobalt), but not recovered, due to the low price for primary lithium. In terms of recycling contribution, the performance of nickel (17%), manganese (8%) and natural graphite (3%) is medium.

Complementary indicators to the EOL-RIR, such as the end-of-life recycling rate (EOL-RR), can be used to deepen the analysis. While the EOL-RIR (Figure 15.1) looks at recycled material inputs to the EU economy as a fraction of total inputs, the EOL-RR captures the amount of (secondary) materials recovered at end-of-life compared to the overall waste quantities generated (i.e. it is an output-related indicator). EOL-RR provides information on the collection and recycling sectors' performance in recovering materials at end-of-life. It is therefore useful from a recycler's perspective.

Figure 15.1: End-of-life recycling input rates (EOL-RIR) in the EU[307]

- > 50%
- 26 - 50%
- 11 - 25%
- 1 - 10%
- < 1%
- changed or new datapoint

H 0%																	He 1%
Li 0%	Be 0%											B* 0.6%	C	N	O	F* 1%	Ne
Na	Mg 13%											Al 12%	Si* 0%	P* 17%	S 5%	Cl	Ar
K* 0%	Ca	Sc 0%	Ti 19%	V 2%	Cr 21%	Mn 8%	Fe 31%	Co 22%	Ni 17%	Cu 17%	Zn 31%	Ga 0%	Ge 2%	As 0%	Se 1%	Br	Kr
Rb	Sr 0%	Y 31%	Zr 12%	Nb 0%	Mo 30%	Tc	Ru 11%	Rh 28%	Pd 28%	Ag 19%	Cd 30%	In 0%	Sn 31%	Sb 28%	Te 1%	I	Xe
Cs	Ba 1%	La-Lu [1]	Hf 0%	Ta 5%	W 42%	Re 50%	Os	Ir 14%	Pt 25%	Au 20%	Hg	Tl	Pb 75%	Bi 0%	Po	At	Rn
Fr	Ra	Ac-Lr [2]	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo

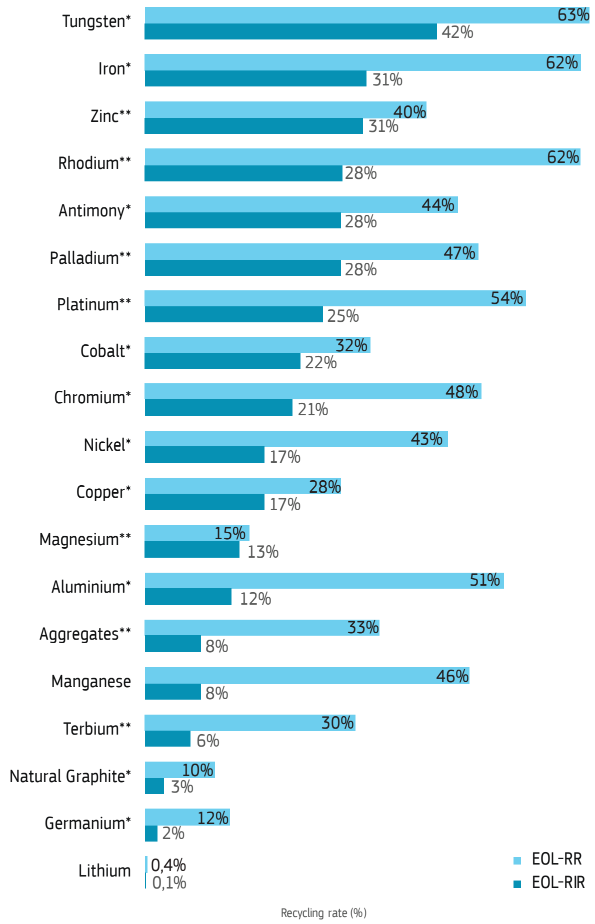
[1]Group of Lanthanide	La 1%	Ce 1%	Pr 10%	Nd 1%	Pm	Sm 1%	Eu 38%	Gd 1%	Tb 6%	Dy 0%	Ho 1%	Er 1%	Tm 1%	Yb 1%	Lu 1%
[2]Group of Actinide	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Aggregates	Bentonite	Coaking Coal	Diatomite	Feldspar	Gypsum	Kaolin Clay	Limestone	Magnesite	Natural Cork	Natural Graphite	Natural Rubber	Natural Teak Wood	Perlite	Sapele wood	Silica Sand	Talc
8%	19%	0%	4%	8%	1%	1%	19%	2%	8%	3%	1%	0%	42%	0%	18%	16%

* F = Fluorspar, P = Phosphate rock, K = Potash; Si = Silicon metal, B = Borates.

Figure 15.2 shows that, despite several materials contained in end-of-life products having recycling rates (EOL-RR) above 40% or 50%, recycling's contribution to overall demand for these materials (EOL-RIR) is lower. This is particularly true for some of the major metals such as iron, aluminium, nickel and manganese, but also for some precious metals such as the platinum group elements for which the EOL-RR can be much higher than the EOL-RIR. For instance, up to 95% of platinum group elements are recycled from industrial catalysts and 50-60% from automotive catalysts[305], but their EOL-RIRs are relatively low. This is due to factors like growing demand, which demonstrate that the high efficiency of the EU's recycling activities in recovering materials from end-of-life products is important, but it is not enough to meet the EU's fast growing needs. The data presented in Figure 15.2 are a snapshot in time, as raw materials are often contained in long-use societal stocks.

Figure 15.2: End-of-life recycling rates (EOL-RR) in comparison to end-of-life recycling input rates (EOL-RIR) for a selection of materials, including 5 battery raw materials (cobalt, nickel, manganese, natural graphite and lithium)[306]. Values are sorted according to decreasing EOL-RIR values.



Recycling estimations are based on:
*EC Material System Analysis Studies. Geographical coverage: EU
**EC 2020 Critical Raw Materials Assessment (EOL-RIR) and UNEP/IRP (2011) (EOL-RR). Geographical coverage: EU/Global

Conclusion

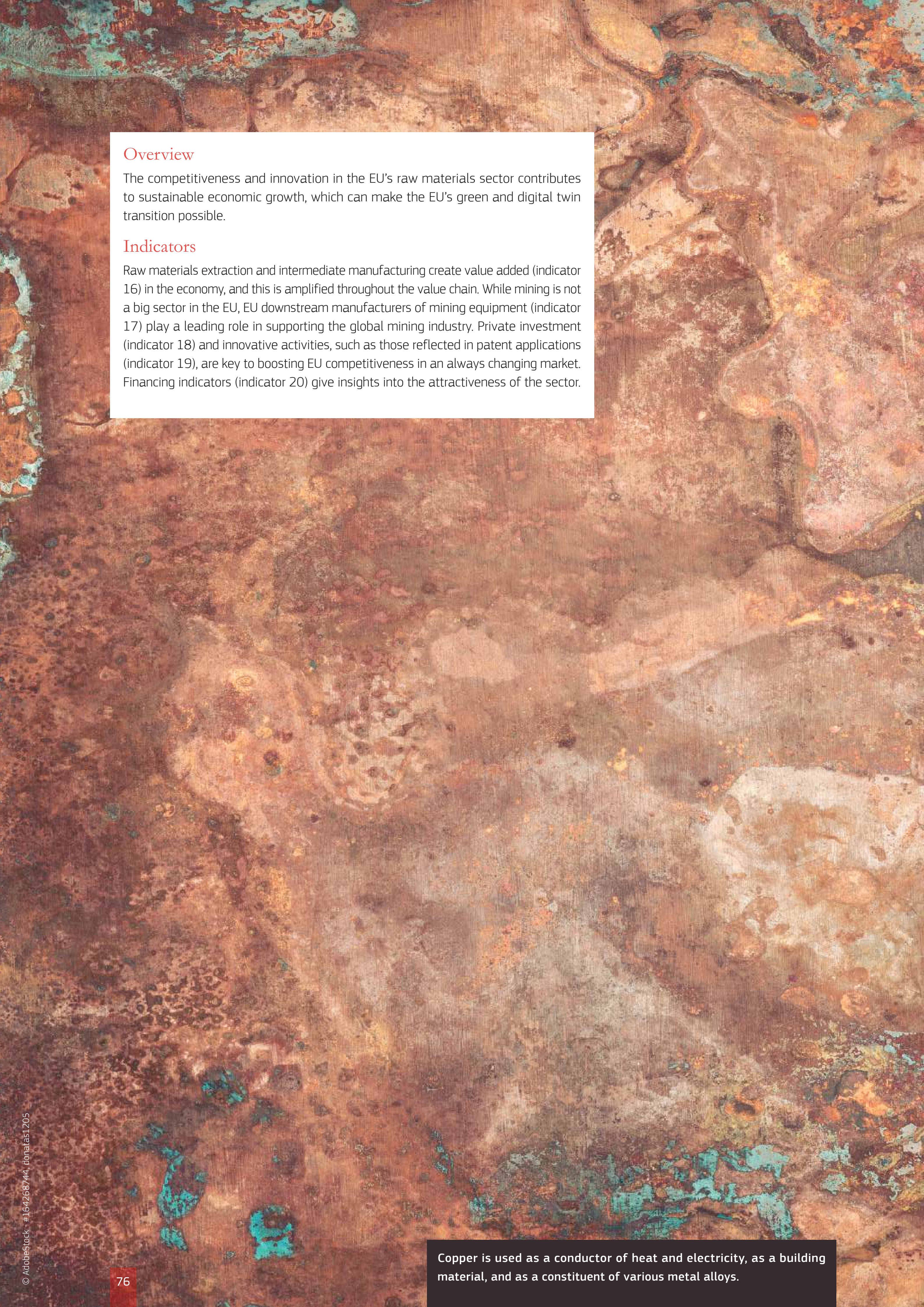
Although recycling activities are relatively well-established in the EU, especially for some metals, the supply of secondary materials is not sufficient to meet the EU's current demand. Technological change or rapidly growing demand may require significant additional effort to even maintain the current recycling input rates. Recycling or downstream processing should therefore be well connected with the infrastructure used to collect and transport materials in a cost-effective and large-scale manner. Design for circularity may also enable more efficient collection and recycling. Increasing the circularity of raw materials is one of the ways in which the EU can become more resilient in its raw materials supply chains.

Overview

The competitiveness and innovation in the EU's raw materials sector contributes to sustainable economic growth, which can make the EU's green and digital twin transition possible.

Indicators

Raw materials extraction and intermediate manufacturing create value added (indicator 16) in the economy, and this is amplified throughout the value chain. While mining is not a big sector in the EU, EU downstream manufacturers of mining equipment (indicator 17) play a leading role in supporting the global mining industry. Private investment (indicator 18) and innovative activities, such as those reflected in patent applications (indicator 19), are key to boosting EU competitiveness in an always changing market. Financing indicators (indicator 20) give insights into the attractiveness of the sector.



Copper is used as a conductor of heat and electricity, as a building material, and as a constituent of various metal alloys.

Competitiveness and innovation

Indicators

16. Value added
17. Mining equipment exports
18. Corporate R&D investment
19. Patent applications
20. Financing

SCOREBOARD

Raw materials supply in the EU:
4. Mining activity in EU, 6. Domestic production;

Raw materials in the global context:
7. EU share of global production, 11. Trade in waste and scraps;

Circular economy and recycling:
12. Material flows in the circular economy, 15. Recycling's contribution to meeting materials demand.

SUSTAINABLE DEVELOPMENT GOALS

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Value added at factor cost;

Number of patents related to recycling and secondary raw materials.

16. Value added

Key points:

- Among the raw materials sectors, the highest annual contribution to value added comes from basic metals and non-metallic minerals. The most dynamic sector was materials recovery, with an increase of 34% over the 2014-2017 period.
- Value added increases along the value chain: in 2017, the value added at the processing stage was four times higher than at the mining stage, while the downstream industries generated almost eightfold the value added of raw materials processing.
- Comparing the 2017 value chain to 2014 data, the downstream sectors grew by 14%, and the extractive and processing industries by 10%.

Overview and context

Economic growth results from the expansion of value added along the value chains that compose the economy. Non-food, non-energy raw materials are key enablers of industrial value chains and thus contribute to the economy's value added. They are incorporated at various stages of the value chain, ranging from primary raw materials such as ores, to intermediates such as metals, to final products such as machinery and equipment. Value added, in absolute and relative terms, is usually higher in downstream sectors than in upstream ones[308].

The value added generated by the raw materials industries is directly linked with domestic production (indicator 6) and implicitly reflected in the EU share in global production (indicator 7). Moreover, value added can be boosted by financing (indicator 20) and technological progress (indicator 19).

Raw materials are essential to green growth in the context of the European Green Deal[309], as well as in the new industrial strategy for Europe[310]. Value added at factor cost is one of the indicators of the Circular economy monitoring framework[311].

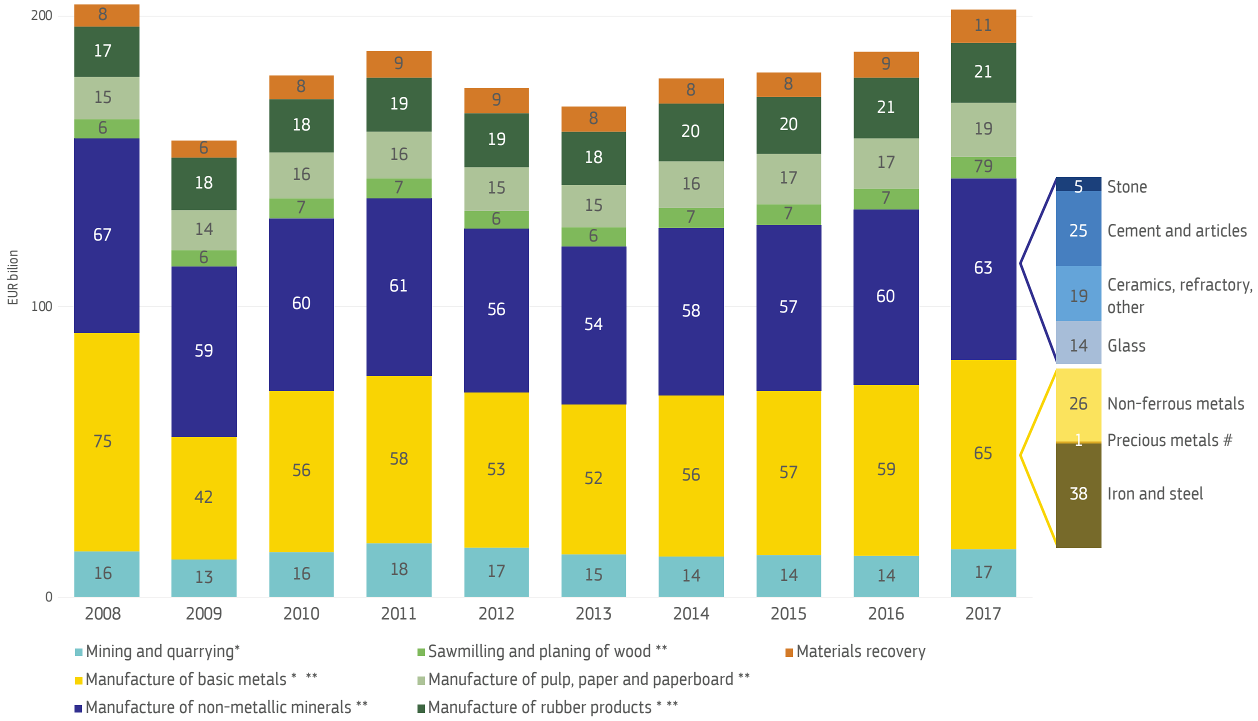
Facts and figures

Figure 16.1 presents the value added of the non-energy, non-agricultural raw materials sectors (extraction, processing and materials recovery) which provide inputs to the downstream industries in the EU between 2008 and 2017. Due to data limitations, this analysis excludes forestry activities[312].

The raw materials sectors that created the largest share of value added were 'basic metals' and 'non-metallic minerals', with EUR 65 billion and almost EUR 63 billion respectively. Within the basic metals sector, as shown by the data breakdown for 2017 (last column of the figure), the biggest contributions to value added came from iron and steel (58%) and non-ferrous metals (41%), while the share of precious metals is negligible. Within the non-metallic minerals sector (see also data breakdown in the last column), the value added originated mainly from the cement industry (40%). Nevertheless, there was a remarkable decrease compared with 2008 in the share of iron and steel within the base metals sector (by 11 percentage points) and for cement within the non-metallic minerals sector (by 9 percentage points).

Around 2008, after the start of the financial crisis, value added decreased in all raw materials sectors except for rubber products manufacturing. The crisis hit the basic metals manufacturing the most, particularly the iron and steel industry. The value added of non-metallic minerals also deteriorated after the crisis, linked to the decline in the demand of raw materials from building and construction.

Figure 16.1: Value added created by the raw materials sectors (EU, 2008-2017)[319].



Data for 2008-2010 refer to the EU without Croatia; data for 2011-2017 refer to the EU-27 (EU without UK).

* Some data are missing due to confidentiality.

** Eurostat highlighted some data as estimated or following different definitions in different countries.

For precious metals, data are missing for the aggregate EU before Brexit and were estimated as with the other sector estimates

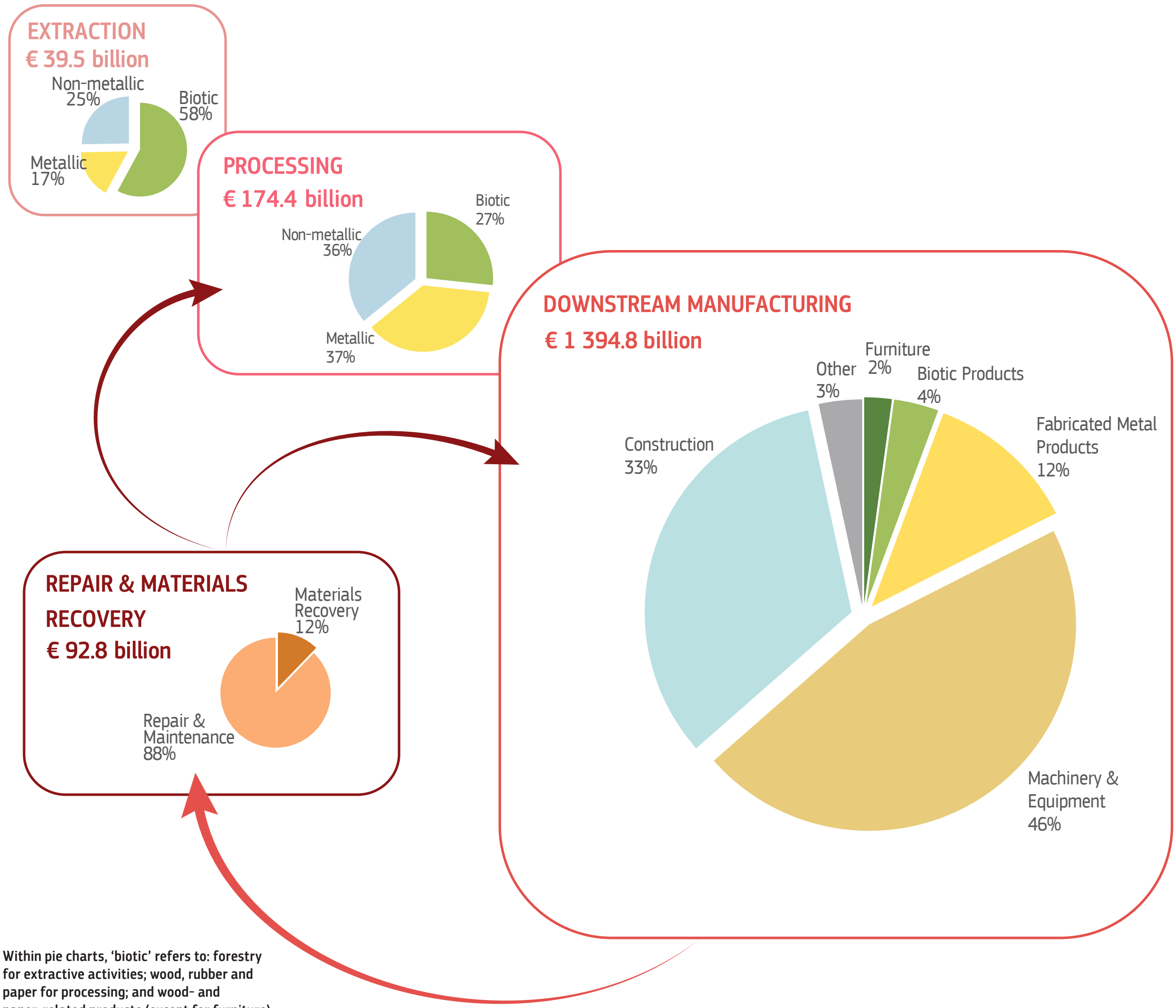
By 2017, the overall value added of the raw materials sectors had not fully recovered to its pre-crisis level, although there was a clear positive trend that started in 2014[313] (the last year referred to in the previous edition of the Scoreboard), corresponding to an increase of 13% over this period. Comparing 2017 to 2014, no major changes in sectoral composition took place, despite the fact that within the raw materials sectors the increase was quite heterogeneous: more than 17% for basic metals, mining and quarrying and pulp and paperboard; 9% for non-metallic minerals; 5% for sawmilling and planing of wood; and 3% for rubber products. Despite the small contribution to total raw materials value added compared with other sectors, materials recovery was the most dynamic sector, with an increase of 34% over 2014-2017 (amounting to almost EUR 3 billion).

Figure 16.2 presents, for the EU, the contribution of the raw materials sectors within each stage of the value chain, from the upstream to the downstream sectors and to repair and materials recovery. The generation of value added is a complex chain, with many interlinked stages of production and flows of foreign trade, but for clarity these are not represented in the figure.

Altogether, the sectors illustrated in Figure 16.2 generated EUR 1 701.5 billion[314] of value added in the EU in 2017. Extraction activities (mining, quarrying and forestry) accounted for almost EUR 40 billion of value added, while materials processing (resulting in intermediate products) generated EUR 174 billion. The downstream sectors (including also the construction sector) generated almost EUR 1 395 billion, almost eightfold the value added of raw materials processing. Repair and materials recovery contributed more (almost EUR 93 billion) to value added than the extractive activities[315].

Comparing the 2017 value chain to the 2014 data (considering EU-27[316]), the downstream sectors grew by 14%, the repair and materials recovery sectors by 13%[317], while the extractive and processing industries created together 10% more value added than in 2014[318]. However, the current data are not fully comparable: looking at a more detailed level, the most noticeable changes in value added occurred for mining of metal ores (an increase of 44%). The value added for non-metallic industries increased at both the extractive and processing stages, but less than in metallic industries.

Figure 16.2: Value added across the value chain for a selection of raw materials and downstream sectors (EU-27, 2017)[320].



Within pie charts, 'biotic' refers to: forestry for extractive activities; wood, rubber and paper for processing; and wood- and paper-related products (except for furniture) for downstream manufacturing.

Conclusion

Non-food, non-energy raw materials are relevant for many sectors of the EU economy and their contribution occurs at various stages of the value chains.

The highest contribution to value added from the industries producing raw materials comes from basic metals (iron and steel and non-ferrous metals) and non-metallic minerals (mostly cement). The overall value added generated by the industries producing raw materials sectors increased by 13% between 2014 and 2017. Growth was heterogeneous among sectors, and the most dynamic was materials recovery.

Value added grows considerably from extraction, to processing and to downstream industries, with downstream industries being by far the largest contributor. Securing raw materials supply is therefore indispensable for the EU economy.

17. Mining equipment exports

Key points:

- The EU, Japan and China were net exporters of mining equipment over the whole 2011-2017 period. From being a net exporter, the United States became a net importer in 2016.
- The EU as a trading bloc was the world's leading exporter of mining equipment over the entire period analysed.
- The United States remained by far the main destination of the EU's exports of mining equipment in 2017, followed by the United Kingdom, the Russia and Australia.

Overview and context

In recent decades, the increasing adoption of more advanced techniques, machinery and equipment transformed mining from a labour-intensive sector to a technology-intensive one. This process has led to a significant rise in mining productivity[321].

Mining equipment is an essential input to mining activities, the extent of its use being dependent on investments in exploration and on the opening of new minerals and metals mines[322]. Global production and trade of mining equipment closely follow global demand. In turn, global demand is driven by the magnitude of mining operations, by the evolution of mined commodity prices and by the demand of minerals and metals from global manufacturing[323].

Mining equipment includes machinery and tools used in various mining activities, such as crushing and milling equipment, drills and breakers, mineral processing machinery, continuous mining and tunnelling machinery, underground load and haul equipment, mining cars, conveying, screening and separating machinery, as well as their components. An ongoing process of machinery and operating system digitalisation is taking place, with the aim of improving the mining sector's operational efficiency, work safety and environmental impact. Some examples of electronics-, computer- and robotics-based applications include: (i) increasing robotic automation of various mining operations[324] ; (ii) use of the 5G network for remote monitoring of equipment and machinery; (iii) integrated process control technology; and (iv) diesel-free wheel-loaders, mine trucks and drill rigs in mining environments[325].

Big players on the global market for mining equipment[326] are companies with wide global reach such as Atlas Copco (Sweden), Caterpillar (the United States), Hitachi Construction Machinery (Japan), Komatsu (Japan), Liebherr-International (Switzerland) and Metso (Finland).

Facts and figures

Figure 17.1 presents the evolution of net exports (i.e. exports minus imports) of mining equipment between 2011 and 2017 by world region[327] and for major countries, based on official trade statistics.

The figure shows that the EU, Japan, China and the United States (the latter only up to 2015) were net exporters of mining equipment over the whole period. Emerging mining regions such as Central and South America, Asia-Pacific (including Australia) and Africa-Middle East, as well as Canada and Mexico, were significant net importers of mining equipment over the whole period.

Compared to 2016, China and Japan increased their net exports of mining equipment in 2017. For China, this rise was mainly due to a sharp decrease in imports accompanied by an increase in exports. This might reflect a change in the way China met its mining industry's demand for mining equipment, shifting from imports towards domestic production.

After reaching a minimum level in 2015, Japan's net exports have continued to increase since 2016, led by the significant rise in exports. From being a net exporter in 2015, the United States became a net importer in 2016-2017. This shift is mainly due to the drastic fall in exports (-34% between 2016 and 2017), due to the significant drop in exports to major export destinations such as China, Canada and Mexico.

Compared to 2013, net exports from the EU decreased substantially until 2017 (-54%), especially due to the 34% drop in exports.

As for emerging regions, the latest data show that the size of net exports increased between 2016 and 2017 for Central and South America and especially for Africa-Middle East, and decreased for Asia-Pacific. Net exports further decreased for Canada and Mexico.

Figure 17.1: Net exports of mining equipment by region and country[331] (world, 2013-2017)[332].

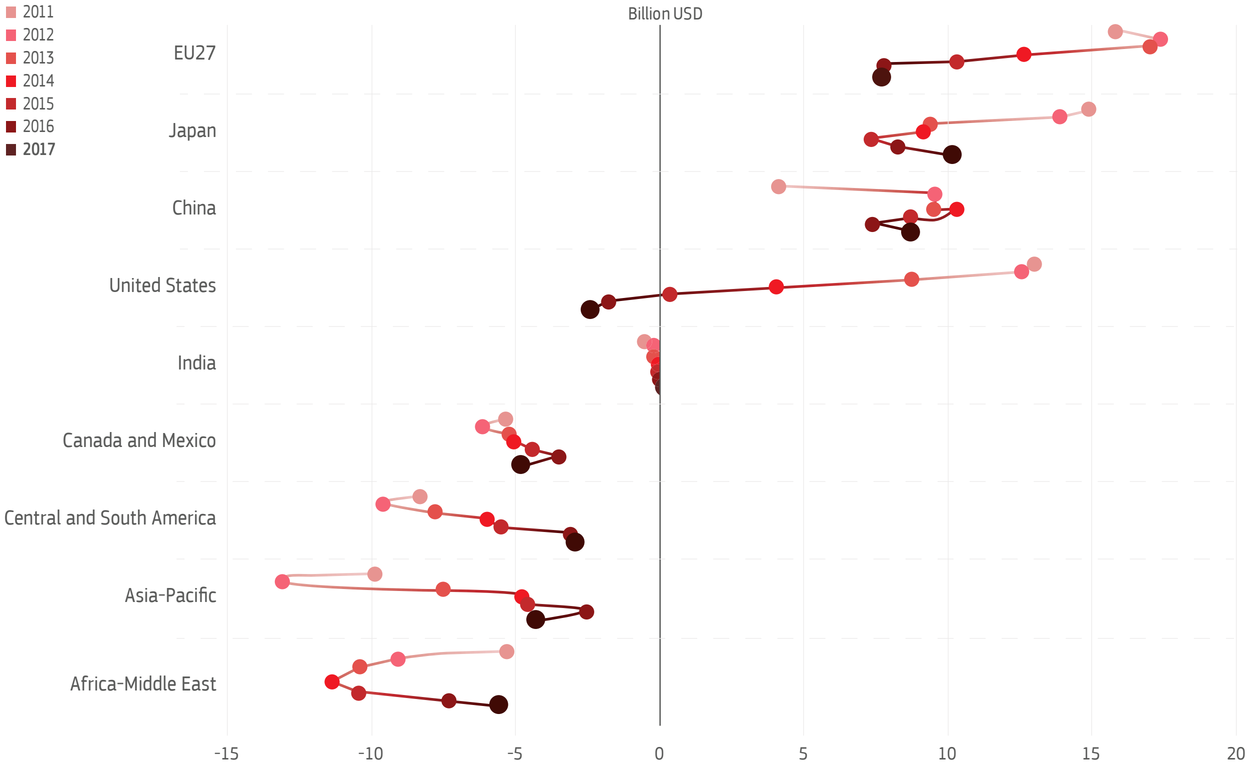


Figure 17.2 shows the export value of the top 10 global exporters of mining equipment in 2017 compared to 2015 (year covered by the 2018 edition of the Scoreboard). Although the EU significantly decreased its exports compared to 2015, it remained the world's largest provider of mining equipment, accounting for 18% of the world's total exports in 2017[328], followed by Japan (14%), China (13%) and the United States (11%).

The EU was also the leading supplier of mining equipment over the entire 2015-2017 period, with an average annual share of 19% in global exports. Within the EU, four countries – Germany, the Netherlands, Italy and France – were among the top 10 exporting countries of mining equipment in the world in 2017[329].

Figure 17.3 presents exports of mining equipment in 2017 for the top 10 destinations of EU (excluding UK) [330]. The United States was by far the main destination (16.9% of EU exports), followed by the United Kingdom (8.9%), Russian Federation (6.2%) and Australia (5.8%).

Conclusion

Over the 2011-2017 period, the EU (considered as a trading bloc), Japan and China were net exporters of mining equipment, whereas emerging mining regions such as Central and South America, Africa-Middle East and Asia-Pacific were net importers. In 2016 the United States turned into a net importer of mining equipment, mainly as a result of a large drop in exports towards major markets such as China.

The EU (excluding UK) was the world's leading exporter of mining equipment, accounting for almost one fifth of world's exports in 2017, and exporting mainly to the United States, the United Kingdom, the Russian Federation and Australia.

Figure 17.2: Export value of top 10 global exporters of mining equipment (EU-27 as trading bloc, excluding UK, 2015 and 2017)[333].

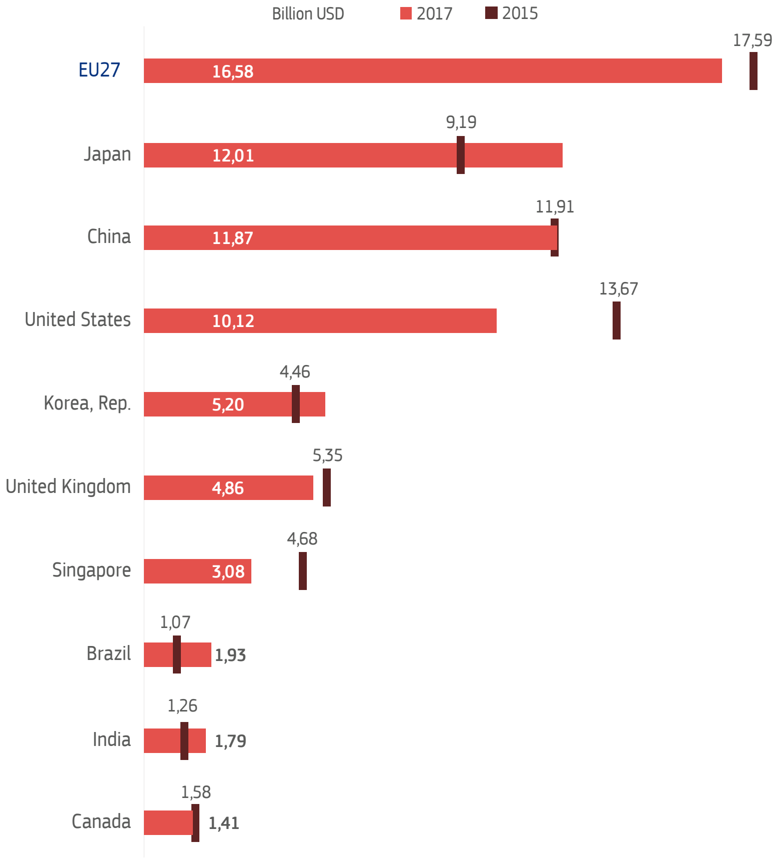
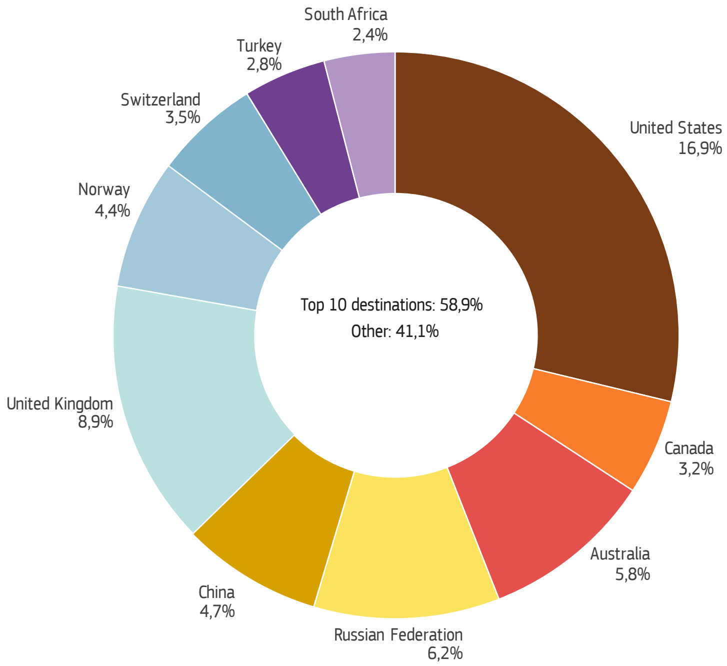


Figure 17.3: Top-10 destinations of EU (excluding UK) exports of mining equipment to the rest of the world (extra-EU-27 exports, 2017)[334].



18. Corporate R&D investment

Key points:

- Corporate R&D investment in the raw materials sectors continued growing in 2017-2018 in absolute terms overall.
- However, the growth of corporate R&D intensity (i.e. R&D investment compared to sales) slowed down in 2017-2018.
- Over the whole 2006-2018 period, the best performing sectors in terms of R&D intensity were non-base-metal mining and construction, while base metals remained constant before declining in 2017-2018. R&D intensity of forestry and paper remained the lowest.

Overview and context

Corporate investment in research and development (R&D) is the backbone of an internationally competitive industry. Corporate R&D aims to reduce costs, identify new market opportunities and develop products and services to better cater to clients' needs. The R&D process may eventually result in patent applications (see indicator 19). Corporate R&D can also serve broader public needs in terms of sustainability, circularity, safety, energy efficiency, reduction of greenhouse gases (GHG) and pollution emissions (see indicators 21 and 22), business digitisation, etc.

The specific nature of corporate R&D activities varies across raw materials sectors. R&D activities in the forestry and paper sector can involve selecting new seedlings, developing methods of pest control, reducing wood waste, improving automation and safety, developing biomaterials and protecting biodiversity and freshwater. In the base metals sectors, R&D efforts may aim to improve the performance and safety of materials and operations, reduce energy consumption, GHG emissions and material wastes and increase circularity[335]. For the construction sector, R&D can consist in developing better mineral binders, foams and coatings, improving the performance of buildings (energy, acoustics, indoor air quality) and using recycled aggregates for roads and surfaces. In the mining sector, R&D can target improved efficiency, safety and automation of mining and smelting, the design of compensation areas for mining deforestation, management of risks from tailings and water storage, development of 3D visualisations, etc. Budget for mining exploration is generally not considered R&D[336].

Facts and figures

Figure 18.1 shows the R&D investment in absolute (monetary) terms by raw materials sector. To give an idea, in Europe a top-10 investing company in these sectors invests between EUR 150 and 450 million a year in R&D. Data comes from the EU Industrial R&D Investment Scoreboard[337]. The sample of companies in raw materials sectors comprises 30 top corporate R&D investors with their headquarters in the EU: 4 forestry and paper companies, 11 base metals production, 2 non-base-metal mining, and 13 construction companies[338].

The figure shows that over the whole period 2006-2018, absolute R&D in the construction and base metal sectors rose, whereas for the forestry and non-base-metal sectors it remained stagnant. During the last 2 years of the period in question (2017-2018), absolute R&D investment has grown for all sectors, especially for the construction industry.

Nevertheless, absolute changes in R&D investment should be interpreted with caution. A positive trend for R&D in monetary terms does not necessarily reflect a rising focus of companies on R&D, but might reflect corporate expansions, out-of-sample acquisitions and/or inflation[339]. In addition, using absolute measures makes cross-sector comparisons difficult due to different sample sizes and due to sector-specific corporate size trends.

R&D intensity, shown in Figure 18.2, is the ratio of R&D investment relative to sales; it is less sensitive to inflation and to sector size as an indicator. Over the whole period 2006-2018, R&D intensity grew for all raw materials sectors except base metals[340]. For the base metal sector, the R&D intensity remained stable around 0.8% before declining to 0.7% in 2017. Non-base-metal mining and construction are the sectors with the highest R&D intensity, and also increased the most (from just under 1% in 2006 up to 1.4% in 2018). The non-base-metal mining sector had the widest oscillations in R&D intensity, which might be due to the cyclicality of exploration. The R&D intensity of the forestry and paper sector remains the lowest, but the trend has been positive (from 0.4% to 0.7%).

Focusing on 2017-2018, however, the growth in all raw materials sectors' R&D intensity was null or even negative. In particular, the R&D intensity of the base metal sector declined, while for the other sectors, R&D intensity remained stable.

Overall, the growth of R&D intensity in the raw materials sectors has been slower than that of the average R&D intensity of the EU economy[341]. The level of R&D intensity for raw materials sectors is structurally lower than that of many other sectors, especially compared to innovation-driven sectors like pharmaceuticals and telecommunications. However, this gap might shrink in the future due to the twin transition towards digitalisation and climate neutrality.

Figure 18.1: Annual R&D investment by top EU-based investing companies, by raw materials sector group (EU-27, 2006-2018)[342].

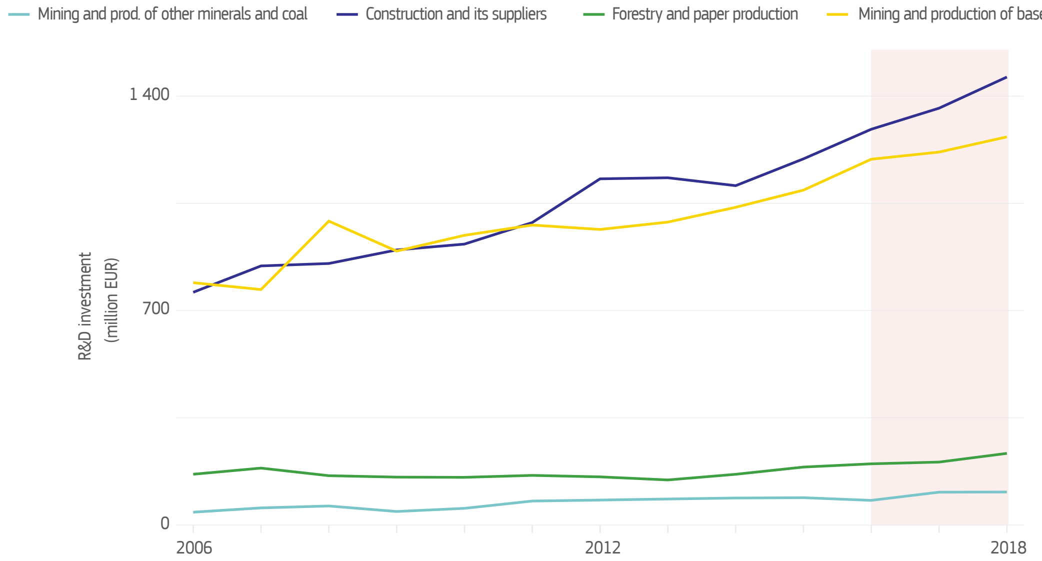
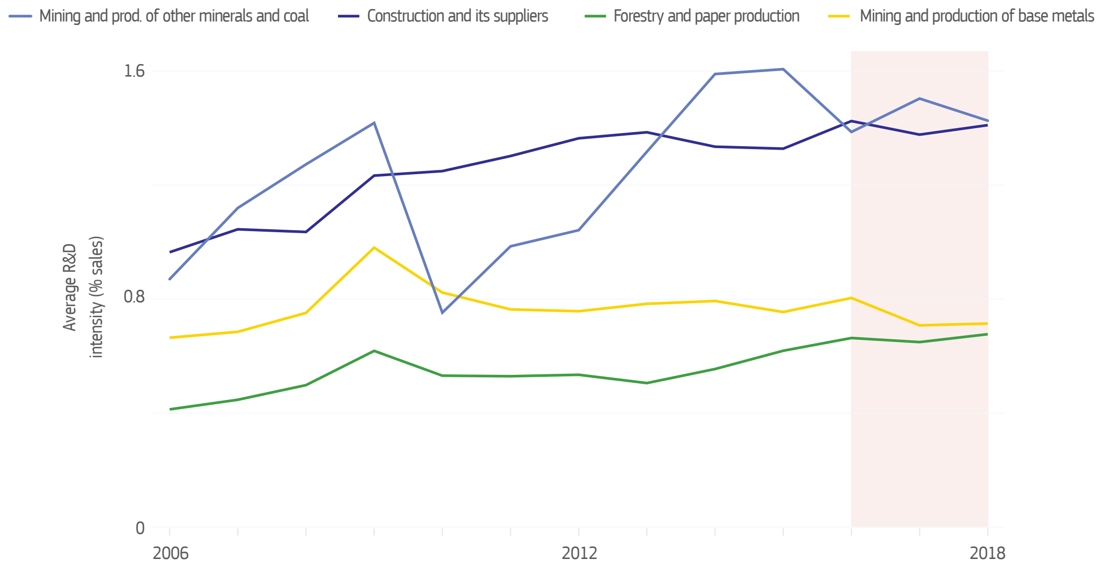


Figure 18.2: Annual average R&D intensity of top EU-based investment companies, by raw materials sector group (EU-27, 2006-2018)[343].



Conclusion

Corporate R&D in the raw materials sectors grew over the period 2006-2018, both in absolute and relative terms, albeit at a slower pace than other, more innovation-driven sectors. The increase in R&D intensity slowed down in 2017-2018 for all raw materials sectors, with base metals' R&D intensity slightly decreasing.

EU funds stimulate and complement corporate investments in technological projects in the raw materials sectors. For these, Horizon 2020 contributed EUR 600 million[344] (between 2014 and 2020), while SPIRE spent EUR 500 million (in 2014-2018, and more in later years[345]). In addition, EIT Raw Materials[346] has a budget of EUR 400 million[347] to support more mature R&D (2016-2022). Other European programmes such as COSME and instruments such as InnovFin facilitate access to debt for innovative firms. European activities also include industry alliances such as the European Battery Alliance and the European Raw Materials Alliance, and bodies such as the European Innovation Partnership on raw materials, providing a framework for research and innovation.

19. Patent applications

Key points:

- Since 2007 EU applicants were ranked third globally by number of patent applications in the raw materials sector, following China and Japan. Several EU countries consistently ranked among the top 10 countries worldwide.
- Between 2012 and 2016, the number of patent applications filed in the EU increased by 16%. The number of Chinese patent applications kept rising at a high pace in almost all sectors, while for Japan there was a steady decrease.
- New patent applications were mostly in production and manufacturing of metals, while those in production and manufacturing of biotic products showed the highest increase.

Overview and context

Patents are used to protect ideas and inventions, and even though their number is not directly relatable to that of exploitable products, they are considered part of the output of the R&D activities of various sectors. Patents reflect the ability of the economy to transform knowledge into technology. Thus, patents are often used as an indicator of technological innovation[348]. This is also reflected by the OECD definition of patents as 'means of protecting inventions developed by firms, institutions or individuals', and as such they may be interpreted as indicators of invention[349]. At EU level, patents – together with copyrights and other intellectual property rights – are seen not only as an indicator for innovation, but also as a major driver for R&I investments[350].

Thus, monitoring trends in patent applications provides important information on the technological evolution rates of different sectors, which can be coupled with the information from the indicator on corporate R&D investments (indicator 18) to obtain a comprehensive picture of innovation trends.

It is, however, important to remember that emerging technologies or sub-sectors may present innovation and patenting trends different from the ones observed at a higher aggregation level (see the case study presented in the box).

Facts and figures

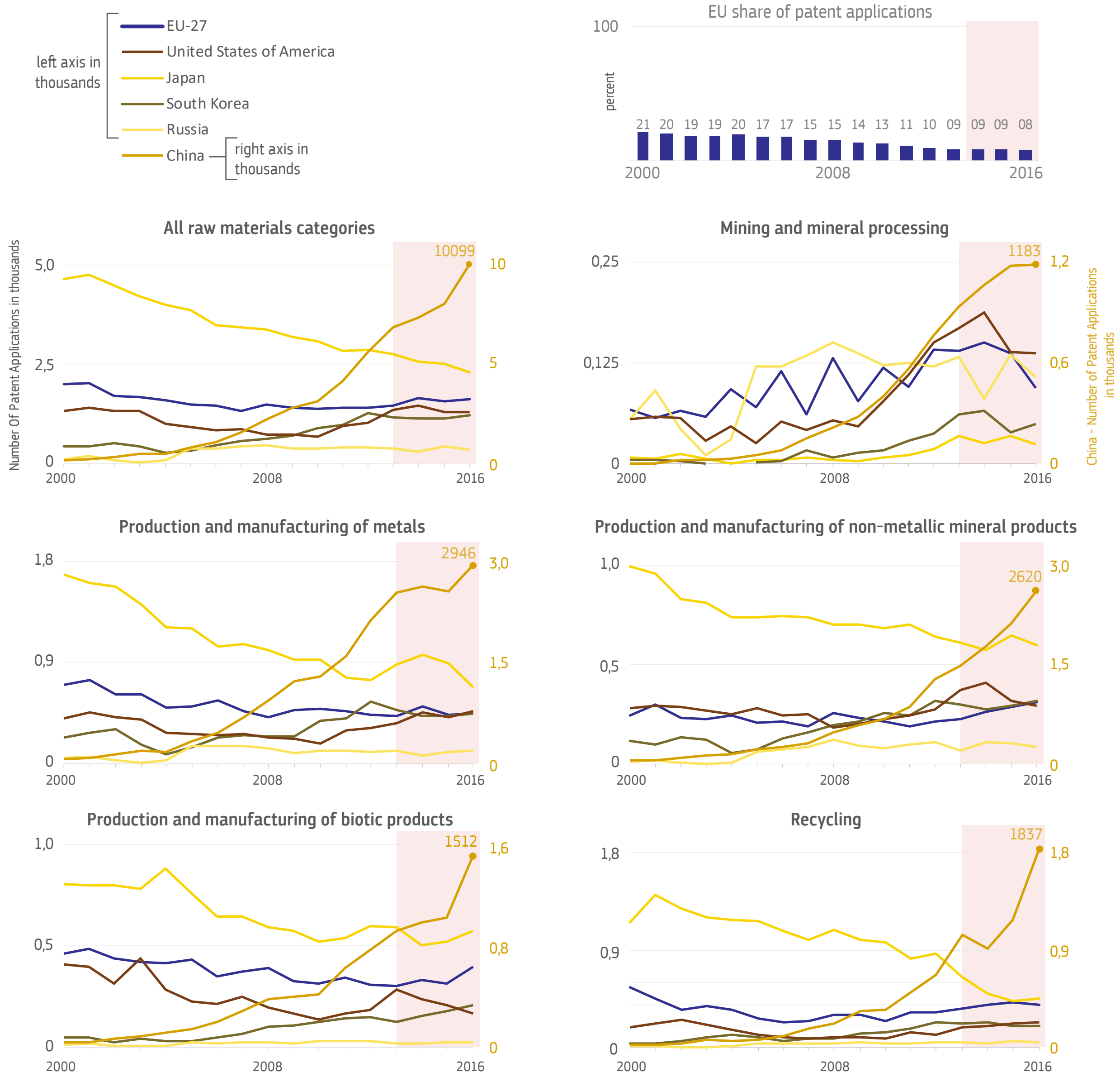
Figure 19.1 presents the number of patent applications in five raw material categories between 2000 and 2016, filed by applicants from the EU and from a group of five non-EU reference countries with the highest number of patent applications in this sector, namely China, Japan, the United States, South Korea and Russia. Unlike in the previous edition of the Scoreboard, it has now been possible to add data covering China to the analysis.[351]. Also, improvements in data processing, made to improve the reliability of the analysis and update the current EU composition[352], challenge the comparability of the data with the previous edition of the Scoreboard[353].

The figure shows that considering all raw materials categories (top figure to the left), the EU was one of the top three players worldwide for the number of patent applications throughout the whole period in question. Looking at the breakdown of data per country, some EU countries ranked among the top 10 countries worldwide (Germany, Finland and France). In the early 2000s, the main players in patent applications in the raw materials sectors were the EU, the United States and Japan. However, starting from 2002 numbers of applications filed in China have been growing drastically, from 357 in 2002 to over 100 000 in 2016, reaching 47% of the worldwide total number of raw materials patent applications. This trend is expected to continue in the near future.

The number of patent applications filed in raw materials categories in the EU, which had been dropping by 30% between 2000 (approx. 2 000 applications) and 2012 (approx. 1 400 applications), was rising with a 16% increment between 2012 and 2016 (approx. 1 600 applications). In contrast, the number of applications filed in Japan kept steadily decreasing. The United States, Russia and South Korea saw no major variations in trends, with applications filed in those countries remaining roughly constant from 2014 to 2016.

The raw materials category with the highest number of patent applications was production and manufacturing of metals, followed

Figure 19.1: Number of patent applications by raw materials sector, and its five contributing raw material categories (applicants from EU-27 and a selection of non-EU reference countries, 2000-2016)[354]. Patent applications from China refer to the right axis.



by non-metallic mineral products, biotic products, recycling, and mining and mineral processing. However, in relative terms the category which grew the most in the last few years of the reference period was the production and manufacturing of biotic products. In this category, patent applications increased for all countries except the United States.

Between 2013 and 2016, patent applications increased moderately in recycling, particularly in the EU and in China, while patent applications in the mining sector generally decreased in all countries (-32% for the EU, -12% cumulative for all other countries except China). The circular economy monitoring framework shows the same general trends on secondary raw materials and circularity: an increased focus of innovation on circularity and sustainability, as well as decreased attention to primary extraction.

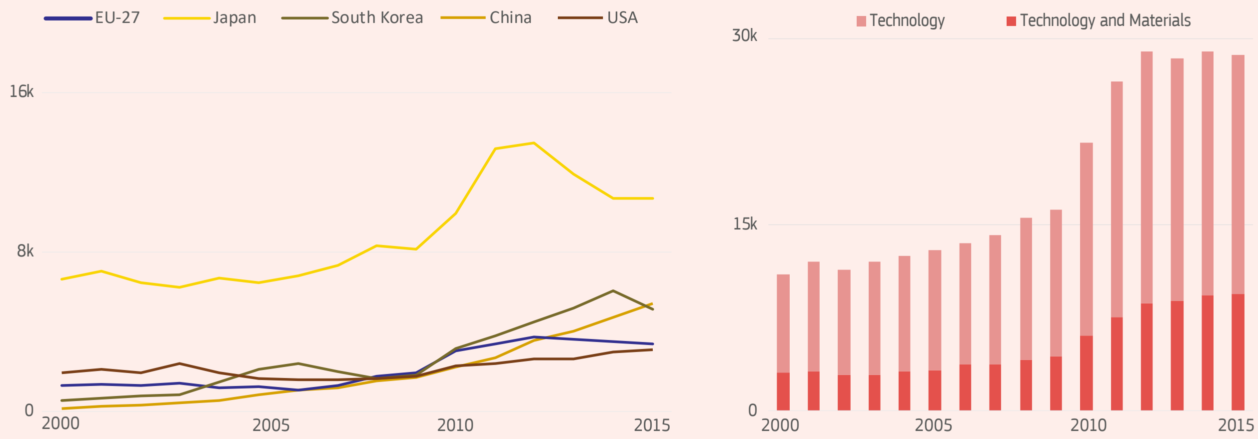
Patent application trends in selected dual-use technologies – the case of lithium-ion batteries

Although general trends in patent applications provide useful information on innovation drivers and activities, individual technologies may follow different paths or timelines. This can be due to a variety of factors, including political or economic interests and the degree of novelty of a specific application.

The data reported here illustrate one of those specific examples, which is the case of lithium-ion batteries[355]. Figure 19.2 shows the number of patent applications for lithium-ion batteries from applicants based in the EU and worldwide (left), as well as the number of applications that could be associated with specific key materials for the development of that technology (aluminium, cobalt, copper, graphite, lithium, manganese, nickel) (right).

In this field, the major player is still Japan, although there are significant and increasing contributions from China and South Korea. At EU level, the number of applications filed per year tripled between 2007 and 2011, and has been stable since. The large majority of patent applications are filed for technologies only, whereas one third only was associated with specific key materials.

Figure 19.2: Lithium-ion batteries patent applications by country[356] (left – EU-27 and a selection of non-EU reference countries, 2000-2015) and by topic (right – worldwide, 2000-2015).



Conclusion

Following the efforts in increasing competitiveness and innovation in the EU, the number of applications filed in the field of raw materials has partially recovered, increasing by 16% between 2012 and 2016. Among the key reference countries, it is only Japan that shows a steady decrease in all the period considered.

As part of its efforts to boost innovation and competitiveness, the EU is acting strongly on protection against patent infringements.

Steps are also being made to make the patenting process cheaper and more efficient by promoting a unitary patent, which will allow applicants to get patent protection in up to 26 countries by submitting one single application to the European Patent Office. This system will be complemented and enforced by a Unified Patent Court and is expected to be in place at the end of 2020.

20. Financing

Key points:

- After a downtrend of financial indicators over the 2011-2015 period, in 2016 the global metals and mining sector started becoming more attractive to investors. For EU-based companies this reversal took place one year earlier, in 2015.
- In the metals and mining sector, the overall share of equity in total assets continued to rise between 2014 to 2018, possibly driven by the increasing profitability of capital investment in this sector.
- After reaching a minimum in 2015, the return on average equity in the global metals and mining sector and base metals subsector has been rising since 2016.

Overview and context

Most companies working in the metals and mining sector have a global reach and raise external funds from the capital markets. Understanding how companies finance their business operations and new projects can shed light on their financial performance, and thus on how attractive they are to investors.

Two relevant monitoring indicators of financial performance are the ones presented in the current analysis: share of equity in total assets and return on average equity. These indicators help understand the magnitude and profitability of the contribution of shareholders' capital to the financial assets of companies from the metals and mining sector.

Facts and figures

Figure 20.1 shows the evolution of the share of total equity in total assets over the 2011-2018 period, of both worldwide and EU-based companies operating in the metals and mining sector and in its two sub-sectors, i.e. basic metals and precious metals.

This indicator provides information about shareholders' contribution to the companies' assets and is a proxy for investment attractiveness. The geographical base of companies refers to the location of the official headquarters, not the location of their activity (i.e. company divisions and branches might be located elsewhere). Data reflects the EU-27 composition[357]. For each sector and subsector, company coverage is not exhaustive[358].

Worldwide, the mining and metal sector companies' equity share in total assets exhibited a decreasing trend until 2015, reversing in 2016. For EU-based companies, this trend reversal took place one year earlier, in 2015. This pattern is a sign of the sector's renewed attractiveness to investors. For the base metals sub-sector, this reversal took place later, in 2017, for both world and EU-based companies.

Over the whole period 2011-2018, the shares of equity in total assets for EU-based companies belonging to both sub-sectors (the precious metals and base metals) were higher than the corresponding shares of overall companies worldwide.

Figure 20.1: Share of total equity in total assets of companies from the metals and mining sector and two of its sub-sectors (world and EU-27-based company aggregates[360], 2011-2018)[361].

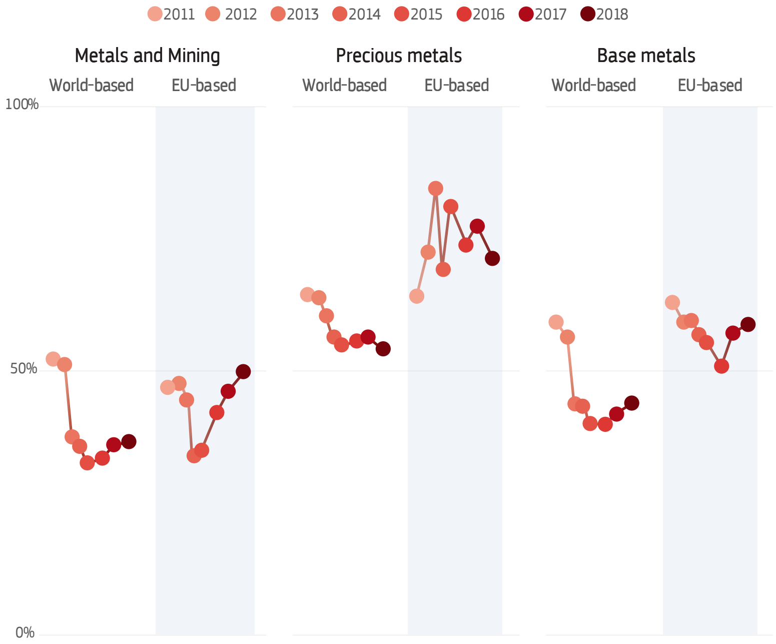
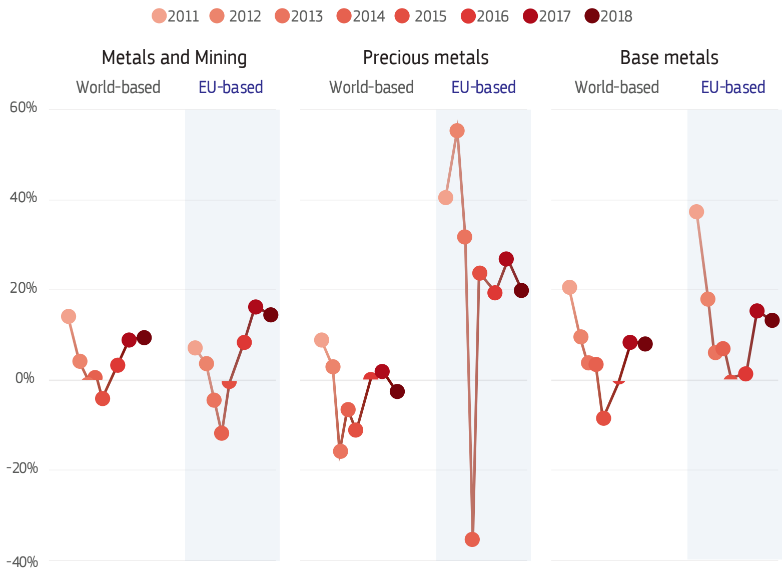


Figure 20.2 shows the evolution of the return on average equity for capital investments in the metals and mining sector and its two sub-sectors, base metals and precious metals. Return on average equity provides information about the investors' earnings, and could potentially explain the evolution of the indicator in Figure 20.1 (share of total equity in total assets). Indeed, the two indicators exhibit a similar trend in the metals and mining sector. This evolution again indicates a higher profitability of stakeholders' investments in the metals and mining sector in 2016 to 2018.

Similar to the previous indicator, returns on average equity for precious metals and base metals sector were higher for the EU-based companies than for the whole set of worldwide companies over practically the entire period analysed.

The 2016 trend reversal, observed in both financial indicators for the metals and mining sector, might be explained by the rebound in prices of base metals (e.g. aluminium, copper, iron ore, lead, nickel and zinc) and in precious metals (e.g. gold, platinum and silver) after the minimum values recorded in 2015[359].

Figure 20.2: Return on average equity in the mining sector and two of its sub-sectors[362] (world and EU-27-based company aggregates, 2011-2018).



Conclusion

After the worldwide decline of the values for these financial indicators for companies in the metals and mining sector over the 2010-2015 period, the trend reversed and became positive in 2016. For the EU-based companies this trend reversal took place one year earlier, in 2015.

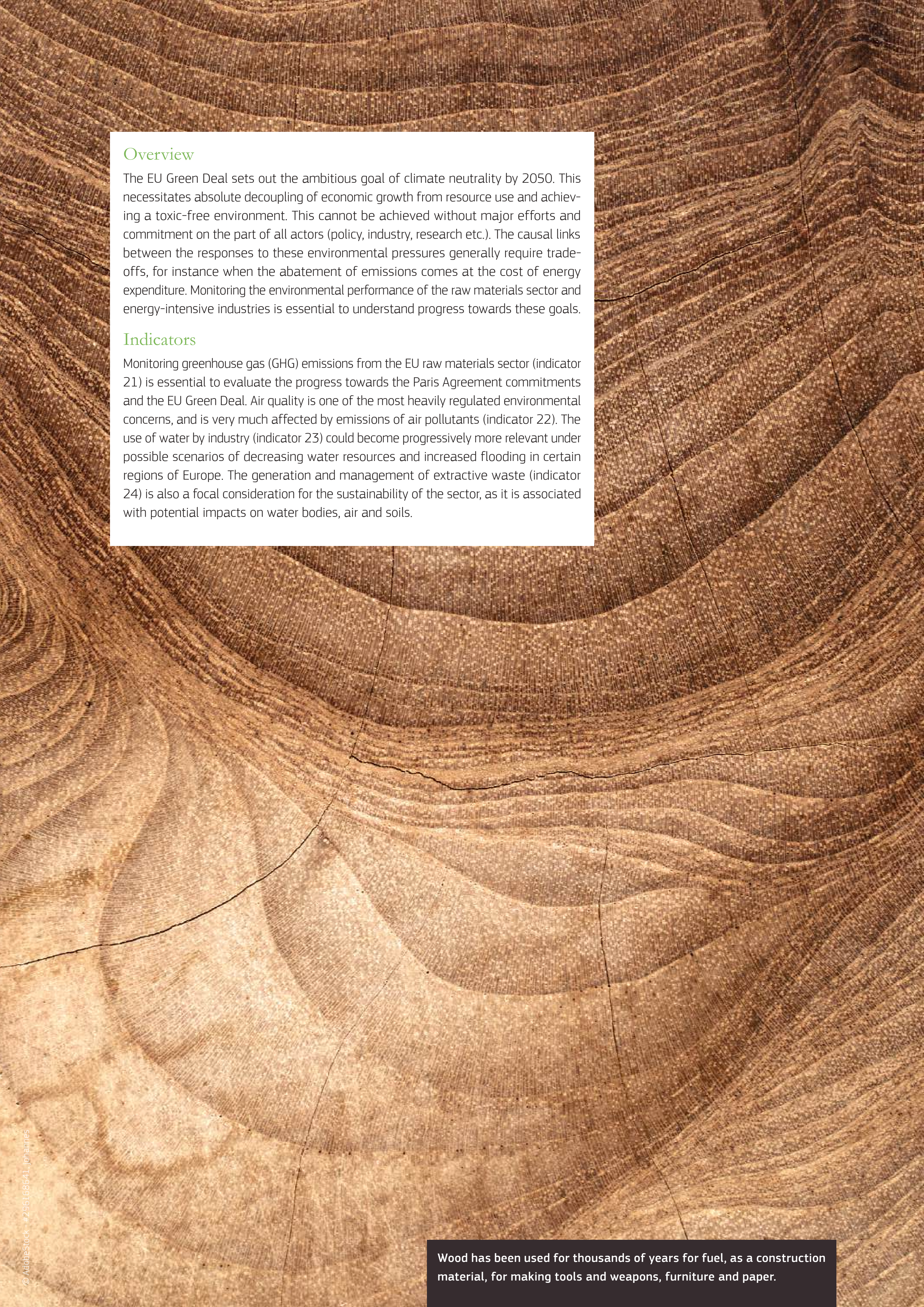
Based on the similar evolution of all financial indicators analysed, it can be inferred that investment profitability enhanced the attractiveness of the metal and mining sector to investors starting from 2016. This change might be linked with increasing commodity prices.

Overview

The EU Green Deal sets out the ambitious goal of climate neutrality by 2050. This necessitates absolute decoupling of economic growth from resource use and achieving a toxic-free environment. This cannot be achieved without major efforts and commitment on the part of all actors (policy, industry, research etc.). The causal links between the responses to these environmental pressures generally require trade-offs, for instance when the abatement of emissions comes at the cost of energy expenditure. Monitoring the environmental performance of the raw materials sector and energy-intensive industries is essential to understand progress towards these goals.

Indicators

Monitoring greenhouse gas (GHG) emissions from the EU raw materials sector (indicator 21) is essential to evaluate the progress towards the Paris Agreement commitments and the EU Green Deal. Air quality is one of the most heavily regulated environmental concerns, and is very much affected by emissions of air pollutants (indicator 22). The use of water by industry (indicator 23) could become progressively more relevant under possible scenarios of decreasing water resources and increased flooding in certain regions of Europe. The generation and management of extractive waste (indicator 24) is also a focal consideration for the sustainability of the sector, as it is associated with potential impacts on water bodies, air and soils.



Wood has been used for thousands of years for fuel, as a construction material, for making tools and weapons, furniture and paper.

Environmental dimension

Indicators

21. Greenhouse gas emissions
22. Particulate matter and NMVOC emissions
23. Water
24. Extractive waste

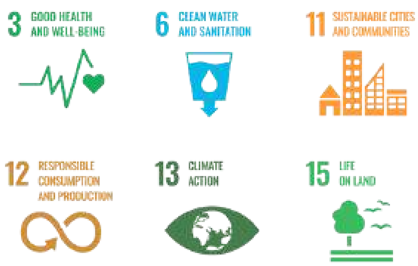
SCOREBOARD

SUSTAINABLE DEVELOPMENT GOALS

Raw materials supply in the EU:
4. Mining activity in the EU, 6. Domestic production;

Circular economy and recycling:
15. Recycling's contribution to meeting materials demand;

Social dimension:
25. Responsible sourcing, 27. Jobs.



21. Greenhouse gas emissions

Key points:

- Overall greenhouse gas emissions from the EU raw materials sector continued to decrease over the period 2012-2015 but increased worldwide.
- Most EU raw materials industries decreased their GHG emissions in absolute terms, except for mining and non-ferrous metals overall. Nonetheless, industries did not always decrease their emissions intensity.
- Industry needs to decarbonise further to meet the targets set by the European Green Deal for climate neutrality by 2050 and the targets set by the Paris Agreements; the decarbonisation potential in each industry will be greatly determined by the availability of cleaner energy options, and whether GHG emissions come more from energy use or other industrial processes.

Overview and context

Decarbonisation is one of the main goals of the European Green Deal. The ambition is to have a carbon-neutral Europe by 2050; this ambition is directly linked to Sustainable Development Goal 13 on Climate action. This is in line with the EU vision to align with the Paris Agreement, as expressed in the *A clean planet for all* Communication[363], which states that the EU should by 2050 be among the first to achieve net-zero GHG emissions, leading the way worldwide[364]. Climate targets are very much linked with EU targets related to air quality (see indicator 22 on air pollutants). In this context, the raw materials industries can both generate GHG emissions and provide the materials needed to deploy low-carbon technologies[365] (renewable energy and e-mobility technologies, etc.)

GHGs are generated throughout the raw materials value chain, by processes such as drilling, hauling, comminution, ventilation, beneficiation, manufacturing, transport, as well as by recycling and waste management. While for some materials, emissions are concentrated in the extraction stages, for other materials emissions during processing are higher (see the box below for the case of aluminium).

Emissions can be direct, i.e. emitted on site at producing facilities, or indirect, i.e. emitted elsewhere. Most direct emissions originate from the use of energy or fuels for mechanical processes (e.g. drilling) or for the production of heat. The raw materials sector is generally considered energy-intensive. In addition, 'process emissions' are derived from some industrial processes where chemical reactions release carbon, e.g. calcination of limestone to yield cement, or metallurgical furnaces.

In a commodity's supply chain, GHG emission hotspots and potential emission cuts can vary strongly according to the material's features. They also depend on whether most emissions come from energy use or from other industrial processes, and on the availability of cleaner energy options.

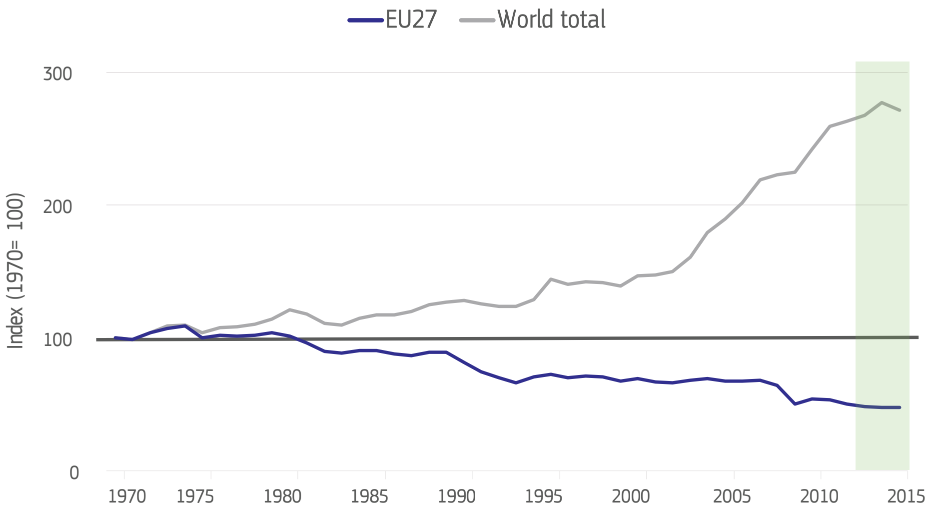
The raw materials industry has already made significant efforts to reduce emissions. Some examples are the optimisation of industrial processes such as steel production, the increase of production based on secondary materials for some materials[366], electrification, and the use of biomass and waste as fuel and for heat generation (in paper industries). Despite this, significant challenges remain. For instance, reliance on fossil fuels used for ventilation, drilling, etc., is high in mining operations, especially in remote areas[367]. Moreover, the average energy demand per mining output is expected to increase due to the trend of decreasing ore grades and more stringent mining conditions. Process-related emissions, often having been optimised for decades, do not show significant potential for further reductions[368]. In the raw materials sector, this lack of potential for further cuts in emissions can be also due to the mineral resources composition. In addition, the sourcing of some materials needed for low-carbon technologies may raise socio-environmental concerns[369].

In 2019, the High Level Group on Energy-intensive Industries developed a masterplan for the competitive transformation of energy-intensive industries[370], recommending a comprehensive enabling framework. The underlying study[371], *Industrial Value Chain: A Bridge towards a Carbon-neutral Europe*, looks at common opportunities and challenges and determines a combination of key solutions.

Facts and figures

Figure 21.1 presents the trend of absolute direct[372] GHG emissions from industrial facilities in the raw materials sector in the EU and globally as an index, with 1970 as the base year. It includes both absolute GHG emissions from fuel use (combustion) and GHG process emissions[373] from six raw material industries: mining, iron and steel production, non-ferrous metals production, non-metallic minerals production, paper, pulp, and print, and wood and wood products. Production in some industries is based also on secondary materials.

Figure 21.1: Index (related to 1970) of absolute direct GHG emissions from the raw materials sector (EU-27 and world total, 1970-2015)[383].



In 2015, GHG emissions from the raw materials industries accounted for 7.2% of total GHG emissions at EU level, while globally they accounted for 12%[374]. Until 1995, in contrast with the current picture, this share was higher for the EU than the world average.

Absolute GHG emissions from the raw materials sector in the EU decreased by 4% between 2012 and 2015. This reflects a net decrease of 15 million tonnes CO_2eq in absolute GHG emissions. Globally, absolute GHG emissions continued growing by 3% over the same period. Despite this, the trend reversed between 2014 and 2015, when the annual decrease in absolute GHG emissions was higher at global level than at EU level.

Figure 21.2 provides a breakdown of absolute direct GHG emissions in the EU by raw materials industry and provides data on the industries' emission intensities, i.e. the amount of emissions per unit of production[375]. Absolute emissions provide information about industry's impact on climate, whereas emission intensities indicate whether improvements in emission efficiency are taking place.

In recent years, absolute GHG emissions from the production of non-metallic minerals were the highest among the raw materials industries, especially process emissions from the production of cement. Emissions from this sector fell by more than 5% between 2012 and 2015. The key driver for this decrease was a decline in production volumes[376]; in contrast, no significant reductions in emission intensity were observed.

Emissions by the iron and steel industry followed in the list of absolute GHG emissions, dominated by fuel-use (combustion) emissions. Despite an increased emission intensity for this industry for both combustion emissions and process emissions, its absolute emissions decreased between 2012 and 2015.

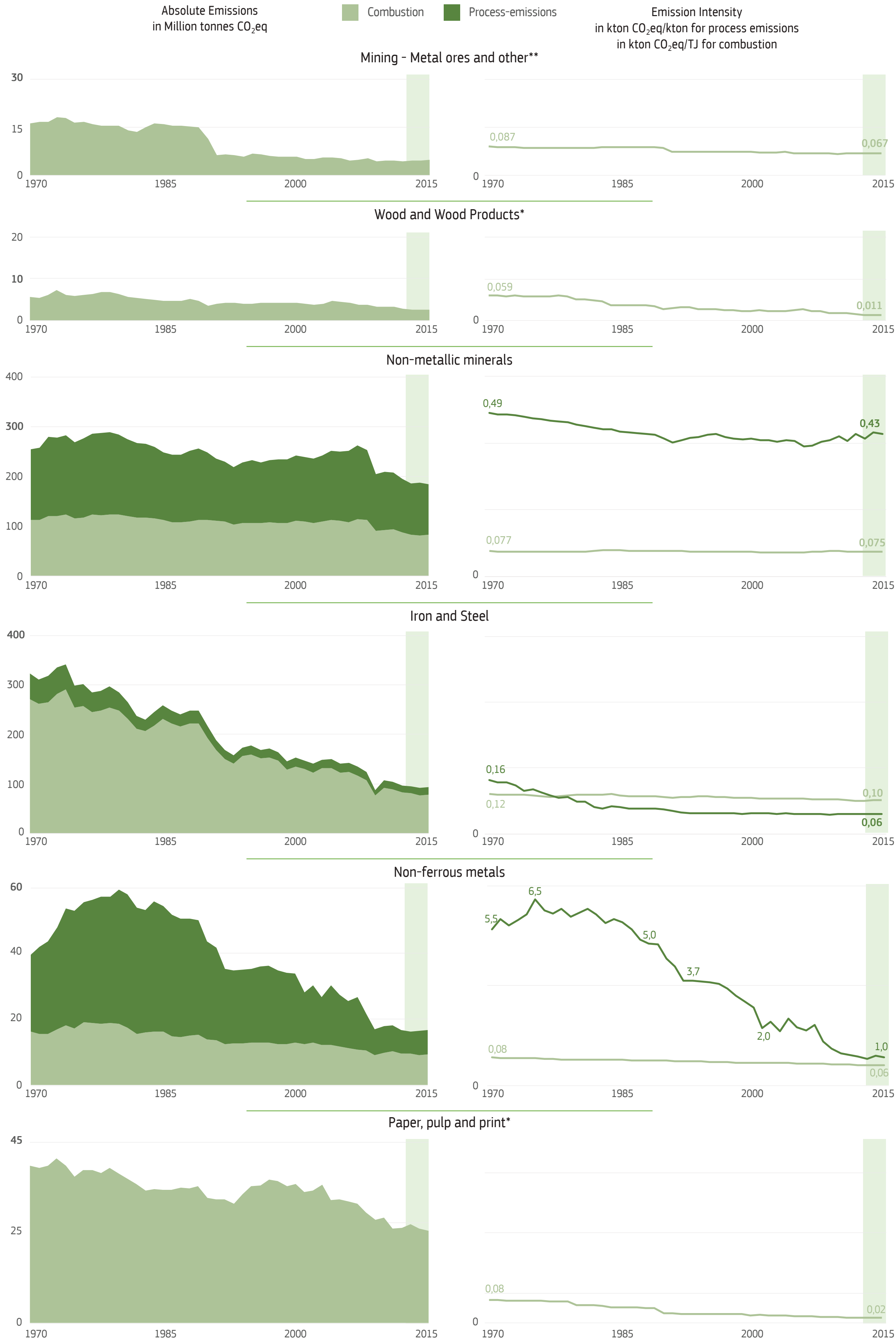
Next, emissions from (fuel use in) the paper industry went down by 9%, while emissions from non-ferrous metals remained rather stable. Absolute GHG emissions from (fuel use in) mining increased by around 9% between 2012 and 2015, with an associated rise in emission intensity of almost 2%.

Finally, the wood industries reduced GHG emissions the most in relative terms (by 18%). Cuts in emissions in the wood and paper industries were supported by the absence of GHG process emissions, which are generally more difficult to reduce than emissions from fuel use.

Looking at future trends, further reductions in GHG emission intensities through technology improvements appear limited[377]. For instance, the cement and non-ferrous metals industries are close to their technological plateaus, while only limited improvements are expected in the iron and steel industry. In contrast, the paper industry has the potential to increase the use of low-carbon energy such as biomass employed as fuel[378]. Key enabling technologies such as clean hydrogen and electrification also show mitigation potential[379].

The move towards a circular economy offers high potential for additional savings of emissions in all industries, in particular through higher recycling rates and the increased use of secondary raw materials to produce industrial goods like glass or steel. However, recycling of increasingly complex products may cause energy intensity to go up. GHG emissions savings could be also achieved through lower material losses at production, more advanced materials, changes in product composition[380], products being designed for re-use and recycling, and circular business models[381], [382].

Figure 21.2: Absolute direct GHG emissions and GHG emission intensities per raw materials industry (EU-27, 1970-2015)[384].



Industries are ordered starting with upstream processes, followed by downstream processes. GHG emissions from some metals and paper might refer to production based on primary resources, but also on secondary materials. * For the paper and wood industries, GHG process emissions are considered null, since they are assumed to be compensated by carbon capture during biomass growth.
** For mining, data availability is limited to combustion-related GHG emissions.
Note the varying y-axes units.

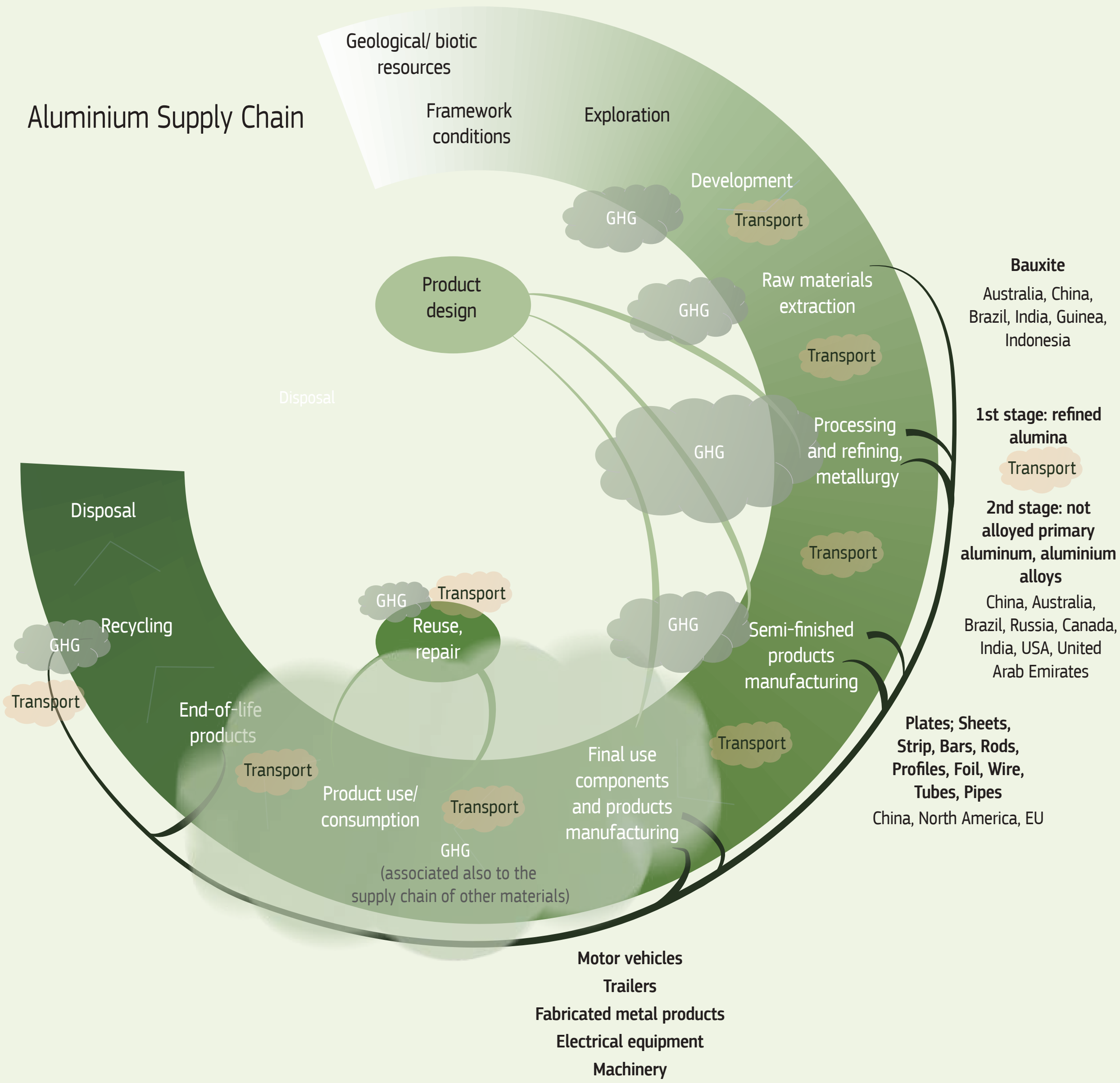
GHG emissions along the supply chain – the example of aluminium[385]

Raw material supply chains can be quite complex, with associated GHG emissions at different stages. Taking the aluminium supply chain as an example, the European Commission's Product Environmental Footprint[386] identified the climate impact caused by GHG emissions as the largest negative impact of its production chain.

The construction of an aluminium-containing product starts with a product's design. This determines the need for exploration and extraction of aluminium ores, of which bauxites are most widely used. The EU production of bauxite is limited, and most bauxite comes from imports, specifically from Guinea, where there are environmental and social concerns about mining practices[387],[388]. Bauxite is first processed into alumina, which then yields primary aluminium through smelting, a very energy-intensive process. Smelting plants are usually not at the same location as the mine sites, with siting mainly determined by logistics and the availability of electricity on favourable terms. Consequently, there are many aluminium smelters located in the EU[389]. Primary aluminium is then rolled or cast into various semi-finished products such as plates or rods. The supply chain continues with the manufacturing of final products, mostly for the transport and automotive sector (from aircrafts to cars), where its lightweight characteristics can increase fuel efficiency and save GHG emissions. Aluminium is also extensively used for construction (e.g. infrastructure, doors, windows), packaging, high-tech engineering, renewable energy and low-carbon technologies.

At its end of life, aluminium can be recycled through well-established collection schemes, scrap preparation techniques and refining processes. Recycled aluminium is highly energy-efficient, using only 5% of the energy that is needed for primary production. It is estimated that recycled aluminium satisfies 12% of the EU's aluminium demand (see indicator 15).

Figure 21.3: Overview of the aluminium supply chain demonstrating schematically the intensity (cloud size) of GHG emissions along supply chain processes[390, 391].



GHG emissions related to raw materials extraction and processing can represent a significant share of the total emissions generated through the whole supply chain of sectors like construction and automotive[392]. Within these production processes, as is the case for other metals, total energy consumption and GHG emissions are higher for smelting and refining than for extraction and ore dressing, where less sophisticated techniques are applied[393]. In the case of aluminium, the smelting of alumina is very energy-intensive. However, emissions from mining and ore processing are expected to become more significant in the future[394] due to decreasing trends in ore grades.

It is important to note that GHG emissions from bauxite extraction, from alumina production outside the EU, from the transportation of materials, and from the distribution of semi-final and final products are not considered in the accounting of direct emissions from aluminium production presented in this Scoreboard indicator (aluminium production falls within the non-ferrous industries covered by figures 21.1 and 21.2). Direct emission figures also do not account for improvements in the energy performance of final products incorporating aluminium.

Conclusion

The decarbonisation of the EU's industrial sector is a key priority. While the EU raw materials industry is exploring potential technological paths for decarbonisation[395], [396], it still faces several challenges like rising competition for low-carbon electricity, technological limitations and the minimisation of carbon leakage[397]. The EU's energy-intensive industries (EIIs) are tackling these challenges by joining forces[398] and developing an industrial transformation masterplan for energy-intensive industries to transition towards a climate-neutral and circular EU economy by 2050[399].

The target of the European Green Deal to become climate-neutral by 2050 is expected to drive a strong transformation of the EU economy. It is also expected to need additional action to move towards a circular economy[400]. This can be seized as an opportunity for modernisation. This will often mean significantly modernising existing installations or completely replacing them. Shifts to new production processes will require new skills[401]. 2050 is one investment cycle away for most energy-intensive companies, and the need to act urgently is clear. Several initiatives are being developed at the European Commission to make a smoother transition possible, while ensuring that the transition is fair across regions and economic sectors.

22. Particulate matter and NMVOC emissions

Key points:

- Emissions of particulate matter and non-methane volatile organic compounds have increased for the raw materials industries overall in recent years in the EU, while they decreased globally.
- The EU increase in absolute emissions was mostly caused by the paper and wood industry. Emissions from wood production and mining increased markedly in relative terms.
- These trends reflect increases in production (e.g. for paper), in fuel use (mining), and in the emission intensity of combustion and other industrial processes.

Overview and context

Preserving air quality is among the main objectives of EU policies on environmental protection and directly links with SDG 3 on Good Health and Well-being and SDG 11 on Sustainable cities and communities. Based on a fitness check of the Ambient Air Quality Directives[402], the European Green Deal[403] announced the adoption of a zero-pollution action plan in 2021 and proposed to align air quality standards with World Health Organization recommendations. The monitoring, modelling and controlling of industry emissions play an interconnected key role in achieving this.

Air quality levels result from complex processes. Primary pollutants are emitted by industrial sources, by households and by transport. Depending on, for example, weather and topographic conditions, these can form secondary pollutants[404] and be transported over long distances. Air quality is also closely interlinked with climate change: variations in weather patterns can lead to changes in the formation of pollutants in the atmosphere and therefore impact air quality levels[405]. In addition, several air pollutants show climatic effects next to their pollution characteristics[406, 407].

As for greenhouse gases (see indicator 21), emissions of pollutants from the raw materials sector can occur across the entire value chain, from the extraction of raw materials to the production of semi-finished products, the manufacturing of final products, waste management and recycling processes. Pollutant emissions may originate from the combustion of fuels, e.g. at industrial facilities or during transport, from non-combustion industrial processes, or from mechanical operations such as land clearing or drilling.

While in the last few decades the raw materials sector in the EU has achieved significant reductions in emissions of some air pollutants, the sector contributes to the emission of what are considered the main air pollutants[408]. These include particulate matter[409], non-methane volatile organic compounds[410] (NMVOCs), and substances that can contribute to acid deposition[411]. The sector is also one of the major sources of heavy metals, which can contribute to toxic deposition[412, 413]; heavy metals release can be also very significant during the use phase.

The two Ambient Air Quality Directives in force[414, 415] determined air quality standards for several pollutants in the EU[416]. To achieve air quality according to these standards, the National Emission Ceilings Directive[417] set emission reduction commitments for 2020 and 2030 for the EU and the Member States[418] regarding five main air pollutants. Related to these reduction commitments, the Industrial Emissions Directive[419] (IED) requires large industrial facilities to apply 'best available techniques' (BATs). These BATs are specified in the BAT reference documents (BREFs), which establish binding pollutant emissions limits for well-determined industrial processes. BREFs have been adopted for iron and steel, ferrous metals processing, non-ferrous metals, cement and lime, wood-based panels, pulp and paper, glass and ceramics[420], among others. There are other source-specific standards on air pollutants such as those coming from rules on ecodesign, energy efficiency, and medium combustion plants.

Facts and figures

Figure 22.1 presents the trend of emissions of the two main air pollutants, particulate matter (measured in terms of PM_{10}) and non-methane volatile organic compounds[421] (NMVOC), from the raw materials industry in the EU and globally. Data are presented normalised relative to absolute emissions of 1970. Data cover emissions from mining, the production of iron and steel, non-ferrous metals, non-metallic minerals, pulp, paper and print, and wood and wood products. Data include emissions from fuel use (combustion) and process emissions[422]. Production in some industries is based also on secondary materials.

At EU level, PM_{10} and NMVOC direct emissions from the raw materials sector accounted for 22% and 9% respectively of all direct emissions in the EU in 2015. These shares have been increasing over time, exceeding the related shares at global level, where the raw materials sector emitted 17% and 5% respectively of all direct PM_{10} and NMVOC emissions[423].

Figure 22.1 also depicts increases of emissions by the EU raw materials sector between 2012 and 2015 of around 2.7% for NMVOC and 1% for PM_{10}. This mirrors a net increase of about 4 600 tonnes for PM_{10} and 20 000 tonnes for NMVOC. Globally, emissions continued increasing on a more moderated path than in previous periods, around 2% between 2012 and 2015. Similarly to GHG emissions, the sector reversed the upward trend at the global level by drops in emissions between 2014 and 2015 for both PM_{10} and NMVOC. This trend reversal was mostly due to China's decrease in the emission of both types of pollutants[424] (India and the United States also had significant contributions to global emissions).

Figures 22.2 and 22.3 provide: (i) a breakdown of PM_{10} and NMVOCs emissions respectively, by raw materials industry in the EU; and (ii) data on their emission intensity.

The pulp and paper industry contributed most to emissions of PM_{10} and NMVOC in the last years of the period under analysis. The largest part of these emissions originated from 'process emissions' (i.e. emissions from processes other than fuel use), which are generally more challenging to reduce. The emissions from the pulp and paper industry continued to increase moderately between 2012 and 2015, around 4% for PM_{10} and 2% for NMVOC, following the trend of previous years. This trend was generally caused by increases in production[425] and, in the case of PM_{10}, also by a rise in emissions intensity.

Figure 22.1: Index (related to 1990) of absolute direct PM_{10} and NMVOC emissions from the raw materials sector (EU-27 and world total, 1970 - 2015)[431].

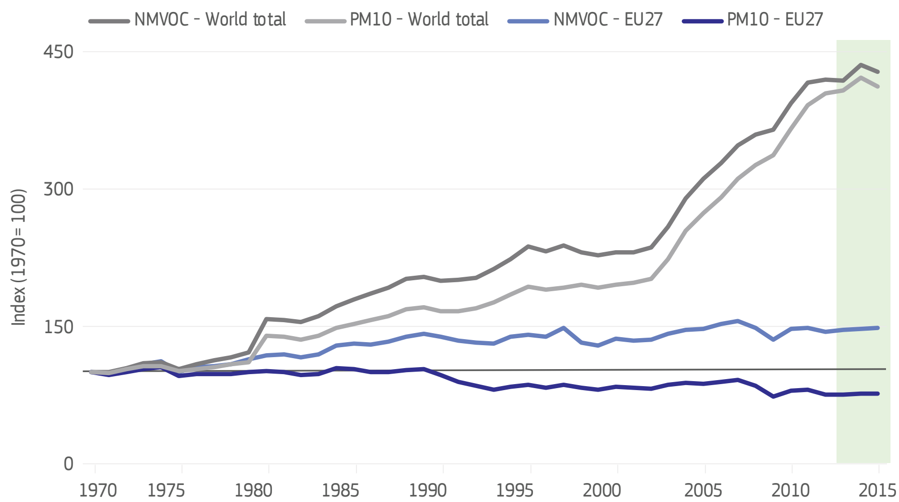
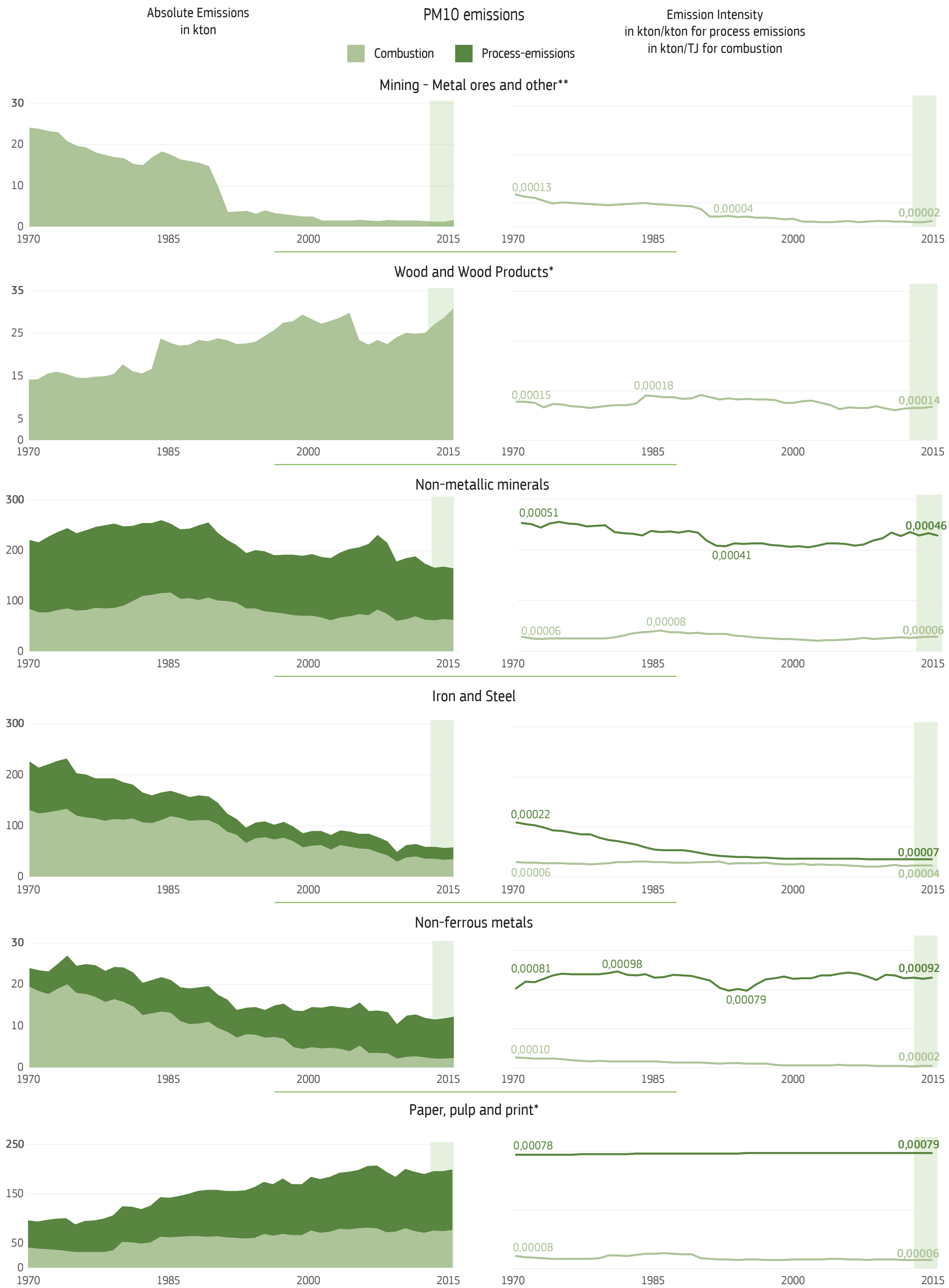
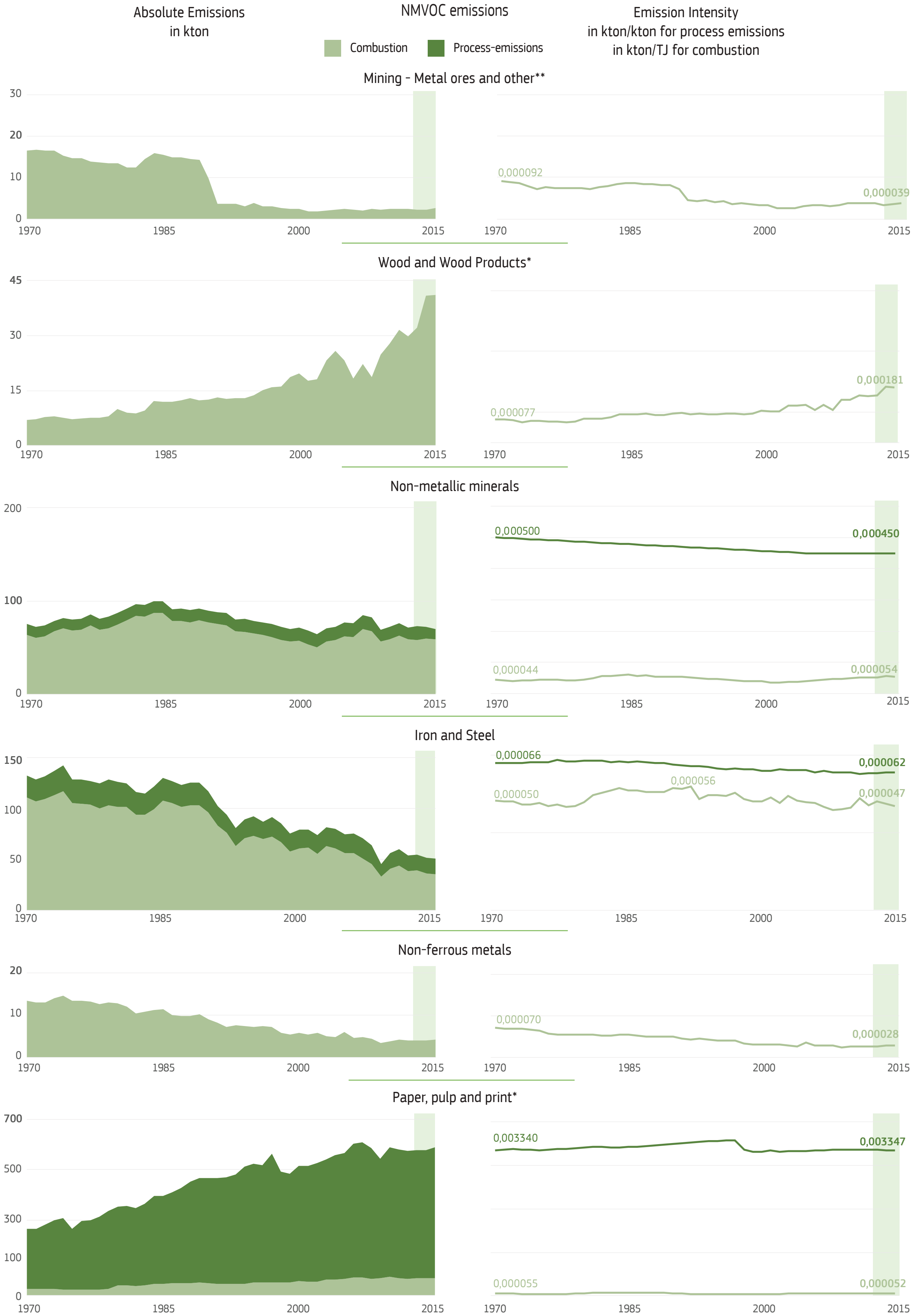


Figure 22.2: Absolute direct PM_{10} emissions and PM_{10} emission intensity per raw materials industry (EU-27, 1970 - 2015)[432].



Industries are ordered starting with upstream processes, followed by downstream processes.
Emissions from some metals and paper might refer not only to the production based on primary resources but also to production based on secondary materials. Note the varying y-axes units.
* For the 'wood and wood products' and 'mining' industries, only combustion-related emissions are available.

Figure 22.3: Absolute direct NMVOC emissions and NMVOC emission intensity per raw materials industry (EU-27, 1970 - 2015)[433].



Industries are ordered starting with upstream processes, followed by downstream processes. Emissions from some metals and paper might refer to production based on primary resources, but also to secondary materials. Note the varying y-axes units.

* For the 'wood and wood products', 'non-ferrous metals', and 'mining' industries, only combustion-related emissions are available.

The production of non-metallic minerals showed the second highest emissions of the six raw materials industries, where more than 60% of its PM_{10} emissions originated from process emissions. PM_{10} emissions from non-metallic minerals production decreased by 5% and NMVOC emissions by 3% between 2012 and 2015, associated with decreasing production volumes; in contrast, the emission intensity of the sector slightly increased.

The iron and steel industry came third in terms of absolute emissions, with most emissions linked to fuel use. On the back of considerable emission reductions since the 1970s, the sector continued to decrease its emissions between 2012 and 2015, around 5% for NMVOC and 2% for PM_{10}.

PM_{10} from process emissions in non-ferrous metals production increased by 5% between 2012 and 2015, mostly derived from increasing production volumes[426], while both PM_{10} and NMVOC emissions derived from fuel use remained rather stable.

The upstream industry sectors of mining and wood production showed small shares in the total emissions of the raw materials sector. However, increases of emissions by 17% for PM_{10} and 13% for NMVOC were reported for mining. Bigger increases were observed for emissions from (fuel use in) wood production: around 23% for PM_{10} and 38% for NMVOC. These trends were associated with increasing fuel use and emission intensity.

Remarkably, emissions trends for PM_{10} and NMVOC from fuel use in paper and wood industries went up, while the GHG emissions of both sectors[427] decreased over the same reference period. This means that the recent changes in the fuel mix have been effective in reducing GHG emissions, but not in controlling emissions of air pollutants. The increasing use of biomass as fuel may be one possible contributor to this state of affairs.

The trends described above are consistent with the most recent EU trends for the industry[428] as reported in the official emissions inventories, which point to stable/increasing trends of PM_{10} and NMVOC, with trends slightly increasing between 2015 and 2017[429].

Conclusion

The raw materials sector in the EU achieved significant reductions in the main air pollutant emissions. NMVOC and PM_{10} emissions are examples depicted in this section of the Scoreboard. While the industries showed heterogeneous trends within the period 2005-2015, the situation generally deteriorated between 2012 and 2015. The production of paper and wood products drove this trend, due to increasing production volumes and simultaneously rising emission intensities in fuel-use processes. At the same time, these industries improved their efficiency regarding GHG emissions (see indicator 21).

Increased production of biotic materials has taken place in recent years and is seen as a possible measure to meet the climate targets in the EU. The results here show that care should be taken to avoid trade-offs between GHG emissions mitigation and other environmental considerations such as air pollution. Strategies such as the cascading use of biomass[430] and the development of innovative products may help improve resource efficiency and reduce the environmental pressures derived from the raw materials sector.

23. Water

Key points:

- In the period 2013-2017, the use of water for basic metals manufacturing increased in some EU countries, while less water was used by the paper industry and mining and quarrying. Increases generally took place in locations with no water stress.
- The variety in raw materials industries and local water conditions makes it challenging to assess the performance across countries and sectors.

Overview and context

Water is an essential input for the raw materials extractive and manufacturing industries, and is used all along the production chain. Water availability can be a decisive factor in determining the location of an operation facility, where often water-intensive processes take place.

Depending on the local water conditions and the features of the raw materials industries, different considerations (water availability, impacts on water quality and quantity) can become relevant in terms of guaranteeing the production of raw materials, while preserving water quantity and quality. Water use efficiency and reduction of pollution fall under SDG 6 on clean water and sanitation[434].

Water requirements for the production of different commodities can vary widely. For instance, the processing of precious metals generally demands more water than other metals[435]. Producing iron, steel and paper is usually waterintensive, while producing wood and non-metallic minerals generally demands less water. Differences depend on ore concentration[436], processing technologies in place and other factors.

Mining industries have reduced water consumption through e.g. water re-use in many locations, since limiting water use helps lower processing costs and increases the ability to operate during dry periods[437]. Similarly, manufacturing industries have considerably improved water re-use and treatment before discharging. However, industry faces challenges: water scarcity and competition for water can limit water availability in some locations. In mining, decreasing trends in ore grade may lead to increasing water demand[438]. Also, in water-rich areas, large amounts of excess water require management. The infrastructure developed for this[439] can improve local water supply.

In the EU, the volume of water used over available resources can be considered sustainable overall[440]. However, some regions show water stress problems, at least during some seasons of the year[441]. Indeed, increasing water stress, alongside flooding, are top risk drivers in the mining and metals industries, both in the short and the medium term[442].

Apart from water quantity, water quality considerations relate to operating and abandoned facilities and their point and diffuse pollution (see box). Extractive practices such as dredging, or seabed and deep-sea mining, can also impact coastal and marine ecosystems[443], affecting SDG 14 on life below water.

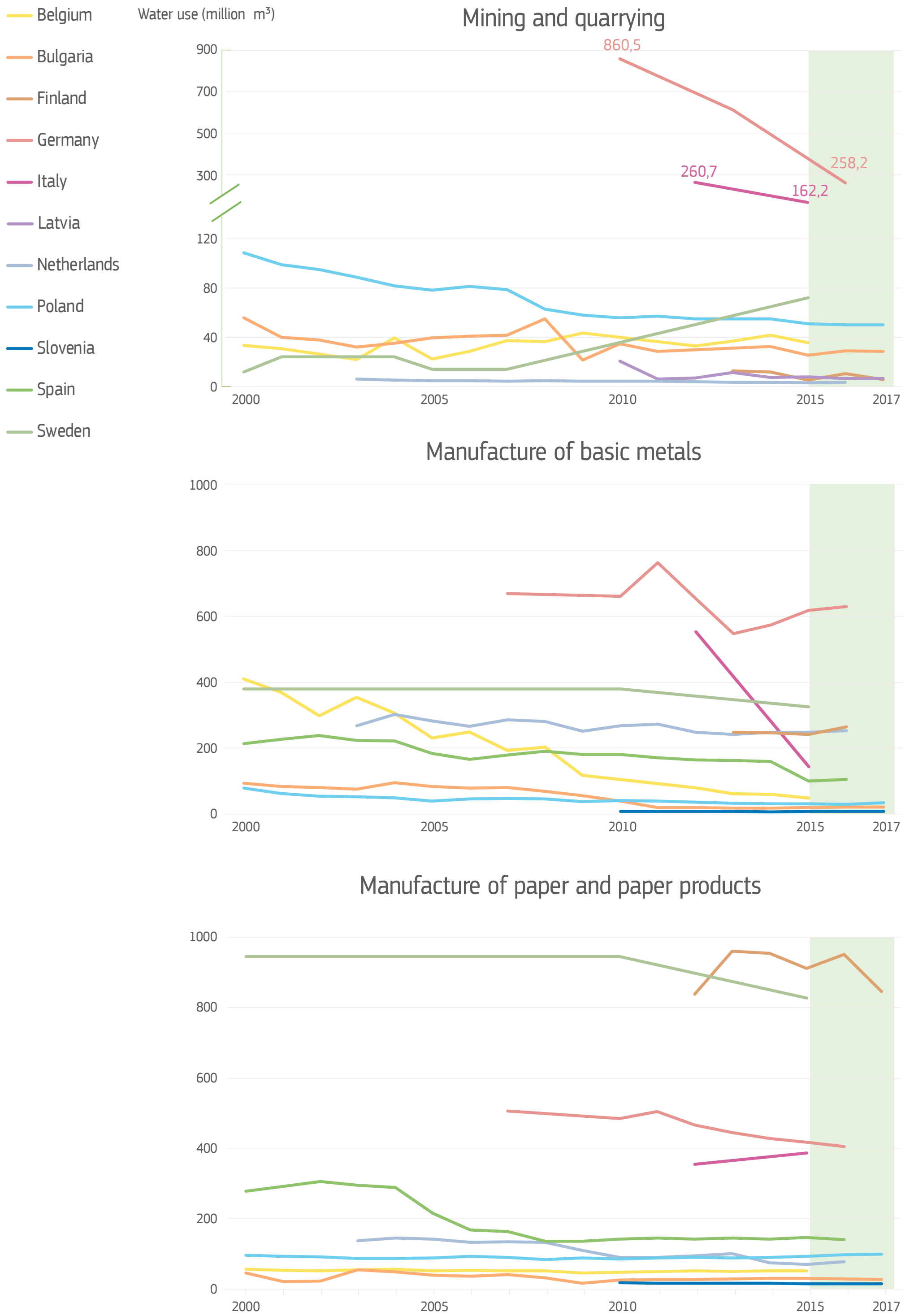
Recently, the fitness check of the Water Framework Directive[444] (WFD) found that despite improvements in the protection of water bodies in the EU, challenges remain, for example in Member States' implementation and for sectors with heavy impact on water. Concerns have been raised in particular that the process for adopting best available technique (BAT) reference documents (BREFs) and corresponding emission levels under the Industrial Emissions Directive[445] does not sufficiently address releases of some relevant (priority) substances[446] into water[447].

Facts and figures

Figure 20.1 displays the trends of water use by three raw materials sectors for a sub-set of EU countries, whose data are available[448]. For water use, data at EU level are not available, so the assessment relies on country-based data. Water use refers to the total volume of water used on site by EU facilities. It does not refer to units of production and is calculated as water abstraction minus distribution losses and water returned before use[449].

The figure shows that between 2016 and 2017 (the last updated years compared to the 2018 Scoreboard), basic metals manufacturing was, on average, the sector using the highest volumes of water in all the countries under analysis, followed by production of paper and paper products. Mining and quarrying (which includes

Figure 23.1: Water use by raw materials sector (sub-set of EU-27 countries, 2000-2017)[454].



mining of energy commodities[450]) showed lower water use levels. It is important to highlight that in addition to water efficiency, water use depends also on the size of the sector[451].

Looking at individual countries, in the period 2013-2017, an increase of water use by the basic metals sector was reported for some countries (e.g. Germany and Finland), while for some other countries (Poland and the Netherlands) there was a lighter increase. On the other hand, a remarkable decrease in water use was observed for the sector in Italy, and overall decreases for Belgium, Sweden and Spain. For the manufacture of paper and paper products, the decreasing water use trends observed in the previous period continued for Germany and Sweden. Finland's water use also decreased. The remaining countries showed rather stable levels. For mining and quarrying, the countries with higher water use volumes (Germany and Italy) showed a remarkable decrease, while Sweden's water use increased, and the remaining countries' water use remained quite stable.

Some increases in water use took place in countries that are not currently under overall water stress, according to the Water Exploitation Index Plus[452] (WEI+), which compares freshwater abstraction with freshwater availability. However, water use increased also in some European areas (central and northern areas) that can be water-scarce for at least some periods of the year[453].

Conclusion

Water is an essential resource for raw materials operations and can be impacted in multiple ways. Given its relevance for environmental sustainability, and in order to meet the SDG 6, it is essential to monitor water use from EU industrial sectors and related pressures on the environment.

Industry is aware of the most relevant water considerations related to its operations; this is reflected in corporate sustainability reporting, where water is usually addressed. In recent years, operators declare that they have made rigorous efforts to reduce water use and wastewater discharges, for instance through improvements in water re-use.

Challenges remain, as water re-use and recycling capacity are limited, can generate additional management needs and are often costly. The sector will also have to adapt to the impacts of climate change and the increasing needs for water for processing lower grade ores. On water quality, pollution from old mine sites is still significant.

Extractive activities – water quality considerations

Extractive activities are placed where the natural resources exist, with no or very limited possibilities for relocation. In some cases, the resource itself can cause a high concentration of some elements in water and soils and/or diffuse pollution. Extractive activities can impact surface and groundwater in different manners, depending on the type of mineral[455], the mining practices, the substances used for mining and processing, or the way mining waste is handled[456].

The prevention of water contamination is an important part of mine operations, where management and monitoring systems are put in place as required by current legislation. Extractive activities need to address, for instance, possible variations in surface and groundwater hydrology. The latter phenomenon may be due to mine dewatering, which can in turn impact water-dependent ecosystems. Extractive activities need also to address the leaching of pollutants into water and soils. Such pollutants may originate from the mined deposit, the chemicals used for extraction and processing or from tailings sludge[457], or from the formation of pit lakes (which may originate from the relief alteration[458]) or acid mine drainage[459] (AMD).

Many of the water impacts from mining may occur long after closure. Reclamation measures intend to minimise post-closure impacts and include works such as diversion of unimpacted waters, improvements of water management infrastructure and handling of waste rock and tailings. Optimally, mine reclamation should be planned before the mining permit is granted and *progressive closure*, i.e. reclamation during operation, should take place[460].

In addition, accidents can occur; these can be responsible for the biggest impacts on water. They are often associated with heavy rainfall or seismic activity, but also with operation and design mistakes[461]. EU spill accidents[462] have led to a strengthening of the rules governing the environmental impact of mines: the Extractive Waste Directive regulating new mines in 2006[463] and, linked to that, the update[464] of the BAT Reference Document for the Management of Waste from Extractive Industries (2018).

While pollutant releases from the mineral industry have increased overall, they show very variable trends among pollutants and countries[465]. Reporting of pollutant releases associated with the Water Framework Directive, which covers diverse relevant aspects, may help the Commission monitor trends in the mining sector, which is considered a relevant source of point and diffuse pollution. However, this reporting does not provide disaggregated figures for non-energy, non-agricultural extractive activities. More accurate reporting is usually provided at sub-national level, albeit without a harmonised data collection system.

The search for RACER data …[466]

There is a need for a comprehensive analysis, from a quantitative and qualitative point of view, of the raw materials sectors' performance regarding water. For instance, data are needed to monitor water stress[467], water efficiency[468] and impacts on water quality. Although safeguarding water is a priority in the policy agenda, trends in the EU reporting entities do not seem to be moving towards the collection of data of sufficient spatial, sectoral and temporal resolution.

Assessing water use is a very complex task. First, water use is very industry-specific. Water supply and distribution networks are complex, often with both public authorities and private stakeholders involved. Regulatory national and sub-national frameworks and local water framework conditions vary widely from location to location. For mining activities, the assessment is even more challenging: water use and water supply increase (from dewatering) often coexist, while several water sources with different quality levels might be used, and water demand might vary strongly depending on the processing requirements of the ore mined.

After an assessment of other potential data sources[469], Eurostat was identified as the only data source that allowed for harmonised monitoring of water use by the raw materials sector over time and across EU countries. However, these data provide only a general, limited overview: the level of aggregation is high, the data do not consider all water requirements along the whole production chain, and coverage (in terms of sector, time and countries) is limited. Data on production output with the same level of aggregation do not exist, so water use per unit of production cannot be assessed. Therefore, these data cannot provide direct information about the underlying reasons for the trends observed.

24. Extractive waste

Key points:

- Available data show that the generation of extractive waste in the EU was relatively constant, with minor changes between 2004 and 2016 and a decreasing trend since 2012.
- The extractive waste-metalliferous ore ratio has been decreasing since 2004, and has remained stable relative to all extracted minerals since 2010.
- A longer time series of data is required to support more profound conclusions on volume and quality trends. Similarly, there is a lack of data on backfilling, recycling and recovery from extractive waste.

Overview and context

The extractive industry generates the second largest waste stream in the EU after construction and demolition waste (see indicator 14), representing 25-30% of the total waste volume[470] (2016 data). Extractive waste generation is linked directly to minerals production (indicators 4 and 6); however, the overall objective is to decouple this volumetric correlation. Volumes and characteristics of extractive wastes vary significantly across commodity groups. About 2% of the bulk volume is hazardous. Metallic minerals extraction poses the highest environmental risk through surface disposal of sulfidic waste rocks, which generate acidic leachates when exposed to surface waters (see indicator 23). Most metalliferous ores are processed using chemicals into enriched concentrates, which usually results in large volumes of non-inert tailings. Tailings seepage (Talvivaara, 2013) and accidental dam failures (Baia Mare, 2000; Kolontár, 2010) have happened in the recent past in Europe and elsewhere in the world.

In response to tailings accidents, the Extractive Waste Directive and its implementing decisions[471] aim to improve the environmental performance of the extractive industry. The amended Seveso Directive[472] focuses on related accident risks. Risk-based inventories of closed or abandoned waste management facilities have been established In most Member States[473]. The relevant 'best available techniques' (BATs) are specified in the BAT reference document (BREF) for the management of waste from extractive industries in accordance with Directive 2006/21/EC[474].

The EU's waste management hierarchy[475] ranks management options and also applies to extractive waste. For instance, the placing of tailings and gangue rocks back in excavation voids, known as ´backfilling´, is preferred. The reprocessing of historical waste heaps and tailings, and the recovery of valuable raw materials from them, are also encouraged. Valuable materials recovered from extractive waste can contribute to a sustainable and secure supply of raw materials.

The limited data available on the recovery of raw materials from extractive waste suggest that the recovery rate is low, for reasons of economic and technological feasibility[476,477]. Therefore, a current objective, as stated in the critical raw materials action plan, is to map the waste volume, determine the minerals and grades across the EU and develop recovery technologies. Such projects are already carried out in Sweden, Hungary and elsewhere.

Available data show that the generation of extractive waste in the EU has been decreasing since 2012. However, a longer time series of data is required to support more profound conclusions on volume and quality trends. Similarly, there is a lack of EU-wide data on backfilling and of recycling of, and recovery from, extractive waste, with the exception of some countries such as Portugal and Hungary. In general, the data indicate that the Extractive Waste Directive is working and waste management practices are improving in the sector.

A significant amount of critical raw materials is stocked in tailings and waste rock heaps. A recent report[478] presents cases on recovery practices, for example, the recovery of tin, niobium, tantalum from extractive waste at the Penouta mine in Ourense, Spain[479]. Meanwhile, the ReeMAP project[480] aims to extract rare earth metals and phosphorus from iron ore residues using a patented process. Two pilot plants are to be set up in Sweden. Another good example is the MSCA – ETN SULTAN[481] ('European Training Network for the Remediation and reprocessing of sulfidic Mining Waste Sites involving different EU countries, institutions and organizations') project.

To be economically viable and resource-efficient, material recovery would have to target all available minerals instead of one material only, especially if it is present in low concentration. This is one potential application of the circular economy concept, which should be extended for the entire minerals value chain. It is of particular importance to recover, recycle and re-use primary mineral resources' and by-products, before they end up as waste.

Energy demand is also a major challenge. Environmental and social aspects are also relevant drivers, as, for example, reworking of extractive waste can lead to restoration of abandoned mines. Community engagement is also important for the success of any recovery projects.

The search for RACER data …

No comparable datasets are available on extractive waste volumes and quality that would make it possible to assess performance on a global or EU scale[482]. Efforts to compile extractive waste time series data by the European Commission[483] and projects[484] have provided limited results. The specific BREF[27] pointed out data gaps and discrepancies among different datasets[485], thus confirming that none of the global raw materials information services has fully suitable data collections. The results of a thorough Commission survey aiming for a more reliable EU inventory on extractive waste facilities, volumes and hazard classifications may become available in 2021.

Eurostat provides data on waste volumes covering Member States' extractive industry every 2 years (Table 24.1). According to the available data, extractive waste volumes in the EU fluctuated moderately between 2004 and 2016. The figure decreased slightly until 2008 and since then has increased, probably due to the broader materials coverage of 'extractive waste' introduced with the adoption of the Extractive Waste Directive in 2006. Data show again a decreasing trend of extractive waste volume since 2012.

The extractive waste to domestic minerals extracted ratio has also decreased since 2012. Extractive waste per metalliferous ore has been permanently decreasing since 2004 and did so during the whole available period. This can be explained by the industry's improving waste management practices, taking into account that metalliferous ore extraction generates orders of magnitude more waste than other minerals.

Table 24.1: Volumes of extractive waste, extracted minerals and their ratios (EU27, 2004-2016)[486].

Data series (1 000 tonnes, Eurostat)	2004	2006	2008	2010	2012	2014	2016
Extractive waste	717 630	574 640	520 660	647 780	709 910	678 990	625 010
Domestic mineral extraction	3 574 536	3 962 946	4 048 456	3 223730	3 085598	2959139	3 075536
Metalliferous ore volume	139 829	142 519	140 045	163 860	184 242	188 279	206 550
Extractive waste to domestic minerals extracted ratio	0.20	0.15	0.13	0.20	0.23	0.23	0.20
Extractive waste to metalliferous ore ratio	5.13	4.03	3.72	3.95	3.85	3.61	3.03

Other data options (e.g. the number and category of licensed extractive management facilities) were also examined but were dismissed as they were not considered reliable (see the European Commission's report on the implementation of the Extractive Waste Directive[487]).

Overview

The European Pillar of Social Rights, launched by the previous European Commission, will be fully implemented under the von der Leyen Commission, as stated in the priority ´an economy that works for people´ [488].

The Commission also promotes corporate social responsibility (CSR), for example through the non-financial reporting Directive[489], which requires that large companies disclose information on how they operate and how they manage social and environmental challenges.

In the minerals and metals sector, the Conflict Minerals Regulation[490] aims to ensure that EU importers of 3TG (tin, tungsten, tantalum and gold) meet international responsible sourcing standards, as set by the Organisation for Economic Co-operation and Development (OECD).

Indicators

Responsible sourcing (indicator 25) describes efforts made in supply chains to ensure a transparent and sustainable supply of raw materials, encompassing environmental and social aspects. Occupational health and safety (indicator 26), considered through accident rates, provides insights into working conditions in the EU. Formerly a part of indicator 16 ´Value added´, jobs in extractive and downstream industries (indicator 27) are now highlighted and complemented by the potential employment effects of the transition to a circular economy.

Cobalt gives Erythrite its distinctive crimson or pink colour. While not used commercially as an ore, its presence indicates cobalt-nickel-silver ores.

Social dimension

Indicators

25. Responsible sourcing
26. Occupational safety
27. Jobs

SCOREBOARD

Raw materials supply in the EU:
2. Public acceptance; 4. Mining activities in the EU. Competitiveness and innovation: 16. Value added.

Raw materials in the global context:
7. EU share of production; 9. Geographical concentration and governance.

Circular economy and recycling:
13. Management of waste of electrical and electronic equipment (WEEE).

SUSTAINABLE DEVELOPMENT GOALS

1 NO POVERTY

8 DECENT WORK AND ECONOMIC GROWTH

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

People employed - percentage of total employment (in circular economy sectors).

25. Responsible sourcing

Key points:

- Due diligence is becoming an increasingly common practice in companies, and, as of 1 January 2021, it is a legal obligation in the EU for companies importing tin, tungsten, tantalum, their ores and gold, as stated in the Conflict Minerals Regulation[491].
- The OECD provides guidance to companies to help them ensure that their mineral supply chains do not contribute to adverse impacts upstream, with a focus on armed conflicts and associated human rights abuses and other risks. The EU Conflict Minerals Regulation draws on the OECD Guidance[492], which can be applied to the sourcing of any metal or material.

Overview and context

Raw materials play an important role in reaching many environmental and socio-economic goals proposed by the United Nations in the 2030 Agenda for Sustainable Development[493]. They are also crucial for achieving the Paris Agreement climate targets[494] and the European Green Deal objectives - a priority of the von der Leyen Commission[495], supported by the EU industrial strategy. This political agenda also aims to strengthen free and fair trade: Europe should maintain its leading role as a standards setter for climate, environmental and labour protection, in particular child labour, in line with EU values[496].

Raw materials are traded in global markets, and information on the conditions of their production is usually not communicated to end users. Manufacturers that adhere to high social and environmental standards may therefore face a competitive disadvantage, as they may incur additional costs. In the EU, under Directive 2014/95/EU[497], large companies have to publish reports on the policies they implement, which include information on e.g. social responsibility and treatment of employees, respect for human rights, anti-corruption and bribery[498].

Investors are also increasingly interested in sustainability disclosures from companies. Indeed, sustainability considerations can be integrated into financial decision-making, and sustainable finance is expected to contribute to the Commission's strategy on the SDGs[499].

Public attention and concern has been growing in recent years regarding the social impacts of global supply chains[500]. For minerals, concerns about ´conflict minerals´[501] used in a variety of materials and devices like mobile phones, cars and jewellery began to emerge in the 2000s[502] and are addressed by Regulation (EU) 2017/821.

Recently, allegations of human rights abuses linked to the extraction of cobalt in the Democratic Republic of the Congo (DRC) have gained public attention following a report by Amnesty International[503]. Given the role of cobalt and other materials in low-carbon energy technologies (for instance, batteries)[504], there is concern about a trade-off between environmental and climate objectives vs social rights and stability in resource-rich countries[505] (see box). At the same time, only a very tiny fraction of EU consumption of cobalt and other metals used for batteries is actually used for battery production, so the underlying problems upstream could not be adequately addressed from the batteries´ perspective.

Several organisations promote ´responsible sourcing´ to ensure and demonstrate that minerals used in supply chains are produced using responsible mining practices and handled responsibly, i.e. according to specific requirements of responsible mining/sourcing standards[506]. Responsible mining can also help improve public acceptance and trust in the sector, and help promote socio-economic development.

The third edition of the *OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas* (hereafter referred to as 'the OECD Guidance')[507] was published in 2016. The OECD Guidance is the most widely recognised international standard for responsible minerals sourcing. It underpins many certification schemes and frameworks as well as corporate policies and initiatives on responsible sourcing including the EU Conflict Minerals Regulation. It can be applied to all mineral supply chains and provides guidance to companies performing supply chain due diligence[508] who wish to ensure they do not indirectly contribute to armed conflicts or to related human rights abuses through their minerals sourcing practices.

The risk areas to check are set out in Annex 2 of the OECD Guidance. They include: serious abuses associated with the extraction, transport or trade of minerals, including human rights abuses; war crimes or other serious violations of international humanitarian law; direct or indirect support to non-state armed groups; risks relating to public or private security forces; bribery and fraud; money laundering; and payment of taxes, fees and royalties due to governments.

To break the link between trade in conflict minerals and the financing of armed conflicts and human rights abuses, the EU adopted the Conflict Minerals Regulation. This came into force in 2017 but its key requirements started to apply in January 2021[509]. The EU Regulation is aligned with the OECD Guidance and requires that EU importers of tin, tantalum, tungsten, their ores and gold (3TG) carry out due diligence on their supply chain. The scope of the Regulation is global, which means that the due diligence requirements apply to EU imports of 3TG from any part of the world. The Regulation aims in part to:

- ensure that EU importers of 3TGs apply the 5-step framework for risk-based due diligence consistent with the OECD Guidance;
- ensure global and EU smelters and refiners of 3TG to source responsibly;
- advance the responsible sourcing of minerals from conflict areas;
- help break the link between conflict and the illegal exploitation of minerals and metals;
- help put an end to the exploitation and abuse of local communities, including mine workers, and support local development.

Given the many voluntary supply chain due diligence initiatives[510] in place, the European Commission has developed a methodology and criteria for assessing and recognising supply chain due diligence schemes[511] in order to facilitate compliance.

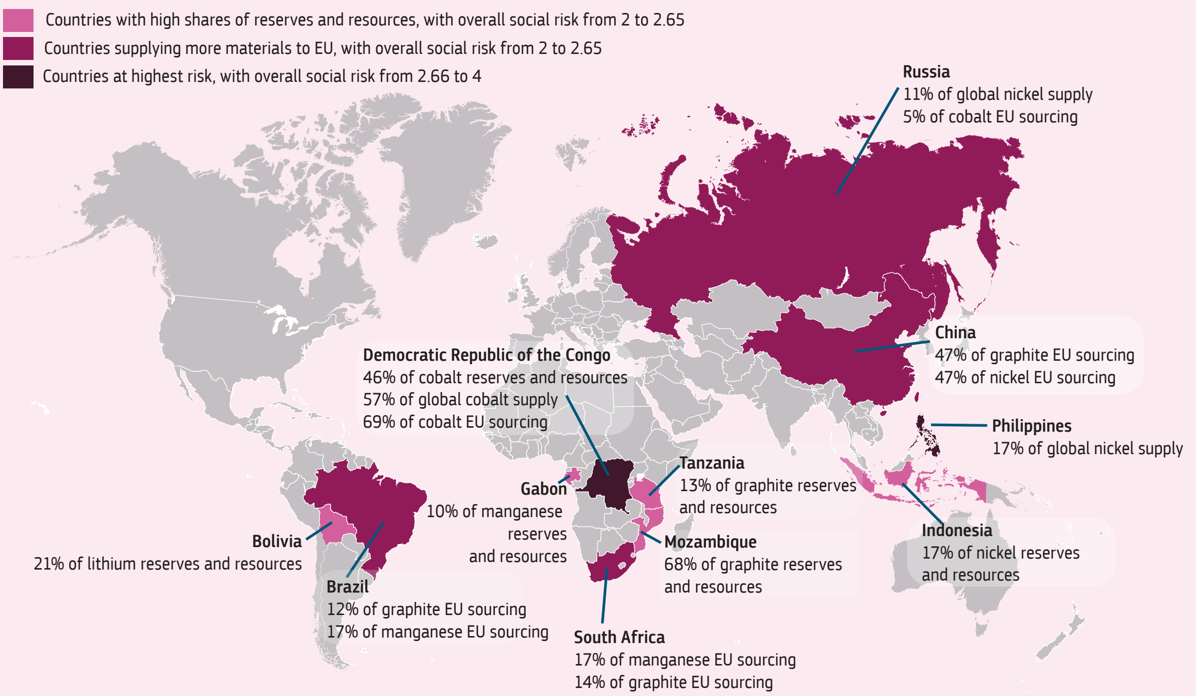
The exact number of existing due diligence initiatives and the number of companies adhering to them is hard to calculate. A review published by the German Federal Institute for Geosciences and Natural Resources (BGR) identifies 19 sustainability schemes for mining and metals, though some of them are not strictly related to responsible sourcing but have a more general scope covering sustainability-related aspects[512]. Of the reviewed schemes, two focus on gold only; six address 3TGs, diamonds and aluminium; and two cover coal and natural stone.

Responsible sourcing of cobalt for batteries

Given their role in the clean energy transition, the European Commission has identified batteries as a strategic value chain warranting huge investment[513]. The European Battery Alliance has been created to build a competitive, sustainable and innovative battery ecosystem in Europe, covering the entire value chain. Import reliance for batteries materials and cells is very high, and some materials are imported from countries with low governance (see indicator 9 on geographical concentration and governance).

A hotspot analysis published in Mancini et al. (2020)[514] considers 10 indicators on governance, conflicts, social and human rights and the environment, and identifies risk hotspots in terms of materials and countries (Figure 25.1). According to this analysis, the Democratic Republic of the Congo (DRC), which provides 57% of the global cobalt supply, is - together with the Philippines - the country at the highest risk. Other countries are highlighted due to their low performance in social indicators together with their role as: (i) suppliers to EU countries (orange countries on the map); or (ii) owners of high shares of resources and reserves (yellow countries) that could become materials suppliers in the future.

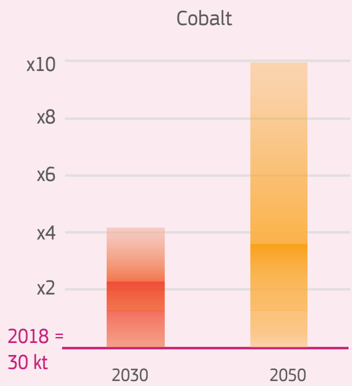
Figure 25.1: Results from a risk hotspot analysis on batteries materials[515]. Average social risk for countries ranges from 1 (low risk) to 4 (very high risk) and is the average of country risk levels on a set of indicators on governance, conflict, child labour, forced labour, fair salary, environmental performance and water stress.



NGOs and media repeatedly reported cases of severe human rights abuses and child labour in the DRC. Some of the issues are linked to artisanal and small-scale mining (the ASM sector), while other problems (e.g. corruption or use of armed forces) are more related to large-scale mining (LSM)[516]. According to Delve[517], a global platform on ASM, 2 million people are employed in the ASM sector in the DRC and, according to recent estimates, around 25% of the DRC's cobalt supply comes from artisanal mining[518].

The consumption of cobalt in batteries has grown from 2 thousand tonnes in 2006 to 5.8 thousand tonnes in 2018[519] and is expected to increase even more in the future, as shown in Figure 25.2. Ensuring that cobalt is sourced responsibly is therefore a primary policy and industry objective.

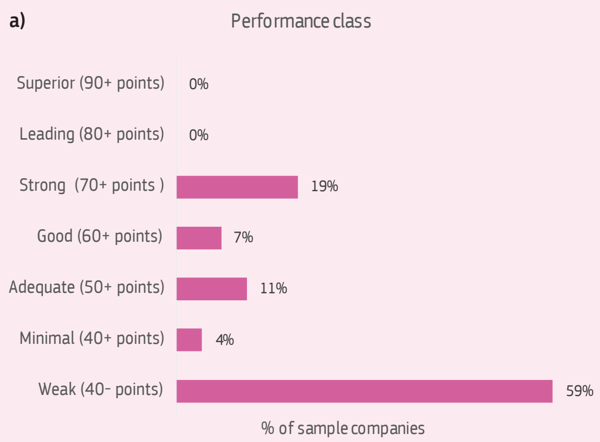
Figure 25.2: Consumption of cobalt for batteries used in renewables and e-mobility in 2018 and in scenarios for 2030 and 2050[520].

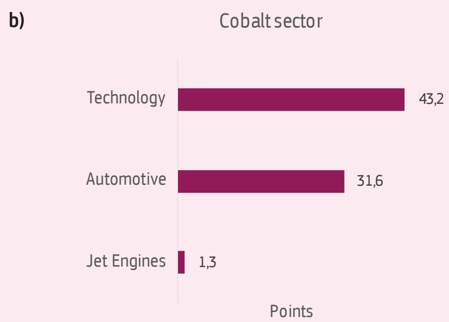


While the Commission has proposed mandatory due diligence requirements in the new Battery Regulation[521], at the downstream side of the supply chain, some cobalt-using companies have already started to perform non-mandatory cobalt due diligence, driven by consumer-to-business as well as business-to-business demand. Figure 25.3 presents the results of an assessment of cobalt due diligence published by Responsible Sourcing Network (RSN), a project of the non-profit organisation ´As you Sow´.

In the assessment, a group of 27 cobalt-using companies in the technology, automotive and jet engines sector, selected for the large prevalence of their cobalt consumption, is investigated. The analysis uses 24 key performance indicators divided across three themes and seven subcategories[522] to assign points to companies and rank them based on the quality of their due diligence. In order to earn points, information on the various indicators must be publicly available in documents or on companies' websites[523].

Figure 25.3: Percentage of sample companies by performance category for cobalt due diligence in 2019 (a) and Cobalt ranking per sector (b)[524].





These results show that most of the companies under evaluation (59%) are weak in cobalt due diligence disclosures (Figure 25.3a). The report also notes profound differences between sectors in terms of CSR strategies on cobalt (Figure 25.3b).

The RSN report also highlights that, as no mandatory framework exists on cobalt due diligence, and because of the concentration of this mineral in the DRC, corporate strategy has adopted a more integrated approach, covering the whole supply chain from product assembly to the mine sites. After significant pressure from stakeholders, the automotive industry has started to adopt due diligence systems and to engage with on-the-ground actors in the ASM and LSM sectors. Six of the 14 auto companies analysed have directly or indirectly engaged with miners, refiners or smelters, and five have mapped their supply chains.

26. Occupational safety

Key points:

- The forestry and logging, and raw materials manufacturing sectors have relatively high rates of non-fatal accidents, as do the fishing and construction sectors.
- Rates of non-fatal accidents in the forestry and paper manufacturing sectors decreased in 2015-2017, while they slightly increased or remained stable in the other sectors.

Overview and context

Ensuring social fairness and defending the dignity of work are among the principles that the von der Leyen Commission advocates. This is expressed in the priority ´An economy that works for people´ set out in the 2019-2024 political guidelines[525]. Specifically, according to the European Pillar of Social Rights[526], workers have the right to a high level of protection of their health and safety at work. EU legislation on occupational safety and health (OSH) has been in place for over 30 years. For instance, the Directive on minimum requirements for personal protective equipment (PPE) used at work dates back to 1989[527].

The UN Sustainable Development Goals also promote decent work for all, notably Goal 8[528] and Target 8.8[529] on labour rights.

The first international standard for occupational health and safety was ISO 45001, ´Occupational health and safety management systems´. This standard provides a framework to increase safety, reduce workplace risks and enhance health and well-being at work.

On risks related to chemicals, the EU's REACH Regulation[530] addresses exposure to chemicals in the workplace. It requires that employers carry out risk assessments and ensure that their workers are protected and provided with information, guidance and training on the safe use of chemicals in the workplace. Moreover, the Regulation for Classification, Labelling and Packaging of substances and mixtures (CLP)[531] aims to protect workers, consumers and the environment by establishing a harmonised system to provide information about hazardous chemicals.

Non-fatal accidents at work in the industrial sectors as a whole decreased by 9% in 1993-2017 and by 21% in 2008-2017[532] in the EU. This may be thanks to better legislation, technology (e.g. level of automation) and industry efforts to improve work organisation and stimulate behavioural change. Many companies in the raw materials value chains (especially large and multinational corporations) monitor and disclose information on accidents at work, fatalities and hours of safety training provided to workers in their sustainability reports.

The causes of accidents are varied. In the mining sector, an investigation by the Spanish Ministry for the Ecological Transition and Demographic Challenge found that 61% of accidents were related to the use of machinery, especially mobile equipment like loaders, dump trucks and backhoes[533]. Automation can help create a safe working environment in this sector, reducing risk and raising productivity[534].

In the forestry sector there was a dramatic reduction in accidents thanks to the increased mechanisation of harvesting and silvicultural operations. Technological developments in motor-manual operations also improved safety[535]. Research and development in new technologies can therefore substantially improve working conditions and reduce the risk of accidents.

Facts and figures

Figure 26.1 compares the incidence rate of non-fatal accidents[536] at work related to raw materials activities with that of other activities in the primary, secondary and tertiary sector. It also presents the average incidence rate in the whole EU economy (black line) and the average for activities in each economic sector (grey dotted lines). Due to differences in the accidents notification system, comparability between countries is limited. Moreover, the underreporting of accidents can be significant in some countries[537].

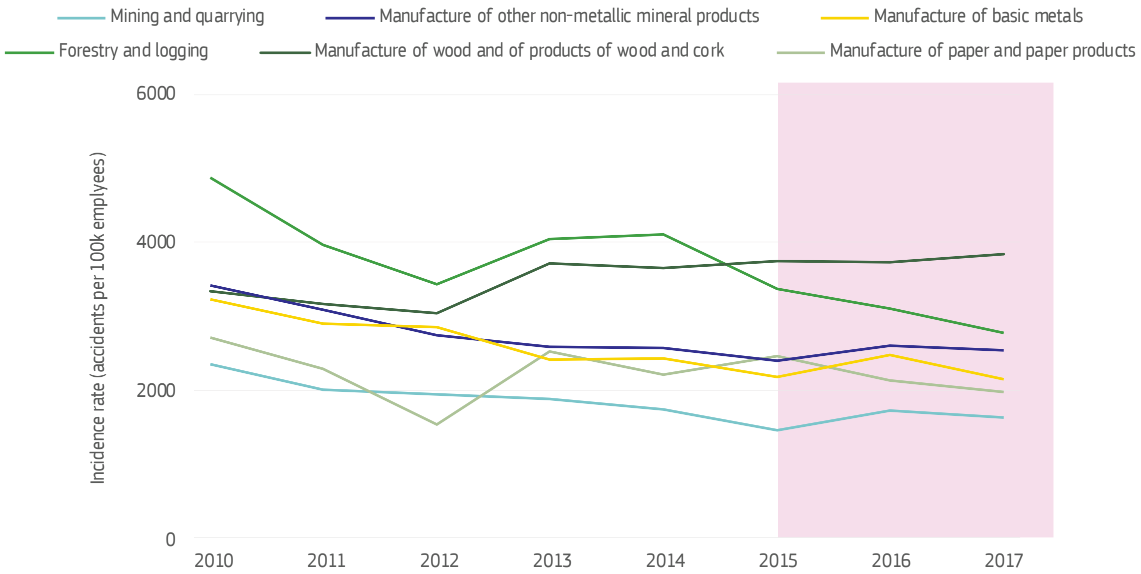
The figure illustrates that the raw materials sectors (displayed in darker colours) have relatively high levels of non-fatal accidents, especially the forestry and logging, and materials manufacturing sectors. The incidence rate in mining and quarrying is slightly above the average for the primary sector, but lower than fishing and forestry. For the secondary sector, the rates observed for raw materials manufacturing activities are similar to construction and are higher than other activities, like food products and chemicals. For the tertiary sector, the incidence rate for mining support activities is lower than the sector average, even though it increased compared with the 2015 rate (included in the 2018 Scoreboard). Given the different sector sizes in terms of employees (indicator 27), the absolute number of accidents is higher in sectors like construction (around 353 000 accidents) and agriculture (around 148 000) and lower in the sector of non-energy materials mining[538] (around 6 000).

Figure 26.1: Incidence rate of non-fatal accidents for a selection of economic sectors (EU-27, 2017)[539]

Figure 26.2 presents the 2010 – 2017 incidence rate of non-fatal accidents for selected raw materials industries. From 2015 (the last year included in the 2018 Scoreboard), the trend was almost stable for the manufacture of basic metals (-1%) and the manufacture of wood (2%). Mining and other non-metallic minerals sector experienced a slight increase in the incidence rate during the same period (12% and 6%, respectively). The incidence rate decreased in the paper manufacturing (-20%) and forestry and logging (-18%) sectors in 2015, and by 43% and 27% respectively in 2010-2017.

Looking at individual countries, some - such as Spain, Germany and Portugal - have incidence rates that are higher than the EU average in several sectors (for instance Spain in the forestry, mining, paper and minerals manufacturing sectors). In other countries (e.g. Bulgaria and Romania) the incidence rate is lower than the EU average in most sectors. However, country comparisons should be taken with caution, as the different accident reporting systems used in different countries can affect accuracy, as can the different ways of dealing with under-reporting[540] and cultural perceptions on health and safety, including attitudes on reporting accidents.

Figure 26.2: Incidence rate of non-fatal accidents of selected raw materials sectors (EU-27, 2010-2017)[541].



Conclusion

The number of non-fatal accidents at work in the raw materials sector is steadily decreasing, especially in the forestry sector. However, the wood manufacturing sector is an exception to this trend.

Technological advances, the regular reporting of accidents and understanding their causes can help maintain this improved health and safety at work in the raw materials industry, which is an essential component of the sector's social sustainability.

The current EU policy framework strongly encourages preventive and protective measures to improve health and safety at work. The Commission is actively updating and modernising relevant EU legislation and policy, e.g. through the Communication ´Safer and Healthier Work for All - Modernisation of the EU Occupational Safety and Health Legislation and Policy´, adopted in January 2017[542]. Moreover, the European Pillar of Social Rights, which includes OSH as one of the main components, will be fully implemented through an action plan under this Commission.

27. Jobs

Key points:

- The contribution of raw materials sectors to employment varies between EU countries. It ranges from 3 to 17% of the total number of employees in the industrial sector.
- The number of employees has grown in almost all raw materials sectors in 2014-2017. The mining and quarrying sector had the highest growth rate during this period. The overall trend in 2008-2017 is negative, especially for non-metallic minerals and metals manufacturing.
- The transition towards a low-carbon and energy-efficient economy can potentially create new ´green' jobs, but new skills will be required, especially in circular economy-related activities.

Overview and context

Ensuring employment and decent working conditions are long-standing policy objectives for the EU, whose employment strategy dates back to 1997. At that time, EU Member States committed to developing common objectives and targets in the area of employment. Then in 2012, as part of the 2020 strategy on smart, sustainable and inclusive growth[543], the EU launched the employment package[544] with a set of policy measures to promote job creation and help countries recover from the 2008 global economic crisis.

Today, employment-related objectives are included in several EU policies and are in line with the Sustainable Development Goals[545], notably Goal 8 on decent work and economic growth. The European Pillar of Social Rights[546] also sets out objectives as well as rights, for example on access to the labour market, equal opportunities and fair working conditions (see indicator 25 on Occupational safety).

The EU industrial strategy[547] recognises the strategic importance of raw materials for the EU manufacturing industry, and therefore their role in competitiveness and job creation, especially in the downstream industries of the supply chains. Opportunities to create employment in the raw materials sectors are also envisaged in the European Green Deal[548] and in the action plan on critical raw materials[549]. In particular, the low-carbon technologies and sustainable products and services markets are expected to grow. Circular economy policies also have the potential to create new activities and jobs (see box). At the same time, the EU will provide support and resources to regions and sectors that depend on fossil fuels or carbon-intensive processes, and that are likely to be affected by the transition to a low-carbon economy. The Just Transition Mechanism provided for in the Green Deal will provide access to, e.g. re-skilling programmes and jobs in new economic sectors.

Facts and figures

Figure 27.1 shows the share of jobs in the raw materials sectors compared with total jobs in industry[550]. The EU countries with the highest shares are Finland (17.3%), Sweden (15.3%) and Latvia (15%). At 2.9%, Luxembourg has the lowest share. In Finland and Sweden, the manufacturing of pulp, paper and paperboard is the sector with the highest number of employees of the raw materials sectors analysed. In Latvia, the sawmilling and planing of wood sector has the highest number of employees.

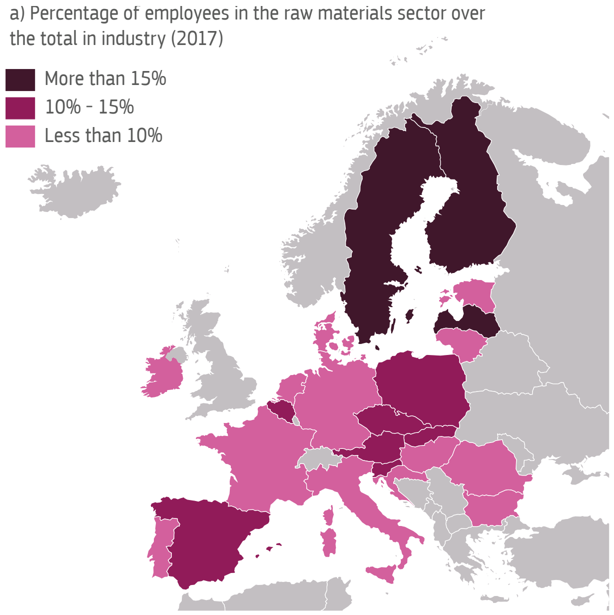
The figure also shows the multiplier effect for jobs within the supply chain (analogous to value added, see indicator 16). While the upstream phases (i.e. mining and quarrying of materials and forestry) account for 724 000 employees, the processing phase of these materials (which includes, for instance, metals casting, manufacture of cement, iron, steel, rubber, paper) employs 2.8 million people. Finally, 23 million people are employed in the downstream manufacturing phase, which includes sectors using raw materials as inputs (for instance, construction, manufacture of finished product and equipment).

Looking at trends (Figure 27.2), the number of employees working in the overall raw materials sector decreased by 13% in 2008-2017 to reach around 3.2 employees in 2017. This was mainly due to a decline in jobs in the non-metallic minerals (-20%) and basic metal manufacturing (-19%) sectors, which are the sectors with the highest number of employees of those analysed (1.2 million and 850 000 employees in 2017 respectively). Jobs also decreased in the pulp, paper and paperboard manufacturing (-18%) sector and, to a lesser degree, in the sawmilling and planing of wood (-5%) sector.

The trend of the last 3 years (2014 was the last year monitored in the 2018 Scoreboard) points to signs of recovery, except for in the sawmilling and planing of wood sector. Mining and quarrying had the highest growth rate (+37%), followed by materials recovery (+12%). The other sectors had growth rates below 10% over the same period (2014-2017).

A different trend was observed in the materials recovery sector and the rubber products manufacturing sector, which increased their number of employees by 32% and 11%[551] respectively in 2008-2017. Due to data limitations, it is not possible to monitor the jobs created by circular economy activities related to non-energy raw materials only, other than material recovery. For instance, data on waste management and treatment is not disaggregated and it is not possible to isolate jobs attributable to the non-energy sectors.

Figure 27.1: Share of jobs in the raw materials sectors over the total jobs in industry (a) and distribution of jobs along the value chain (b)[552] (EU-27, 2017).



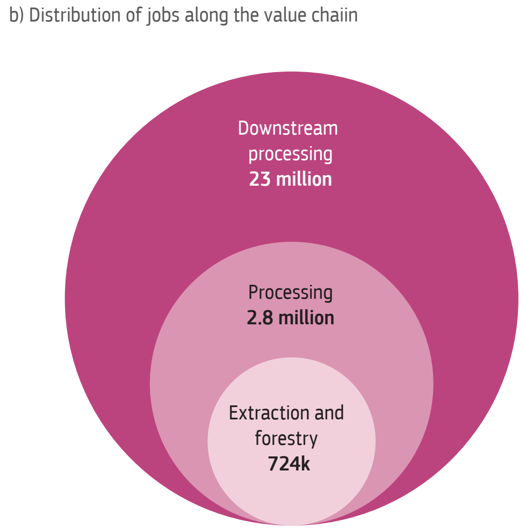
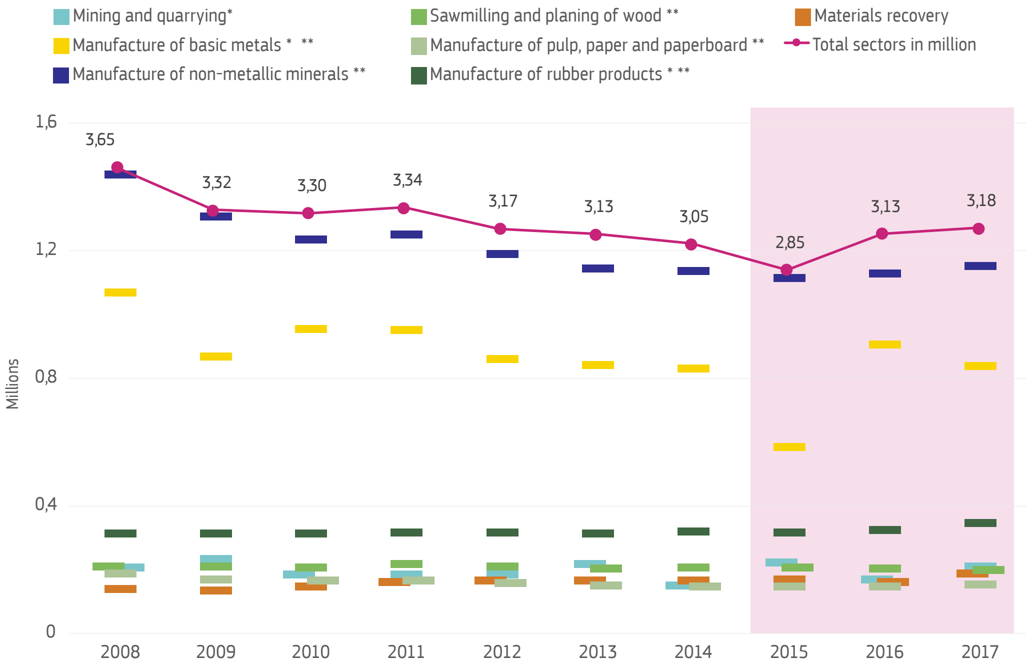


Figure 27.2: Trends in number of employees by raw materials sector (EU-27, 2008-2017)[553]



Conclusion

Raw materials extraction and processing activities provided jobs to almost 3.5 million people in the EU in 2017. However, the socio-economic importance of these sectors goes beyond their direct employment potential, as most of the jobs are created by downstream industries.

The most relevant sectors in terms of employment are the manufacturing of non-metallic minerals and the manufacturing of basic metals. In both there was a slight increase in the number of employees in 2014-2017 (1.2 and 1% respectively). On the other hand, the materials recovery sector, which is relatively small in terms of employment, experienced the highest growth rate. This suggests that circular economy-related activities have the potential to create jobs and contribute to environmental policy objectives. The European Green Deal therefore aims to combine environmental objectives with an inclusive and just economy.

New skills for green jobs

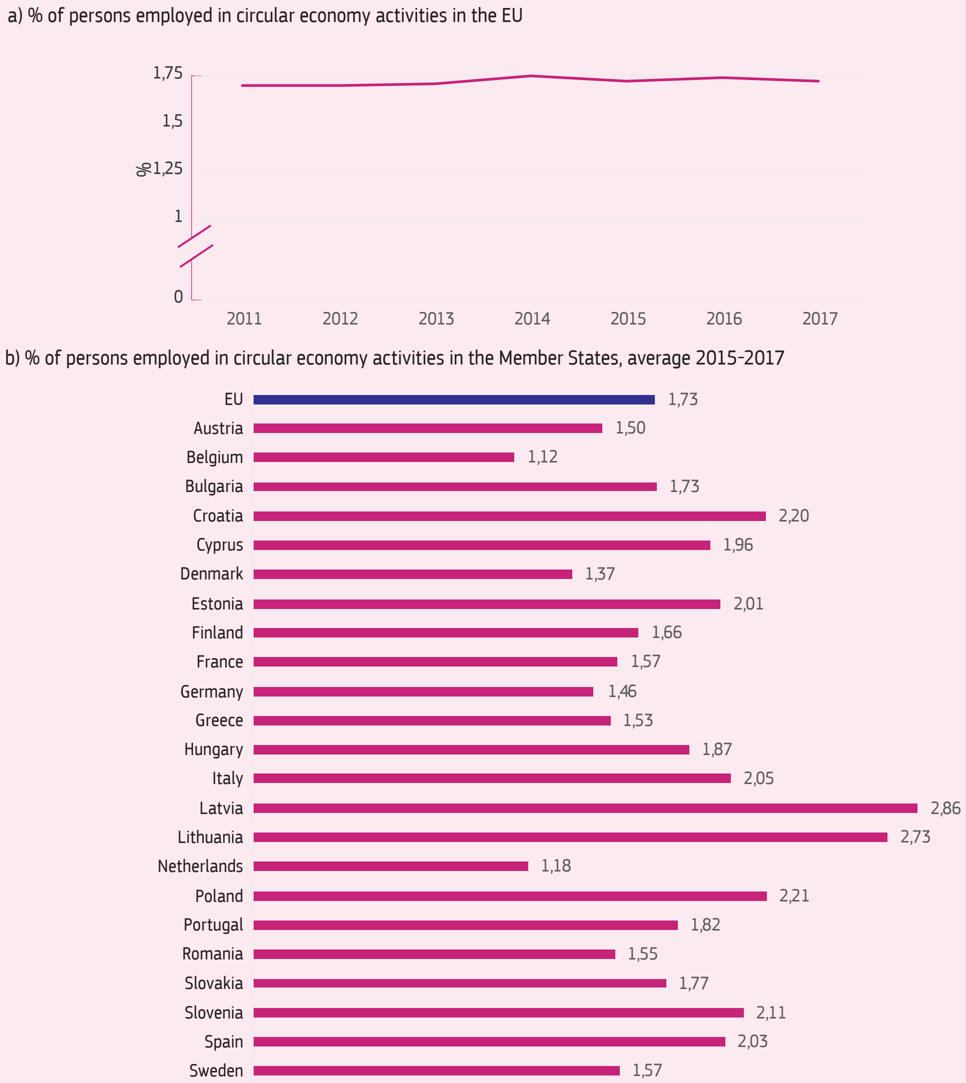
As acknowledged in the circular economy action plan[554] moving towards a circular economy is expected to reduce environmental impacts and to decouple economic growth from resource use and the related impacts (see indicators in Cluster 3). Moreover, consumers will benefit from more durable and safe products, trustworthy and relevant information on products and protection against green washing and premature obsolescence.

Circular economy activities can also have a positive net effect on job creation if workers acquire the skills required by the green transition. Currently, some EU countries have national regulations that support employment and skills development in the transition to greener and more circular economies. However, definitions and methods for estimating green skills vary between Member States[555].

Waste classification and management is a circular economy-related skills gap identified in national programmes, for instance in Spain[556]. However, given that different kinds of jobs will be needed in the circular economy, both technical, manual and entrepreneurial skills could be required in future (for instance, product design, repairers and information managers)[557].

According to Eurostat data, almost 3.5 million people in the EU were employed in circular economy-related activities in 2017[558]. The share of people employed in circular economy sectors vs total employment (one of the indicators in the circular economy monitoring framework) has been growing in recent years and ranges from 1.1 to 2.8% in the various Member States (Figure 27.3).

Figure 27.3: Employment in the circular economy sectors in the EU-27 (% of total employment, 2017) (a) and by Member State (% of total employment, average 2015-2017) (b)[559]

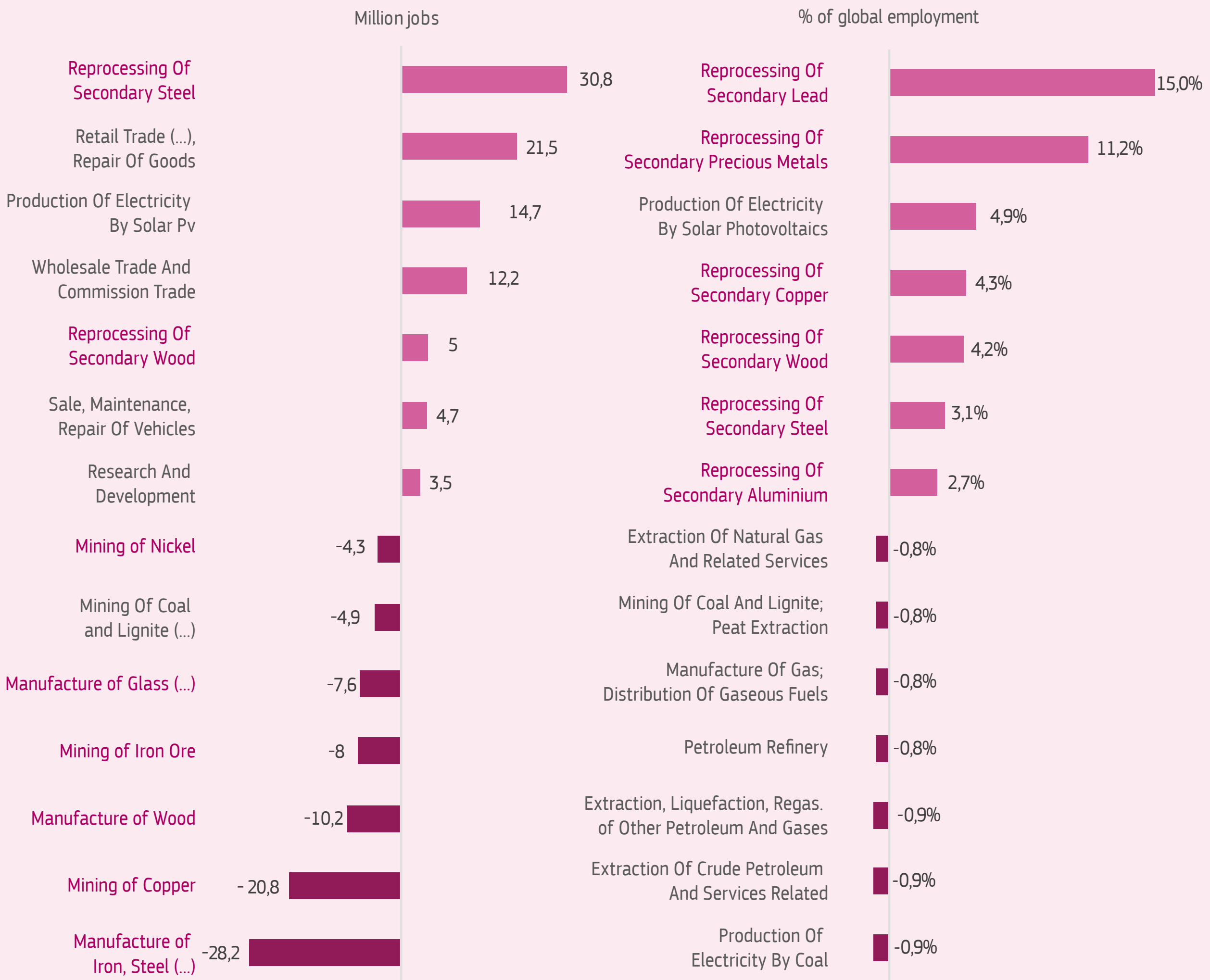


A study by Cambridge Economics estimates that moving towards a more circular economy could bring about a net increase of 700 000 jobs in the EU by 2030[560]. However, the sectoral composition will probably change, in that sectors producing primary raw materials could decrease in size, while the recycling and repairing sectors could grow further.

Similarly, at global level, a study by the International Labour Organization (ILO)[561] forecasts which sectors are expected to create more jobs and which could decline in jobs demand, under a circular economy scenario[562] (Figure 27.4).

The metals reprocessing (e.g. lead, copper, precious metals) and reprocessing of steel and wood materials sectors are likely to see the highest growth in job demand. By contrast, the basic iron and steel manufacturing, mining of copper and manufacturing of wood sectors are likely to have the sharpest decline in job demand (Figure 27.4 a and b).

Figure 27.4: Sectors forecast to be affected by the transition to a circular economy in terms of jobs demand, in absolute terms (million jobs) (a) and percentage (b) (forecast for 2030)[563]. Raw materials sectors are in fuchsia



Silicon is used mainly in the manufacture of silanes and silicones, as a "hardener" or alloying element to produce aluminium alloys, and in the manufacture of micro-processors and solar cells.

Methodological notes

1. National minerals policy framework

Description: The PPI of the Fraser Institute, previously known as the Policy Potential Index, provides an assessment of the attractiveness of mineral policies in a jurisdiction. It is a composite index that captures managers' opinions on the effects of policies in a jurisdiction. All survey policy questions are included in its calculation (i.e. those on uncertainty about the administration, interpretation, and enforcement of existing regulations; environmental regulations; regulatory duplication and inconsistencies; taxation; uncertainty about disputed land claims and protected areas; infrastructure; socioeconomic agreements; political stability; labour issues; geological database; security). The methodology considers answers in all five response categories, as well as how far a jurisdiction's score is from the average. The score is estimated for all 15 policy factors by calculating each jurisdiction's average response. The score is standardised, the average response is subtracted from each jurisdiction's score on each of the policy factors and divided by the standard deviation. A jurisdiction's scores on each of the 15 policy variables are added up to generate a PPI score that is then normalised using the formula:

$$\frac{Vmax - Vi}{Vmax - Vmin} \; x \; 100$$

The IAI combines both the PPI and the Best Practices Mineral Potential Index (BPMPI). It is weighted 40% by policy and 60% by mineral potential. BPMPI is based on the percentage of responses for 'encourages investment' and a half-weighting of the responses for 'not a deterrent to investment'. It might not provide an accurate measure of investment attractiveness at extremes, or where it is unlikely that the 60/40 weighting is stable. For example, extremely bad policy that would virtually use up all potential profits, or an environment that would expose workers and managers to high personal risk, would discourage mining regardless of mineral potential. In this case, mineral potential - far from having a 60% weight - might carry little weight. Poor policy solutions also may lead to a reduction in knowledge about mineral potential, e.g. non-reasonable data classification.

Geographic coverage: Available EU countries (same as in the 2018 Scoreboard edition, except for Bulgaria, France, Hungary, Greece and Romania, which are not covered here since there were less than five responses to the survey in each country) and selection of non-EU countries with relevant non-energy minerals trade with the EU.

Data source/reference: Fraser Institute, Annual Survey of Mining Companies (2011-2020)

Data update frequency: Annual

Data source URL: https://www.fraserinstitute.org/categories/mining

JRC data processing: The countries chosen were the ones included in most of the annual surveys examined - this covers six EU countries from surveys conducted over the past 9 years. Non-EU countries were selected based on the volume of their non-energy extractive sector, their importance in trade with the EU and a fair representation of all continents. As a result - unlike the previous edition of the Scoreboard - Norway, India, Indonesia, Kazakhstan, Turkey and Zimbabwe are not covered. JRC used the publicly available background datasets of the 2014 and 2020 annual reports, respectively. Since for the United States, Canada and Australia, the Fraser Reports give scores at individual state level, the JRC calculated their average value for each country.

3. Minerals exploration

Description:

Figure 3.1: Mineral exploration activities in the EU. Data covers early and late-stage exploration projects. Projects that belong to the early stage encompass grassroots, exploration, and target the outline stage. The grassroots stage means that claims have been staked on prospects. The exploration stage means that preliminary testing is under way, which may include geological mapping and sampling, geophysical and geochemical work and exploration drilling. The target outline stage means that targets have been identified and more detailed surface and/or underground exploration and drilling is under way. For late-stage projects an initial reserve/resource has been estimated. It includes advanced exploration, reserves development, and pre-feasibility/scoping. Advanced exploration involves drilling activities to add additional reserves/resources. Reserves development indicates that an initial reserve/resource has been calculated. Pre-feasibility/scoping involves working on a preliminary assessment to determine mining and processing methods, and other projected economic metrics such as capital costs, net present value, and internal rate of return, and is described by S&P Global Market Intelligence as a project with a defined resource that has not yet reached a production decision.

Figure 3.3: Exploration budget by world mining region (1997-2019) (A) and distribution of exploration budget among various metals in the EU (2019). Data on budget exploration for 2019 reflect budgeted expenditure rather than actual spending.

Material/sector coverage:

Figure 3.1: Antimony, chromite, cobalt, copper, gold, graphite, ilmenite, iron, lead, lithium, molybdenum, nickel, palladium, phosphate, platinum, rare earth elements (lanthanides), potash, scandium, silver, tantalum, tin, tungsten, vanadium, zinc, and fluorspar (data availability limited to Spain).

Figure 3.3: Gold, copper, nickel, zinc, and platinum group metal

Data source/reference:

Figure 3.1: S&P Global Market Intelligence, European Innovation Partnership on raw Materials, Sherpa group representative for Spain of the High Level Steering Group.

Figure 3.3: S&P Global Market Intelligence

Data update frequency: Daily

Data source URL: https://www.spglobal.com/marketintelligence/en (on subscription)

Data source metadata URL: https://www.spglobal.com/marketintelligence/en (on subscription)

JRC data processing:

Figure 3.1: Selection of mineral commodities, collection of the most updated location of mineral exploration activity, and conversion to a georeferenced map.

Figure 3.3: Data for EU-27 was aggregated separately from SP&G region classification.

4. Mining activity in the EU

Description: Mine production of metal and selected industrial minerals. The map includes the geographic location and approximate production size of mines (considering the main commodity) by commodities. The map also includes the producing/non-producing status of each mine.

Material/sector coverage:

- Precious metals: gold, silver and platinum group metals (PGM)
- Selected metals and industrial minerals: bauxite, chromite, copper, graphite, iron ore, lanthanides, lead, lithium, manganese, nickel, phosphate, potash, tin, tungsten, vanadium, zinc, fluorspar and strontium (data for fluorspar and strontium were limited to Spain).

Data source/reference: S&P Global Market Intelligence, complemented with information from Member States national geological surveys and the European Innovation Partnership on Raw Materials' Sherpa group of the High Level Steering Group.

Data update frequency: S&P Global Market Intelligence – very frequent updates, often even daily. National geological surveys, which might complement the data, are updated with heterogeneous frequency.

Data source URL: http://www.snl.com/ (available through subscription)

Data source metadata URL: http://www.snl.com/ (available through subscription)

For Bulgaria: https://public.tableau.com/profile/ivan.andreev#!/vizhome/Metal_BG/Sheet1?publish=yes

For Finland: http://gtkdata.gtk.fi/fmd/

For Poland: https://www.pgi.gov.pl/dokumenty-pig-pib-all/publikacje-2/bilans-zasobow/4895-bilans-zasobow-zloz-kopalin-w-polsce-2016/file.html and: http://geoportal.pgi.gov.pl/surowce/metaliczne

For Sweden: https://www.sgu.se/en/mineral-resources/swedish-ore-mines

JRC data processing: Selection of mineral commodities, collection of the most updated mine location and production data, and conversion to a georeferenced map. The location of mines with no specific coordinates and for cases in which the database provided coordinates for the headquarters but not for the operation site, was obtained from each company's and operation's website.

5. Wood supply

Figure 5.1

Description: Forest felling (utilisation) rates. Annual fellings as a percentage of the net annual increment of wood. This indicator of forest management is used as a way of measuring the sustainability of the production and use of forest resources. FOREST EUROPE definition : Average standing volume of all trees, living or dead, measured overbark to minimum diameters as defined for ´Growing stock´ (min. diameter of 10 cm at breast height) that are felled during the given reference period, including the volume of trees or parts of trees that are not removed from the forest, other wooded land or other felling site. Includes: silvicultural and pre-commercial thinnings and cleanings left in the forest; and natural losses that are recovered (harvested). 'Net annual increment' is the Volume over bark of all living trees with a minimum diameter of 10 cm at breast height (or above buttress if these are higher). Includes the stem from ground level up to a top diameter of 0 cm, excluding branches. 'average annual volume over the given reference period of gross increment less that of natural losses on all trees to a minimum diameter as defined for ´Growing stock´ (min. diameter of 10 cm at breast height)'.

Material/sector coverage: Wood fellings from trees in areas available for wood supply.

Data source/reference: 'State of Europe's Forests 2020', Forest Europe (2020). This report, which presents data provided by Member States for 2015, relies on the updated set of Pan-European criteria & indicators (C&I) for sustainable forest management, which is a core tool for monitoring changes to all dimensions of sustainable forest management in Europe.

Figure 5.2

Description: Forest growing stock in forest available for wood supply (FAWS) – forecasted data. Growing stock represents the standing volume of living trees. Growing stock is closely linked to forest felling rates: a positive change in the stocks indicates that wood removals did not surpass the wood increment, and stocks were allowed to increase. FAO definition: 'Growing stock' is the 'volume over bark of all living trees with a minimum diameter of 10 cm at breast height (or above buttress if these are higher). It includes the stem from ground level up to a top diameter of 0 cm, excluding branches'.

Material/sector coverage: Wood growing stock in forest available for wood supply (FAWS).

Data source/reference: 'State of Europe's Forests 2020', Forest Europe (2020). See above for more details.

JRC data processing: The data on growing stocks was normalised in line with the country area to allow comparison across countries. This normalisation was chosen over the corresponding annual forest area because changes in country forest area from one year to the next would hide real changes in the growing stock.

6. Domestic production

Figure 6.1

Description: Domestic extraction (DE) and domestic material consumption (DMC) of raw materials by material category. Data depicts domestic extraction of materials that are further used in economic processes, usually accounted for at the point when the natural resource becomes commoditised and a price is attached. DMC measures the total quantity of materials directly used within an economic system. DMC equals the sum of domestic extraction and imports minus exports.

Material/sector coverage:

- Construction minerals, non-metallic minerals - primarily construction: ornamental or building stone, chalk, dolomite, limestone, gypsum, structural clays, sand gravel and crushed rock for construction. Gypsum, dolomite and structural clays were formerly counted as industrial minerals in the 2018 Scoreboard. The datasets used in the 2018 Scoreboard refer to the previous standard MFA accounting published by the UNEP Resource Panel in 2016.
- Industrial minerals: other mining and quarrying products, chemical and fertiliser minerals, salt, specialty clays, industrial sand and gravel, other non-metallic minerals n.e.c. and kaolin.
- Metals: aluminium, copper, iron, zinc, lead, nickel, tin, gold, silver, platinum and other precious metals, and other metals.
- Woods: In addition to timber, in the UNEP Global Material Flows Database published in 2018, wood for energy is accounted under this category.

Data source/reference: Global Material Flows Database, International Resource Panel of the United Nations Environment Programme (IRP-UNEP)

Data update frequency: Annual

Data source URL: https://www.resourcepanel.org/global-material-flows-database

Data source metadata URL: https://www.resourcepanel.org/global-material-flows-database

JRC data processing: Aggregating the data on domestic production of construction minerals, industrial minerals, metals and wood from all EU Member States.

Figure 6.2

Description: Domestic production of a selection of metals at various production stages.

Material/sector coverage: Mining stages (bauxite, iron, copper and zinc) include domestic, primary production. Bauxite and iron ore production data are provided in gross weight irrespective of the metal content, while copper and zinc figures are given as metal content of domestic ores and concentrates. The production of semi-finished materials (alumina, pig iron and smelter production of copper) include primary production from both domestic and imported ores. The production of crude steel, refined copper, and zinc slab include primary and secondary production (i.e. scrap), either domestically sourced or imported. Primary aluminium may also come from imported sources but not from secondary materials.

Data source/reference: British Geological Survey (BGS)

Data update frequency: Annual

Data source URL: https://www.bgs.ac.uk/mineralsuk/statistics/wms.cfc?method=searchWMS

Data source metadata URL: https://www.bgs.ac.uk/downloads/start.cfm?id=3512

JRC data processing: Aggregation of domestic production of the selected metals and stages in EU Member States.

7. EU share of global production

Figure 7.1

Description: Production for different material categories by world region.

Material/sector coverage:

- o Iron and ferro-alloy metals are iron (Fe), chromium (Cr), cobalt (Co), manganese (Mn), molybdenum (Mo), nickel (Ni), niobium (Nb), tantalum (Ta), titanium (Ti), tungsten (W), vanadium (V).
- o Non-ferrous metals are aluminium (Al), antimony (Sb), arsenic (As), bauxite, beryllium (Be), bismuth (Bi), cadmium (Cd), copper (Cu), gallium (Ga), germanium (Ge), indium (In), lead (Pb), lithium (Li), mercury (Hg), rare earth minerals, rhenium (Re), selenium (Se), tellurium (Te), tin (Sn), zinc (Zn)
- o Precious metals includes gold (Au), Platinum group metals (palladium (Pd), platinum (Pt), rhodium (Rh)), silver (Ag).
- o Industrial minerals comprise asbestos, baryte, bentonite, boron minerals, diamond, diatomite, feldspar, fluorspar, graphite, gypsum, anhydrite, kaolin, magnesite, perlite, phosphate, potash, salt, sulfur, talc, vermiculite and zircon.
- o Industrial roundwood, as defined by the United Nations' Food and Agriculture Organisation (FAO), includes all industrial wood in the rough (sawlogs and veneer logs, pulpwood and other industrial roundwood) and, in the case of trade, chips and particles and wood residues.

Data source/reference: World Mining Data for mining production (all metal and industrial minerals). The data for industrial roundwood production was collected from FAOSTAT .

Table 7.1:

- o Production data shown in Table 7.1 correspond to the stage with higher supply risk, according to the 2020 Study on the list of critical raw materials (CRMs) for the EU.
- o For abiotic commodities, the data presented was collected from the 2020 Study on the EU's list of CRMs. This data corresponds to a five-year production average from 2012 to 2016. The underlying data sources in this study are:

Materials	Stage	Source
Bauxite	Extraction	World Mining Data 2019
Chromium	Processing	British Geological Survey (BGS) database ('World Mineral Production'); United States Geological Survey (USGS), Mineral yearbook for Ferro-alloys 2015
Copper	Extraction	World Mining Data 2019
Iron ore	Extraction	British Geological Survey (BGS) database ('World Mineral Production'); World Steel Association
Lead	Extraction	British Geological Survey (BGS) database ('World Mineral Production')
Nickel	Extraction	World Mining Data 2019
Zinc	Extraction	British Geological Survey (BGS) database ('World Mineral Production')

For industrial roundwood, data were collected from the FAO database (FAOSTAT) , and updated based on the five-year average for 2012-2016.

Data from the same sources mentioned above were used to disaggregate by region data reported in the 2020 CRMs study as 'other non-EU countries'.

8. Import reliance

Figure. 8.1

Description: Import reliance in the EU by raw materials categories.

Material/sector coverage: Timber, metal ores and non-metallic minerals (classification from the Material Flow Accounts, namely Regulation (2011) 691, Annex III).

Data source/reference: Eurostat Material Flow Accounts database. It provides detailed material flows, in thousand tonnes per year (among other units), into the EU economy (domestic extraction and imports) and out of the EU (exports).

Data update frequency: Annual; data here extracted on 20/02/2020.

Data source URL: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_mfa&lang=en

Data source metadata URL: https://ec.europa.eu/eurostat/cache/metadata/en/env_ac_mfa_esms.htm

JRC data processing: Based on the Eurostat data on materials flows in mass units per year, the calculation of import reliance was aligned with the revised methodology for identifying the list of critical raw materials for the EU, using the formula: IR = net imports / apparent consumption, where:

net imports= imports minus exports;

apparent consumption = domestic production plus net imports.

When exports exceed imports (i.e. the calculated value of import reliance results negative), the value for import reliance indicator has been set to zero (in line with the criticality methodology).

Figure 8.2

Description of the data: Import reliance for selected raw materials. Data are based on the Criticality 2020 (at two processing stages, when applicable/available), as compared with the Criticality 2017 (one processing stage).

Material/sector coverage: Selection of five raw materials: cobalt, copper, platinum, REE and tungsten.

Data source/reference: Production data from international data providers (BGS/USGS) and trade data from ESTAT (COMEXT), as used in the CRMs 2020 and CRMs 2017 studies.

Data update frequency: The CRMs study is updated every 3 years (for the update of the critical raw materials list).

JRC data processing: Import reliance is calculated using the formula: IR = net import / apparent consumption; where: apparent consumption = domestic production + import — export.

9. Geographical concentration and governance

Description: Geographical concentration of global production and supply to the EU and the correspondence country governance level. The figure builds on data from the 2020 European Commission's 'Study on the review of the list of Critical Raw Materials Criticality Assessment'. Global supply (%) refers to the percentage of global supply of raw materials by country per raw material, averaged for the period 2012-2016. Supply to the EU (%) refers to the percentage of raw materials supply from which the EU sources raw materials, which can be calculated based on the sum of EU domestic production and imports from other countries, also averaged for 2012-2016. The figure shows only countries with more than a 5% of share in both global supply and EU sourcing for each material, so the totals do not necessarily amount to 100%. The level of country governance is given by the colour code, which is based on the worldwide governance indicators (WGI). WGI scores are based on stakeholders' perceptions in industrial and developing countries and cover six dimensions of governance: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law and control of corruption. The WGI country scores correspond to the average value of the six governance dimensions for the year 2016.

Geographic coverage: Global. AR: Argentina, AT: Austria, AU: Australia, BE: Belgium, BG: Bulgaria, BO: Bolivia, BR: Brazil, BY: Belarus, CA: Canada, CD: Congo, (Kinshasa), CI: Côte d'Ivoire, CL: Chile, CN: China, CZ: Czechia, DE: Germany, DZ, Algeria, ES, Spain, ET: Ethiopia, FI: Finland, FR: France, GA: Gabon, GB: United Kingdom, GF: French Guiana, GN: Guinea, GR: Greece, GT: Guatemala, ID, Indonesia, IL: Israel, IN: India, IR: Iran, Islamic Republic of, IS: Iceland, JP: Japan, KE: Kenya, KR: Korea (South), KZ: Kazakhstan, MA: Morocco, MN: Mongolia, MX: Mexico, MY: Malaysia, MZ: Mozambique, NA: Namibia, NG: Nigeria, NO: Norway, PE: Peru, PL: Poland, QA: Qatar, RU: Russian Federation, RW: Rwanda, SE: Sweden, SK: Slovakia, SL: Sierra Leone, SY: Syrian Arab Republic (Syria), TH: Thailand, TJ: Tajikistan, TR: Turkey, UA: Ukraine, US: United States of America, VN: Viet Nam, ZA: South Africa, ZW: Zimbabwe.

Material/sector coverage: Critical raw materials and the following non-critical raw materials: aluminium, chromium, coking coal, copper, helium, iron ore, manganese and potash. Bauxite, strontium and titanium are the new critical raw materials in 2020, while helium is no longer a critical raw material.

In line with 2020 assessment of critical materials, the supply stage presented in Figure 9.1 has changed compared with the 2018 Scoreboard. The bottle neck of supply changed from the processing to the extraction stage for antimony, coking coal, and vanadium; and from the extraction stage to the processing stage for HREE, LREE, titanium and tungsten.

The 2020 criticality study also identified several data gaps that are shown as ´N/A´ in the figure. No information was available for the global supply of HREE and LREE at the processing stage, for the EU sourcing of beryllium at the extraction stage and for the EU sourcing of PGM, titanium and vanadium at the processing stage. For tungsten, the bottleneck of supply occurs at the processing stage. However, the global supply figure presented in the figure reflects the distribution of tungsten smelters worldwide as a proxy of supply concentration of tungsten at this stage. No solid information was found for the EU sourcing of tungsten at this stage.

Data source/reference: Report on the 2020 list of critical raw materials; and World Bank, worldwide governance indicators (WGI) project.

Data update frequency: The study on critical raw materials takes place every 3 years.

Data source URL: http://info.worldbank.org/governance/wgi/#home (WGI). https://ec.europa.eu/docsroom/documents/42883/attachments/1/translations/en/renditions/native

Data source metadata URL: https://info.worldbank.org/governance/wgi/#doc (WGI) *JRC data processing:* Combination of a country's supply of raw materials to the global and EU market, assigning the governance level, based on WGI, to each country with corresponding colour code.

10. Export restrictions

Description: Figure 10.1 refers to the restrictions imposed on global exports, showing the total annual number of HS 6-digit industrial commodities affected by each type of export restrictions imposed worldwide over the period 2009-2017. Figure 10.2 presents the proportion of the global production of primary raw material commodities subject to export restrictions in 2014 (i.e. reference year in the previous edition of the Scoreboard) and 2017, by material.

Material/sector coverage: The 13 export-restricting measures shown in Figure 10.1 are those covered in the OECD's 'Inventory of export restrictions on industrial raw materials'. They are: export tax; export surtax; licensing requirement; export prohibition; export quota; VAT tax rebate reduction/withdrawal; domestic market obligation; minimum export price/price reference for exports; qualified exporters list; fiscal tax on exports; restrictions on customs clearance point; captive mining; other measures. For the detailed description of the 13 export-restricting measures, see the OECD's Methodological note to the Inventory of Export Restrictions on Industrial Raw Materials, Table 1.

The OECD's dedicated database contains export restrictions on HS2007 6-digit commodities containing metals, minerals and wood, in both raw and semi-processed forms, for 64 materials (57 mineral and metals, 6 wood products, and metal waste and scrap). The HS2007 chapters and subchapters covered are: 25, 26, 27 (270112, 270400), 28, 31 (310420, 310430, 310490), 4403, 4407, 4412, 71-74, 76-81 (apud the OECD's ´Methodological note to the Inventory of Export Restrictions on Industrial Raw Materials´).

Table 10.1 below presents the HS2007 6-digit commodities and their corresponding processing stage considered in the calculation of the share of restricted production for each material presented in Figure 10.2, as listed in the OECD's Inventory of Restrictions on Exports of Raw Materials. For all five materials, the scope of analysis is the first stage of the supply chain, i.e. metal ores and minerals.

Table 10.1: The HS2007 6-digit commodities and their processing stage used for Figure 10.2.

Material	Processing stage	HS 6-digit code	Commodity description	Producing countries
Cobalt	Metal ores and minerals	260500	Cobalt ores and concentrates	Congo (Democratic Republic of); Indonesia; Madagascar; Morocco; Philippines; Zambia;
Copper	Metal ores and minerals	260300	Copper ores and concentrates	Argentina; Congo (Democratic Republic of); Indonesia; Kazakhstan; Mongolia; Russia; Zambia
Platinum	Metal ores and minerals	261690*	Precious metal ores and concentrates (excl. silver ores & concentrates)	China, Colombia, Russia; Zimbabwe;
Rare earth minerals	Metal ores and minerals	253090*	Mineral substance, n.e.s. in HS chapter 25;	China; Malaysia
Tungsten	Metal ores and minerals	261100	Tungsten ores and concentrates	Bolivia; China; Russia; Rwanda; Vietnam

* This HS 6-digit code covers more HS10-digit products than rare earth minerals.

Geographical coverage: In Figure 10.1, the country coverage is the same as in the OECD's database, i.e. 73 countries, which account for 96% of the world's production of minerals and metals and 84% of world's wood production. In Figure 10.2, the coverage is global for both production of materials and export restrictions.

Data sources/reference: For data on the global export restrictions, the source of data is the OECD's 2019 'Inventory on Restrictions on Exports of Raw Materials', https://qdd.oecd.org/subject.aspx?Subject=ExportRestrictions_IndustrialRawMaterials

The data source used for global production is C. Reichl and M. Schatz (2020), 'World Mining Data 2020', Volume 35, Minerals Production, Vienna, 2020,

https://www.world-mining-data.info/wmd/downloads/PDF/WMD2020.pdf

Data update frequency: Periodically for the OECD's 'Inventory on Restrictions on Exports of Raw Materials'; annually for C. Reichl and M. Schatz (2020).

Data source metadata URL: For OECD data on global export restrictions, 'Methodological note to the Inventory of Export Restrictions on Industrial Raw Materials', http://www.oecd.org/trade/topics/trade-in-raw-materials/documents/methodological-note-inventory-export-restrictions-industrial-raw-materials.pdf

For data on global production, C. Reichl and M. Schatz, 'World Mining Data 2020', Volume 35, Minerals Production, Vienna, 2020,

https://www.world-mining-data.info/wmd/downloads/PDF/WMD2020.pdf

JRC data processing:

- o For Figure 10.1: calculation of the total number HS 6-digit commodities affected by export restrictions, for each measure type and for each year (2009-2017).
- o For Figure 10.2, the following steps were taken: (i) identification of the HS 6-digit codes for the first fabrication stage - i.e. metal ores and minerals - of each five materials; (ii) identification of countries imposing export restrictions in 2014, 2017 and 2018; (iii) comparison of producing countries with those imposing export restrictions for each materials in 2014, 2017 and 2018; and (iv) calculation of the share of the global production of primary raw material commodities subject to export restrictions in 2014 (i.e. reference year in the previous edition of the Scoreboard) and 2017 and 2018, by material. Production of a certain raw material is considered as being subject to export restrictions if at least one of the 13 export-restricting measures was in place in the producing countries in 2014, 2017 and 2018 respectively.

11. Trade in waste and scraps

Figure 11.1

Description: Trade of selected waste and scrap - 'iron and steel', 'paper and cardboard', 'copper', 'aluminium and nickel' and 'precious metals' in mass.

Material/sector coverage: Iron and steel waste; copper, aluminium and nickel; precious metals; paper and cardboard. They refer to flows of the following Combined Nomenclature (CN) codes: (i) for 'iron and steel' (72041000, 72042110, 72042190, 72042900, 72043000, 72044110, 72044191, 72044199, 72044910, 72044930, 72044990 and 72045000); (ii) for 'copper, aluminium and nickel' (74040010, 74040091, 74040099, 75030010, 75030090, 76020011, 76020019 and 76020090); (iii) for 'precious metals' (71123000, 71129100, 71129200 and 71129900); and (iv) for 'paper and cardboard' (47071000, 47072000, 47073010, 47073090, 47079010 and 47079090).

Data source/reference: Eurostat data, International trade in goods statistics, Comext

Data update frequency: Annual

Data source URL:

http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wastrd&lang=en

Data source metadata URL: https://ec.europa.eu/eurostat/cache/metadata/en/env_wastrd_esms.htm

JRC data processing: Selection of waste stream coverage from the CN codes (see above).

Figure 11.2

Description: Volumes and values of selected wastes and scrap.

Material/sector coverage: Iron and steel waste; copper, aluminium and nickel; precious metals; paper and cardboard. They refer to the same CN flows as used in Figure 11.1 (see above).

Data source/reference: Eurostat data, International trade in goods statistics, Comext

Data update frequency: Annual

Data source URL: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wastrd&lang=en

Data source metadata URL: https://ec.europa.eu/eurostat/cache/metadata/en/env_wastrd_esms.htm

JRC data processing: Selection of waste stream coverage from the CN codes (see above).

12. Material flows in the circular economy

Figures 12.1 and 12.2

Description: Total material flows in the EU economy in 2017, in a Sankey diagram. It shows the flows of materials as they pass through the EU economy and are eventually discharged back into the environment or re-fed into the economic processing.

- Flows of waste are approximated using European waste statistics collected under Regulation (EC) No 2150/2002.
- European statistics on international trade in goods (ITGS) are used to approximate total imports and exports as well as the net imports of waste destined for recycling.
- Economy-wide material flow accounts (EW-MFA) provide an aggregate overview, in thousand tonnes per year, of the material flows into and out of an economy.

Material/sector coverage: The data refer to all sectors and materials of the aggregated EU economy.

Data source/reference: The background data used to prepare the Sankey diagram was provided by Eurostat. Three existing statistical data sources are used to compile the different flows of the diagram: 1) Management of waste by waste management operations and type of material - Sankey diagram data (code: env_wassd); 2) Material flows for circular economy - Sankey diagram data (env_ac_sd) and 3) Material flow accounts (env_ac_mfa).

Data update frequency: Annual

Data source URL: https://ec.europa.eu/eurostat/web/circular-economy/material-flow-diagram; https://ec.europa.eu/eurostat/cache/sankey/circular_economy/sankey.html for the new experimental interactive tool to visualise material flow diagrams that Eurostat has created. The tool allows you to build and customise your own diagram by playing with different options (country, year, unit, material type, etc.).

Data source metadata URL: https://ec.europa.eu/eurostat/cache/metadata/en/env_nwat_esms.htm; https://ec.europa.eu/eurostat/cache/metadata/en/env_ac_sd_esms.htm; https://ec.europa.eu/eurostat/cache/metadata/en/env_ac_mfa_esms.htm.

JRC data processing: Preparation of the Sankey diagram with data provided by EUROSTAT.

13. Management of waste from electrical and electronic equipment (WEEE)

Figure 13.1

Description: WEEE officially reported as collected, prepared for re-use and recycled (amounts per capita); and collection targets of WEEE from households for all EU countries. Eurostat compiles statistics on collected WEEE based on data reported by EU countries. These statistics also include the amounts of total WEEE 'recycled and prepared for re-use', and details on WEEE prepared for re-use.

Material/sector coverage: Total WEEE

Data source/reference: Eurostat data, waste electrical and electronic equipment (WEEE) by waste management operations (´env_waselee´)

Data update frequency: Annual

Data source URL: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_waselee&lang=en

Data source metadata URL: https://ec.europa.eu/eurostat/cache/metadata/en/env_waselee_esms.htm

JRC data processing: Selection and retrieval of the WEEE data, and calculation of the WEEE Directive collection targets for households for each country. The amount of WEEE collected per inhabitant is calculated as the ratio between the amount of WEEE collected in the year and the average population of each EU country. The amount of recycled WEEE is calculated as the difference between the amount of WEEE 'recycled and prepared for re-use' minus the amount of WEEE prepared for re-use in that year.

Figure 13.2

Description: Amount of WEEE 'prepared for re-use and recycled', and percentages per WEEE category.

Material/sector coverage: All WEEE categories

Data source/reference: Eurostat data, waste electrical and electronic equipment (WEEE) by waste management operations (´env_waselee´)

Data update frequency: Annual

Data source URL: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_waselee&lang=en

Data source metadata URL: https://ec.europa.eu/eurostat/cache/metadata/en/env_waselee_esms.htm

JRC data processing: Selection and retrieval of the WEEE data by WEEE category, calculation of the preparation for re-use and recycling index, and percentage for different WEEE categories.

Figure 13.3

Description: 'Preparation for re-use rate and recycling rate (in percentage) per WEEE category; and number of EU countries achieving the WEEE Directive targets.

Material/sector coverage: Total WEEE

Data source/reference: Eurostat data, waste electrical and electronic equipment (WEEE) by waste management operations (´env_waselee´)

Data update frequency: Annual

Data source URL: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_waselee&lang=en

Data source metadata URL: https://ec.europa.eu/eurostat/cache/metadata/en/env_waselee_esms.htm

JRC data processing: The WEEE recycling rate is calculated as the ratio between the amount of recycled WEEE divided by the amount of WEEE collected in that year. The 'preparation for re-use' rate is calculated as the ratio between the WEEE prepared for re-use divided by the amount of WEEE collected in that year. The 'preparation for re-use and recycling' rate is calculated as the amount of the WEEE prepared for re-use and recycled, divided by the amount of WEEE collected in that year.

The minimum targets (as in Annex V to Directive 2012/19/EU) applicable from 15 August 2015 until 14 August 2018 are: 80% to be prepared for re-use and recycled of WEEE falling within category 1 or 10, and 85% to be recovered; 70% to be prepared for re-use and recycled of WEEE falling within category 3 or 4, and 75% to be recovered; 55% to be prepared for re-use and recycled of WEEE falling within category 2, 5, 6, 7, 8 or 9, and 75% to be recovered; for gas discharge lamps, 80% to be recycled.

15. Recycling's contribution to meeting materials demand

Figure 15.1

Description: A compilation of end-of-life recycling input rates (EOL-RIR) in the EU shown by means of a periodic table (adapted to insert industrial minerals and bio-based materials). No trends are shown due to lack of data and limited comparability.

Geographic coverage: EU countries, based on the main data source

Time coverage: 2012-2016 averaged

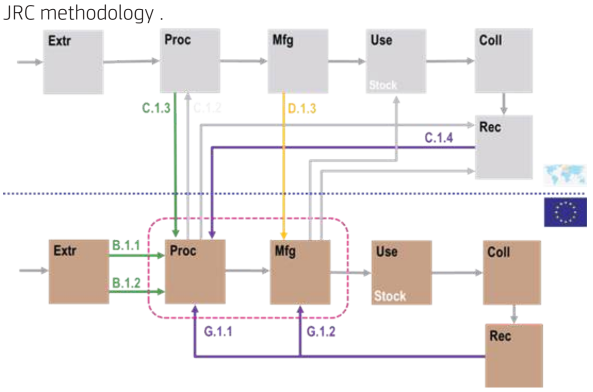
Material/sector coverage: All raw materials assessed in the context of the list of critical raw materials for the EU.

Data source/reference: European Commission (2020), Study on the EU's list of Critical Raw Materials (2020)

Data update frequency: Every 3 years

JRC data processing: End-of-life recycling input rates (EOL-RIR) are calculated as shown in Figure 15.3 and as described in a dedicated JRC technical report . Figure 15.3 illustrates the system boundaries and flows for the calculation of the EOL-RIR when using material system analysis (MSA) data. The top part of the figure shows the life-cycle stages of a raw material in the rest of the world, while the brown boxes below represent life-cycle stages of a raw material in Europe. The system boundary is represented in pink dashes. Flows used for the calculation of the EOL-RIR are shown in green (primary material), yellow (processed material), and purple (secondary material).

Figure 15.3: Flows included in the 'EOL-RIR' calculation based on the JRC methodology .



The following abbreviations are used in Figure 15.3: 'Extr' means 'extraction'; 'Proc' means 'processing'; 'Mfg' means 'manufacturing'; 'Use' means 'use'; 'Coll' means 'collection'; 'Rec' means 'recycling'.

The EOL-RIR is calculated by applying the following formula:

EOL-RIR = (G.1.1 + G.1.2) / (B.1.1 + B.1.2 + C.1.3 + D.1.3 + C.1.4 + G.1.1 + G.1.2)

When MSA data are not available, in the context of the List of CRMs for the EU , as well as in the Scoreboard, UNEP data and then industry data are used in a cascade approach. Recycling rates used in the Commission's criticality assessment are validated through dedicated expert workshops.

Figure 15.2

Description: End-of-life recycling rates (EOL-RR) compared with end-of-life recycling input rates (EOL-RIR) for a selection of materials, including five battery raw materials (cobalt, nickel, manganese, natural graphite and lithium). Data are shown as a bar chart, with values sorted according to decreasing EOL-RIR values. No trends are shown due to lack of data and limited comparability.

Geographic coverage: EU countries, based on the main data sources

Time coverage: 2012-2016 averaged

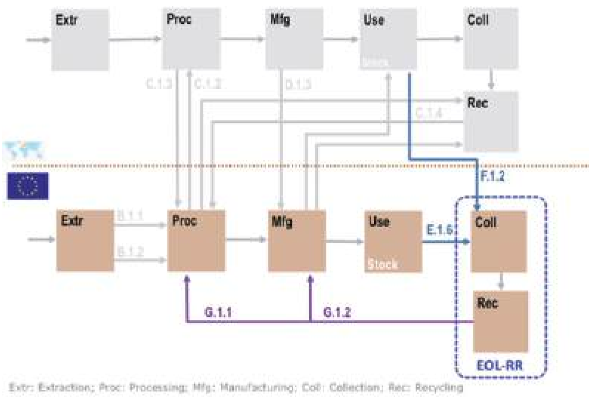
Material/sector coverage: Selection of raw materials: tungsten, iron, zinc, rhodium, antimony, palladium, platinum, cobalt, chromium, nickel, copper, magnesium, aluminium, aggregates, manganese, terbium, natural graphite, germanium, lithium.

Data source/reference: European Commission (2020), 'Study on the EU's list of Critical Raw Materials (2020)' and material system analysis (MSA) - final report (forthcoming).

Data update frequency: Every 3 years for the 'Study on the EU's list of Critical Raw Materials' and one-off for material system analysis (MSA) - final report (forthcoming).

JRC data processing: End-of-life recycling rates (EOL-RR) are calculated as shown in Figure 15.4 and as described in a dedicated JRC technical report . Figure 15.4 illustrates the system boundaries and flows for the calculation of the EOL-RR when using MSA data. The figures and underlying methodology for the EOL-RIR are the same as for Figure 15.1.

Figure 15.4: Flows included in the 'EOL-RR' calculation based on the JRC methodology



The EOL-RR is calculated by applying the following formula:

EOL-RR = (G.1.1 + G.1.2) / (E.1.6 + F.1.2)

16. Value added

Figure 16.1

Description of the data: Value added for a selection of raw materials sectors. Value added at factor cost is the gross income from economic activities after adjustment for subsidies and indirect taxes. Value adjustments (such as depreciation) are not subtracted.

Geographic coverage: EU without Croatia between 2008 and 2010, and EU between 2011 and 2017.

Material/sector coverage:

- Mining and quarrying: B07 — Mining of metal ores; B081 — Quarrying of stone, sand and clay; and B089 — Mining and quarrying not elsewhere classified (n.e.c.); B099 — Support activities for other mining and quarrying. Extraction of peat (B0892) has been removed from sector B089, since it refers to energy commodities and therefore falls outside the scope of the EIP on raw materials.
- Manufacturing of non-metallic minerals: C231 — Manufacture of glass and glass products; C232 — Manufacture of refractory products; C233 —Manufacture of clay building materials; C234 — Manufacture of other porcelain and ceramic products; C235 — Manufacture of cement, lime and plaster; C236 — Manufacture of articles of concrete, cement and plaster; C237 — Cutting, shaping and finishing of stone; C239 — Manufacture of abrasive products and non-metallic mineral products n.e.c.
- Manufacturing of basic metals: C241 — Manufacture of basic iron and steel and of ferro-alloys; C242 — Manufacture of tubes, pipes, hollow profiles and related fittings of steel; C243 — Manufacture of other products of first processing of steel; C244 — Manufacture of basic precious and other nonferrous metals; C245 — Casting of metals. The processing of nuclear fuel (B2446) has been removed from sector B244, since it refers to energy commodities and therefore falls outside the scope of the EIP on raw materials.
- Sawmilling and planing of wood (C161)
- Manufacture of pulp, paper and paperboard (C171)
- Manufacture of rubber products (C221)
- Materials recovery (E383)

Due to the many data gaps in the forestry sector dataset, forestry is not covered in Figure 16.1.

Within the manufacturing of basic metals category (C24), one highlights three sub-sectors: Iron and steel (C241, C242, C243, C2451, C2452), Precious (C2441) and Non-ferrous (C2442, C2443, C2444, C2445, C2453, C2454).

Within the manufacturing of non-metallic minerals category, one highlights four sub-sectors: Glass (C231), Ceramics, refractory and others (C232, C233, C234, C239), Cement (C235, C236) and Stone (C237).

Data source/reference: Eurostat annual detailed enterprise statistics for industry (NACE Rev. 2, sections B-E)

Data update frequency: Annual

Data source URL: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_ind_r2&lang=en

Data source metadata URL: http://ec.europa.eu/eurostat/cache/metadata/en/sbs_esms.htm

JRC data processing: Selection of economic sectors and gap fillings. For the gap filling, whenever possible, data were interpolated between available data points. When data for interpolation were missing (there was not an initial or end value), they were assumed equal to the value of the closest year.

Figure 16.2

Description of the data: Value added across the production chain for a selection of raw materials and downstream sectors. Value added at factor cost is the gross income from economic activities after adjustment for subsidies and indirect taxes - but not taking depreciation into account.

Material/sector coverage: Same as in the 2018 edition. The NACE Rev2 sectors have been cauterised following the value chain, as following:

- Extraction: Coverage for Figure 16.1 (see above) plus A02 — Forestry and logging
- Processing: Same coverage as Figure 16.1 (see above)
- Downstream manufacturing:

  - Fabricated metal products: C25 — Manufacture of fabricated metal products, except machinery and equipment

  - Machinery, vehicles and equipment: C26 — Manufacture of computer, electronic and optical products; C27 — Manufacture of electrical equipment; C28 — Manufacture of machinery and equipment n.e.c.; C29 — Manufacture of motor vehicles, trailers and semi-trailers; C30 — Manufacture of other transport equipment; C332 — Installation of industrial machinery and equipment

  - Construction: F — Construction

  - Biotic: C162 — Manufacture of products of wood, cork, straw and plaiting materials; C172 — Manufacture of articles of paper and paperboard

  - Furniture: C31 — Manufacture of furniture

  - Other: C32 — Other manufacturing
- Repair and materials recovery:

  - Maintenance and repair: C331 — Repair of fabricated metal products, machinery and equipment (minus sector C3319, which covers repair of other equipment); G4520 — Maintenance and repair of motor vehicles; S95 — Repair of computers and personal and household goods (minus S9523 and S9529, which cover, respectively, repair of footwear and leather goods, and repair of other personal and household goods)

  - Materials recovery: E383 — Materials recovery

Data source/reference: Eurostat annual detailed enterprise statistics for industry (NACE Rev. 2, sections B-E, Section F, Section G and Division S95). For Forestry: net value added from Economic aggregates of forestry and logging ´for_eco_cp´

Data update frequency: Annual

Data source URL: https://ec.europa.eu/eurostat/web/structural-business-statistics/data/database. For forestry : https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=for_eco_cp&lang=en

Data source metadata: http://ec.europa.eu/eurostat/cache/metadata/en/sbs_esms.htm (metadata description). For forestry: https://ec.europa.eu/eurostat/cache/metadata/en/for_eaf_esms.htm

JRC data processing: Selection of economic sectors

17. Mining equipment exports

Description: The three charts are entirely based on data from UN Comtrade, accessed via the World Bank's World Integrated Trade Solution . The data on exports/imports do not include re-exports/re-imports.

For calculating net exports in Figure 17.1, a country's annual imports are subtracted from exports.

In the construction of Figures 17.1 and 17.2, only extra-regional trade flows are taken into account for regional trading blocs. For example, data on the EU aggregate only account for extra-EU exports.

Geographical coverage: The country composition of regions included in Figure 17.1 is as follows:

- ‘Central & South America’ includes Aruba, Argentina, Antigua and Barbuda, Bahamas, Belize, Bolivia, Brazil, Barbados, Chile, Colombia, Costa Rica, Cuba, Cayman Islands, Dominica, Dominican Republic, Ecuador, Grenada, Guatemala, Guyana, Honduras, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, Nicaragua, Panama, Peru, Puerto Rico, Paraguay, El Salvador, Suriname, Saint Maarten, Turks and Caicos Islands, Trinidad and Tobago, Uruguay, St. Vincent and Grenadines, Venezuela and Virgin Islands.
- ‘Asia-Pacific’ includes American Samoa, Australia, Brunei, Fiji, Micronesia, Guam, Hong Kong, Indonesia, Cambodia, Kiribati, Republic of Korea, Laos, Macao, Marshall Islands, Myanmar, Mongolia, Northern Mariana Islands, Malaysia, New Caledonia, New Zealand, Philippines, Palau, Papua New Guinea, Dem. Rep. of Korea, French Polynesia, Singapore, Solomon Islands, Thailand, Timor-Leste, Tonga, Tuvalu, Vietnam, Vanuatu and Samoa.
- ‘Africa-Middle-East’ includes the United Arab Emirates, Bahrain, Djibouti, Algeria, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia and Yemen.

Material/sector coverage: See details on the selection of mining equipment-related commodities in the section on ´JRC data processing´ below.

	HS 2007 codes	Product description	Areas of use
HS 2007 6-digit codes retained			
1	842831	Continuous-action elevators & conveyors, for goods/materials, specially designed for underground use (excl. of 8428.10 & 8428.20)	mining + others
2	842911	Bulldozers and angle dozers: Track laying	mining + others
3	842919	Bulldozers and angle dozers: --Other	mining + others
4	842951	Mechanical shovels, excavators and shovel loaders:- Front-end shovel loaders	mining + others
5	842952	Mechanical shovels, excavators and shovel loaders:- Machinery with a 360-degree revolving superstructure	mining + others
6	842959	Mechanical shovels, excavators and shovel loaders: Other	mining + others
7	843031	Coal or rock cutters and tunnelling machinery: -- Self-propelled	mining + others
8	843039	Coal or rock cutters and tunnelling machinery: 8430.39 — Other than self-propelled	mining + others
9	843041	Other boring or sinking machinery: Self-propelled	mining + others
10	843049	Other boring or sinking machinery: Other	mining + others
11	843050	Moving/grading/levelling/ scraping/tamping/ compacting/excavating/ extracting machinery, for earth/mins./ores (excl. of 8430.10-8430.49), self-propelled	mining + others
12	843142	Parts suit. for use solely/ principally with bulldozer/ angle dozer blades	mining + others
13	843143	Parts for boring or sinking machinery of subheading 8430.41 or 8430.49	mining + others
14	843149	Parts suit. for use solely/ principally with the machinery of 84.26/84.29/84.30 (excl. of 8431.41-8431.43)	mining + others
15	847410	Sorting, screening, separating or washing machines	mining + others
16	847490	Machinery for sorting, screening, separating, washing, crushing, grinding, mixing or kneading earth, stone, ores or other mineral substances, in solid (including powder or paste) form; machinery for agglomerating, shaping or moulding solid mineral fuels, ceramic paste, unhardened cements, plastering materials or other mineral products in powder or paste form; machines for forming foundry moulds of sand — Parts	mining + others
17	870130	Track-laying tractors	mining + others
18	870410	Dumpers designed for off-highway use	mining + others
19	843069	Moving/grading/levelling/ scraping/tamping/ compacting/excavating/ extracting machinery, for earth/mins./ores (excl. of 8430.10-8430.49), other than self-propelled	mining + others
20	847420	Crushing/grinding machines for earth/stone/ores/other mineral substance, in solid (incl. powder/paste) form	mining + others

21	847439	Mixing/kneading machines for earth/stone/ores/other mineral substance, in solid (incl. powder/paste) form (excl. of 8474.31 & 8474.32)	mining + others
HS 2007 6-digit codes excluded (codes referring to equipment mainly used in infrastructure & construction)			
22	842920	Self-propelled graders & levellers	road + construction
23	842930	Self-propelled scrapers	road + construction
24	842940	Self-propelled tamping machines & road rollers	mostly road
25	843010	Pile-drivers & pile-extractors	construction
26	843020	Snow-ploughs & snow-blowers	mostly road
27	843061	Tamping/compacting machinery, not self-propelled	road + construction
28	847910	Machinery for public works/ building/the like having individual functions, n.e.s. in Ch.84	road + construction
29	847431	Concrete/mortar mixers	construction
30	847432	Machines for mixing mineral substance with bitumen	road

Based on current knowledge, there is no methodological way of clearly separating the HS codes referring to equipment used exclusively in mining from those used in other activities, especially construction. This is because many of the selected HS codes refer to multi-purpose equipment that is used not only in mining but also in other activities such as infrastructure and construction. This limitation is recognised both by the US Department of Commerce and by Farooki (2012) . Also, to our knowledge, it is not possible to split the resulting HS codes into coal-, metal- and mineral-mining equipment.

Data source/reference: UN Comtrade, accessed via World Bank's World Integrated Trade Solution (WITS), Reference Data, https://wits.worldbank.org/referencedata.html

Data update frequency: Annually

Data source URL: https://wits.worldbank.org

Data source metadata URL: WITS, Reference Data, https://wits.worldbank.org/referencedata.html

JRC data processing: Identification of mining equipment-related commodities: selection of HS commodities by the statistical correspondence between NACE Rev. 2, PRODCOM and Harmonised System, starting from the products covered by the 4-digit NACE class 28.92, 'Manufacture of machinery for mining, quarrying and construction', as listed in Eurostat's PRODCOM List 2013 . Out of the resulting 30 six-digit HS codes, only 21 were retained. The remaining nine codes were not taken into consideration, since they appear to refer to equipment mostly used in infrastructure and construction (see table above). Import and export data were extracted through specific queries, based on the selected HS codes and country groups created. Calculation of net exports (for Figure 17.1).

18. Corporate R&D investment

Description: corporate R&D investment and R&D investment intensity of top investor companies in the raw material sectors, headquartered in the EU. The data are a subsample of the 'EU 1000' section of the EU Industrial R&D Investment Scoreboard dataset ('R&D Scoreboard' henceforth, see details on subsample selection in 'JRC processing' below). The R&D Scoreboard collects every year the companies that invest most in R&D (in absolute terms). R&D investment is the nominal cash investment in research and development (in million euros) funded by the companies themselves. Values are not inflation-adjusted because of the lack of standard R&D-specific or even industry-specific deflators (OECD, 2015). R&D intensity refers to the ratio between R&D investment and net sales, as contained in the R&D Scoreboard. Note that other official statistics use value added as the denominator instead of net sales.

Material/sector coverage: The following four raw material sectors, as categorised by the original data provider according to the Industry Classification Benchmark (ICB):

- ´Construction and its suppliers´ (ICB 235). This sector covers companies engaged in heavy surface and underground construction, producers of building materials and fixtures. ('Construction and materials' in the R&D Scoreboard)
- ´Forestry and paper production´ (ICB 173). It covers forestry producers and operators, paper production, conversion, and distribution. ('Forestry and paper')
- ´Mining and production of base metals´ (ICB 175). It covers producers, manufacturers and distributors of iron and steel and of non-ferrous metals, including mining of bauxite and iron ores, excluding final production. ('Industrial metals and mining')
- ´Mining and production of other minerals and coal´ (ICB 177). It covers companies engaged in the exploration or extraction of coal or gem-stones, and companies engaged in the exploration, extraction or production of precious metals and of non-metal minerals. ('Mining')

According to this classification, recycling is not considered as a separate group but is integrated within the four sectors.

Data source/reference: EU Industrial R&D Investment Scoreboard, editions 2007-2019

Data update frequency: Annual

Data source URL: https://iri.jrc.ec.europa.eu/rd_monitoring

JRC data processing: Selecting the companies whose main activity in 2018 concerns one of the four selected raw materials sectors described under ´Material/sector coverage´. Filling in minor gaps in the time series by retrieving annual reports of related companies, cross-checking nearby time periods for consistency. Finally, further restricting the sample to those companies for which data were available throughout the period 2006-2018, taking into account acquisitions, de-mergers, etc., between them (out-of-sample acquisitions and demergers are not controlled for). The final sample follows back in time 30 companies (for a total of 35 different legal entities): 4 forestry and paper companies, 11 base metals production, 2 non-base-metal mining, and 13 construction companies. R&D investment (Figure 18.1) is the summation of single companies' investments within each sector. R&D intensity (Figure 18.2) is the unweighted average of the individual companies' R&D intensities within each sector.

19. Patent applications

Description: Number of patent applications in five raw materials categories.

Geographic coverage: EU and other five non-EU top applicant countries, namely China, Japan, Russia, South Korea and the United States.

Data source/reference: Worldwide Patent Statistical Database (PATSTAT database), 2019 autumn edition. Published by the European Patent Office (EPO)

Data update frequency: PATSTAT is updated biannually (spring and autumn).

Data source URL:

https://www.epo.org/searching-for-patents/business/patstat.html#tab-1

Data source metadata URL:

https://www.epo.org/searching-for-patents/business/patstat.html#tab-1

JRC data processing: Data are extracted through specific queries based on international patent classification (IPC) codes. For all sectors except recycling, queries were also based on keywords (Table 1) as the relevant IPC codes were often too generic. For recycling, keywords were not needed as the IPC classification already provides a comprehensive selection. Additional bibliographic information of patent applicants (such as name and country of residence) is retrieved and linked to patent applications. Only applicants classified as a company, university or governmental non-profit organisation were included in the analysis. Based on this panel of information, the fractional count technique was applied to take into account the proportional contribution to patent applications of each applicant, thus preventing multiple counting. Further details can be found in (Fiorini et al. (2017)) , Section 2 (pp. 8-18). Starting with this Scoreboard edition, prior to the application of the fractional count technique, data were cleaned in order to increase accuracy and completeness . This was particularly important to improve data coverage for Asian countries, such as China and Japan, whose data are often associated with an incorrect or missing country code.

Table: List of IPC codes and keywords use for the patent applications queries per category.

Category	IPC codes	Keywords (title or abstract)
Mining	E21B, E21C, E21D, E21F, B02C, B03B, B03D, B03C, B07	(Drilling AND Mineral), Mining, Ores, Minerals, Quarrying, Mine
Basic metals	B22D, C21B, C21C, C21D, C22B, C22C, C22F, C25C, C25F, B21C	Refining, Metals, Casting, Metallic
Non-metallic	B32B, C03C, C03B, B28B, B28C, C04B	Minerals, Clay, Cement, Lime, Silica
Biotic	C08C, B27D, B27H, B27M, B27N, D21C, D21H, D21J	Wood, Rubber, Paper
Recycling	C04B33/132, B23D25/14, B30B9/32, H01B15, D01F13, D21C11, D21C5/02, B62D67, C08B16, C08L17, C09K11/01, C10L5/48, D21B1/08, D21B1/32, D21F1/66, G03G21/10, H01J9/52, H01M6/52, H01M10/54, C22B7, C22B19/28, C22B19/30, C22B25/06, B22F8, C04B7/24, C04B11/26, C04B18/04, C04B33/132, D21C5/02, D21H17/01	-No keywords used

20. Financing

Description: ´Share of equity in total assets´ and ´Return on average equity´. Average values of the financial indicators are size-weighted by the data provided for each sector/subsector.

- o ´Share of total equity in total assets´ is calculated by dividing a company’s equity by its total assets. Equity means the value of assets a company attracts from shareholders. The sum of equity and debts equals the company’s financial assets. In general, the lower the share of total equity in total assets, the higher the company’s reliance on debt. This may be the result of diminishing investor interest, possibly due to a downtrend in companies’ performance or higher financial risk.
- o ´Return on average equity´ measures a company’s efficiency in using capital from equity as profit.

Geographic coverage: Worldwide - and EU-27-based company aggregates. While in the former aggregate the worldwide companies are consolidated into a single entity, regardless of the location of their headquarters, in the latter only the companies with headquarters in the EU-27 are considered. The distinction between world- and EU-based companies does not separately consider divisions and branches located worldwide.

Material/sector coverage: Metals and mining aggregates constructed by the data provider, which consolidate companies from two separate sectors - mining and metals - into a single one. Disaggregated financial indicators for each of the two sectors are not available. The company coverage for each sector or subsector is not exhaustive. These aggregates are size-weighted, being calculated by the data provider through consolidation of companies belonging to a certain sector/subsector into a single entity.

Data source/reference: S&P Global Market Intelligence

Data update frequency: Annually

Data source URL: https://www.spglobal.com/marketintelligence/en/ (access by subscription).

Data source metadata URL: https://www.spglobal.com/marketintelligence/en/ (access by subscription).

21. Greenhouse gas emissions

Description:

- o Absolute GHG emissions: emissions from fossil fuel combustion and process emissions from on-site production for the EU and for the world. This analysis covers emissions of CO2 (the main component), CH4, N2O and fluorinated gases (F-gases) - not all industries and processes emit all types of GHGs. CO2 emissions from large-scale biomass burning are excluded. Emissions are calculated based on the level of activity of the industry (e.g. fuel use, output, etc.) and the emission factors, which gauge the emissions generated by each activity unit. Activity data mostly come from the International Energy Agency (IEA) , the World Steel Association (worldsteel), and the United States Geological Survey (USGS). The emissions factors are from the Intergovernmental Panel on Climate Change (IPCC). These factors may use different tiers, i.e. degree of analytical complexity and the quantity of information required, depending on whether facility-, industry- and country-specific emission factors are available. The accuracy of the emission estimates will partly depend on the specificity of the tiers followed, where different countries and different sectors might allow for more accurate estimates than others. GHG emissions are expressed in CO2 equivalents units based on a 100-year time horizon, as adopted in the IPCC’s Fourth Assessment Report. Global warming potential conversion factors are 1 for CO2, 25 for CH4, 298 for N2O and for F-gases is calculated by multiplying the mass of the gas (in tonnes), by the gas’ global warming potential (GWP).
- o GHG emission intensity. It depicts absolute emissions divided by the activity data (see description below under ‘JRC data processing’).

Material/sector coverage: Mining, iron and steel, non-ferrous metals, non-metallic minerals, pulp and paper, and wood and wood products. For more details see source classification in 2006 IPCC Guidelines: for combustion, Volume 2 (Energy) , Chapter 2 (Stationary combustion); for process emissions, Volume 3 (Industrial processes and product use) , Chapter 1 (Introduction, for an overview of the sector coverage), Chapter 2 (Mineral industry emissions) and Chapter 4 (Metal industry emissions). For mining and for the production of wood, and pulp and paper, only combustion-related emissions are available. For wood and paper production, zero process emissions are assumed since emissions are accounted for in other sectors (forestry and land use), in which often emissions are compensated by vegetation planting/ growth. Emissions from energy use of mining activities are aggregated for all minerals mined, covering NACE divisions B07 (mining of metal ores), B08 (other mining and quarrying) and B099 (support activities for other mining and quarrying), and excluding the mining of fuels.

Data source/reference: For absolute emissions, the Emissions Database for Global Atmospheric Research (EDGAR) is applied. EDGAR is a research database that calculates emissions generated by economic activities. It has global coverage, estimates emissions of a comprehensive set of substances and covers the industrial sectors cited in the 2006 IPCC guidelines. For emission intensity, activity data, which is not publicly available, managed by the JRC EDGAR team, mostly coming from major, trustworthy producer associations, International Energy Agency (IEA) and the United States Geological Survey (USGS).

Data update frequency: Annual for CO2, less frequent for other GHGs.

Data source URL: https://edgar.jrc.ec.europa.eu/overview.php?v=50_GHG (data not fully disaggregated as in the graphs presented here).

JRC data processing: Selection of the GHGs and sector coverage. For Figure 21.1, absolute GHG emissions in CO2 equivalents from combustion and process emissions were aggregated for all raw material industries under scope, for the EU and for the world. Further, emissions intensity was calculated, depicted by the 'implied emission factors' (IEF). IEF estimate the amount of GHG emissions divided by the activity data of each raw materials sector. IEFs for each industry are the average of several industry types - for instance, the non-ferrous metals sector includes the production of primary and secondary aluminium, magnesium, lead, zinc, etc. For combustion processes, IEFs are calculated as the amount of GHGs emitted per unit of fuel used in energy-related processes. For process emissions (i.e. non-combustion industrial processes), IEFs are calculated as GHG emissions per unit of material produced. For process emissions, no data on emission is provided for some industrial processes - e.g. due to the lack of significant emission of GHGs for this process. IEFs were calculated as emissions divided by production, considering only the processed for which emission and production data were available. The table below indicates the industrial processes used for the calculation of the average IEFs by the raw materials industry:

Industry	Industrial processes considered for the sector average IEF
Iron and steel	Crude steel production, ferro-alloy production and sinter production
Non-metallic minerals	Cement production, glass production, lime production and limestone and dolomite use
Non-ferrous metals	Aluminium production (primary), aluminium production (secondary), aluminium foundries: SF6 use, magnesium production (primary), magnesium production (secondary), magnesium foundries: SF6 use, SF6 use in die casting of magnesium, lead production (primary) and zinc production (primary)

22. Particulate matter and NMVOC emissions

Description: Absolute PM10 and non-methane volatile organic compounds (NMVOC) emissions: emissions from on-site production for the EU and for the world. Emissions are calculated based on the level of activity of the industry (e.g. fuel use, output, etc.) and the emission factors, which gauge the emissions generated by each activity unit.

PM10 and NMVOC emission intensity. It depicts absolute emissions divided by the activity data (see 'JRC data processing' for indicator 21. Greenhouse gas emissions).

- o Particulate matter is a complex mixture of microscopic solid or liquid matter in the air, and a key pollutant affecting human health. The current analysis uses PM10 as an indicator for emissions of particulate matter to air. PM10 refers to a particle size up to 10 μm, which can, for example, enter the lungs and reduce visibility. By definition, PM10 includes the PM2.5 fraction (particles of smaller diameter that are responsible for the most severe damage to human health given their greater potential to pass much deeper into the respiratory system). For most of the sectors considered here, PM2.5 constitutes a very high proportion of PM10.
- o NMVOCs are emitted by combustion activities and certain industrial production processes. They are a mixture of organic compounds with various chemical compositions that behave similarly in the atmosphere; exposed to sunlight, they react with ultraviolet (UV) rays to ground-level ozone, which can have severe negative impacts on human health. As besides NMVOC, NOx, CO and CH4 are also emissions that can potentially form tropospheric ozone, they are summarised as having tropospheric ozone formation potential (TOFP). This analysis focuses on NMVOCs, which is often the key precursor of ground-level ozone. Like national emission inventories, EDGAR emission estimates are based on the level of activity of the industry (e.g. fuel use, output, etc.) and the emission factors, which gauge the emissions generated by each activity unit.

Material/sector coverage: Mining, iron and steel, non-ferrous metals, non-metallic minerals, pulp and paper, and wood and wood products. For PM10, only combustion-related emissions are available for the wood industries and mining. For NMVOC, only combustion-related emissions are available for the wood industries, non-ferrous metals and mining. Emissions from energy use of mining activities are aggregated for all minerals mined, covering NACE divisions B07 (mining of metal ores), B08 (other mining and quarrying) and B099 (support activities for other mining and quarrying), and excluding the mining of fuels.

Data source/reference: For absolute emissions, the Emissions Database for Global Atmospheric Research (EDGAR) is applied. EDGAR is a research database that calculates emissions generated by economic activities. It has global coverage, estimates emissions of a comprehensive set of substances and covers the industrial sectors cited in the 2006 IPCC. For emission intensity, non-public activity data are used, which is managed by the JRC EDGAR team, mostly coming from major, trustworthy producer associations and the United States Geological Survey (USGS).

Data update frequency: Periodically - less than annually.

Data source URL: https://edgar.jrc.ec.europa.eu/overview.php?v=50_AP (data not fully disaggregated as in the graphs presented here).

JRC data processing: Selection of air pollutants and sector coverage. For Figure 22.1, absolute pollutant emissions from combustion and process emissions were aggregated for all raw materials industries under scope, for the EU and for the world. For emission intensity see explanations for indicator 21. The table below indicates the industrial processes used for the calculation of the average IEF by raw materials industry:

Industry		Industrial processes considered for the sector average IEF
Iron and steel	For PM10	Crude steel production, ferro-alloy production, pig iron production and sinter production
	For NMVOC	Crude steel production, ferro-alloy production and sinter production
Non-metallic minerals	For PM10	Cement production, glass production, lime production, soda ash use and soda ash production
	For NMVOC	Glass production
Non-ferrous metals	For PM10	Aluminium production (primary), aluminium production (secondary), aluminium foundries: SF6 use, copper production (primary), copper production (secondary), magnesium production (primary), magnesium production (secondary), SF6 use in diecasting of magnesium, molybdenum productionSF6 use in die casting of magne-sium, lead production (primary), lead production (secondary), zinc production (primary), zinc production (secondary)
	For NMVOC	-
Pulp and paper	For PM10	Paper production and pulp production
	For NMVOC	Paper production and pulp production

23. Water

Description: Water use for a selection of raw materials sectors. Water use refers to water that is actually used by end users for a specific purpose within a territory, such as for domestic use, irrigation or industrial processing. It excludes distribution losses and water returned before its use. Distribution losses refer to losses between the point of abstraction and the point of use. Water returned before use refers to water abstracted from any freshwater source and discharged into freshwaters without or before use, for instance, in the course of mining activities. Water use and returned after being use is considered.

Material/sector coverage: Manufacture of paper and paper products (C17) and the manufacture of basic metals (C24) belong to the 'water use in the manufacturing industry by activity and supply category' dataset (´env_wat_ind´). Data for the mining and quarrying sector (B) belong to the 'water use by supply category and economical sector' dataset (´env_wat_cat´).

Data source/reference: Eurostat water statistics, which are based on Member States' (voluntary) responses to the Eurostat/OECD joint questionnaire on inland waters, include indicators on water abstrac-tion, water use and water discharges, with various degrees of data completeness. Water-use data were chosen since they account for the internal re-use of water at facilities and cover some raw materials manufacturing sectors.

Country coverage: Country coverage relies on countries that reported data, on a voluntary basis, to the Eurostat/OECD joint questionnaire on inland waters. In this new update of the data, data for three additional countries was available for manufacturing sectors (Italy, Finland and Sweden) and for two additional countries for mining and quarrying (Italy and Sweden). Among the set of countries for which data were available, we filter out further the list of countries (see 'JRC data processing below').

Data update frequency: Annual. Data refers to the last update in the Eurostat database available on 29 November 2019.

Data source URL: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wat_cat&lang=en (env_wat_cat), http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wat_ind&lang=en (env_wat_ind)

Data source metadata URL: https://ec.europa.eu/eurostat/cache/metadata/en/env_nwat_esms.htm

JRC data processing: Countries are displayed for which at least two time series data points were available and for which water use volume was at least 5 million m3.

24. Extractive waste

Table 24.1:

Data on extractive wastes are taken from the Eurostat dataset 'generation of waste by economic activity' (data code ten00106)) . The data used refer to NACE Rev.2 Section B ´mining and quarrying´ and come from Member States' reporting to Eurostat, which was reinforced by the Extractive Waste Directive in 2009.

Eurostat categories are based on legislation on the NACE classifica-tion, waste statistics and the European list of waste (LoW) . They correspond partially to the categories used in the Extractive Waste Directive; for example, certain wastes covered by NACE Rev.2 Section B, e.g. maintenance waste, are not regarded as extractive waste for the purposes of the Extractive Waste Directive. Conversely, certain wastes (e.g. removed inert overburden rocks) were not reported to Eurostat before the implementation of the Directive.

Domestic mineral extraction volumes are taken from the Eurostat dataset 'material flows and resource productivity': Material flow accounts (´env_ac_mfa´) . The data used refer to the EW-MFA indicator ´domestic extraction´, which is the total amount of material extracted from the natural environment for further processing in the economy. Data from the following material categories were selected:

- o MF2 metal ores (gross ores); and
- o MF3 non-metallic minerals,

in order to make distinction between the two categories, since metallic ore usually show significantly higher waste-to-ore ratios than non-metallic minerals.

26. Occupational safety

Figure 26.1

Description: Incidence rate of accidents at work in selected economic sectors, for EU 27 (after 2020). Non-fatal accidents are accidents without fatal consequences, but which result in more than 3 days' absence from work.

Material/sector coverage:

- o Raw materials sectors: Mining and quarrying; Forestry and logging; Raw materials manufacturing; Mining support.
- o Others (for comparison): Fishing; Agriculture; Chemicals; Food products; Construction; Retail trade; Transportation; Sports, activities and recreation.

Data source/reference: ESTAT Non-fatal accidents at work by NACE Rev. 2 activity and sex ´hsw_n2_01´

Data update frequency: Annual

Data source URL: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=hsw_n2_03&lang=en

Data source metadata URL: https://ec.europa.eu/eurostat/cache/metadata/en/hsw_acc_work_esms.htm

JRC data processing: Filtering and selection of relevant sectors. The figure covers the following sectors (NACE Rev.2 codes in brackets):

- Primary sector: Agriculture (A01), forestry and logging (A02), fishing (A03) and mining and quarrying (B07 and B08). The incidence rate for mining and quarrying was obtained as the weighted average of mining of metal ores (B07) and other mining and quarrying (B08). Weights reflect the number of employees in each activity.
- Secondary sector: Manufacture of chemicals (C20), manufacture of food products (C10), construction (F), raw materials manufacture (C16 and C23 C25). The incidence rate for (the manufacture of) raw materials was obtained as the weighted average of the manufacture of basic metals (NACE C24), fabricated metals (C25), other non-metallic mineral products (C23) and wood and wood products (C16). Weights reflect the number of employees in each activity.
- Tertiary sector: Retail trade (G47), transportation and storage (H), sport activities and recreation (R93) and mining support service activities (B09).

Figure 26.2

Description of the data: Incidence rate of accidents at work in selected raw materials sectors, in EU-27 (after 2020) - trends over time.

Material/sector coverage: Mining and quarrying, Forestry and logging, Manufacture of wood, Manufacture of basic metals, Manufacture of other non-metallic minerals and Manufacture of paper and paper products.

Data source/reference: ESTAT Non-fatal accidents at work by NACE Rev. 2 activity and sex ´hsw_n2_01´

Data update frequency: Annual

Data source URL: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=hsw_n2_01&lang=en

Data source metadata URL: https://ec.europa.eu/eurostat/cache/metadata/en/hsw_acc_work_esms.htm

JRC data processing: Filtering and selection of relevant sectors and years.

27. Jobs

Figure 27.1

Description:

- Graph a): Share of jobs in the raw materials sectors over the total jobs in industry has been calculated as percentage of employees in non-energy raw materials sectors over employees in the whole industrial sector.
- Graph b): Distribution of jobs along the value chain has been calculated by adding up the number of employees in the sector under investigation.

´Employees´ includes people having a contract of employment or an economic remuneration: wage, salary or fee.

Material/sector coverage:

- Graph a):

  NACE codes of raw materials sectors: B07 Mining of metal ores; B081 Quarrying of stone, sand and clay; B089 Mining and quarrying n.e.c. (B0892 Extraction of peat has been removed from B089); B099 Support activities for other mining and quarrying; C161 Sawmilling and planing of wood; C171 Manufacture of pulp, paper and paperboard; C221 Manufacture of rubber products; C231 Manufacture of glass and glass products; C232 Manufacture of refractory products; C233 Manufacture of clay building materials; C234 Manufacture of other porcelain and ceramic products; C235 Manufacture of cement, lime and plaster; C236 Manufacture of articles of concrete, cement and plaster; C237 Cutting, shaping and finishing of stone; C239 Manufacture of abrasive products and non-metallic mineral products n.e.c.; C241 Manufacture of basic iron and steel and of ferro-alloys; C242 Manufacture of tubes, pipes, hollow profiles and related fittings, of steel; C243 Manufacture of other products of first processing of steel; C244 Manufacture of basic precious and other non-ferrous metals C245 Casting of metals (C2446 Processing of nuclear fuel has been removed from C244).

  NACE codes for total industry: B Mining and quarrying; C Manufacturing; D Electricity, gas, steam and air conditioning supply; E Water supply; sewerage, waste management and remediation activities

- Graph b)

  NACE codes:

  Extractive sector and forestry: A02 Forestry; B07 Mining of metal ores; B081 Quarrying of stone, sand and clay; B089 Mining and quarrying n.e.c. (B0892 Extraction of peat has been removed from B089); B099 Support activities for other mining and quarrying.

  Processing: C161 Sawmilling and planing of wood; C171 Manufacture of pulp, paper and paperboard; C221 Manufacture of rubber products; C231 Manufacture of glass and glass products; C232 Manufacture of refractory products; C233 Manufacture of clay building materials; C234 Manufacture of other porcelain and ceramic products; C235 Manufacture of cement, lime and plaster; C236 Manufacture of articles of concrete, cement and plaster; C237 Cutting, shaping and finishing of stone; C239 Manufacture of abrasive products and non-metallic mineral products n.e.c.; C241 Manufacture of basic iron and steel and of ferro-alloys; C242 Manufacture of tubes, pipes, hollow profiles and related fittings, of steel; C243 Manufacture of other products of first processing of steel; C244 Manufacture of basic precious and other non-ferrous metals C245 Casting of metals (C2446 Processing of nuclear fuel has been removed from C244).

  Downstream manufacturing: C162 Manufacture of products of wood, cork, straw and plaiting materials; C172 Manufacture of articles of paper and paperboard; C25 Manufacture of fabricated metal products, except machinery and equipment; C26 Manufacture of computer, electronic and optical products; C27 Manufacture of electrical equipment; C28 Manufacture of machinery and equipment n.e.c.; C29 Manufacture of motor vehicles, trailers and semi-trailers; C30 Manufacture of other transport equipment; C31 Manufacture of furniture; C32 Other manufacturing; F Construction; C332 Installation of industrial machinery and equipment.

Data source/reference: 'Annual detailed enterprise statistics for industry' (NACE Rev. 2). Data for the mining and manufacturing industry comes from the B-E NACE sections (code sbs_na_ind_r2); data for construction, from the F NACE section (code sbs_na_con_r2). Data on forestry come from Eurostat's statistics on employment in forestry and forest-based industry (code for_emp_lfs).

Data update frequency: Annual

Data source URL: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_ind_r2&lang=en

Data source metadata URL: https://ec.europa.eu/eurostat/cache/metadata/en/sbs_esms.htm

JRC data processing: Filtering and selection of relevant sectors. Calculation of shares between employees in the raw materials sectors and total employees in industry. Filling of data gaps (missing data were assumed to be the same as the closest available year or interpolated between available data points).

Figure 27.2

Description: Number of employees in the non-energy raw materials sectors. ´Employees´ includes people having a contract of employment or an economic remuneration: wage, salary or fee.

Material/sector coverage:

- o Mining and quarrying: B07 — Mining of metal ores; B081 — Quarrying of stone, sand and clay; and B089 — Mining and quarrying not elsewhere classified (n.e.c.); B099 — Support activities for other mining and quarrying. Extraction of peat (B0892) has been removed from sector B089.
- o Manufacturing of non-metallic minerals: C231 — Manufacture of glass and glass products; C232 — Manufacture of refractory products; C233 — Manufacture of clay building materials; C234 — Manufacture of other porcelain and ceramic products; C235 — Manufacture of cement, lime and plaster; C236 — Manufacture of articles of concrete, cement and plaster; C237 — Cutting, shaping and finishing of stone; C239 — Manufacture of abrasive products and non-metallic mineral products n.e.c.
- o Manufacturing of basic metals: C241 — Manufacture of basic iron and steel and of ferro-alloys; C242 — Manufacture of tubes, pipes, hollow profiles and related fittings of steel; C243 — Manufacture of other products of first processing of steel; C244 — Manufacture of basic precious and other non-ferrous metals; C245 — Casting of metals. The processing of nuclear fuel (B2446) has been removed from sector B244.
- o Sawmilling and planing of wood (C161)
- o Manufacture of pulp, paper and paperboard (C171)
- o Manufacture of rubber products (C221)
- o Materials recovery (E383)

Data source/reference: Eurostat's 'Annual detailed enterprise statistics for industry' (NACE Rev. 2)

Data update frequency: Annual

Data source URL: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_ind_r2&lang=en

Data source metadata URL: https://ec.europa.eu/eurostat/cache/metadata/en/sbs_esms.htm

JRC data processing: Filtering and selection of relevant sectors.

Figure 27.3

Description:

- o Graph a): Percentage of people employed in circular economy activities as a percentage of total employment in the EU, in the period 2011-2017.
- o Graph b): Percentage of people employed in circular economy activities as a percentage of total employment in Member States, average of years 2015, 2016 and 2017.

Material/sector coverage: The list of NACE Rev. 2 codes used for calculation of ´person employed in the activities related to circular economy´ includes:

- o Proxy NACE Rev. 2 codes for recycling: E 38.11 Collection of non-hazardous waste; E 38.12 Collection of hazardous waste; E 38.31 Dismantling of wrecks; E 38.32 Recovery of sorted materials; G 46.77 Wholesale of waste and scrap; G 47.79 Retail sale of second-hand goods in stores;
- o Proxy NACE Rev. 2 codes for repair and re-use: C 33.11 Repair of fabricated metal products; C 33.12 Repair of machinery; C 33.13 Repair of electronic and optical equipment; C 33.14 Repair of electrical equipment; C 33.15 Repair and maintenance of ships and boats; C 33.16 Repair and maintenance of aircraft and spacecraft; C 33.17 Repair and maintenance of other transport equipment; C 33.19 Repair of other equipment; G 45.20 Maintenance and repair of motor vehicles; G 45.40 Sale, maintenance and repair of motorcycles and related parts and accessories; S 95.11 Repair of computers and peripheral equipment; S 95.12 Repair of communication equipment; S 95.21 Repair of consumer electronics; S 95.22 Repair of household appliances and home and garden equipment; S 95.23 Repair of footwear and leather goods; S 95.24 Repair of furniture and home furnishings; S 95.25 Repair of watches, clocks and jewellery; S 95.29 Repair of other personal and household goods.

Data source/reference: Statistical Office of the European Union (Eurostat). Structural business statistics (SBS). Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) (sbs_na_ind_r2), Annual detailed enterprise statistics for trade (NACE Rev. 2 G) (sbs_na_dt_r2), Annual detailed enterprise statistics for services (NACE Rev. 2 H-N and S95) (sbs_na_1a_se_r2), National accounts: GDP and main components (output, expenditure and income) (´nama10_gdp´).

Data update frequency: Annual

Data source URL: https://ec.europa.eu/eurostat/tgm/table.do?tab=table&tableSelection=6&labeling=labels&footnotes=yes&layout=time,geo,cat&language=en&pcode=cei_cie010&plugin=1

JRC data processing: For Figure b) calculation of average percentages between the years 2015, 2016 and 2017.

Figure 27.4

Description: Number of jobs and percentage of jobs increase and decrease, under the circular economy scenario.

Material/sector coverage: All economic sectors were considered. Those with the highest increase/decrease are shown.

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Introduction

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105 As at 20 November 2019.

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107 Kotkina, I., Petrov, L., Woule Ebongue, W., (2019), *Social acceptance in the European raw materials sector*, European Commission, 29 p.; https://ec.europa.eu/easme/en/workshop-social-acceptance-european-raw-materials-sector

108 https://www.tillvaxtanalys.se/download/18.6f15c8d16854162f48d7bef/1549527461996/Sustainable%20materials%20choice%20experiment%20in%20six%20countries.pdf

109 Brown, T. et al. (2018), *SCRREEN D3.3. Challenges of locating, mining and extracting CRM resources*.

110 Brown, T. et al. (2018).

111 S&P Global (2017), *Lithium – Exploration budgets more than double for 2nd year* https://www.spglobal.com/marketintelligence/en/news-insights/trending/v7sqsh9oqhxnxukmliko9q2

112 USGS - U.S. Geological Survey (2018), *Mineral Commodity Summaries, January 2018*, https://s3-us-west-2.amazonaws.com/prd-wret/assets/palladium/production/mineral-pubs/lithium/mcs-2018-lithi.pdf

113 Hinde, C. and Farooki M. (2018), *Strategic Dialogue on Sustainable Raw Materials for Europe (STRADE) – Promoting Investor Interest in the EU Mining Sector*. http://www.stradeproject.eu/fileadmin/user_upload/pdf/STRADE_Report_02_2018_Promoting_Mining_in_the_EU.pdf

114 Hinde, C. and Farooki M. (2018).

115 Source: JRC elaboration, based on data from S&P Global Market Intelligence (2019).

116 Source: European Commission and Member States

117 S&P Global (2019). 'PDAC Special Edition: World Exploration Trends 2018 - March 2019'. https://www.spglobal.com/marketintelligence/en/documents/world-exploration-trends-march-2019.pdf

118 Junior company includes pure explorers and many aspiring producers with revenues below the $50 million intermediate-company threshold. The exploration activity is mainly funded through equity financing (S&P Global Market Intelligence, 2019).

119 Hinde, C. and Farooki M. (2018).

120 New EXploration Technologies - https://ec.europa.eu/growth/content/new-exploration-technologies_en

121 Sustainable supply of raw MAteRails by uTilizing new EXPLORATION technologies -https://ec.europa.eu/growth/content/sustainable-supply-raw-materails-utilizing-new-exploration-technologies_en

122 JRC, based on exploration budget data provided by S&P Global Market Intelligence exploration budget survey. The exploration budget allocation only covers a selection of metals (gold, copper, nickel, zinc, and platinum group metals) due to data availability.

123 See introduction.

124 European Investment Bank Newsroom, 19 May 2020, 'EIB reaffirms commitment to a European battery industry to boost green recovery' - https://www.eib.org/en/press/all/2020-121-eib-reaffirms-commitment-to-a-european-battery-industry-to-boost-green-recovery

125 COM(2020) 474 final.

126 www.erma.eu

127 Source: JRC, based on data from the S&P Global Market Intelligence (2019) and publicly available data from geological surveys and other sources for the following countries: Bulgaria, Spain, Poland, Sweden and Finland (see the methodological notes).

128 E.g. small stem wood, sawdust, trimmings, bark, tree tops and branches (EC, 2018a) Guidance on cascading use of biomass with selected good practice examples on woody biomass. Publications Office of the European Union, Luxembourg, ISBN 978-92-79-93153-6 doi:10.2873/911487 ET-01-18-916-EN-C.

129 European Commission (2018), *Guidance on cascading use of biomass with selected good practice examples on woody biomass*, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-93153-6 doi:10.2873/911487 ET-01-18-916-EN-C.

130 FAOSTAT, data for industrial roundwood, (total) production quantity.

131 EUR 23 billion from forestry, EUR 31 billion from wood manufacturing industries and EUR 44 billion from the paper industries (data for 2017), see *Jobs and wealth in the EU bioeconomy*, https://datam.jrc.ec.europa.eu/datam/mashup/BIOECONOMICS/index.html (last update 5.7.2018).

132 Data for 2015, some sources remained unaccounted (JRC, 2019a, Wood Resource Balances of EU-28 and Member States year 2015, https://ec.europa.eu/knowledge4policy/sites/know4pol/files/wrb_2015_w_cover.pdf.)

133 JRC, Camia A. et al. (2018), *Biomass production, supply, uses and flows in the European Union. First results from an integrated assessment*, EUR 28993 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-77237-5, doi:10.2760/539520, JRC109869.

134 By energy industries, internal use at industrial facilities and the households. Taken from (JRC (2019), ´Wood Resource Balances of EU-28 and Member States year 2015´, https://ec.europa.eu/knowledge4policy/sites/know4pol/files/wrb_2015_w_cover.pdf)

135 JRC (2018) and JRC (2019), ´Wood Resource Balances of EU-28 years 2009 – 2015´, https://ec.europa.eu/jrc/en/publication/wood-resource-balances-eu-28-and-member-states).

136 JRC (2019).

137 European Commission (2018), *Guidance on cascading use of biomass with selected good practice examples on woody biomass*, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-93153-6 doi:10.2873/911487 ET-01-18-916-EN-C.

138 Different forest management strategies may foster certain forest functions and/products for instance, while younger forests can generally capture more carbon and produce more wood, more mature forests may have higher biodiversity values.

139 UN Sustainable Development Goals, target 15.2 ´By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally´.

140 European Commission (2018), *A sustainable bio-economy for Europe: strengthening the connection between economy, society and the environment, Updated Bioeconomy Strategy*, ISBN: ISBN 978-92-79-94145-0.

141 COM(2018) 773 final.

142 Brand name of the Ministerial Conference on the Protection of Forests in Europe. It is the forum for dialogue and cooperation on forest policies in Europe, responsible for monitoring and reporting on SFM. It currently collects the pan-European indicators for SFM, covering data on forest grow, age, carbon stock, land use, ecosystems health, wood production, use and value, etc.

143 EU forests currently offset about 9% of total EU greenhouse gas emissions. Increasing felling, even if still maintained below the annual net increment, can imply a reduction of this carbon sink.

144 See methodological notes for further details.

145 EEA Scoreboard: outlook for the EU´s natural environment, https://www.eea.europa.eu/publications/eea-snapshot

146 Forest Europe (2020), *State of Europe's forests 2020*.

147 Source: JRC, based on data from Forest Europe (2020).

148 European Commission (2018), *Guidance on cascading use of biomass with selected good practice examples on woody biomass*.

149 For instance, the guidance document refers to cases in which advances in technology and research can reduce the number of low-value products, for example through more precise cutting methods or better assessment of the quality of wood before it is harvested. It also shows new ways of using low-value woody biomass streams.

150 EU circular economy monitoring framework, https://ec.europa.eu/eurostat/web/circular-economy/indicators/monitoring-framework.

151 Brown, T. et al. (2018), *SCRREEN D3.3. Challenges of locating, mining and extracting CRM resources*.

152 Domestic material consumption measures the total quantity of materials directly used within an economic system. It equals the sum of domestic extraction and imports minus exports.

153 See methodological notes.

154 Wood fuel is defined as all types of fuels originating directly or indirectly from woody biomass. FAO report Sustainable woodfuel for food security - A smart choice: green, renewable and affordable, http://www.fao.org/3/a-i7917e.pdf

155 Source: JRC elaboration based on the UNEP Global Material Flows Database, https://www.resourcepanel.org/global-material-flows-database.

156 See details in the methodological notes.

157 Source: JRC elaboration based on British Geological Survey.

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158 The difference seen between 2003 and 2004, for the EU and other European regions, is explained in the methodological notes.

159 Source: JRC elaboration, using data from World Mining Data, WMD (2019) and from the UN Food and Agriculture Organization database, FAOSTAT (2019).

160 European Commission, *Study on the EU's list of Critical Raw Materials (2020)*.

161 Source: JRC elaboration, based on data from European Commission, *Study on the EU's list of Critical Raw Materials (2020)* and for industrial roundwood production data from FAOSTAT.

162 Self-sufficiency is defined as 1-(net) import reliance.

163 COM(2018)29 final, *Monitoring Framework for the Circular Economy*, https://ec.europa.eu/environment/circular-economy/pdf/monitoring-framework.pdf.

164 Source: JRC, based on data from Eurostat's material flow accounts, from 20 February 2020, code ´env_ac_mfa´, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_mfa&lang=en.

165 This is the same materials selection used in indicator 10 (export restrictions).

166 For tungsten, import reliance could be assessed only at the mining stage. For platinum, only the metallurgical (processing) stage was assessed.

167 China, the major global supplier of tungsten, applies two types of export restrictions: a tax on exports and a licensing requirement.

168 The 2018 edition of the Scoreboard is based on European Commission *Study on the review of the list of Critical Raw Materials* (2017).

169 The methodological adjustment was determined by several factors, among which data updates accommodating the confidential information on trade flows (COMEXT) and inputs from interactions with stakeholders. A major change was the expansion of the product coverage to include intermediates (cobalt and nickel mattes) beyond ores and concentrates. The intermediates represent about 83% of EU consumption at this stage of the value chain.

170 Source: JRC, based on data from the European Commission, *Study on the review of the list of Critical Raw Materials* (2017), except for the import reliance of copper, which has been updated.

171 In the EU, cobalt is mainly used as a superalloy to make parts for gas turbine engines.

172 The 2017 criticality study (European Commission *Study on the review of the list of Critical Raw Materials* (2017)) considered an average copper content of 0.1% for ores, while in the 2020 assessment, a metal content of 20% for concentrates was used (European Commission, *Study on the EU's list of Critical Raw Materials* (2020)).

173 REE are a group of 17 elements, comprising the elements scandium (Sc), yttrium (Y) and the 15 lanthanides.

174 European Commission, *Study on the EU's list of Critical Raw Materials* (2020).

175 Adamas Intelligence, *Rare Earth Elements: Market Issues and Outlook*, 2019.

176 For instance, Australia, the world's second producer of REE, might become an important REE supplier.

177 In 2015, China eliminated its export tax and export quota but still applies export licensing on REE.

178 COM(2020) 474 final.

179 https://eitrawmaterials.eu/booster-call-for-start-ups-scale-ups-and-smes-in-response-to-the-covid-19-crisis/.

180 The World Bank (2020), ´What is meant by governance?´, Worldwide Governance Indicators FAQ, https://info.worldbank.org/governance/wgi/Home/FAQ.

181 Referred to as 'EU sourcing' in European Commission *Methodology for establishing the EU list of critical raw materials* (2017), https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en.

182 European Commission *Methodology for establishing the EU list of critical raw materials* (2017).

183 Selection of materials relevant to the EU economy, a relevant share of them identified as critical.

184 The World Bank (2020), *The Worldwide Governance Indicators*, https://info.worldbank.org/governance/wgi/. Note that WGI do not take into account factors such as the level of government intervention in domestic policies, which can be relevant for the raw materials sector.

185 See methodological notes.

186 The 2020 study on critical raw materials faced data availability challenges regarding global supply and EU sourcing of some raw materials at the considered stage (see methodological notes for more details).

187 Source: JRC elaboration, based on European Commission, *Study on the EU's list of Critical Raw Materials (2020)*. See methodological notes for the country codes.

188 Regulation (EU) 2017/821 of the European Parliament and of the Council of 17 May 2017 laying down supply chain due diligence obligations for Union importers of tin, tantalum and tungsten, their ores, and gold originating from conflict-affected and high-risk, http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1525350998792&uri=CELEX:32017R0821.

189 Press release 'Commission announces actions to make Europe's raw materials supply more secure and sustainable' – https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1542.

190 Sustainable supply of raw materials from EU sources – https://ec.europa.eu/growth/sectors/raw-materials/policy-strategy/sustainable-supply-eu_en.

191 COM/2015/0614 final *Closing the loop – An EU action plan for the Circular Economy*; and COM (2020) 98 final, *A new Circular Economy Action Plan – For a cleaner and more competitive Europe*.

192 B. Fliess, C. Arriola and P. Liapis, 'Recent developments in the use of export restrictions in raw materials trade', in OECD, *Export Restrictions in Raw Materials Trade: Facts, fallacies and better practices*, 2014.

193 OECD, *Global Material Resources Outlook to 2060 - Economic drivers and environmental consequences*, OECD Publishing, 2018, Paris, https://www.oecd.org/environment/waste/highlights-global-material-resources-outlook-to-2060.pdf.

194 Source: Reuters, 'U.S. dependence on China's rare earth: Trade war vulnerability', 28 June 2019, https://www.reuters.com/article/us-usa-trade-china-rareearth-explainer-idUSKCN1TS3AQ, and E. Gholz (2019), 'The rare earths industry can weather any Chinese trade battle', CNN Business, 23 July 2019, https://edition.cnn.com/2019/07/23/perspectives/rare-earths-china-argentina-trade-war/index.html.

195 For the importance of China's supply of rare earths to US industry, see Y. Li, 'Here's why China's trade war threat to restrict rare earth minerals is so serious', CBNC, 30 May 2019, https://www.cnbc.com/2019/05/30/heres-why-chinas-trade-war-threat-to-restrict-rare-earth-minerals-is-so-serious.html.

196 Harmonized System for classifying goods.

197 JRC, based on data on export restrictions provided by OECD, *Inventory on Restrictions on Exports of Raw Materials*, updated in 2021.

198 JRC, based on data on export restrictions provided by OECD, Inventory on Restrictions on Exports of Raw Materials (updated in 2021) and data on global production data from C. Reichl and M. Schatz (2020). See methodological notes.

199 For example, the production of secondary aluminium can save up to 95% of the carbon emissions of primary aluminium (European Aluminium Association, 2018. Environmental Profile Report https://www.european-aluminium.eu/media/2052/european-aluminium-environmental-profile-report-2018-executive-summary.pdf (accessed on 27/2/2020).

200 SWD(2018) 17 final, *Measuring progress towards circular economy in the European Union – Key indicators for a monitoring framework*.

201 Such as Regulation (EC) 1013/2006 on shipments of waste and Regulation (EC) 1418/2007 concerning the export for recovery of certain waste.

202 World Trade Organization (2017), Notification 20 July 2017 https://docs.wto.org/dol2fe/Pages/FE_Search/FE_S_S009-DP.aspx?language=E&CatalogueIdList=237688 (accessed on 27/2/2020).

203 European Environment Agency (2012), *Movements of waste across the EU's internal and external borders*, Report No 7/2012, 2012.

204 World Customs Organization (2019), 'Illegal waste trafficking: more data is key to getting a better grip on this trade', WCO News n. 88. February 2019. https://mag.wcoomd.org/uploads/2019/02/WCONews88_UK.pdf (accessed in February 2020).

205 Source: Nickel Institute (2018), ´Nickel Magazine´, Nickel, Vol. 33, n. 1, 2018. https://www.nickelinstitute.org/about-nickel/nickel-in-batteries/ (accessed on 27/2/2020).

206 European Environment Agency (2012), *Movements of waste across the EU's internal and external borders*, Report No 7/2012, 2012.

207 Source: JRC, based on Eurostat data (Comext).

208 Source: JRC, based on Eurostat data (Comext).

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209 COM(2015) 614 final, *Closing the loop — An EU action plan for the Circular Economy*.

210 COM (2020) 98 final, *A new Circular Economy Action Plan For a cleaner and more competitive Europe*.

211 Mayer A., Haas W., Wiedenhofer D., Krausmann F., Nuss P., Blengini G.A. (2018), 'Measuring progress towards a Circular Economy - a monitoring framework for economy-wide material loop closing in the EU28´, *Journal of Industrial Ecology*, Volume 23(1), doi: 10.1111/jiec.12809.

212 COM(2018)29 final, Monitoring framework for the circular economy.

213 As part of its circular economy monitoring framework, the Commission provides time series for the EU, Member States and material groups in the Eurostat material flow diagram, https://ec.europa.eu/eurostat/cache/sankey/circular_economy/sankey.html.

214 ´In-use stocks´ are defined by the ProSUM project as ´the products which are in use or stored in households, businesses, and organisations before being thrown away´. Source: ProSUM H2020 Project final report (2017), http://prosumproject.eu/sites/default/files/DIGITAL_Final_Report.pdf.

215 Differences between these figures and other materials flows on biomass prepared by the JRC (see for instance https://ec.europa.eu/knowledge4policy/bioeconomy/topic/biomass_en#biomassflows; https://ec.europa.eu/jrc/en/publication/biomass-flows-european-union-sankey-biomass-diagram-towards-cross-set-integration-biomass) are due to the different considerations and assumptions used. In particular, they stem from the fact that Eurostat's economy-wide material flow accounts (EW-MFA) include moisture content of biomass (see sections 2.5 and 4.2.3 in the EW-MFA Handbook).

216 Source: JRC analysis based on data provided by EUROSTAT on the circular economy material flows.

217 Source: JRC analysis based on data provided by EUROSTAT on circular economy material flows.

218 Material flow analysis (MFA) is a well-known systematic assessment of the flows and stocks of materials within a system in space and time. It connects the sources, the pathways, and the intermediate and final sinks of a material. An MSA is an MFA applied to material systems within the geographical scope of the European Union and considering the best available data available in the EU.

219 European Commission (2017), *Study on the review of the list of critical raw materials. Critical Raw Material Factsheets*, European Commission. https://doi.org/10.2873/398823.

220 Strategic action plan on batteries. Annex 2 to the Communication from the Commission to the European Parliament, The Council, the European Economic and Social Committee and the Committee of the Regions: Europe On The Move - Sustainable mobility for Europe: safe, connected and clean (COM(2018) 293 final).

221 Source: Matos C.T, Ciacci, L; Godoy León, M.F.; Lundhaug, M.; Dewulf, J.; Müller, D.B.; Georgitzikis, K.; Wittmer, D.; Mathieux, F., *Material System Analysis of five battery-related raw materials: Cobalt, Lithium, Manganese, Natural Graphite, Nickel*, EUR 30103 EN, Publication Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16411-1, doi:10.2760/519827, JRC119950.

222 Source: Matos, et al. (2020).

223 Source: Matos, et al. (2020) and Cobalt Institute (2019), *Socio-economic analysis of the cobalt industry in the EEA*, Summary Report by Roskill, https://www.cobaltinstitute.org/assets/files/Pages%20PDFs/Socio_Econ_Infog.pdf.

224 Stocks of products at end of life still kept by the users.

225 Eurostat-estimated data for the EU data in 2017, as available on 'Waste electrical and electronic equipment (WEEE) by waste operations´ (´env_waselee´) (accessed in May 2020).

226 Directive 2012/19/EU on waste electrical and electronic equipment (WEEE) (recast).

227 Huisman et al. (2015), *Countering WEEE illegal trade (CWIT)*, http://www.cwitproject.eu/ (accessed in February 2020).

228 Directive 2012/19/EU.

229 Estimation for the EU based on the Urban Mine Platform, http://www.urbanmineplatform.eu/urbanmine/eee/weightpercountry (accessed in February 2020).

230 SWD(2018) 36 final.

231 Zhang and Xu (2016), *A review of current progress of recycling technologies for metals from waste electrical and electronic equipment*, J. Clean. Prod. (17), 19-36.

232 Andersson et al. (2019), ´Challenges of recycling multiple scarce metals: The case of Swedish ELV and WEEE recycling´, *Resources Policy* (63), 101403.

233 Mathieux et al. (2017), ´Critical raw materials and the circular economy. Background report´, *JRC Science-for-Policy Report*, December 2017, EUR 28832 EN.

234 CEWASTE Horizon 2020 project (2020),´Deliverable WP2´, https://cewaste.eu/wp-content/uploads/2019/12/CEWASTE-normative-requirements-for-public-consultation.pdf) (Access February 2020.

235 Ardente and Mathieux (2014), ´*Identification and assessment of product's measures to improve resource efficiency: the case-study of an Energy using Product*´, *Journal of Cleaner Production* (83), 126-141.

236 Ardente et al. (2019), ´Resource efficient recovery of critical and precious metals from waste silicon PV panel recycling´, *Waste Management*, 156-167.

237 Huismans et al. (2017), *Prospecting Secondary raw materials in the Urban mine and Mining waste (ProSUM) - Final report*, Project results available at: http://www.prosumproject.eu/ (accessed 22 June 2020).

238 According to Directive 2008/98/EC on waste, 'preparing for re-use' means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used. This differs from the definition of 're-use', which implies any operation by which products or components that are not waste are used again for the same purpose for which they were conceived. Moreover 'recycling' is defined as any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes.

239 This Directive established that ´from 2016, the minimum collection rate shall be 45% calculated on the basis of the total weight of WEEE collected (...) in a given year in the Member State concerned, expressed as a percentage of the average weight of EEE placed on the market in the three preceding years in that Member State´. This percentage was further raised to 65% from 2019.

240 Eurostat-estimated data for the EU in 2017 (accessed in February 2020).

241 Ibid.

242 Estimated amount of WEEE generated per country are available in the Urban Mine Platform of the EU project 'PROSum', http://www.urbanmineplatform.eu/ (accessed in February 2020). It considers WEEE put on the market and the average life-time of products.

243 Eurostat-estimated data for the EU in 2015 (accessed in May 2020).

244 Huisman et al. (2015), *Countering WEEE Illegal Trade (CWIT)* — http://www.cwitproject.eu/ (accessed in February 2020).

245 Eurostat-estimated data for the EU in 2017 (accessed in May 2020).

246 Eurostat-estimated data for the EU in 2015 (accessed in May 2020).

247 Based on available ´env_waselee´ statistics (accessed in May 2020).

248 Source: JRC, based on Eurostat data (information updated in May 2020, data from Cyprus, Italy and, Romania not available).

249 Eurostat-estimated data for the EU in 2017 and 2015 (accessed in February 2020).

250 See methodological notes for details.

251 Dewulf et al. (2019), ´Diversified recycling strategies for high-end plastics: Technical feasibility and impact assessment´, *CIRP Annals-Manufacturing Technology*, Vol 68, pp. 29 – 32. 2019.

252 Source: JRC, based on Eurostat data 'Waste electrical and electronic equipment (WEEE) by waste operations' (´env_waselee´). Total WEEE prepared for reuse and recycled based on Eurostat estimations for 2015 and 2017 (accessed in February May 2020). Shares of WEEE categories did not consider data from Cyprus, Italy, and Romania (data not available in May 2020).

253 Source: JRC, based on Eurostat data. The number of EU countries reporting reuse and recycling data was 24 (since data from Cyprus, Italy and Romania were not available in May 2020).

254 Mathieux et al. (2017), ´Critical Raw Materials and the Circular Economy. Background report´, *JRC Science-for-Policy Report*, December 2017, EUR 28832 EN.

255 The WEEE generated approach considers the lifespan of electric and electronic equipment and includes waste collected by the official compliance schemes, as well as those captured by complementary flows. From 2019, the collection rate according to the WEEE Directive (2012/19/EU) can be calculated based on volumes of EEE placed on the market or WEEE generated.

256 http://www.urbanmineplatform.eu/composition/eee/elements (accessed on 11 February 2020).

257 https://rmis.jrc.ec.europa.eu/?page=contributions-of-h2020-projects-236032 (accessed on 11 February 2020).

258 Nelen et al. (2014), *A multidimensional indicator set to assess the benefits of WEEE material recycling*. J. Clean. Prod. 83, 305–316.

259 Van Eygen et al. (2016), ´Resource savings by urban mining: The case of desktop and laptop computers in Belgium´. *Resour. Conserv. Recycl.* 107, 53–64.

260 Horta Arduin, R., Mathieux, F., Huisman, J., Andrea, G., Charbuillet, C., Wagner, M., Baldé, C.P., Perry, N. (2020), 'Novel indicators to better monitor the collection and recovery of (critical) raw materials in WEEE : Focus on screens' *Resour. Conserv. Recycl.* 157. https://doi.org/10.1016/j.resconrec.2020.104772.

261 Critical raw materials: antimony (Sb), cobalt (Co), indium (In), lithium (Li), magnesium (Mg), neodymium (Nd) and palladium (Pd); Non-critical raw materials: aluminium (Al), copper (Cu), gold (Au) and silver (Ag).

262 Cucchiella et al. (2015), ´Recycling of WEEEs: An economic assessment of present and future e-waste streams´, *Renew. Sustain. Energy Rev*, 51, 263–272.

263 Deloitte (2017), ´Rapport annuel du registre des déchets d'équipements électriques et électroniques 2017´. 132 p. (in French).

264 ´Complementary flows´ refer to all e-waste flows that are not reported at a national level by the official compliance systems. They include flows of WEEE that are collected by non-compliant operators, or that are illegally exported, incinerated or landfilled (adapted from (Huisman et al., 2017)).

265 Source: Horta Arduin, R., Mathieux, F., Huisman, J., Blengini,G.A., Charbuillet,C., Wagner, M., Balde, C. P., Perry,N. (2020).

266 https://cewaste.eu/ (accessed on 28/04/2021).

267 Referring to 'waste from NACE F' (hazardous and non-hazardous), EU 27, 2016.

268 Data from ESTAT Waste generation and treatment (´env_wasgt´), https://ec.europa.eu/eurostat/web/waste/data/database

269 Directive (EU) 2018/851.

270 The recovery rate to be used in verification of compliance is calculated based on the rules given in Annex III of Decision 2011/753/EU (EC 2011).

271 European Environmental Agency (EEA) (2020), ´Construction and Demolition Waste: challenges and opportunities in a circular economy´, *Eionet Report* - ETC/WMGE 2020/1.

272 Chakkrit Luangcharoenrat et al. (2019), ´Factors Influencing Construction Waste Generation in Building Construction: Thailand's Perspective,´ *Sustainability, MDPI, Open Access Journal*, vol. 11(13), pages 1-17.

273 Studies in the literature considered different waste categories, being not fully consistent with the categories of waste considered in statistics.

274 Bergsdal,H., Bohne,R.A., Brattebø,H. (2008), ´Projection of Construction and Demolition Waste in Norway´, *Journal of Industrial Ecology*, Vol. 11(3) https://onlinelibrary.wiley.com/doi/abs/10.1162/jiec.2007.1149.

275 Llatas,C. (2011), ´*A model for quantifying construction waste in projects according to the European waste list*´, *Waste Management*, Vol. 31(6), Pages 1261-1276 https://www.sciencedirect.com/science/article/pii/S0956053X11000559?via%3Dihub.

276 SWD(2018)17 final.

277 Deloitte (2017), ´Study on Resource Efficient Use of Mixed Wastes, Improving management of construction and demolition waste – Final report´. Prepared for the European Commission, DG ENV.

278 Eurostat data on the treatment of waste by waste category, hazardousness and waste management operations (´env_wastrt´), EU-27, EWCStat 12.1.

279 European Environmental Agency (EEA) (2020).

280 SWD (2018) 17 final.

281 https://ec.europa.eu/growth/content/eu-construction-and-demolition-waste-protocol-0_en.

282 https://ec.europa.eu/docsroom/documents/29203/attachments/1/translations/en/renditions/native.

283 Source: JRC analysis based on data from https://ec.europa.eu/eurostat/web/waste/data/database.

284 See ´Waste generation and waste treatment´ (´env_wasgt´).

285 https://ec.europa.eu/eurostat/web/circular-economy/indicators/monitoring-framework.

286 SWD(2018) 17 final.

287 Deloitte (2017).

288 Deloitte (2017).

289 Deloitte (2017).

290 https://ec.europa.eu/environment/waste/studies/mixed_waste.htm#workshop.

291 https://ec.europa.eu/environment/waste/studies/pdf/CDW%20infrastructure%20study.pdf

292 European Commission (2008), *The Raw Materials Initiative – meeting our critical needs for growth and jobs in Europe*, COM(2008) 699; European Commission, 2011, *Tracking the challenges in commodity markets and on raw materials*, COM(2011) 25.

293 European Commission (2015), *Closing the loop – An EU Action Plan for the Circular Economy*, COM(2015) 614.

294 European Commission (2020), *Circular Economy Action Plan: For a cleaner and more competitive Europe*, https://ec.europa.eu/environment/circular-economy/

295 European Commission (2012), *Establishing a framework for the setting of eco-design requirements for energy-related products*, Directive 2009/125/EC.

296 COM(2020) 474 final.

297 Schrijvers D., Hool A, Blengini G.A., et al. (2020), 'A review of methods and data to determine raw material criticality', *Resources, Conservation and Recycling*, Volume 155.

298 Mathieux, F. et al., (2017), 'Critical Raw Materials and the Circular Economy – Background report', *JRC Science-for-policy report*, EUR 28832 EN, Publications Office of the European Union, Luxembourg, doi:10.2760/378123.

299 For example, zinc in galvanising and chemical application or copper in brake pads, see: Ciacci,L., Reck,B.K., Nassar,N.T., Graedel, T. E., 'Lost by Design', *Environ. Sci. Technol.*, 2015, 49 (16), pp 9443–9451, doi:10.1021/es505515z.

300 Talens Peiro, L., Nuss, P., Mathieux, F. and Blengini, G. (2018), *Towards Recycling Indicators based on EU flows and Raw Materials System Analysis data*, EUR 29435 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-97247-8 (online), doi:10.2760/092885 (online), JRC112720.

301 Indicator 7, https://ec.europa.eu/eurostat/web/circular-economy/indicators/monitoring-framework.

302 83 individual materials or 66 candidate raw materials comprising 63 individual and 3 grouped materials (ten individual heavy rare earth elements (REEs), five light REEs, and five platinum-group metals (PGMs)).

303 European Commission, Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability COM(2020)474.

304 Material system analyses (MSAs) are material flow analyses (MFAs) applied to material systems within the geographical scope of the EU and considering best available data available in the EU. See methodological notes.

305 Mathieux, F. et al. (2017).

306 Source: JRC analysis based on: *the Commission's material system analysis studies (geographical coverage: EU) and **the 2020 critical raw materials assessment (EOL-RIR) and UNEP/IRP (2011) (EOL-RR) (geographical coverage: EU/Global).

307 Source: European Commission (2020), *Study on the EU's list of Critical Raw Materials (2020)*. See methodological notes.

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308 Council of the EU (2017), Joint Employment Report from the Commission and the Council accompanying the Communication from the Commission on the Annual Growth Survey 2017.

309 European Commission (2019), The European Green Deal, COM(2019) 640 final.

310 European Commission (2020), A New Industrial Strategy for Europe, COM(2020) 102 final.

311 The Circular economy indicator only includes 'value added at factor costs' in the following three sectors: recycling, repair and reuse. Nevertheless, our analysis and CE indicators use different NACE codes to define these sectors.

312 Complete time series for value added were not available for forestry. However, data for 2017 were available, and are included in Figure 16.2.

313 Over 2014-2017, the total value added of raw materials sectors presented in Figure 16.1 increased by 13%.

314 The total value added of the sectors represented in Figure 16.2 accounts for almost 80% of the total EU value added of the NACE Rev2 sectors B-F (Industry and Construction sections).

315 Comparing the 2017 value added for the current EU to that of the EU plus the UK suggests that Brexit affected mostly the EU value added of the downstream sectors (-13%) and to a much lesser extent that of processing and extractive sectors (-6% and -4% respectively).

316 Statistics here refer to EU-27. Therefore the comparison of the 2017 with the 2014 figures is not straightforward when comparing Figure 16.2 with the corresponding chart in the previous edition of Scoreboard (2018).

317 At this stage of the value chain, materials recovery alone increased by 34%, as showed in Figure 16.1.

318 Over the 2014-2017 period, the value added at the extraction stage grew by 8%, while for processing it grew by 11%.

319 Source: JRC, based on data from Eurostat's annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) ´sbs_na_ind_r2´. See the methodological notes for more details.

320 Source: JRC, based on data from Eurostat's annual detailed enterprise statistics for industry and construction, and additional Eurostat statistics for forestry and logging. See the methodological notes.

321 Farooki, M. (2012), 'The diversification of the global mining equipment industry — Going new places?', Resources Policy 37, https://doi.org/10.1016/j.resourpol.2012.06.006.

322 Freedonia (2018), 'Global Mining Equipment', Industry Study #3629 (complete brochure), https://www.freedoniagroup.com/industry-study/global-mining-equipment-3629.htm.

323 Ibid.

324 https://www.wired.com/story/factory-robots-may-point-way-5g-future/.

325 SIMS project, https://www.simsmining.eu/.

326 Ibid.

327 See methodological notes.

328 As the EU is taken as a trading bloc, only external trade flows with extra-EU-27 countries are accounted for.

329 For the EU countries, both intra- and extra-EU-27 exports are accounted for.

330 Only extra-EU-27 export flows are accounted for.

331 EU is considered as a trading bloc; thus, intra-EU-27 trade flows are not taken into account.

332 Source: JRC calculations based on UN Comtrade data, accessed via World Integrated Trade Solution (details in the methodological notes). Net export data for regional country aggregates only account for the extra-region trade flows.

333 Source: JRC calculations, based on UN Comtrade data, accessed via World Integrated Trade Solution. Data on the EU aggregate only account for extra-EU exports.

334 Source: JRC, based on UN Comtrade data, accessed via World Integrated Trade Solution.

335 E.g. within the ULCOS programme for steel, co-financed by the EU.

336 In principle, the mining exploration budget is not R&D (OECD, Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development). However, it is accounted as R&D expenses in some companies' annual report; this constitutes a limitation of the present analysis.

337 https://iri.jrc.ec.europa.eu/rd_monitoring.

338 This sample might not be representative. See methodological notes for further details on sector coverage.

339 Over 2006-2017, GDP inflation for the EU was low: on average 1.2% per year (European Central Bank data).

340 The removal of the UK from the EU dataset resulted in an upward shift in R&D intensity of mining and production of other minerals and coal (red series in Figure 18.2). This is due to the exclusion of two large UK-based mining companies: Anglo American and Rio Tinto.

341 Based only on the comparable period: 2012-2017, and on the R&D Scoreboard sample. Average R&D intensity for the 497 top EU-based corporate investors grew from just over 2.5% in 2012 to just under 3.5% in 2017 (Hernández, H., Grassano, N., Tübke, A., Potters, L., Gkotsis, P., & Vezzani, A. (2018), The 2018 EU Industrial R&D Investment Scoreboard).

342 Source: JRC elaboration based on the EU Industrial R&D Investment Scoreboard (Hernández, H., et al. (2019)).

343 Ibid.

344 Horizon 2020 is implemented by the EU's Executive Agency for Small and Medium-sized Enterprises (EASME). https://ec.europa.eu/growth/sectors/raw-materials/eip_en.

345 SPIRE Progress Monitoring Report 2019. See https://www.spire2030.eu/.

346 EIT RawMaterials is an Innovation Community within the European Institute of Innovation and Technology (EIT). See https://eitrawmaterials.eu/

347 Strategic agenda 2018-2022 of EIT RawMaterials.

348 Vertesy, D. & Deiss, R. (2016), The Innovation Output Indicator 2016. Methodology Update, doi:10.2788/261409.

349 OECD (2009), Patent Statistics Manual, ISBN 978-92-64-05412-7.

350 European Commission (2011), Europe 2020 Flagship Initiative Innovation Union, ISBN 978-92-79-17688-3.

351 The data for China has undergone a thorough cleaning.

352 The UK was sixth in the EU for number of applications and accounted for roughly 5% of the patents filed in each category. As its patenting trends are closely aligned with those of the EU as a whole, the overall trends for EU are the same excluding the UK.

353 Improvements in data cleaning and queries, which improve the reliability of the trends in patent applications. See methodological notes.

354 Source: JRC analysis of PATSTAT data. See Methodological notes.

355 Blagoeva, D., Pavel C., Wittmer, D., Huisman, J. and Pasimeni, F. (2019), Materials dependencies for dual-use technologies relevant to Europe's defence sector, ISBN 978-92-76-12194-7

356 Source: JRC analysis of PATSTAT data. See methodological notes.

357 The main differences in scope are due to the update of data to take account of the EU's current composition: the UK's contribution to the total number of companies (not depicted here) is as follows: (i) metals and mining sector - 118 out of 156 companies; (ii) precious metals subsector – 57 out of 66; (iii) base metals subsector – 20 out of 27.

358 See methodological notes.

359 According to the data on London Metal Exchange's annual commodity price evolution provided by S&P Global Market Intelligence, Commodity Price.

360 These S&P Global Market Intelligence aggregates are calculated by consolidating all companies into a single entity and weighted by size (i.e. market capitalisation). See section 'The search for RACER data' and methodological notes.

361 Source: JRC, based on the S&P Market Intelligence, Industry Trends & Statistics. See details in methodological notes.

362 Source: JRC, based on the S&P GMI Platform, Industry Trends & Statistics. See methodological notes.

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363 COM(2018) 773 final. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank, *A Clean Planet for all – A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy*.

364 The Paris Agreement sets out a global commitment to limit global warming to well below 2 °C, aiming to limit the increase to 1.5 °C. In this Communication and its supporting in-depth analysis, the Commission assessed the EU situation and explored detailed scenarios for decarbonisation to align with the Paris Agreement.

365 See RMIS, Climate & Low-Carbon and EPSC (European Political Strategic Centre) (2018), *10 Trends Reshaping Climate and Energy*, https://ec.europa.eu/epsc/publications/other-publications/10-trends-reshaping-climate-and-energy_en.

366 Secondary production, for the case of aluminium, reduces energy consumption by 95% and absolute emissions by up to 98% (from European Commission (2018), *In-depth analysis in support of the Commission communication COM(2018) 773*). Recycling will depend on the availability of quality scrap and the final product quality requirements. Other materials such as cement cannot be recycled, but can be reused (e.g. intelligently designed building components) and/or recovered at their end-of-life (e.g. clinker from concrete). For further information, see indicator 15.

367 Euromines (2019), *Producing metals and minerals for carbon neutrality*, http://www.euromines.org/publications/providing-metals-and-minerals-for-carbon-neutrality.

368 UBA (2018) Submission by the German Environment Agency (Umweltbundesamt, UBA) regarding the strategy for long-term EU greenhouse gas emissions reductions.

369 IISD (International Institute for Sustainable Development) (2018), *Green Conflict Minerals - The fuels of conflict in the transition to a low-carbon economy*, https://www.iisd.org/story/green-conflict-minerals/.

370 https://op.europa.eu/en/publication-detail/-/publication/be308ba7-14da-11ea-8c1f-01aa75ed71a1/language-en.

371 VUB-IES, *Industrial Value Chain: A Bridge towards a Carbon-Neutral Europe*, 2018. https://www.ies.be/files/Industrial_Value_Chain_25sept_0.pdf.

372 Emitted on site at production facilities, without accounting for emissions off site related to e.g. the production of electricity, transport, or the production of chemicals used at the production facility.

373 For the paper and wood industries, GHG process emissions are disregarded since they are assumed to be compensated by the carbon capture resulting from biomass growth. For mining, only combustion-related GHG emissions are reported.

374 JRC calculations based on EDGAR version 5 (see methodological notes for more details). Data for 2015.

375 See methodological notes.

376 See indicator 6. Domestic production.

377 According to the data presented in EU (2018), *In-depth analysis in support of the Commission communication COM(2018) 773*.

378 Ibid.

379 VUB-IES, *Industrial Value Chain: A Bridge towards a Carbon-Neutral Europe*, 2018. https://www.ies.be/files/Industrial_Value_Chain_25sept_0.pdf

380 For instance, the increase in aluminium content in some steel-based products, the decrease in the clinker content in cement, or the increase in wood-based construction.

381 COM(2018) 773 final. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank, *a Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy*.

382 Material Economics (2018), *The Circular Economy a Powerful Force for Climate Mitigation Transformative innovation for prosperous and low-carbon industry*, https://materialeconomics.com/publications/the-circular-economy-a-powerful-force-for-climate-mitigation-1.

383 Source: JRC, based on EDGAR version 5. See methodological notes for more details.

384 Source: JRC, based on EDGAR data (see methodological notes).

385 Information on the supply chain and production processes mostly comes from RMIS, *Aluminium Raw Materials profile*, https://rmis.jrc.ec.europa.eu/?page=rm-profiles#/Aluminium

386 DG ENVIRONMENT (2019), *Results and deliverables of the Environmental Footprint pilot phase*, https://ec.europa.eu/environment/eussd/smgp/PEFCR_OEFSR_en.htm. See Product Environmental Footprint Category Rules (PEFCRs) and Life Cycle Inventory for 'Metals sheets'.

387 IISD (2018).

388 RMIS, Aluminium Raw Materials profile (sub-section 'Environmental and social sustainability aspects').

389 RMIS, Aluminium Raw Materials profile (sub-section 'Overview' > 'Processing').

390 Source: JRC elaboration adapted from RMIS, *Aluminium Raw Materials profile* (sub-sections 'Overview' and 'Raw material supply chain').

391 Sources: European Commission (2020), *Study on the EU's list of Critical Raw Materials (2020), Factsheets on Critical Raw Materials' (Aluminium and Bauxite)*; European Commission (2020), *Study on the EU's list of Critical Raw Materials (2020)*; and International Aluminium Institute (2020), *Global Aluminium Cycle 2018*, https://alucycle.world-aluminium.org/public-access/#global. Data updated on: 12.5.2020 (accessed May 2020).

392 Deloitte (2016), *Circular economy potential for climate change mitigation*, https://www2.deloitte.com/content/dam/Deloitte/fi/Documents/risk/Deloitte%20-%20Circular%20economy%20and%20Global%20Warming.pdf.

393 Norgate, T., & Haque, N. (2010), ´Energy and greenhouse gas impacts of mining and mineral processing operations´, *Journal of Cleaner Production*, 18(3), 266-274.

394 Ibid.

395 See Chapter 7.6 Sectoral Industry Transformation, in EC (2018), *In-depth analysis in support of the Commission communication COM(2018) 773*).

396 European Commission – Strategic Forum for IPCEI (2019), *Strengthening Strategic Value Chain for a future-ready EU industry*, https://ec.europa.eu/docsroom/documents/37824

397 This may be most felt in those regions where the energy-intensive industries concentrate. See figure 5, in COM(2018)773 final.

398 IES (2018), *Value Chain A Bridge Towards a Carbon Neutral Europe - Energy Intensive Industries' contribution to Europe's long-term climate strategy*, https://www.ies.be/node/4758

399 High-level Group on Energy-intensive Industries (2019), *Masterplan for a Competitive Transformation of EU Energy-intensive Industries Enabling a Climate-neutral, Circular Economy by 2050*.

400 European Commission (2018), *In-depth analysis in support of the Commission communication COM(2018) 773)*.

401 COM(2018)773 final.

402 SWD(2019) 427 final, *Fitness check of the Ambient Air Quality Directives*.

403 COM(2019) 640 final, *The European Green Deal*.

404 Primary pollutants can interact with the atmosphere and form secondary pollutants after being in contact with water, sun light, other pollutants, etc.

405 EEA (2019), *Air quality in Europe — 2019 report*.

406 Moore, F.C. (2009), ´Climate Change and Air Pollution: Exploring the Synergies and Potential for Mitigation in Industrializing Countries´. Review article. *Sustainability*, 1, 43-54; doi:10.3390/su1010043

407 DEFRA (2007), *Air Quality and Climate Change: A UK Perspective*. Report produced by the Air Quality Expert Group, Department for the Environment, Food and Rural Affairs (UK), Defra Publications, London.

408 Under the Directive on National Emission Ceilings (Directive 2016/2284/EU), the main air pollutants include nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO_2), ammonia (NH_3) and fine particulate matter ($PM_{2.5}$).

409 See methodological notes.

410 Ibid.

411 Such as SO_2, primarily from the burning of fuels that contain sulphur, or NO_x, coming mostly from road transport.

412 EEA (2019), *Environmental pressures of heavy metal releases from Europe's industry*, https://www.eea.europa.eu/themes/industry/industrial-pollution-in-europe/heavy-metal-pollution, (accessed November 2019)

413 Pollution of heavy metals is addressed by the EU air quality policy, the Convention on Long-Range Transboundary Air Pollution (CLRTAP) on heavy metals and the Mercury Regulation (2017/852/EU), developed as a response to the Minamata Convention on Mercury.

414 Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.

415 Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air. Directives 2004/107/EC and 2008/50/EC have undergone a fitness check (SWD(2019) 427 final).

416 DG ENVIROMENT (2019). Air, Air quality standards, https://ec.europa.eu/environment/air/quality/standards.htm, last updated: 07/08/2019.

417 Directive 2016/2284/EU of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC. See data available at the EEA dedicated website at: https://www.eea.europa.eu/themes/air/national-emission-ceilings.

418 Member States should undertake assessments of air pollution and air quality, and develop programmes to reduce national emissions. See DG ENVIRONMENT, Reduction of National Emissions - National Air Pollution Control Programmes, https://ec.europa.eu/environment/air/reduction/NAPCP.htm,

419 Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).

420 https://eippcb.jrc.ec.europa.eu/reference.

421 For details about these pollutant types see the methodological notes.

422 Those associated with industrial processes other than combustion of fuels. For the wood industries, no PM_{10} process-emissions are considered; for wood and non-ferrous metals industries, no NMVOC process-emissions are considered. Only combustion-related emissions are available for mining.

423 JRC calculations based on EDGAR version 5 (see methodological notes for more details). Data for 2015.

424 Mostly due to the trends for non-metallic minerals, and iron and steel.

425 See indicator 6. Domestic production.

426 Ibid.

427 See indicator 21.

428 Energy use in industry and Industrial processes and product use.

429 EEA (2019), Air pollutant emissions data viewer (Gothenburg Protocol, LRTAP Convention) 1990-2017, https://www.eea.europa.eu/data-and-maps/dashboards/air-pollutant-emissions-data-viewer-2.

430 Source: European Commission (2019), *Guidance on cascading use of biomass with selected good practice examples on woody biomass*, https://op.europa.eu/s/nv79.

431 Source: JRC, based on EDGAR version 4 (see methodological notes for more details).

432 Source: JRC, based on EDGAR data.

433 Source: JRC, based on EDGAR data.

434 UN General Assembly (2015), *Transforming our world: the 2030 Agenda for Sustainable Development*, New York United Nations.

435 Such as copper and nickel as described in in Vidal-Legaz, B., Torres de Matos, C., Latunussa, C., Bernhard, J.H. (2018), *Non-energy, non-agriculture raw materials production: data to monitor the sector's water use and emissions to water*, EUR 29424 EN, Publications Office of the European Union, Luxembourg, ISSN 1831-9424, ISBN 978-92-79-97037-5, doi:10.2760/007059, JRC113206.

436 For the case of metals and minerals.

437 See Raw Materials Information System > Environmental & social sustainability > Environmental dimension > Water, https://rmis.jrc.ec.europa.eu/?page=water-914f2b.

438 Due to further ore processing needs.

439 For instance, for mine dewatering (which should assess and implement the required environmental mitigation measures).

440 EEA (2019), Water exploitation index plus (WEI+) for river basin districts (1990-2015), https://www.eea.europa.eu/data-and-maps/explore-interactive-maps/water-exploitation-index-for-river-2

441 Ibid.

442 CDP (2019), *In too deep: Analysis for institutional investors of critical water security issues facing the metals and mining sector*, https://www.cdp.net/en/reports/archive.

443 IRP (2020), ´Mineral Resource Governance in the 21st Century: Gearing extractive industries towards sustainable development´, *Report by the International Resource Panel*, United Nations Environment Programme, Nairobi, Kenya, Chapter 4.
See also: Raw Materials Information System > Environmental & social sustainability > Environmental dimension > Water, https://rmis.jrc.ec.europa.eu/?page=water-914f2b > Seabed mining and dredging.

444 Directive 2000/60/EC establishing a framework for the Community action in the field of water policy, and establishes water bodies' quality objectives by river basin.

445 Directive 2010/75/EU on Industrial Emissions (integrated pollution prevention and control): https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0075&from=EN.

446 Priority substances under the Water Framework Directive, https://ec.europa.eu/environment/water/water-dangersub/pri_substances.htm.

447 SWD(2019) 439 final. Commission Staff Working Document *Fitness Check of the Water Framework Directive, Groundwater Directive, Environmental Quality Standards Directive and Floods Directive* (...). Annex V.

448 See methodological notes.

449 See methodological notes.

450 Disaggregated data for non-energy commodities are not available.

451 See section ´The search for RACER data´.

452 EEA (2019), Water exploitation index plus (WEI+) for river basin districts (1990-2015), https://www.eea.europa.eu/data-and-maps/explore-interactive-maps/water-exploitation-index-for-river-2.

453 Ibid.

454 Source: JRC analysis, based on Eurostat (see methodological notes).

455 Younger P.L., Wolkersdorfer C., (2004), ´ERMITE-Consortium, Mining Impacts on the Fresh Water Environment: Technical and Managerial Guidelines for Catchment Scale Management´, *Mine Water and the Environment*.

456 Dolega P, Degreif S, Buchert M and Schüler D (2016), ´Strategic Dialogue on Sustainable Raw Materials for Europe´, STRADE, No. 04/2016, *Outlining Environmental Challenges in the Non-Fuel Mining Sector*.

457 Bide T, Brown T, Evans E, Idoine N, Kresse C, Petavratzi E, Mancini L and Vidal-Legaz B, *Deliverable 1.3 Report on the datasets available relating to social and environmental dimensions of extraction*, Optimizing quality of information in RAw MAterial data collection across Europe (ORAMA) project, https://orama-h2020.eu/wp-content/uploads/ORAMA_WP1_DEL1.3_20190329_BGS_v1.0.pdf

458 Dolega P et al. (2016).

459 AMD occurs when sulphide minerals react with oxygen and water, leading to the formation of sulphuric acid forms, which can dissolve heavy metals.

460 ICMM (International Council on Mining & Metals), Integrated mine closure, https://www.icmm.com/en-gb/environment/mine-closure/integrated-mining-closure (accessed November 2019).

461 Dolega P et al. (2016).

462 E.g. tailings dam failures in Aznalcóllar (Spain) and Baia Mare (Romania) in 1998 and 2000.

463 Bide et al. (2019).

464 https://eippcb.jrc.ec.europa.eu/reference/BREF/jrc109657_mwei_bref_-_for_pubsy_online.pdf.

465 Data 2007-2014, according to data from the European Pollutant Release and Transfer Register (E-PRTR). See EEA (2017). However, these data show significant limitations (consistency of data over time is not granted and therefore is not good for monitoring trends over time; data do not cover all facilities in Europe; and data do not cover all relevant considerations related to the impact of extractive activities on water quality).

466 Extracted from Vidal Legaz et al. (2018), *Non-energy, non-agriculture raw materials production: data to monitor the sector's water use and emissions to water*, EUR 29424 EN, Publications Office of the European Union, Luxembourg, ISSN 1831-9424, ISBN 978-92-79-97037-5, doi:10.2760/007059, JRC113206.

467 Promoted by the Sustainable Development Goals (SDGs) through indicator 6.4.2 — Level of water stress.

468 As suggested by SDG indicator 6.4.1 — Change in water efficiency over time.

469 See Vidal-Legaz, B., et al. (2018), *Non-energy, non-agriculture raw materials production: data to monitor the sector's water use and emissions to water*, EUR 29424 EN, Publications Office of the European Union, Luxembourg, ISSN 1831-9424, ISBN 978-92-79-97037-5, doi:10.2760/007059, JRC113206

470 https://ec.europa.eu/eurostat/data/database; https://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=ten00106&language=en.

471 EC Raw Materials Information System > Policy & Legislation > EU legislation > EU Community Secondary Law > Extractive waste, https://rmis.jrc.ec.europa.eu/uploads/ExtractiveWaste.pdf.

472 Directive 2012/18/EU.

473 https://ec.europa.eu/environment/waste/mining/implementation.htm.

474 https://ec.europa.eu/environment/waste/mining/pdf/MWEI%20BREF.pdf.

475 http://ec.europa.eu/environment/waste/framework/.

476 Mathieux, F., Ardente, F., Bobba, S., Nuss, P., Blengini, G., Alves Dias, P., Blagoeva, D., Torres De Matos, C., Wittmer, D., Pavel, C., Hamor, T., Saveyn, H., Gawlik, B., Orveillon, G., Huygens, D., Garbarino, E., Tzimas, E., Bouraoui, F. and Solar, S. (2017), *Critical raw materials and the circular economy — background report*, JRC, 100 p., ISBN 978-92-79-74283-5, doi:10.2760/977855.

477 Gislev, M., Grohol, M., Mathieux, F., Ardente, F., Bobba, S., Nuss, P., Blengini, G., Alves Dias, P., Blagoeva, D., Torres De Matos, C., Wittmer, D., Pavel, C., Hamor, T., Saveyn, H., Gawlik, B., Orveillon, G., Huygens, D., Garbarino, E., Tzimas, E., Bouraoui, F. and Solar, S. (2018), *Report on Critical raw materials and the circular economy*, European Commission, 76 p.

478 Blengini, G.A., Mathieux, F., Mancini, L., Nyberg, M., Viegas, H.M. (Editors); Salminen, J.; Garbarino, E., Orveillon, G., Saveyn, H., Mateos Aquilino, V., Llorens González, T., García Polonio, F., Horckmans, L., D'Hugues, P., Balomenos, E., Dino, G., de la Feld, M., Mádai, F., Földessy, J., Mucsi, G., Gombkötő, I., Calleja, I. (2019), *Recovery of critical and other raw materials from mining waste and landfills: State of play on existing practices*, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-03391-2, doi:10.2760/494020.

479 https://www.strategicminerals.com/en/our-job/penouta/.

480 https://www.lkabminerals.com/en/video/ulrika-hakansson-reemap-introduction/.

481 https://etn-sultan.eu/.

482 BiPRO-Oakdene Hollins (2016), Provision and analysis of information for the preparation of the Commission's report on the implementation of Directive 2006/21/EC on the management of waste from extractive industries (COM(2016) 553 final); http://ec.europa.eu/environment/waste/studies/mining/waste_extractive_industries.pdf.

483 DG ENVIRONMENT, http://ec.europa.eu/environment/waste/mining/index.htm.

484 E.g. Minerals Intelligence Network for Europe (Minerals4EU), http://www.minerals4eu.eu/; Prospecting Secondary raw materials in the Urban mine and Mining wastes (ProSUM), http://www.prosumproject.eu/;
SmartGround, http://www.smart-ground.eu/public/20161118141030.pdf.

485 E.g. the WU Vienna Global Material Flows Database, http://www.materialflows.net/materialflowsnet/home/.

486 Source: JRC analysis based on Eurostat data on extractive waste and domestic extraction, and World Mining Data for non-aggregates, non-fuel material extraction concentrates. See methodological notes for description of the content of each data series.

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Cluster 6

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539 Source: JRC analysis based on Eurostat data on non-fatal accidents at work by economic activity and sex (´hsw_n2_01´), incidence rate. Incidence rates in 2015 referred to EU-28, while those in 2017 refer to EU27 (from 2020), http://ec.europa.eu/eurostat/en/web/products-datasets/-/HSW_N2_01

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552 Source: JRC elaboration, based on data from Eurostat's annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) ´sbs_na_ind_r2´. See the methodological notes for more details.

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